Flora of Usery Mountain Regional Park and Pass Mountain Region of Tonto National Forest, Arizona and Distribution of Saguaro (*Carnegiea gigantea*) on Pass Mountain in Southern Tonto National Forest

by

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of the Requirements for the Degree
Masters of Science

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ABSTRACT

This study was designed to produce a comprehensive flora of Usery Mountain Regional Park and Pass Mountain of the Tonto National Forest. A total of 168 vascular plant species representing 46 families and 127 genera were collected or documented at this study area. Sixteen species were not native to the flora of Arizona and represent 9.5% of the flora. Nevertheless, the study area does not appear to be significantly damaged or degraded in spite of its historical and current land use. The location and types of invasive species recorded in this study will assist with implementing preventative measures to prevent further spreading of certain species. The complete list of all vascular species recorded in this study will provide a valuable tool for land management decisions and future restoration projects that may occur at this area or similar sites and invasive species control.

The distribution of the saguaro (*Carnegiea gigantea*) population on Pass Mountain was documented through the measurement of saguaros by random sampling. ArcGIS was used to generate 50 random points for sampling the saguaro population. Analysis to determine saguaro habitat preferences based on the parameters of aspect, slope and elevation was conducted through ArcGIS. The saguaro population of Pass Mountain significantly favored the southern aspects with the highest concentration occurring in the southwest aspects at an average density of 42.66 saguaros per hectare. The large numbers of saguaros recorded in the younger size classes suggests a growing populations.

ACKNOWLEDGMENTS

I want to acknowledge my Graduate Supervisory Committee for their support and expertise; committee chair Dr. Kelly P. Steele for sharing her vast knowledge and love of plants with me in the classroom and out in the field, committee member Dr. William H. Miller for his expertise and guidance in GIS and statistical analysis, and committee member Dr. Eddie J. Alford with his background of the Sonoran Desert and Tonto National Forest area and experience with saguaro research.

I appreciate Dr. Douglas Green, Chair of the Department of Applied Sciences and Mathematics, for supporting my efforts as both a student and an employee during this research project. Dr. Les Landrum, ASU Herbarium Curator, was instrumental in both the selection of my study area and training I received on the process of creating voucher specimens. Robert Wilson, State Resources Soil Scientist for NRCS, provided information and resources for my research project.

Usery Mountain Regional Park Supervisor Jennifer Johnston granted permission for off-trail access and issued a letter allowing me to collect plants for this study. Park Ranger Brennan Basler was available as needed for interviews and historical information. Tonto National Forest Mesa Ranger District office provided the documentation required for plant collecting within their boundaries.

Most of all, special thanks to my children; Tasha, Jake, Josh, Zach and Jordan Marshall. They unconditionally supported me as a full time student and assisted me with a majority of the field work required for this research project.

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CHAPTER 1

FLORA OF USERY MOUNTAIN REGIONAL PARK AND PASS MOUNTAIN REGION OF TONTO NATIONAL FOREST, ARIZONA

INTRODUCTION

A flora is a comprehensive, systematic account of all the plant species of a given area (FNA, 2008). A flora provides a baseline database of vascular plant species and a tool for assessing changes over time, management decisions and restoration projects. They create a collection of plant specimens that are pressed, dried, mounted and referenced in space and time then deposited in herbaria (ASU, 2011). The Society of Ecological Restoration International recommends that species list and herbarium specimens be used as a reference for restoration projects occurring in the same area or similar sites (SER, 2004). Information about indigenous plant species is important for the management of ecosystems to preserve biodiversity and to monitor invasive species, which threaten native plants (FNA, 2008).

Rationale for Study and Location

There are a number of reasons for the choice of Usery Mountain Regional Park (UMRP) and Pass Mountain as the location for this flora. Previous surveys were not extensive, but lists of species observed were available and some specimens were present in the Arizona State University herbaria (ASU). This information provided a foundation for the current study. The impact of recreation and the proximity to an urban area on native vegetation is of interest to land managers in the central Arizona region. Recreation occurs in the forms of hiking, horse riding, mountain biking, picnicking and camping at UMRP and Pass Mountain where they receive an average of 200,000 visitors a year. The peaks of Pass Mountain rise high above the desert floor and may provide a habitat for species that typically occur in higher latitudes and elevations, analogous to the "sky island" mountains of southeastern Arizona (Perez-Alquicira et al., 2010). In addition, there are several other floras from central Arizona (SEINet, 2011) whose species composition can be compared to that of the UMRP with regard to, for example, the presence of certain introduced species.

The study area for this flora includes all of UMRP and an adjacent southern portion of the Tonto National Forest and comprises approximately 6,400 acres (10 square miles) in all (Figure 1). It falls between the latitude boundaries of 33.49^0 N to the north and 33.44^0 N to the south with the longitude boundaries of 111.62^0 W to the west and 111.58^0 W to the east. Elevation ranges from a maximum of 945 m (3,100 ft) to a minimum of 549 m (1,800 ft). The southern portion of the study area is the UMRP section located east of Usery Pass road. The park is in the northeast corner of the city of Mesa in Maricopa County with residential neighborhoods of Mesa bordering the south and east sides of UMRP. The entire park is 3,648 acres, set at the western end of the Goldfield Mountains between Usery and Pass Mountain. The park is adjacent to the Tonto National Forest along the north border and to Pinal County on the east border. The northern portion of the study site is located on approximately three sections of the adjacent Tonto National Forest. Several trails from UMRP cross over onto the Tonto National Forest where Pass Mountain is located.

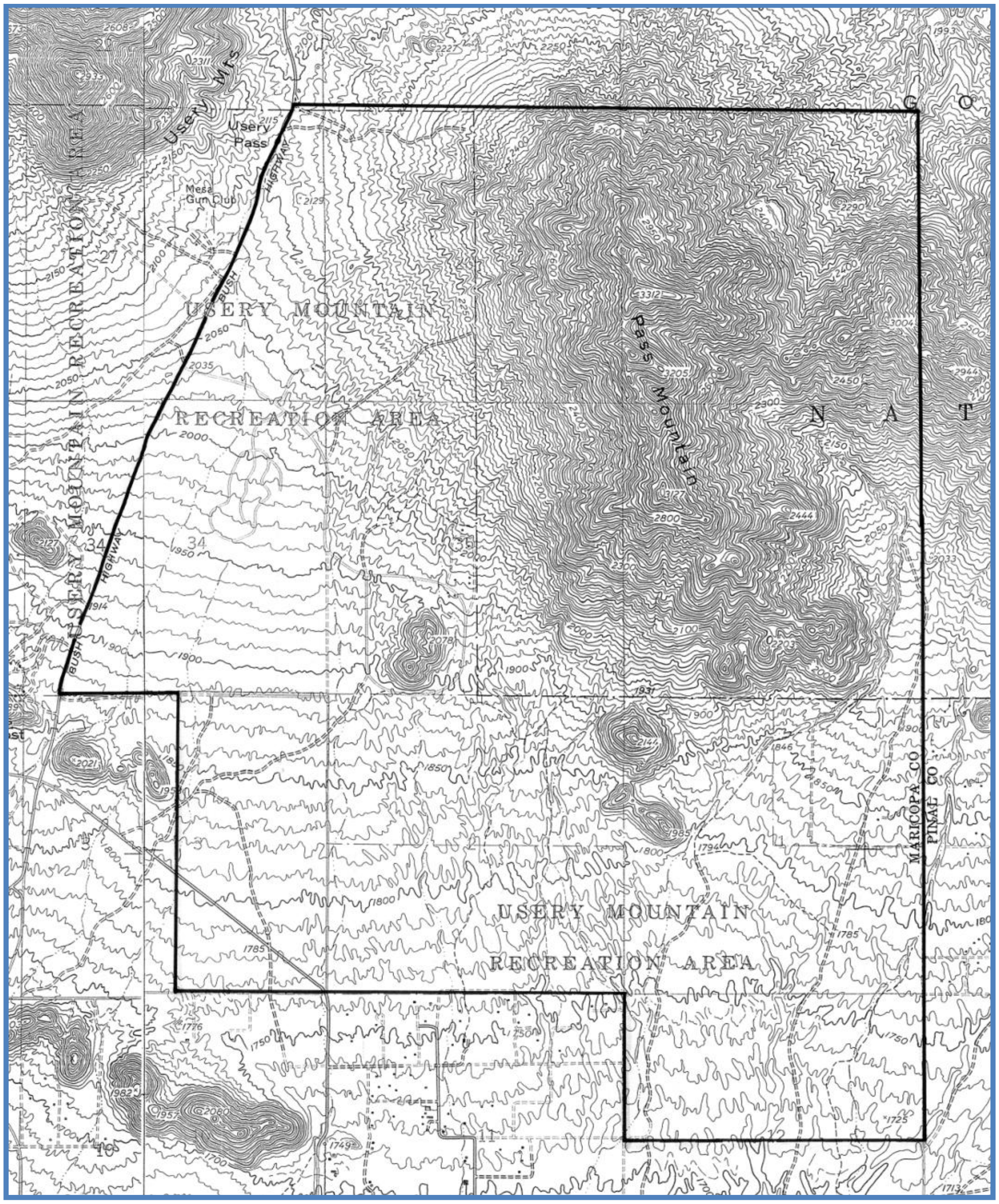

Figure 1. Boundary and Topography of the UMRP Study Area as Displayed on USGS Buckhorn and Apache Junction 7.5 min Quadrangle Maps.

Geology. The Sonoran Desert is within the Basin and Range Geologic Province where mountain ranges are low to mid-elevation and generally trend northwest-southeast and parallel one another (Rowland, 2000). The landscape at the study area is dominated by the mountains and rock outcrops of the Goldfield range. The mountains are igneous, composed of granitic rocks and extractive basalt consisting of andesite, rhyolite, andesitic tuff, rhyolitic tuff and schist (Robert Wilson, NRCS, pers. com.). The base of Pass Mountain (Figure 2) was formed during the Precambrian Period approximately 1.2 billion years ago. It is comprised of granite, an intrusive rock high in silica and low in iron and magnesium, consisting of low temperature minerals. The distinct lighter yellow colored cliffs about two thirds up the slopes of Pass Mountain is made up of Geronimo Head Tuff, a layer of compacted volcanic ash that flowed out over the surrounding landscape when the Goldfield Caldera collapsed about 15–16 million years ago. The peak of Pass Mountain has been classified as basaltic, an extrusive rock low in silica and high in iron and magnesium, consisting of high temperature minerals and forming approximately 12-14 million years ago (Nations & Stump, 1996). One of the more popular features of the park is the 2.4 km (1.5 mile) trail to the Wind Cave which is formed at the boundary between the granite base and volcanic tuff layer on Pass Mountain at 2,840 foot elevation (Maricopa County, 2010). The flats and lower slopes surrounding Pass Mountain are largely comprised of decomposed granite. A soil survey of UMRP was obtained online from the Natural Resource Conservation Service (NRCS) Web Soil Survey with the study site outlined as the Area of Interest (AOI) (NRCS, 2010). The data was acquired from the soil map titled, Aguila-Carefree Area, Arizona, Parts of Maricopa and Pinal Counties (AZ645). Pinamt-Tremant complex soil comprised 29.2% of the area surveyed within the park with Gunsight-Cipriano complex and Tremant-Rillito complex both at 8% and Ebon very gravelly loam at 7% of the area (NRCS, 2010).

Figure 2. Photo of Pass Mountain Located in the Southern Portion of the Tonto National Forest and the Northern Portion of the UMRP Study Area.

Climate. The study area is located within the Arizona Upland subdivision on the eastern and northern portions of the Sonoran Desert and has the highest elevation and lowest temperatures, sometimes referred to as an arboreal desert (Brown, 1982). Precipitation in the Sonoran Desert falls in a bimodal pattern with a definite period of winter rains and a period of late summer rains. A severe drought is common in late spring and a more moderate drought occurs in the fall. Winter rains tend to be steady, moderate rainfall while during the summer rainy season all of the season’s precipitation may be received in an hour or so, resulting in flash floods (Ives, 1949). Temperature and precipitation data from four weather stations (Table 1) that surround the study area were available from the Western Regional Climate Center (2010). Thirty year average (1971 to 2000) of maximum, average and minimum annual temperatures and average annual precipitation were available. The four weather stations are; Granite Reef #023621 (Figure 3) located at latitude 33.52^0 N and longitude 111.70^0 W at 403 m (1,322 ft) elevation, approximately 8.9 km (5.5 miles) northwest of UMRP; Stewart Mountain #028214 (Figure 4) located at latitude 33.55^0 N and longitude 111.53^0 W at 432.8 m (1,420 ft) elevation, approximately 10.5 km (6.5 miles) northeast of UMRP; Apache Junction #020288 (Figure 5) located at latitude 33.45^0 N and longitude 111.47^0 W at 630.9 m (2,070 ft) elevation, approximately 9.7 km (6 miles) east of the UMRP; and Falcon Field #022927 (Figure 6) located at latitude 33.43 ^{0} N and longitude 111.73^0 W at 409 m (1,342 ft) elevation located approximately 13.7 km (8.5 miles) southwest of UMRP.

Table 1

Thirty Year (1971-2000) Mean Annual Temperature and Precipitation Data for the UMRP Study Area (WRCC, 2010).

Weather Station	Distance/Direction From Study Area	Mean Annual Temperature	Mean Annual Precipitation
Granite Reef Dam	5.5 mi/Northwest	69.8^0 F	9.1”
Stewart Mountain	6.5 mi/Northeast	69.4^0 F	12.5”
Apache Junction	6 mi/East	71.6^0 F	12.3”
Falcon Field	8.5 mi/Southwest	67.6^0 F	7.9”

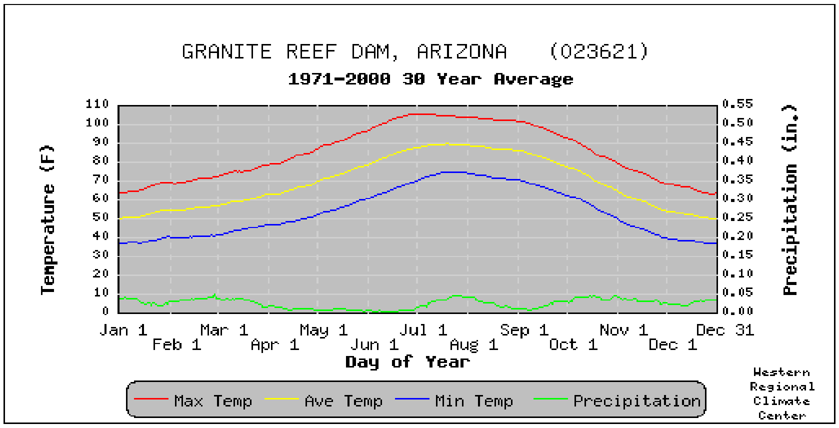

Figure 3. Average Monthly Precipitation and Temperatures of Granite Reef Dam Weather Station Located Northwest of the UMRP Study Area.

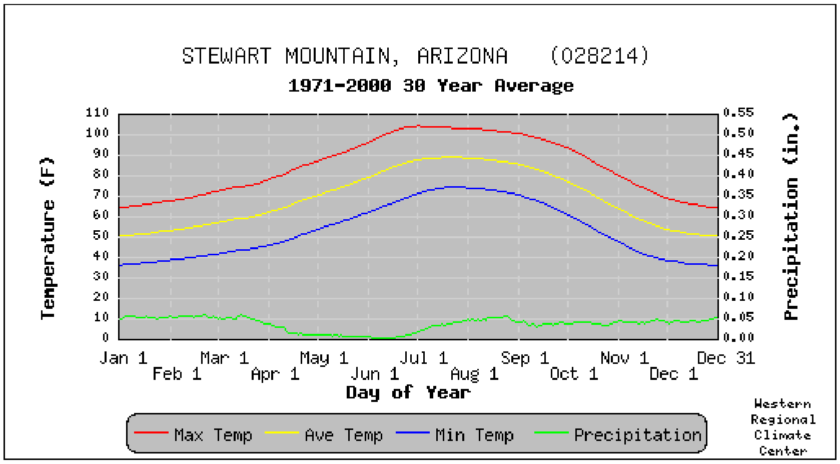

Figure 4. Average Monthly Precipitation and Temperatures of Stewart Mountain Dam Located Northeast of the UMRP Study Area.

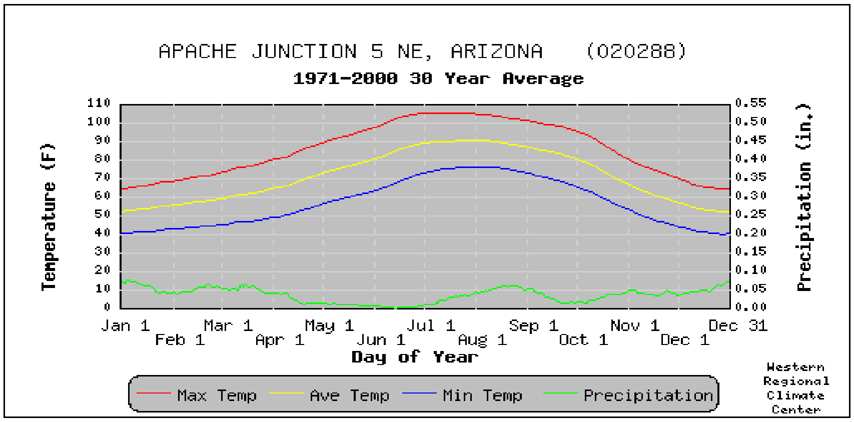

Figure 5. Average Monthly Precipitation and Temperatures of Apache Junction Weather Station Located East of the UMRP Study Area.

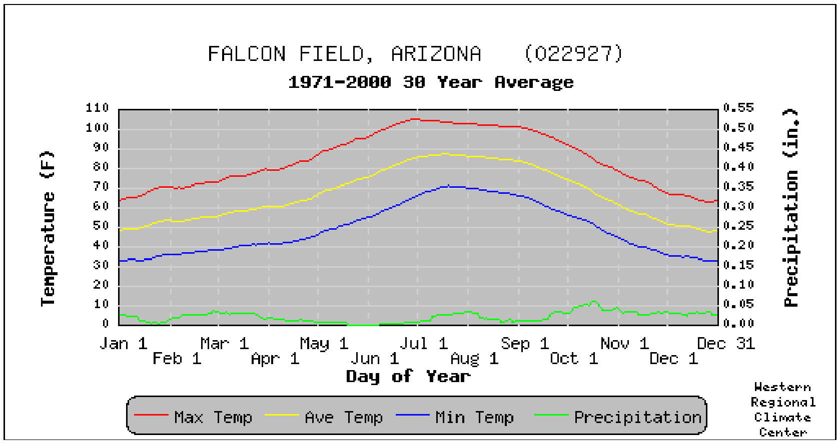

Figure 6. Average Monthly Precipitation and Temperatures of Falcon Field Weather Station Located Southwest of the UMRP Study Area.

Vegetation. The vegetation of the Arizona Upland subdivision of the Sonoran desert often takes on the appearance of a low woodland or scrubland (Brown, 1982). Some of the signature species of this area include the saguaro (*Carnegia gigantea*), yellow palo verde (*Parkinsonia microphylla*), blue palo verde (*Parkinsonia florida*), creosote bush (*Larrea tridentata*), prickly pear (*Opuntia* spp.), several species of cholla (*Cylindropuntia* spp.), and brittle bush (*Encelia farinosa*) (Brown, 1982).

Annual and perennial plant species that populate this ecosystem are dependent on rainfall events to trigger growth and reproduction. The bimodal pattern of rainfall results in two distinct pulses of vegetation growth corresponding to the two seasons of precipitation in late spring-early summer and then the monsoon rainfall in late-summer early fall (Notaro et al., 2010), resulting in rich species diversity.

Non-native plant species, largely of Mediterranean origin, have entered the region over time. Red brome (*Bromus rubens*) and Asian mustard (*Brassica tournefortii*), often referred to as Sahara mustard, are two of several species present at this study site. Non-natives species can reduce the density of native species by competing for resources and some create a cover of fine fuels that can increase fire frequency and severity (Bowers et al., 2006).

Sky islands are mountains with a steep vegetation gradient that exist in the Sonoran Desert of the southwestern United States and northern Mexico (Davison et al., 2011). Their base is surrounded with desert scrub but the mountain top may be home to species typically found in other biomes. These islands are thought to be the consequence of climate change 11,000 years ago that resulted in drier, warmer conditions resulting in isolation of some mountain top communities where the climate can still sustain them (Perez-Alquicira et al., 2010). They are of interest for studying the effects of isolation on both plant and animal species.

Historical and Current Land Use

Land Use Impacts. The potential impact of pre-historic, historic and current land use upon the local vegetation and species composition was of great interest in this study. It takes several decades for desert vegetation to recover from human impacts (Guo, 2004) thus effects of past land use may be apparent in the study area. Early on the Hohokam designed canal systems, some of which are still visible today in the surrounding Salt River Valley, to support their agriculture (Palacios-Fest, 1997). Tailings from mine shafts and open pit mines from the nineteenth and twentieth centuries scar the landscape. Roads and trails created in arid environments for mining access remove vegetation, cause habitat fragmentation and compact the soil. Increased water runoff from the compacted soil or surfaces of roads and trails facilitate the producing of flowers and fruits by roadside plants while plants further away are not able to produce (Jansen et al., 2009), somewhat altering the function of the local ecosystem. Heavy grazing often decreases the diversity and abundance of herbaceous species (Guo, 2004) and can alter the composition of the local vegetation. Recreational activities can cause damage in a variety of forms if not contained within designated areas. Disturbance to an ecosystem resulting from human activities can often facilitate the establishment of invasive species (SER, 2004).

Hohokam. The Hohokam began occupying the Salt River Valley sometime between 1 - 300 ADD It is still unclear whether they migrated to the area or if they were indigenous hunters and gatherers who learned agriculture. The Hohokam developed the most complex irrigation system known in North America with over 800 km (497 miles) of canals (Palacios-Fest, 1997). The study area is over 122 m (400 ft) above the elevation of the Salt River and does not contain any evidence of canals probably due to the incline nor is there any evidence of cultivated agave gardens. According to Brennan Basler, a park ranger at UMRP, shards of Hohokam pottery, stone projectiles such as arrowheads and spearheads, and the remains of a degraded pit house have been found within the park (Brennan Basler, UMRP Ranger, pers. com.). The Hohokam constructed the pit houses by digging a single room approximately two feet into the ground to help stay cool. The framework was built with tree branches and the roof with saguaro or ocotillo spines. The structure was then covered with brush and plastered with mud (Gregonis & Reinhard, 1979). In the 1200's the society had an ambitious agricultural system, but by the 1450's the Hohokam population was only one tenth of what it had been. Possible causes of the disappearance of their civilization include salinization of the soil along with over-population (Palacios-Fest, 1997).

Mining. There is no record of Pass Mountain itself having been mined although extensive mining occurred in other mountains of the Goldfield range and the Superstition Mountains (Arizona Historical Foundation, 1963). On the east side below Pass Mountain a shallow pit mine was seen during the study and a coke oven was noted along the park and forest boundary built in the late 1800's. Coke ovens were built to slowly burn and reduce mesquite wood to coke, a hotter burning fuel for use in smelting ore (Digital West Media, 2010). Dry pan mining was quite common in the area up until the park was established in 1967 at which time mining activities were no longer allowed (Brennan Basler, UMRP Ranger, pers. com.).

Grazing. The entire area has been subject to grazing from the 1870's to the late 1940's. Usery Mountain, located northwest of Pass Mountain, is named for the cattleman King Usery who ran livestock in the area during the late 1870's and early 1880's. James E. Bark used the area for grazing from the mid 1880's through the 1920's. A grazing lease was issued to R. K. Gibson in 1927. According to the records of the USDA Tonto National Forest Range Appraisal Atlas, the study site was part of grazing allotment 75. Other permittees recorded in the Range Appraisal Atlas in 1927 for this allotment included Barkley & Steward, Fred Weeks & Son and Geo. D. Weeks (TNF, 1927). The next recorded lease within the park area was to Edward Mathisson between the years of 1945 and 1947. He utilized all of Sec. 12, the south ½ of Sec. 2 and the east ½ of Sec. 16, T1N, R7E for grazing cattle (Arizona Historical Foundation, 1963).

Heber-Reno Sheep Driveway. In 1890 the Heber-Reno sheep driveway became a designated driveway according to U.S. Forest documents (TNF, 1916a). This trail is approximately 370 km (230 miles) with the northern end point in the White Mountains near Sun Rise Ski Resort and the southern end of the trail entering the east side of the Salt River Valley though Mesa into Chandler for winter grazing (Hacker, 2007). Men riding donkeys drive the sheep north with the assistance of sheep dogs once the snow melts in the spring. The sheep spend the summer in cooler weather foraging and mating before returning south to the East Valley when the temperatures drop (Grado, 2009). Usery Pass Road (referred to as Bush Highway on some maps), which currently borders the east side of the park, originally began as a section of the historical sheep trail that crossed between Usery and Pass mountains as the starting/gathering and ending/dispersal point (TNF, 1916a). The historic Reno-Heber Sheep trail was in use at the time the park was established in 1967 and is considered the most interesting historical feature of Usery Mountain Park (Van Cleve, 1967). A parcel of State Land, the North half of Section 2, T1N, R7E was leased by the Arizona Wool Growers Assoc. as a holding ground for the sheep drive. The proposed area for Usery Mountain Regional Park surrounded this half section on three sides with the Tonto National Forest on the fourth**.** Consultants were instructed to include this half section in the master plan with the hope it could be acquired (Van Cleve, 1967). The Heber-Reno sheep driveway is still in use today by the Sheep Springs

Sheep Co. located in Chandler, Arizona (Figure 7). In 2009 about 4,000 sheep were moved up north through Heber in April and then back down south entering the East Valley the last week of September and early October (Grado, 2009). The flock did not cross into the UMRP boundaries although a sheep camp further north is located on the Tonto National Forest just outside of the UMRP study area.

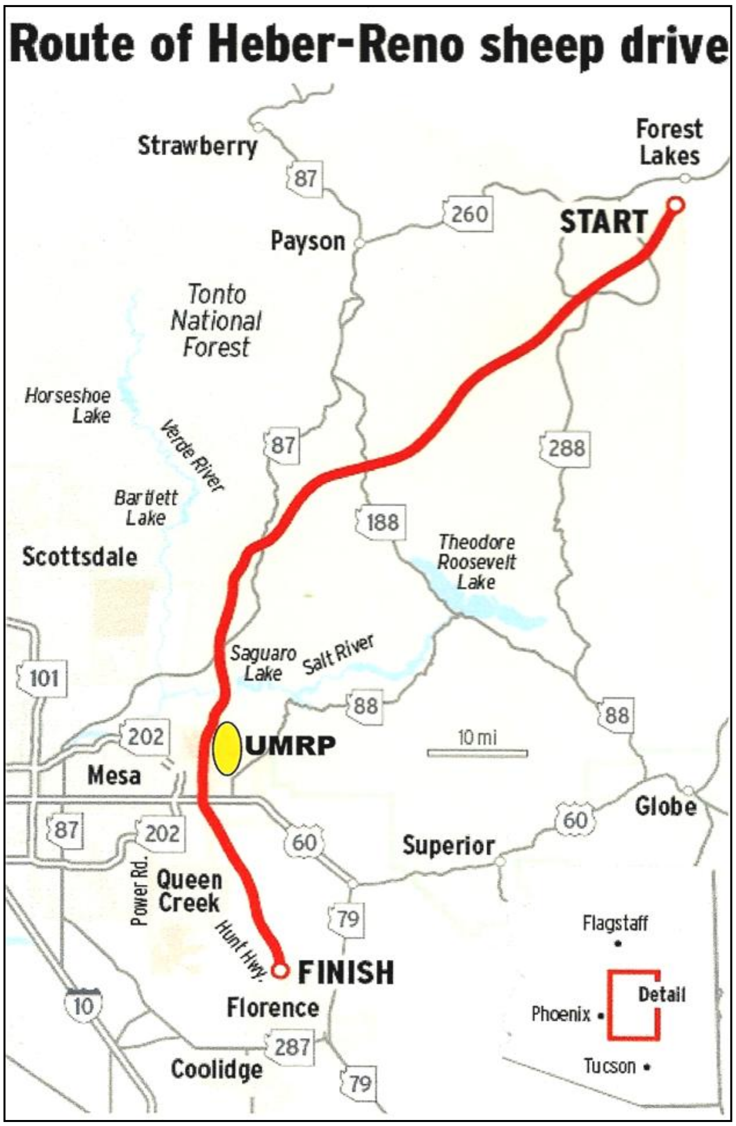

Figure 7. Route of the Heber-Reno Sheep Drive through Central Arizona in Relation to the UMRP Study Area (Hacker, 2007).

Homesteading. Three people sought to claim a homestead within the boundaries of what is now UMRP. It is recorded by the Bureau of Land Management that only Chester A. McGill of Mesa succeeded in obtaining a patent in 1932 to his claim of 160 acres located in the NE ¼ of Section 1, T1N, R7E. This parcel changed hands many times up to 1953 when it was purchased by Irwin F. Barlow who began selling small portions of it in 1955 (Arizona Historical Foundation, 1963).

Recreational Use. The Maricopa County park system began in 1954 to preserve the mountain areas surrounding the valley of metropolitan Phoenix for future generations to enjoy. A federal act called the Recreation and Public Purposes Act allowed the county to acquire thousands of acres of parkland from the Bureau of Land Management at $2.50 an acre (Maricopa County, 2010). In 1965 a survey of the proposed UMRP and surrounding area was conducted. A master plan for Usery Mountain Semi-Regional Park was prepared by Van Cleve Associates, Consulting Planners in 1967. The Maricopa County Parks and Recreation Commission and the Executive Park Committee unanimously adopted the document as the official plan for development of the park on July 5th, 1967. The master plan provided approximately 13 km (8 miles) of horse riding trails and about 26 km (16 miles) of hiking trails (Van Cleve, 1967) Today UMRP (Figure 8) offers over 47 km (29 miles) of trails for hiking, mountain biking and horseback riding, most are multi-use. The Archery Range at UMRP is the only "Five Star" rated archery range in Arizona and hosts over 30 tournaments annually (Maricopa County, 2010). The 1967 master plan provided for about 170 primitive campsites (Van Cleve, 1967). UMRP currently offers an RV campground of 73 individual sites with water and electrical hook-ups, dump station, a picnic table and a barbecue fire ring. There are also two group campgrounds, each with a large ramada containing six tables, large patio, and shared restrooms with showers. The park also provides several day use picnic areas and two group picnic areas (Maricopa County, 2010). Recreational users are instructed by signs throughout the park to remain on designated trails, camping and picnic areas to preserve the desert habitat and protect the wildlife.

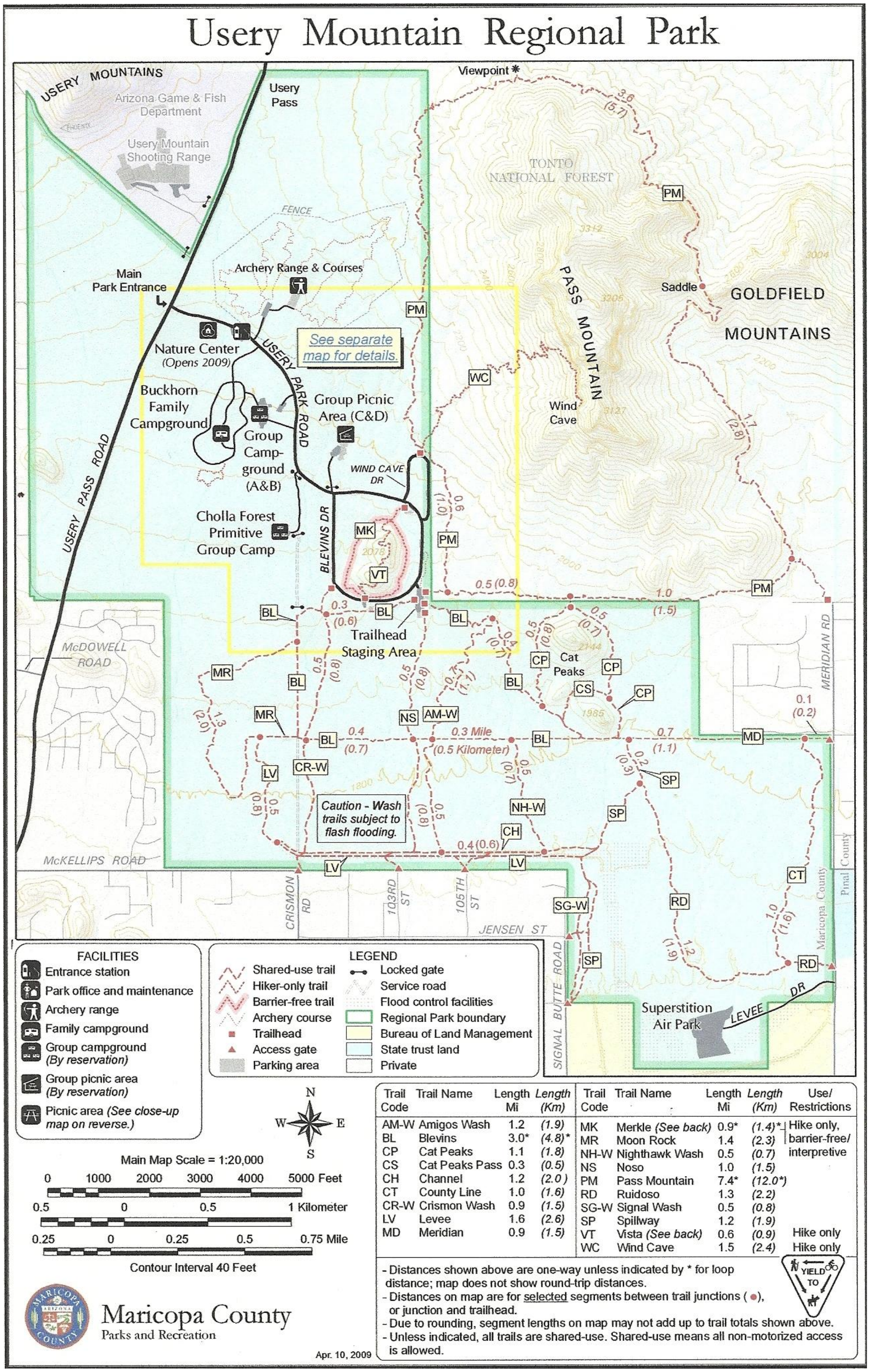

Figure 8. Usery Mountain Regional Park Map, Maricopa County Parks and Recreation (2009).

MATERIALS AND METHODS

Remote Sensing

Remote sensing images were used to examine the study area's topography and to locate washes. Desert washes create a microhabitat that will often support plant growth during drier periods of the year. An image taken by the USGS Landsat 5 satellite was downloaded into ERDAS IMAGINE geospatial data authoring software. The satellite's Thematic Mapper (TM) sensor collects spectral reflectance in seven bands ranging from 360nm to 14,500nm (USGS, 2010). The image that covered the study area was located on Path 37, Row 37. An unsupervised classification with a maximum of 20 classes and 20 iterations was preformed. A subset to the area of interest for the study site was created and an edge enhancement preformed with a 3 x 3 mean convolution to bring out image contrast and enhance the topography, making the washes more distinct. Two additional datasets were downloaded from the seamless USGS website from the Landscape Fire and Resource Management Planning Tools Project known as LANDFIRE. A Landfire NED image provided raster digital data of the elevation and a Landfire Existing Vegetation Cover image provided canopy cover types and urban development of the study site. These spatial layers were overlaid with the vegetation layer set at 40% transparency allowing the elevation to show through. With these two spatial layers the urbanized areas at the park boundaries and Pass Mountain were very distinct. A layer was created of the UTM coordinate points for each plant specimen collected was overlaid on the above spatial layers. This provided a visual tool to track the plant collecting process, the distribution of the collection locations and showed areas within the study area that had not yet been collected to ensure sampling throughout the entire site. In addition, by performing an inquiry on each point one could acquire the exact elevation, slope and aspect at which that plant specimen was collected.

Frequency of Invasive Species

To estimate the abundance of invasive species within the UMRP study area, the presence of selected species were recorded along the Pass Mountain trail. The trail is located on the Tonto National Forest and is the longest hiking trail of the park. Pass Mountain trail is an approximately 11 km (7 miles) loop around the base of Pass Mountain. A Magellan Meridian Gold GPS unit was used to map the entire trail by recording the UTM coordinates from 5 to 20 meter increments depending on direction change of the trail. A map was created in ArcGIS with a shape file of the trail overlaid on a Digital Elevation Map (DEM) of Pass Mountain (Fig. 9). In between each point that a coordinate was taken the presence or absence of select invasive species was recorded. The species recorded were *Avena fatua, Bromus rubens, Pennisetum ciliare, Pennisetum setaceum, Brassica tournefortii* and *Sisymbrium irio*. The number of points at which the species were present was then divided by the total number of points (314) collected to calculate a percent presence for each species along the Pass Mountain trail.

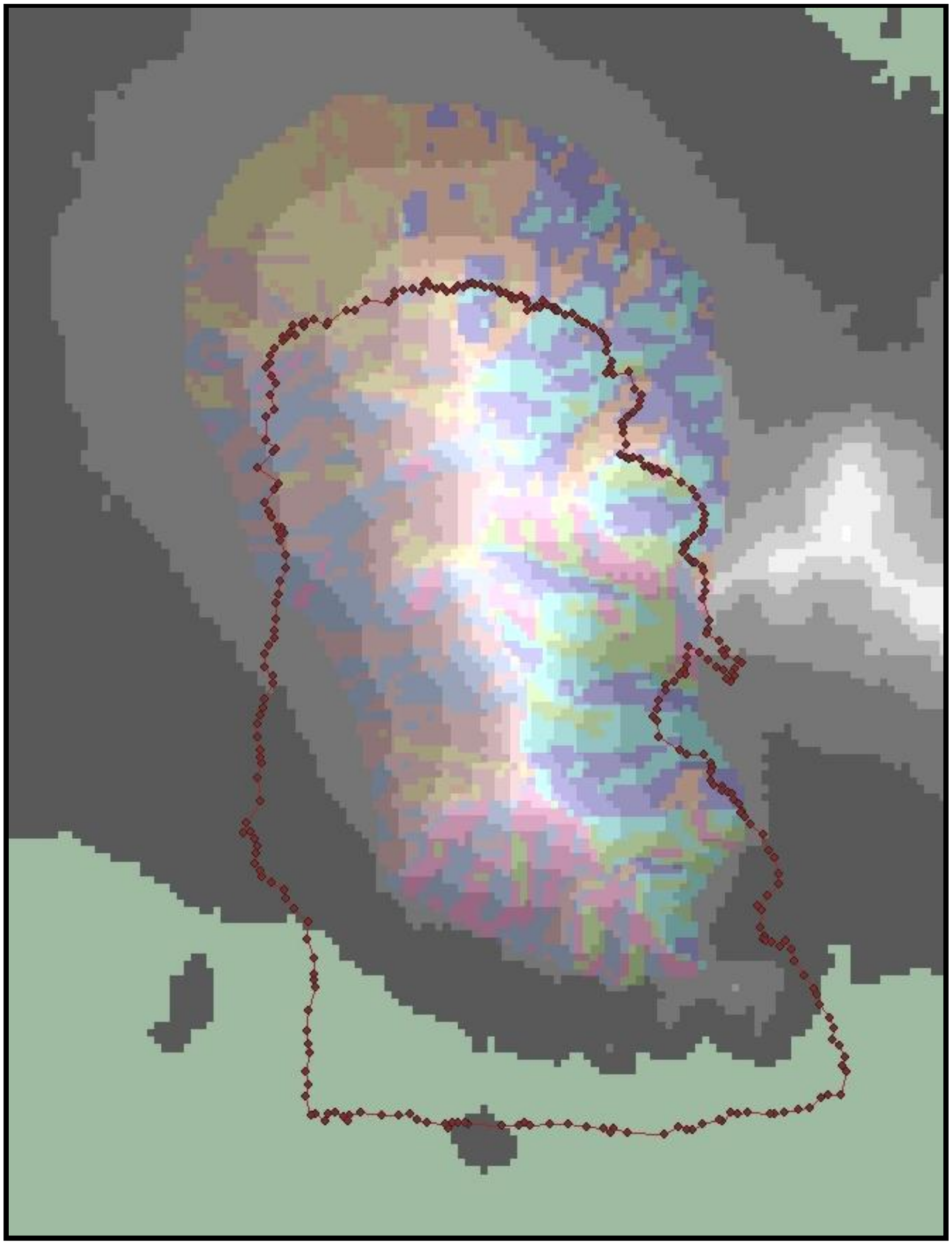

Figure 9. ArcGIS Map of Pass Mountain Trail Within the UMRP Study Area Recorded by GPS in May 2010.

Herbarium searches

A herbarium stores collections of pressed and mounted plant specimens referenced in space and time (ASU, 2011). Most plants collected from the study area prior to this flora are at the Arizona State University Vascular Plant

Herbarium (ASU) with some at the University of Arizona Herbarium located in Tucson, Arizona (ARIZ). Lists of plants that had been previously collected at Usery Mountain Regional Park were reviewed on the Southwest Environmental Information Network (SEINet) website throughout the collection process. The species checklists available on this site were compiled using a combination of voucher specimens, photo observations and survey projects (SEINet, 2011).

Plant Collection

A collecting permit was received from the Mesa Ranger District office for collecting in the Tonto National Forest portion of the study area and the park supervisor of UMRP sent an email granting permission to collect and remove plants within the park boundaries for this study. Collection began in March of 2005 and continued through May of 2010 for a total of 54 days. This does not include the days spent at the study area when either no new species were found to collect or the plants were not in flower or fruit. Most collecting took place in the spring months of March, April and May after the winter rains. Very little collecting took place during June and July, but after the monsoon rains the number of collections increased during August and September, but relatively little collecting took place October through February. Numerous visits were made to the study area every month throughout the year at the beginning of the study and then as most species had been collected the visits were concentrated more around the flowering and fruiting periods shortly after rain events.

Field notes that include a collection number, UTM coordinates, date, location details, terrain, and associated species were recorded with each specimen at the time of collection. Characteristics of the plant such as flower color were recorded due to color changes associated with the drying process. For grasses and forbs the entire plant was removed from the ground with roots attached if possible. Clippings were taken of shrub and tree species that included flowers or fruit. Three species of cactus were collected with either fruit or flower. Due to the difficult process of collecting and preparation required to press cactus specimens, I listed the remaining cactus species at the study area as, “observed but not collected.”

Plant Identification

All plants collected had flowers, fruits or both as is standard for voucher specimens. Each specimen was arranged, pressed and dried in a plant press as soon as possible after being collected. Dried specimens were then examined, compared to other specimens, and dissected under a microscope if necessary to determine the exact species. The following references were used in the identification process; Arizona Flora (Kearney & Peebles, 1960), the United States Department of Agriculture PLANTS Database (USDA & NRCS, 2011) and the online version of the Flora Of North America (FNA, 2008). Nomenclature throughout the text follows United States Department of Agriculture PLANTS database (USDA & NRCS, 2011).

Identified plant specimens were mounted on herbarium grade paper with a label identifying the family, genus and species of the specimen, date and location of collection, name of the collector and other information such as the terrain and associated species. An envelope was attached to capture and store any seeds or other parts of the specimen that may come loose. The plant specimens from this study were deposited at the ASU herbarium as a permanent record. A duplicate set of specimens was donated to UMRP for their use.

A comparison was made between this flora of the UMRP study area and the flora of the mountain ranges within South Mountain Park (Daniel & Butterwick, 1992). The study areas for both these floras border the Phoenix metropolitan area in central Arizona and are located approximately 30 miles across the Salt River valley from each other. They each contain a public park within its boundaries.

RESULTS

Figure 10 indicates the number of specimens collected by month for the period March 2005 to May 2010. The highest percentage of plants collected within a month during this study was 40% in March, with 24% collected in April and 10% in May. Up to twenty-one species were collected within a single day on March 16, 2005. Only two specimens were collected for 1% in June and one specimen for 1% in July during this study. After the monsoon rains, collections rose to 7% in August and 9% in September. October dropped back to 1% percent while collecting rose slightly in November to 3%. No specimens were collected in December or January but 4% of the specimens were collected in February.

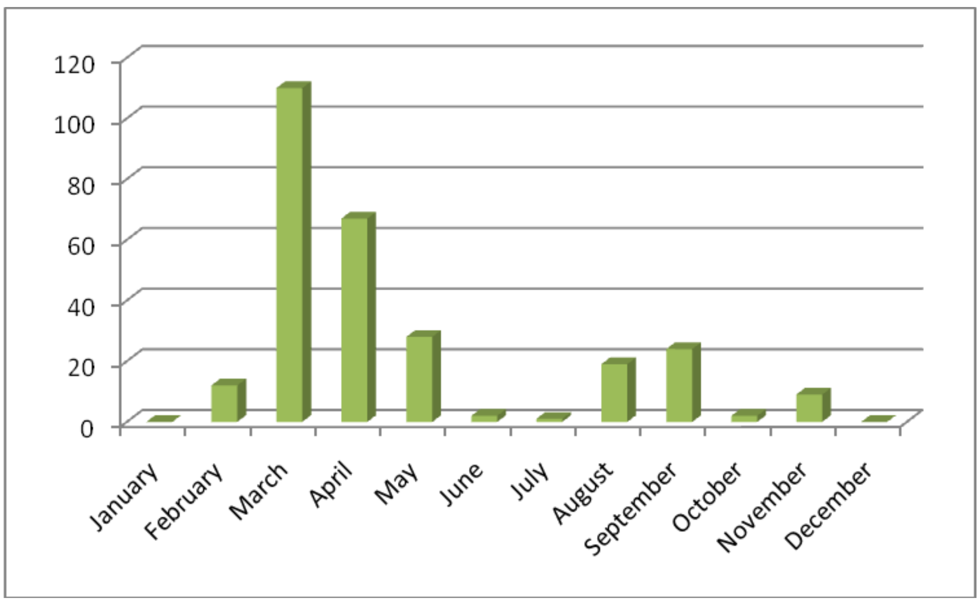

Figure 10. Number of Specimens Collected by Month at the UMRP Study Area (2005 to 2010).

A total of 168 species representing 46 families and 127 genera have been collected or documented at this study area. The largest family is Asteraceae representing 18% of the flora with 30 species (Table 2). The Poaceae are the second largest family with 17 species at 10% and Fabaceae with 13 species represents 8% of the flora for this study. Other large families are: Boraginaceae, with nine species; Cactaceae, with eight species; Euphorbiaceae, with seven species; Brassicaceae, with six species; Malvaceae, with six species and Polygonaceae with five species. The rest of the 35 families combined contain 67 species and represent 40% of the entire flora as shown below in Figure 11.

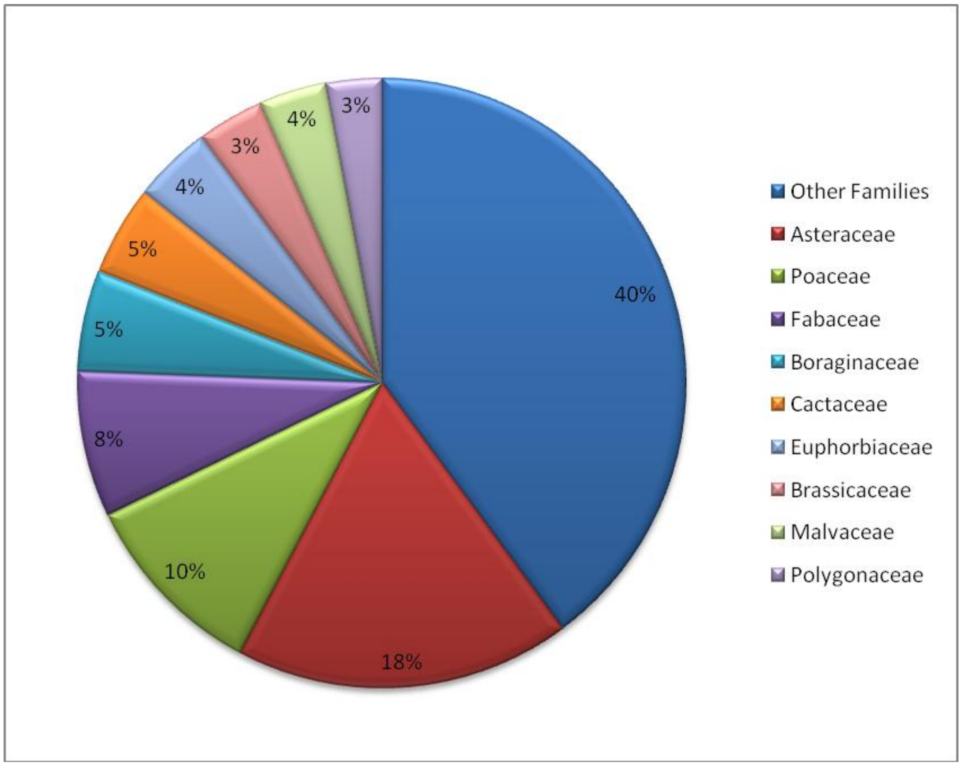

Figure 11. Families Represented in Flora of the UMRP Study Area (2005 to 2010).

Table 2

Number of Genera and Species in Largest Families and Number of Species in Largest Genera (2005 to 2010).

Largest	Genera/Species	Largest Genera	Species
Asteraceae	25/30	*Ambrosia*	4
Poaceae	12/17	*Bromus*	3
Fabaceae	9/13	*Lotus*	3

The major taxonomic categories of the flora are summarized in Table 3. The three divisions used are: Pteridophyta, which contains the Pteridaceae (fern) family; Gnetophyta which contains the Ephedraceae (Mormon tea) family and Magnoliophyta, which contains the two classes of Liliopsida (monocots) with the Poaceae and Liliaceae family; and Magnoliopsida (dicots), which contains the remaining 42 families represented in the flora. A total of 16 species that have been documented or previously collected at this study area were not encountered during this study (Table 4). Seven of the species were observed but not collected due to either the difficulty or inability to collect the species during fruiting or flowering (Table 5). Sixteen of the species recorded were non-native to the flora of Arizona and accounted for 9.5% of species observed (Table 6). The origin of these non-native species include Europe, the Mediterranean region, Asia, and Africa. Six of the non-native species were observed along the Pass Mountain trail system (Table 7). For prospective purpose the UMRP physical characteristics and flora were compared with of South Mountain Municipal Park (Table 8 and 9).

Table 3

Taxonomic Composition of the UMRP Study Area (2005 to 2010).

Division	Class	Families	Genera	Species
Pteridophyta	Filicopsida	1	2	3
Gnetophyta	Gnetopsida	1	1	1
Magnoliophyta	Liliopsida	2	13	18
Magnoliophyta	Magnoliopsida	34	112	147
	Total	**46**	**127**	**168**

Table 4

Species not Encountered During this Study (2005 to 2010).

Species	**Common Name**
Abutilon abutiloides (Jacq.) Garcke ex Hochr.	Shrubby Indian mallow
Amsinckia tessellata A. Gray	Bristly fidleneck
Anemone tuberosa Rydb.	Tuber Anemone
Argemone gracilenta Greene	Sonoran Pricklypoppy
Aristolochia watsonii Woot. & Standl.	Watson's Dutchman's
Chaenactis stevioides Hook. & Arn.	Esteve's pincishion
Cryptantha barbigera (A. Gray) Greene	Bearded cryptantha
Cynanchum arizonicum (A. Gray) Shinners	Arizona swallow-wort
Eriogonum palmerianum Reveal	Palmer's Buckwheat
Eriogonum thomasii Torr.	Thomas' Buckwheat
Lepidium lasiocarpum Nutt.	Shaggyfruit pepperweed
Lotus humistratus Greene	Foothill deervetch
Lotus rigidus (Benth.) Greene	Shrubby deervetch
Machaeranthera pinnatifida (Hook.) Shinners	Lacy tansyaster
Muhlenbergia porteri Scribn. ex Beal	Bush muhly
Pterostegia drymariodes Fisch. & C.A. Mey.	Woodland Pterostegia

Table 5

Species Observed but Not Collected During This Study (2005 to 2010).

Species	**Common Name**
Carnegia gigantica (Engelm.) Britton & Rose	Saguaro
Cylindropuntia bigelovii (Engelm.) F.M. Kunth	Teddybear cholla
Cylindropuntia fulgida (Engelm.) F.M. Kunth	Chainfruit cholla
Datura stramonium L.	Sacred Datura
Echinocereus engelmannii (Parry ex Engelm.) Lem.	Englemann's hedgehog
Fouquieria splendens Engel.	Ocotillo
Mammillaria grahamii Engelm.	Graham's nipplecactus

Table 6

Non-Native Species Within the UMRP Study Area (2005 to 2010).

Species	Common Name
Arctotis stoechadifolia P.J. Bergius	African daisy
Avena fatua L.	Wild oat
Brassica tournefortii Gouan	Asian mustard
Bromus diandrus Roth.	Ripgut brome
Bromus rubens L.	Red brome
Cynodon dactylon (L.) Pers.	Bermudagrass
Erodium cicutarium (L.) L'Hér. ex Aiton	Redstem stork's beak
Malva parviflora L.	Cheeseweed mallow
Oncosiphon piluliferum (L.F.) Källersjö	Stinknet
Pennisetum ciliare (L.) Link	Bufflegrass
Pennisetum setaceum (Forssk.) Chiov.	Fountaingrass
Schismus arabicus Nees	Arabian schismus
Schismus barbatus (Loefl. ex L.) Thell.	Common Mediterranean
Sisymbrium irio L.	London rocket
Sonchus oleraceus L.	Common Sowthistle
Sorghum bicolor (L.) Moench	Sorghum

Table 7

Non-native Species Present Along Pass Mountain Trail in 2010.

Non-Native Species	Form	% Presence
Avena fatua L.	Grass	<1%
Brassica tournefortii Gouan	Forb	9%
Bromus rubens L.	Grass	46%
Pennisetum ciliare (L.) Link	Grass	1%
Pennisetum setaceum (Forssk.) Chiov.	Grass	<1%
Sisymbrium irio L.	Forb	5%

Table 8

Comparison of Location Information with the Flora of UMRP and the Flora of the South Mountains Study Area.

Location Information		
	Flora of UMRP	**Flora of S. Mtn.**
Area	6,400 acres	17,920 acres
Slope Range	0% - 70%	15% - 45%
Elevation Min.	549 m	366 m
Elevation Max.	945 m	820 m
Elevation Range	396 m	454 m
Mountain Ranges	Goldfield	Ma Ha Tauk, Gila & Guadalupe
Park Est.	1967	1924
Administration	Maricopa Co. Parks & Rec.	City of Phoenix Parks & Rec.
Avg. Visitors	200,000/ yr	3,000,000/ yr
Trails	47 km	67 km

Table 9

Comparison of Number of Vegetation Types between the Flora of UMRP (2005 to 2010) and the Flora of South Mountains Study Areas (1985).

Vegetation types		
	Flora of UMRP	**Flora of S. Mtn.**
Tree	6	12
Shrub	31	84
Cactus	9	11
Forb	92	143
Vine	7	9
Grass	17	34
Fern	3	8
Aquatic	0	2
Total Species	168	287
Non-natives	16 / 9.5%	28 / 10%

DISCUSSION

Land Use Impacts

The UMRP study area does not appear to be significantly damaged or degraded in spite of its historic and current land use. There was no evidence of canals or cultivated agave from the Hohokam, more than likely due to the distance and steady incline from the Salt River to the study area. An open pit mine was observed on the Tonto National Forest northwest of Pass Mountain but it was quite shallow from filling in over the years and overgrown with native vegetation. Remnants of old roads and trails that were blocked off when the park was established are now overgrown and merge with the local vegetation. There was a relatively low density of most introduced species throughout the study area. On the Tonto National Forest side of the UMRP study a few saguaros were observed with multiple bullet holes from target shooting but the wounds appeared to be quite old and no fresh damage was observed. There is a camp area used for the Heber Reno sheep drive that is just outside of the study area to the north on the Tonto National Forest. It is approximately 30 meters in diameter and is clear of most vegetation with a few campfire rings. Just north of the UMRP study area is the Bulldog Canyon Off-highway vehicle area, but legal travel is only permitted on designated routes (USFS, 2010b); none of these trails cross over into the study area.

The lack of apparent damage to the UMRP vegetation may be due to several factors. Park visitors encountered during this study seemed quite respectful and appreciative of the surrounding desert. UMRP offers several classes and guided tours every month educating its visitors on the local vegetation and wildlife. The Maricopa County Parks and Recreation current park rules consider the damaging or removing of any of vegetation vandalism. The rules also prohibit park users from leaving designated trails (Maricopa County, 2010). UMRP employs a staff member specifically to maintain their trails by ensuring they are well marked for visitor use and to create barriers that help prevent soil erosion (Brennan Basler, UMRP Ranger, pers. com.). Many of the park trails utilize gravelly washes as part of the trail, minimizing impact on surrounding vegetation. The presence of invasive species was documented in the study area, but they are not currently a significant problem. A few potential problem species are discussed below. UMRP does not have any specific plan for invasive species control in place, but the park supervisor is very interested in learning the location and types of invasive species recorded in this study to implement preventative measures (Jennifer Johnston, UMRP Supervisor, pers. com.).

Invasive Species

Invasive species can irreversibly change natural ecosystems but a lack of historical information on their distribution makes it difficult to determine the rate of spreading (Bower et al., 2006). Floras provide a reference in space and time that can be used as a tool for future tracking of the invasive species documented within them. A total of nine introduced grasses were documented and collected in the UMRP study area and are discussed in order from the most frequently encountered to those rarely encountered during this study. A total of seven invasive herbaceous dicot species were collected and are discussed in a similar order. Only the three following invasive species were previously recorded within the study area; Red brome grass (*Bromus rubens*), London rocket (*Sisymbrium irio*) and Common sowthistle (*Sonchus oleraceus*) (SEINet, 2011).

These introduced grass species; Red brome, Arabian schismus, and Common Mediterranean grass are very common in the Sonoran desert and in the study area. These species are unlikely to be eradicated from the park, but the remaining species could be.

Red brome grass (*Bromus rubens*) is native to the Mediterranean region and is a cool season annual adapted to warm temperatures (Northam & Meyer, 2010). Red brome will germinate with less rainfall and lower temperatures than most native species require. In the Sonoran Desert, dead and dry red brome easily ignites and fuels fast moving surface fires, promoting fires in areas where fire was previously infrequent due to insufficient fuels and shortens fire return intervals (USFS, 2010a). Red brome was considered the major catalyst in the Cave Creek fire of 2005 that burned 248,310 acres approximately 56 km (35 miles) northwest of this study area (Dugan, 2010). Red brome is the most common of all invasive species throughout the study area and has a 46% presence recorded along Pass Mountain trail. It is even more abundant in some of the flatter areas of the study area.

Two species in the genus of *Schismus*, Arabian schismus (*S. arabicus*) and Common Mediterranean grass (*S. barbatus*), are native to Africa, Asia and Europe. By the 1970's they were present within all of the desert counties of Arizona (Halvorson & Guertin, 2003b). In the Lower Colorado River Valley and

Arizona Upland subdivisions of the Sonoran Desert both species are currently listed among the most abundant of annual plant species (Halvorson & Guertin, 2003b). The Desert Laboratory in Tucson, Arizona recorded *S. arabicus* and *S. barbatus* together with a 39.8% increase in their survey (Bower et al., 2006). Both species were observed throughout the current study area.

Bufflegrass (*Pennisetum ciliare*) is native to Africa, Asia, and the Middle East. It is extremely drought tolerant and reestablishes and spreads quickly after fires (Northam & Meyer, 2010). Bufflegrass was introduced in the late 1930's for erosion control and livestock forage in southern Arizona. By the 1980's it had spread to Organ Pipe Cactus national monument north of Lukeville, Arizona and the Saguaro national monument outside Tucson, Arizona (Dugan, 2010). Bufflegrass is also becoming more common further north, for example, the Tonto National Forest had a bufflegrass removal in November 2010 in Superior, Arizona (Dugan, 2010). Bufflegrass is listed as both a prohibited noxious weed (PNW) and a regulated noxious weed (RGNW) for the state of Arizona. The Desert Laboratory in Tucson, Arizona showed an alarming several thousand fold increase of bufflegrass in their study area from just a few plants in 1983 to hundred of plants along their transects in 2005 (Bower et al., 2006). This species had a 1% presence recorded along Pass Mountain trail on the east side and was observed near the roadside along the east boundary of the park.

Fountaingrass (*Pennisetum setaceum*) originated in Africa, southwest Asia, and the Middle East. Its low palatability facilitates competition with native species (Northam & Meyer, 2010). There is one large bunch of Fountaingrass growing along the roadside inside the park at the intersection of Usery Park Road and Wind Cave Drive. In addition and much more worrisome, it is growing in a wash on the opposite side of Pass Mountain above and below the Pass Mountain Trail, approximately 5 km around the trail away from any other known population. Thus, it is in a good location to invade relatively undisturbed habitat. It currently has less than 1% presence recorded on the east side of Pass Mountain, but this is likely to change. The species is increasing in other areas of Arizona as well, the Desert Laboratory in Tucson, Arizona had no Fountaingrass in their study area in 1983 but recorded it at 33 locations along their transects in 2005 (Bowers et al., 2006).

Ripgut brome (*Bromus diandrus*) is native to Europe and North Africa and is known to cause eye and nose injury to grazing animals with its long stiff awns (Whitson et al., 2006). It was only observed a few times during this study in the lower elevations of UMRP along the banks of washes and was not present along the Pass Mountain trail.

Wild Oats (*Avena fatua*) is native to Europe and can be distinguished from domestic oats by its twisted awn that bends at a right angle (Whitson et al., 2006). Seeds of Wild oats are listed as "restricted noxious-weed seed" in Arizona. This law limits the amount of Wild oats seed to 100 seeds allowed per pound in commercial planting seed (Parker & Hamilton, 1958). Wild oats had a presence of less than 1% along Pass Mountain trail and was observed occasionally along the roadside near boundaries of the study area.

Bermudagrass (*Cynodon dactylon*) is native to Africa and has become established in the warmer regions of the Southwest where it is used as lawn and pasture grass (Whitson et al., 2006). It was only observed near the roadside on the east boundary of the park along Meridian Road during this study in narrow patches one to two meters in length.

A single specimen of Sorghum (*Sorghum bicolor*) was encountered and collected from a wash near the north trailhead of Merkle Hill Trail inside the park during this study. Sorghum is a warm season, annual grain crop grown in the lower elevations of Arizona (Ottman & Olsen, 2009). A seed may have been dropped by a bird or washed down from a multi-use trail where horseback riding occurred.

London rocket (*Sisymbrium irio*) is a European native (Whitson et al., 2006). It was first collected in Arizona in 1909 and abundant in the Phoenix area in 1933 (Halvorson & Guertin, 2003c). The Desert Laboratory in Tucson, Arizona showed a 20.5% increase of London rocket in their survey from 1983 to 2005 (Bowers et al., 2006). It was observed throughout the study area and had a 5% presence along Pass Mountain trail.

Asian mustard (*Brassica tournefortii*), locally referred to as Sahara mustard, originates from the Mediterranean region, the Middle East, and North Africa. The seeds are “sticky” and are easily spread by animals, humans and vehicles. It flourishes in wet winters below 1067 km (3,500 ft) elevation (Northam & Meyer, 2010). Seeds of Asian mustard are listed as "restricted noxious-weed seed" in Arizona. This law limits the amount of *Brassica* spp. seed to 300 allowed per pound in commercial planting seed (Parker & Hamilton, 1958). The Desert Laboratory in Tucson, Arizona showed a 144% increase of Asian mustard in their survey from 1983 to 2005 (Bowers et al., 2006). Asian mustard had a 9% presence along the Pass Mountain trail, primarily on the southeastern side of Pass Mountain.

Cheeseweed mallow (*Malva parviflora*) originated from the Mediterranean region, Asia and northern Africa. It was established in California by 1824 and was present in Tucson, Arizona by 1891 (Halvorson & Guertin, 2003a). It was most often observed along washes in the study area and was not observed on the Pass Mountain Trail survey.

Redstem stork's beak (*Erodium cicutarium*) is a native of Asia and Europe that is now common world-wide (Whitson et al., 2006). It was much more common than the native Texas stork's beak (*Erodium texanum*) throughout the study area. Redstem stork's beak seemed to prefer flatter sites and was especially common in disturbed areas around picnic and restroom facilities.

Stinknet (*Oncosiphon piluliferum*), is a native to South Africa. Locally referred to as Globe chamomile, this species is very common on the west side of the Phoenix metropolitan area and is now starting to appear on the east side of the valley. This species was not encountered until the last two years of the study. One specimen was first observed and collected in April of 2008 on the east side of the study area at the trail head off of Meridian Road that leads to Pass Mountain Trail. In 2010 approximately a dozen plants were observed in the same area.

Because it is not yet common this species would be a good candidate to target for monitoring and removal with a goal of eradication.

Common sowthistle (*Sonchus oleraceus*) is native to the Mediterranean region of Africa, Europe and Asia. It requires a reasonable amount of water and is a riparian zone species but can be found in other areas during wet years (Halvorson & Guertin, 2003d). It is a winter or summer annual and harbors pests that threaten fruit and vegetable crops (Stand et al., 2010). Common sowthistle was only observed once during this study on the Tonto National Forest near Usery Pass Road and the fence that borders UMRP.

The African Daisy (*Arctotis stoechadifolia*) is a native of South Africa and it has naturalized throughout much of the southwest. It is commonly used as an ornamental plant (USDA, 2010). Only two were encountered and collected during this study. This species is new to Arizona; it is not recorded in the Flora of Arizona nor is it mentioned in the supplement (Kearney & Peebles, 1960). However, this species has been collected near Ajo, AZ and in Tucson, AZ (SEINet, 2011).

Species of Interest

There are several native species collected during this study that were only observed once and listed as rare in the study area. Only the three following rare species were previously recorded within the study area; starry bedstraw (*Galium stellatum*), brittlestem (*Mabrya acerifolia*) and fringed amaranth (*Amaranthus fimbriatus*) (SEINet, 2011). The four following species were located on the northern side of Pass Mountain. Wright's beebush (*Aloysia wrightii*) was only observed during this study alongside the Pass Mountain trail (collected August, 2006). At low elevations Wright's beebush grows on the northern slopes while at higher elevations it prefers the southern slopes (Kearney & Peebles, 1960). Miner's lettuce (*Claytonia perfoliata*) was located under the edge of a large boulder that protruded out over the trail on the north side of Pass Mountain (collected April 2008). Its range covers the western United States and in Arizona it is often found in moist hollows (Miller, 1978). Parish's larkspur (*Delphinium parishii*) was only observed in flower once during the time of the study after substantial rains in the spring of 2010. Starry bedstraw (*Galium stellatum*) was also located in a shaded area of the Pass Mountain trail (collected April 2006). These four species represent elements of a more northern or higher elevation flora and so were found only in wetter years and/or in the more mesic habitats of the study area.

Another species listed as rare was found on the southwest side of Pass Mountain. A single shrub of Rough mendora (*Menodora scabra*) was observed on the southwest side of Pass Mountain about two thirds of the way up the slope along the Wind Cave trail, just below the stripe of light colored tuff. The range of Rough mendora extends from northern Mexico up through southern Utah and Nevada from 1,500 to over 6,000 ft elevation (Kerney & Peebles, 1960) but this species is likely to be found at more northern latitudes or higher elevations to the south. It was found along a section of the trail where it is in shadow morning and evening.

Brittlestem (*Mabrya acerifolia*) is a species of special interest at UMRP and grows in the Wind Cave itself. Plants with small cream colored flowers grow suspended from the roof and walls of the cave. This is its only location in the UMRP study area and it is believed to be at the west end of its range (SEINet, 2011). There are only a few populations of Brittlestem recorded within its small range in central Arizona (Elisens & Crawford, 1988). The nearest specimens were collected in the Superstition Wilderness area which is located approximately 10 km (6.2 miles) to the east of UMRP study area while farthest specimen recorded was collected in Pinal county near Superior, Arizona approximately 55 km (34 miles) to the east of UMRP study area (SEINet, 2011). All known populations occur on north and east facing cliff and canyon walls where shade and water seepage are common (Elisens & Crawford, 1988). Brittlestem specimens from the Superstition Wilderness area were collected from rock face in shaded areas and canyons (SEINet, 2011), thus the habitat for the species is similar in both locations. It was not recorded in the flora of the South Mountains (Daniel &Butterwick, 1992).

The remaining uncommon species were all located within UMRP in generally flat areas in habitats that are uncommon in the study area. The fringed amaranth (*Amaranthus fimbriatus*) was found in the gravel parking lot of the horse staging area under a tree the first spring of the study (May 2005). Repeated trips were made to the area each year until 2010 but it was not observed again. Woolly tidestromia (*Tidestromia lanuginosa*) was located along a trail in a small sandy area. Sandy soil is not typical for the study area which is mostly composed of decomposed granite. Fourwing saltbush (*Atriplex canescens*) and Rose globemallow (*Sphaeralcea ambigua* ssp. *rosacea*) were located only a few meters away from each other on top of the levee bank which runs along the south side of the UMRP. The levee runs east and west parallel with McKellips Road to capture and divert runoff from entering the residential area just south of UMRP and McKellips Road. Fingerleaf gourd (*Cucurbita digita*) vine was found in a wash just north of the levee.

Comparison with the Flora of South Mountains

The flora of the South Mountains study area contains the mountain ranges of Ma Ha Tauk, Gila and Guadalupe (Table 8) which are comprised of both metamorphic and igneous rock. They are within the lower Colorado valley subdivision of the Sonoran desert. The UMRP and the Goldfield mountain range that includes Pass Mountain is 38 km (24 miles) northeast of the South Mountain study area, is comprised of igneous rock and lies within the Arizona upland subdivision of the Sonoran desert. There are 14 families in the South Mountain flora not represented at the UMRP study area including; Aizoaceae, Burseraceae, Campanulaceae, Gentianaceae, Juncaceae, Martyniaceae, Orobanchaceae, Primulaceae, Rhamnaceae, Salicaceae, Simaroubaceae, Sterculiaceae, Tamaricaceae, and Typhaceae. Major washes within the South Mountains flora area contained two wetland species *Prosopis velutina* and *Populus fremontii* in spite of an absence of perennial streams. Several other riparian species documented in the South Mountains flora were not present in the current study area such as *Tamarix ramosissima, Juncus bufonius, Samolus valerandi* and

Typha domingensis. High numbers of non-native species present at the South Mountains were considered to be due to proximity to major urban and agricultural regions (Daniel & Butterwick, 1992).

Both floras share the same families of Asteraceae, Poaceae, Fabaceae and Boraginaceae with the largest number of species (Figure 12). However, the largest differences between families represented in both locations are as follows: Chenopodiaceae with only one species at UMRP and eight in the South Mountain flora; Malvaceae with six species at UMRP and 11 in the South Mountain flora; and Solanaceae has four species at UMRP and 13 in the South Mountains flora. However, UMRP included some species which were not present in the South Mountain flora such as *Aristolochia watsonii* and *Simmondsia chinensis* for example.

The South Mountain flora study area contains habitats which support wetland species and has a lower elevation overall the than UMRP study area. These factors combined with the metamorphic along with igneous parent material of the soil may contribute to the larger variety of vascular plant species at the South Mountain flora study area than that present at the UMRP study area.

Comparison of the UMRP flora with other floras of southern and central Arizona would also be of interest. To the north the Arizona Uplands subdivision transitions into the interior chaparral community of Arizona and a detailed comparison between the flora of UMRP and the flora of Mount Ord (Price, 2008) would be of interest, investigating the difference in species and vegetation composition at a somewhat more northern latitude and a higher elevation.

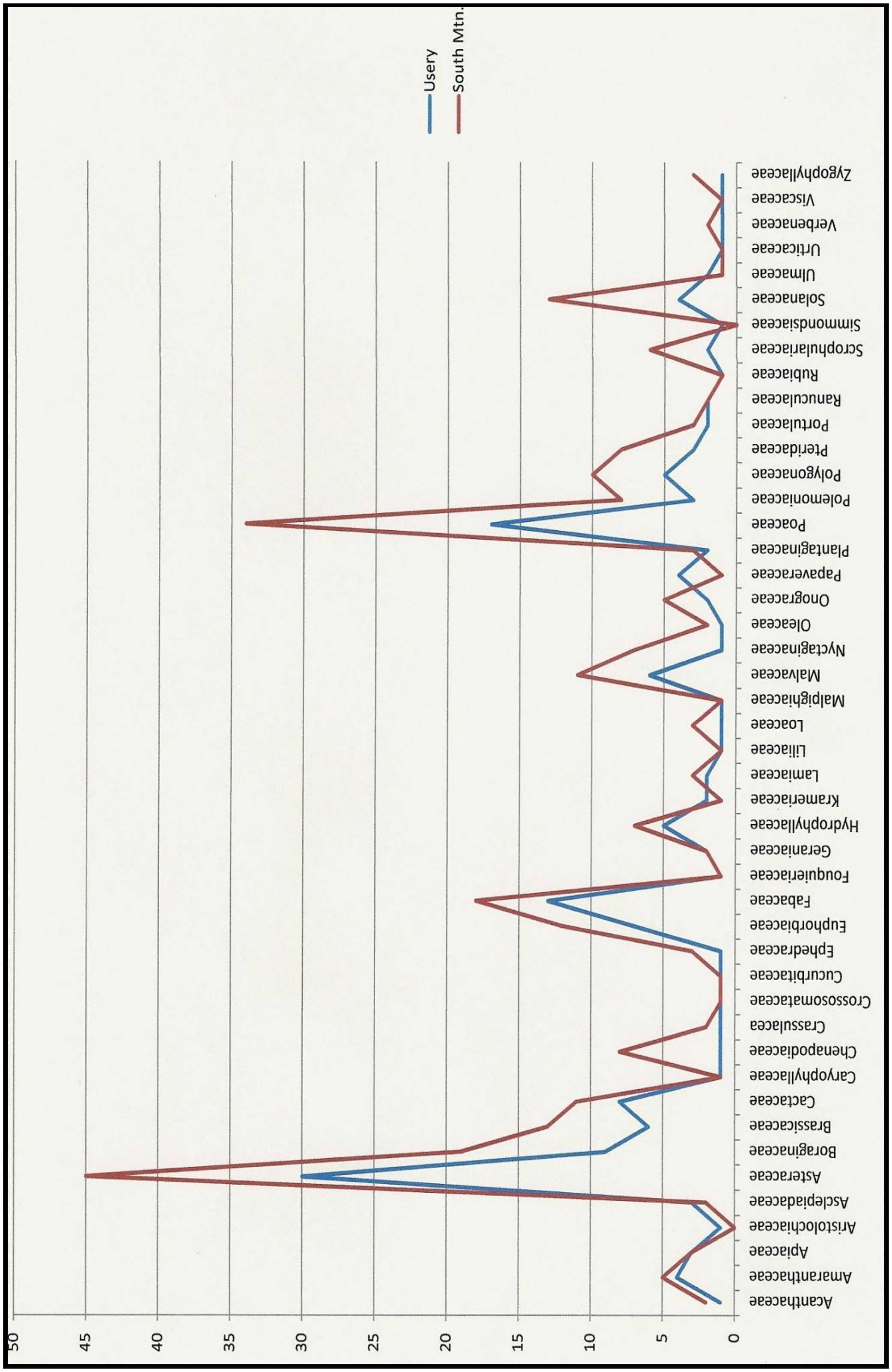

Figure 12. Comparison of Vascular Plant Families Between the Flora of UMRP (2005 to 2010) and the Flora of South Mountains (1985).

CHAPTER 2

DISTRIBUTION OF SAGUARO (CARNEGIEA GIGANTEA) ON PASS MOUNTAIN IN SOUTHERN TONTO NATIONAL FOREST

INTRODUCTION

Saguaro (*Carnegiea gigantea* [Engelm.] Britton & Rose)

The saguaro, a large columnar cactus, is the largest cactus in the state of Arizona, capable of reaching a height of more than 15 meters (50 ft) with as many as 50 arms branching from its erect truck (Kearney & Peebles, 1960). The saguaro is considered a keystone species of the Sonoran Desert due to its importance in the ecosystem with many species of insects, birds and mammals relying on it for survival (Danzer & Drezner, 2010). The Sonoran Desert is shaped by its climate with bi-seasonal winter and summer precipitation separated by spring and fall drought periods that result in drought adapted flora and fauna (Brown, 1982). The drought-tolerant saguaro is a massive succulent (Nobel, 1980) with a great capacity for water storage. It requires soils that are well drained (Kearney & Peebles, 1960). Historically the saguaro provided subsistence for the Pima and Papago Indians as a food source with its fruit eaten fresh or preserved and the seeds ground into a type of butter while the ribs of the saguaro were used as shelter materials (Kearney & Peebles, 1960). Today the saguaro is protected and the Arizona Department of Agriculture requires the purchase of a Blue Seal Permit for moving or salvaging any saguaro over four feet tall on private as well as public lands (ADA, 2011).

Saguaros are located within the Sonoran Desert from sea level up to approximately 1,220 m (4,000 ft) in elevation but do not grow in all parts of the Sonoran Desert. They range from central Arizona down through the arid portions of Sonora, Mexico (Figure 13) and marginally in southeastern California (Kearney & Peebles, 1960, Turner et al., 1966). In Arizona they are best represented in the Arizona Upland subdivision (Figure 14) but are also present in the Lower Colorado Valley subdivision (Brown, 1982).

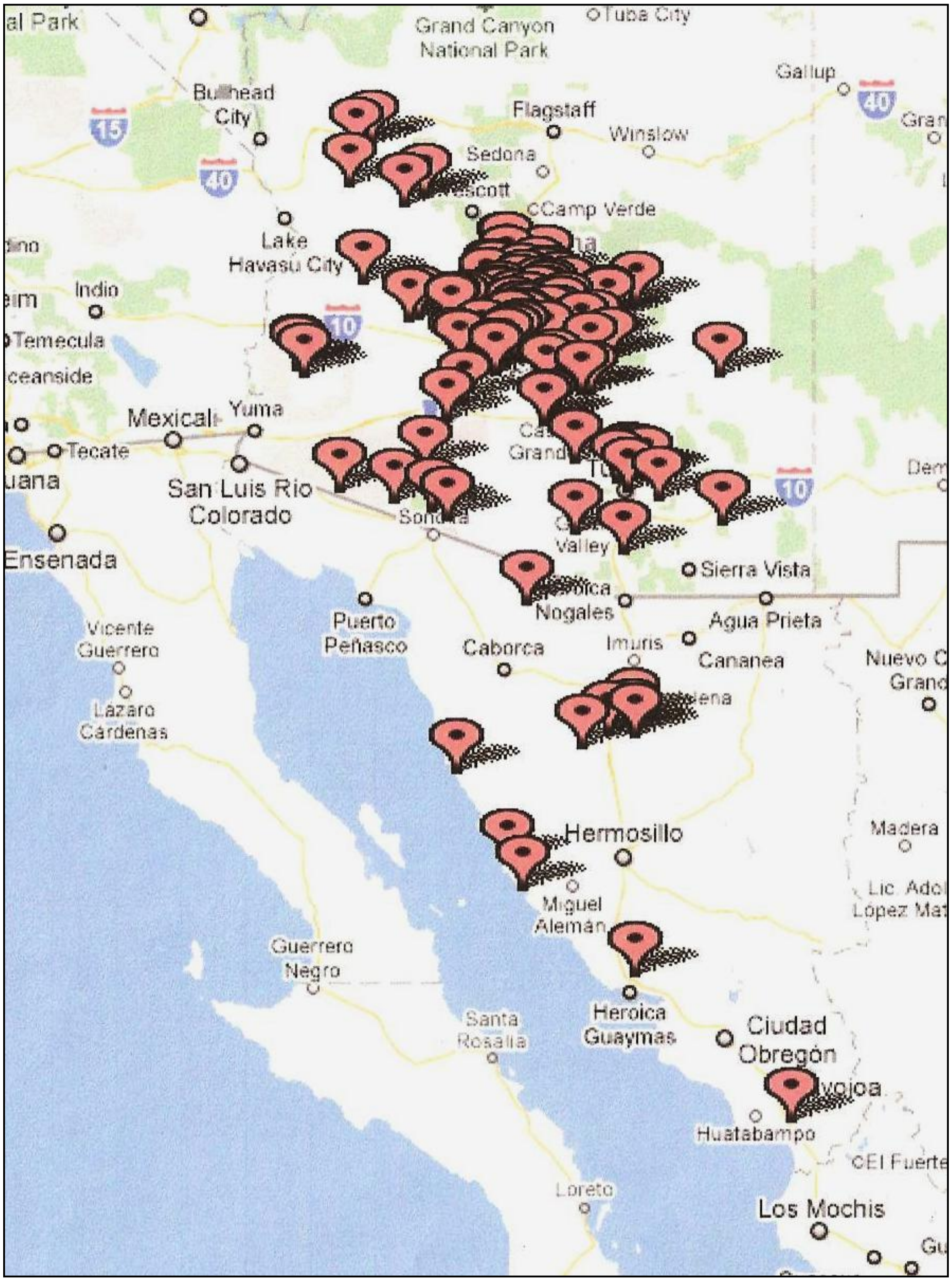

Figure 13. Map of Saguaro Distribution Created by SEINet with Markers Linked to Saguaro Specimens That Have Been Collected and Documented (2011).

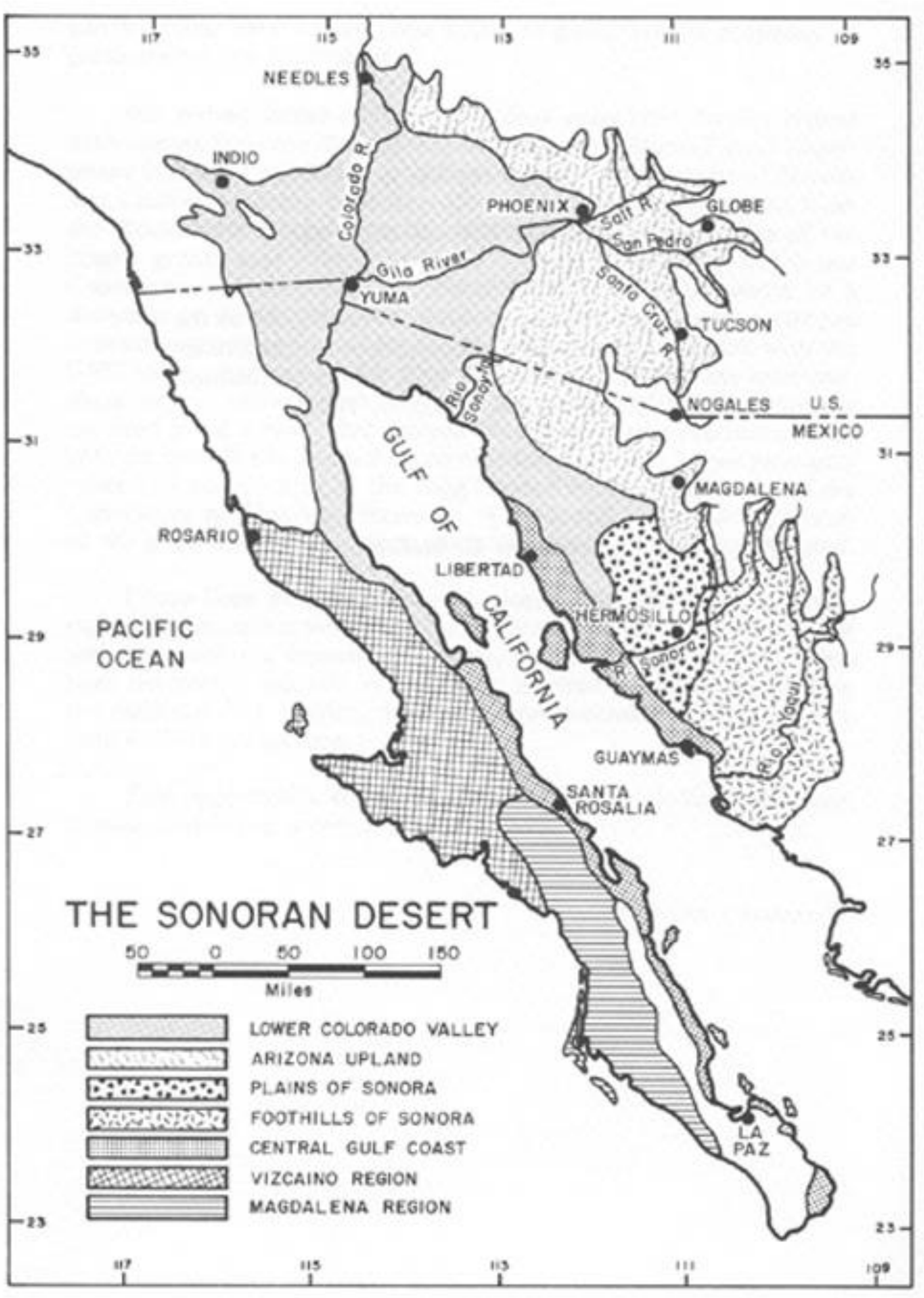

Figure 14. Map of Sonoran Desert Subdivisions (Shreve, 1951).

In Mexico saguaros are present in the Arizona Upland, Lower Colorado Valley and into the Central Gulf Coast subdivision along the eastern coast of the Gulf of California but do not grow in the Baja California portion of the Sonoran Desert. In the Vizcaino Region of the Baja California Peninsula the large columnar cactus Cadon (*Pachycereus pringlei*) takes the place of the Saguaro (Brown, 1982).

Brown (1982) mapped and defined the biotic communities of the American Southwest in the United States and Mexico and noted that while there is climatic variation throughout the Sonoran Desert, a unifying factor is the short duration of freezing temperatures. The saguaro is listed as one of the dominant perennial species within the Sonoran Desertscrub biotic community. Its distribution is influenced by both temperature and precipitation (Drezner, 2008). Its range is confined to arid portions with bimodal rainfall within Arizona, California and Mexico (Turner et al., 1966). In the northern Sonoran Desert average winter temperatures lower as Sonoran Desertscrub transitions to a chaparral community and the saguaro drops out. In the southern Sonoran Desert the vegetation increases in density and stature until it merges with the tropical biome of Sinaloan Thornscrub where summer storms dominate with increased precipitation (Brown, 1982) and the arid climate required by the saguaro is no longer present. These saguaros at the southern end of their range tend to favor north facing slopes, perhaps they create a rain shadow effect that block some of the precipitation from the storms moving up from the equator. To the east Sonoran Desertscrub merges with semidesert grasslands and Chihuahuan

Desertscrub where precipitation also increases and mostly occurs in the summer (Brown, 1982), but the saguaro disappears as night time temperatures drop below freezing almost one third of the year because most of it lies above 1,220 m (4,000 ft) elevation (CDRI, 2011). To the west precipitation decreases and mostly occurs in the winter while temperatures remain high and succulents including the saguaro are replaced with drought deciduous shrubs and annuals (Gurevitch et al., 2002). In Arizona the saguaro is at the northern end of its range and they favor south-facing slopes while further south into Mexico, at the southern end of the saguaro's range, they are found primarily on north-facing slopes (Cohn, 1996). Studies conducted in the early 1900's at the Desert Laboratory on Tumamoc Hill in Tucson, Arizona reported the saguaro's strong preference for south-facing aspects (Peirson & Turner, 1998). Aspect is known to affect soil temperature and moisture, for example, a study conducted on mountains of southwestern Texas recorded soil temperatures up to 20^0 F warmer at depths of two inches on south-facing slopes than on north-facing slopes (Hasse, 1970).

The saguaro is particularly limited by freezing temperatures during establishment and throughout its life (Drezner, 2007). Frost damage can occur on saguaros in the northern latitudes of their distribution and those at high-elevations in more southern latitudes (Nobel, 1980). Freezing events are the greatest threat to the survival of the saguaro during the first critical years and can drastically thin the population (Drezner, 2008). Nobel (1980) suggested that low temperature extremes have a limiting effect on saguaro recruitment and growth at the northern extents of their distribution. One way to help prevent frost injury to the apical meristem of the saguaros may be to increase diameter of the mature stems (Nobel, 1980). Observations have indicated that the diameters of mature stems on saguaros increase toward the northern part of its range. At a central Arizona location (33.56^0 N, 112. 55^0 W) the average mid-height diameter of saguaros was 41.0 cm. At a southern Arizona location near Tucson (31.97^0 N, 112.80^0 W) the average mid-height diameter of saguaros was 36.2 cm (Nobel, 1980).

Saguaro establishment often occurs beneath desert trees and shrubs, termed nurse plants, and not in the open areas between woody plants (Turner et al., 1966). The canopy of a nurse plant provides a microhabitat with reduced day time temperatures in the summer and increased night time temperatures in the winter (Drezner, 2007) which extends the northern range of saguaros (Drezner & Garrity, 2003). The shade induces more favorable soil temperatures and lower transpiration rates (Turner et al., 1966). Once the cactus grows large enough it no longer requires the protection of the nurse plant and often displaces the tree or shrub by outcompeting it for water (Gurevitch et al., 2002).

An uneven distribution among size classes within a saguaro population suggests that establishment occurred in pulses (Godinez-Alvarez et al., 2003). Regeneration does not occur evenly every year, but only in years with the right conditions (Drezner, 2004). Favorable conditions for germination and establishment require the right combination of precipitation and temperature (Godinez-Alvarez et al., 2003). Saguaros establish during summer rain seasons which provide adequate amounts of precipitation and reduced temperatures due to cloud cover (Drezner, 2004). A saguaro population structure in which the number of individuals decreases with increased age suggests a growing populations with constant regeneration (Godinez-Alvarez et al, 2003). A saguaro population near Tucson, Arizona exhibited decline from the 1800s up to early 1900s but current records show it to be recovering (Drezner, 2006).

As saguaros age the growth rates varies from one population to the next based primarily on the water availability of their location (Drezner, 2008). However, the shape of the growth curves remains similar between different populations (Drezner, 2003). A study conducted by Drezner (2008) compared four different populations of saguaro within Arizona to determine the height at which reproduction occurs. In the Usery Mountain area, just east of the study area for the current research, with an average annual precipitation of 20.1 cm (7.9 inches) (WRCC, Falcon Field #022927) the average height at which the saguaro began producing flowers was 2.73 meters at an average age of 80 years old (Drezner, 2008). On the other hand in Saguaro National Park near Tucson with a higher average annual precipitation of 32.5 cm (12.8 inches) (WRCC, Tucson 17 NW #022927) the average height at which flower production began was only 2.44 meters with an average age of 52 years old (Drezner, 2008). The average life span of the saguaro is 125 – 175 years with the potential to live over 200 years (Pierson & Turner, 1998).

Current Study

This study was conducted to determine the influence of aspect upon the density and height distribution of saguaro (*Carnegiea gigantea*) populations in central Arizona. An earlier study conducted by Pierson and Turner (1998) near

Tucson, Arizona has shown that the relative abundance of saguaros is higher on south and east aspects. Data collected by Pierson and Turner (1998) indicated that aspect strongly influenced recruitment and survival of young saguaros. My hypothesis is that the distribution and abundance pattern of saguaro found in the Pass Mountain study area, located in the southern portion of Tonto National Forest in central Arizona, will be similar to that reported by Pierson & Turner (1998).

MATERIALS AND METHODS

Study Area

The study area is located within the Tonto National Forest section of the UMRP study area and is exclusive to the area around Pass Mountain and is within the northern part of the range of the saguaro (Figure 15. Boundary of the Pass Mountain Study Area Within the UMRP used for the Evaluation of Saguaro Distribution (2009 to 2010).). It falls between the latitude boundaries of 33.4909^0 N to the north and 33.4689^0 N to the south with the longitude boundaries of 111.6042^0 W to the west and 111.5868^0 W to the east. It is comprised of approximately 2560 acres (4 square miles) with a maximum elevation of 945 m (3,100 ft) to a minimum of 658 m (2,159 ft).

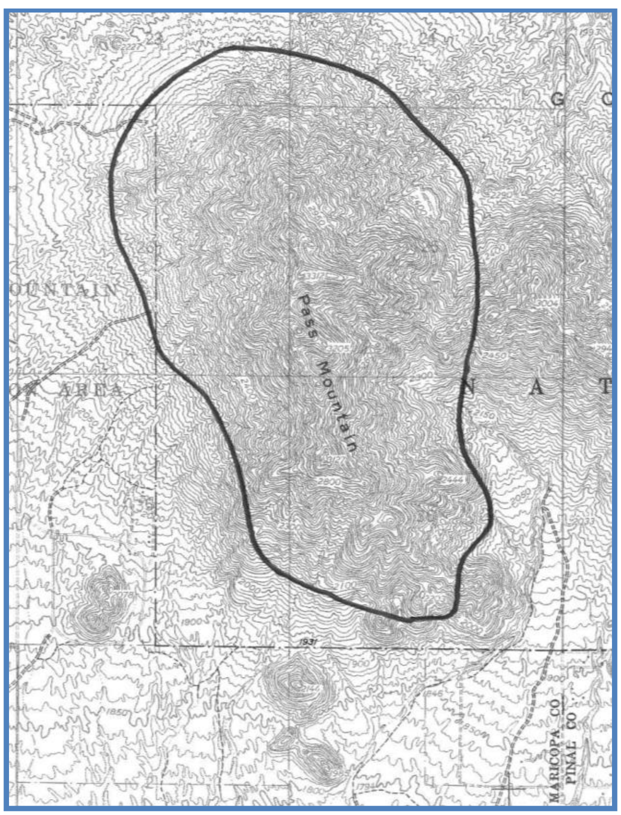

Figure 15. Boundary of the Pass Mountain Study Area Within the UMRP used for the Evaluation of Saguaro Distribution (2009 to 2010).

Climate

Weather at Pass Mountain study area can be estimated by comparison of information from four weather stations in the surrounding area with the minimum average annual temperature, minimum average temperature of January (the coldest month) and the mean annual precipitation **(**Table 10).

Table 10

Thirty Year (1971-2000) Minimum Average Temperature and Mean Annual Precipitation of the Pass Mountain Study Area (WRCC, 2010).

Station	Distance/Direction From Study Site	Min. Avg. Annual Temp.	Min. Avg. Jan. Temp.	Mean Annual Precipitation
Granite Reef	5.5 mi/Northwest	54.1 F	38.2^0 F	9.1”
Stewart Mtn.	6.5 mi/Northeast	53.8^0 F	37.6^0 F	12.5”
Apache Junction	6.0 mi/East	57.3^0 F	42.2^0 F	12.3”
Falcon Field	8.5 mi/Southwest	50.5^0 F	34.9^0 F	7.9”

Sample Point Identification

Using ArcGIS (version 9.3.1) software Pass Mountain was masked out from the Tonto National Forest portion of the study area. An initial 200 random points on Pass Mountain were identified using a random location generator in ArcGIS. From this dataset, 50 locations, homogenously distributed across all available aspects, were selected to extract information on slope and aspect using the surface analysis tools based on a digital elevation model (DEM) input layer (Figure 16). Stein’s two-stage test was used to determine the sample size required for testing the spatial variation of saguaro density and fifty plots was found to be adequate.

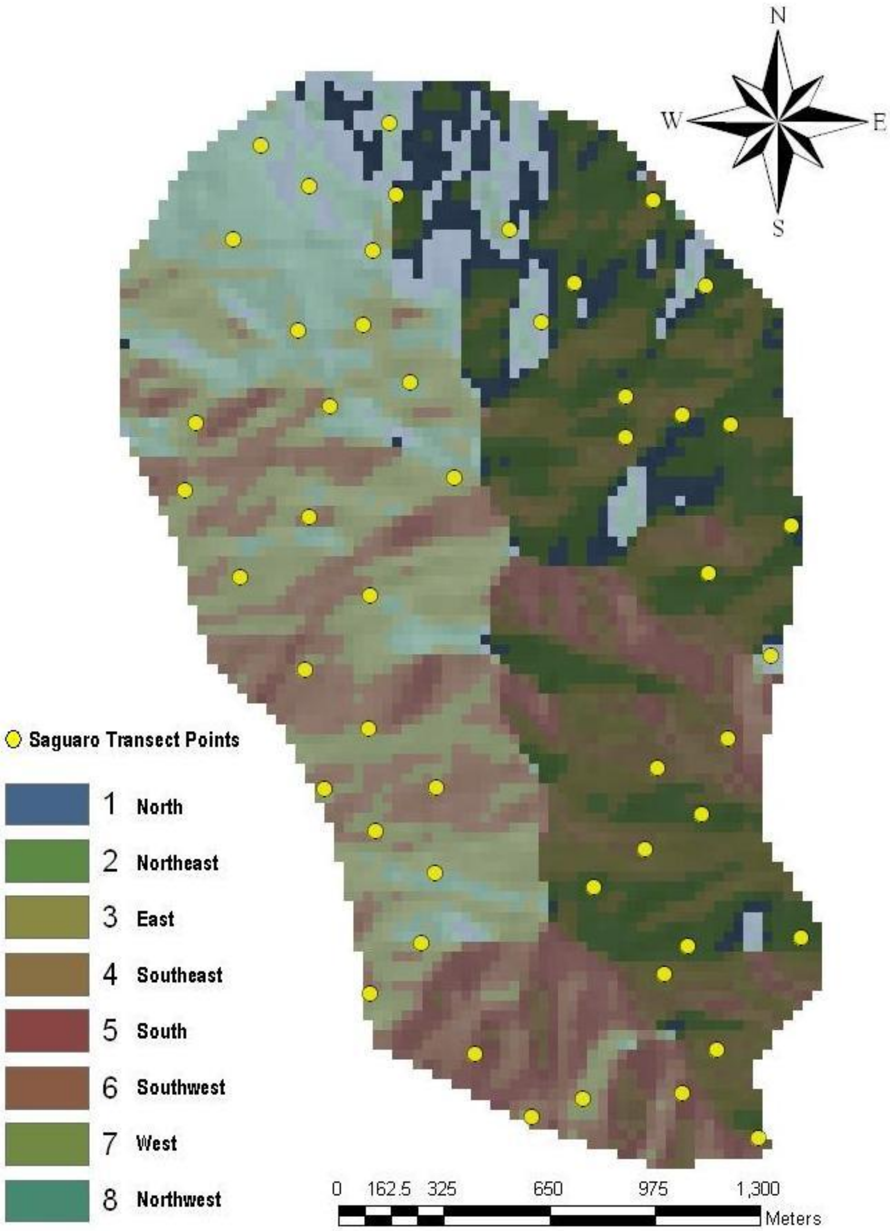

Figure 16. ArcGIS Map of the 50 Random Points for the Saguaro Plots Joined With an Aspect Layer of the Pass Mountain Study Area.

Location of Plots

Each of the 50 points were located in the field using a Magellan Meridian Gold GPS unit based on the UTM coordinates of the point. If a specific point was inaccessible it was replaced from a list of alternative points to maintain the 50 point sample size. At each field location a randomly oriented 0.5 ha (50m x 100m) plot was established centered on the point. The direction of the plot was determined using the second hand on a watch with 12 equivalent to north, and six to south. The width of the plot was established by stretching a 25 m piece of nylon rope perpendicular to the long axis of the plot. From each side of the point a flag was placed to mark the width of the plot. Next, using the compass for accuracy, the 25 m rope was stretched from the point and marked. This process was repeated three more times to measure out the 100 meter length of the plot. The flags marking the 50 meter width were moved as needed to keep the boundaries in sight. The slope of the plot was measured with a clinometer from the initial point in the direction recorded from the compass. All information was recorded on a whiteboard and placed as a maker in a photo point for each of the 50 plots (Figure 17).

Figure 17. A Photo Point of a Saguaro Plot Located on the West Side of Pass Mountain Taken on April 17th 2009.

Field Data Collection

All saguaro cacti within each plot were counted and the height estimated in meters. The nearest shrub, tree or cactus was recorded along with its estimated height, width and distance from the saguaro. Dead saguaro were also noted within each transect to determine if the population is increasing or declining, but the plant nearest to those saguaros was not recorded. The dead saguaros were included in the total saguaro counts of each plot. The collected information listed above was uploaded into ArcGIS and attached to each corresponding point to determine the influence of slope and aspect upon the density and size class distribution of the saguaro population of Pass Mountain. Any noticeable scars on saguaros hypothesized to be due to fire or significant landmarks within each transect were noted but that information was not uploaded into ArcGIS.

GIS Derived Data

The information recorded for the plot at each of the 50 points was uploaded into ArcGIS to create a shapefile layer. This shapefile of the 50 points was then joined with a digital elevation map (DEM) of the Pass Mountain study area (Fig 16). Slope and aspect distribution within the Pass Mountain area were derived from the DEM using ArcGIS surface tools. Slope, aspect and elevation were then joined to each of the saguaro sample locations. This data derived from ArcGIS was then used to determine saguaro habitat preference based on these physical parameters. Due to the orientation of canyons and ridges it was possible to have a point with a southwest aspect on the north side of Pass Mountain.

Statistical Analyses

For calculations and for display of results, aspect was divided into eight cardinal directions (clockwise from north, northeast, east, southeast, south, southwest, west, and northwest). Saguaro height was estimated in 0.25 m increments out in the field and converted into size classes for analysis. Eight size classes were created with saguaros less than 2 m for the first class of <2 m, 2 m up to 3.75 m for the second class of 2 m, up through 14 m and greater in the last class of 14 m. Saguaro counts per 0.5 ha. (50 m x 100 m) were converted into density (saguaros/ha). The hypothesis of no differences in the distribution of saguaro as influenced by aspect, elevation or slope within the Pass Mountain study area was tested using chi-square likelihood analysis (Zar, 2006). Any significant chi-square values were further analyzed using test of proportion analysis to determine the nature of that significance (Zar, 2006). Observed values for these analyzes were based on the count of the number of individuals observed within each category of aspect, elevation and slope (n=647). The expected values were based on the availability of each category as derived from surface analysis of the elevation data using ArcGIS. The sample size for the expected for all three traits were based on the number of 30m x 30m cells within the Pass Mountain study area (n=5640).

The densities of saguaro as influenced by size class and aspect were investigated using the hypothesis that aspect and/or size class had no influence in saguaro density within the Pass Mountain study area. This hypothesis was tested using a two factor factorial analysis of variance with aspect and size class as the factors (Zar, 2006). In the event of a significant F-value, significant means were identified using a Tukey's mean separation test (Zar, 2006). All analyzes were performed at P=0.05 using R (version 2.11.1) statistical computing software.

RESULTS

Using chi-square analysis the locations of the 647 live saguaros recorded in this study were compared with the 5640 points of available habitat to determine habitat suitability based on aspect, elevation and slope (Table 11). Saguaro were found in numbers significantly greater than expected on southwest and west aspects, while in significantly fewer numbers than expected on northwest, north, east and south aspects and in numbers equal to expected on northeast and southeast aspects. Saguaros were present in numbers greater than expected at elevations of <660m and from 700 to 740 m, for elevations 660 to 700 m and 740 to 780 m, observed numbers were equal to expected, and for elevations >780 fewer were observed than expected. Slopes with $<15^{0}$ of slope had significantly greater numbers than expected, while slopes of $15\text{-}30^{0}$ were as expected, and slopes $>30^{0}$ had significantly fewer saguaro than expected (Table 11).

The 2-factor factorial analysis of variance was performed to look at the saguaro distribution on Pass Mountain as a function of both aspect and size class. The model was highly significant among aspects in the distribution of the Pass Mountain saguaro population. There was no significant difference among the size classes of the saguaro population based on aspect.

Table 11

Chi Square Test of Saguaro Habitat Suitability Based on Aspect, Elevation and Slope for the Pass Mountain Study Area.

Aspect	# of Saguaros	Available Habitat	Z Value	Habitat Suitability
N	9%	11%	1.35395	NS
NE	10%	16%	3.88297	Unsuitable
E	8%	13%	3.25135	Unsuitable
SE	16%	7%	8.00742	Suitable
S	13%	8%	4.15586	Suitable
SW	20%	15%	3.40131	Suitable
W	11%	19%	4.72802	Unsuitable
NW	13%	12%	0.39347	NS
			Total Chi Sqr = 159.6632	

Elevation (m)	# of Saguaros	Available Habitat	Z Value	Habitat Suitability
< 660	3%	1%	8.03091	Suitable
660-680	2%	3%	2.38457	NS
680-700	18%	17%	0.02474	NS
700-720	35%	15%	13.14438	Suitable
720-740	16%	11%	3.87306	Suitable
740-760	6%	9%	2.09801	NS
760-780	9%	7%	1.88354	NS
>780	9%	37%	13.29972	Unsuitable
			Total Chi Sqr = 360.4199	

Slope (%)	# of Saguaros	Available Habitat	Z Value	Habitat Suitability
< 5	17%	7%	8.43376	Suitable
5-10	13%	21%	4.54028	Unsuitable
10-15	29%	17%	7.39981	Suitable
15-20	15%	13%	0.93539	NS
20-25	10%	13%	2.18217	NS
25-30	13%	11%	1.71782	NS
30-35	2%	8%	5.65874	Unsuitable
35-40	0%	6%	6.13510	Unsuitable
40-45	2%	3%	1.38199	NS
> 45	0%	2%	3.13761	Unsuitable
			Total Chi Sqr = 256.1721	

The average density (saguaros/ha) in each of the eight size classes for each aspect are listed below (Table 12). The last column is the average density (saguaros/ha) of all size classes that were recorded for each aspect. The overall saguaro population of Pass Mountain shows that the smaller saguaro size classes have the largest number of individuals, and that there are smaller numbers of individuals in the larger size classes.

Table 12

Mean Density (Saguaros/ha) by Size Class per Aspect in the Pass Mountain Study Area (2009 to 2010).

Aspect	<2m d/ha	2m d/ha	4m d/ha	6m d/ha	8m d/ha	10m d/ha	12m d/ha	14m d/ha	Total d/ha
N	4.50	5.50	2.00	2.00	4.00	1.50	0.50	0.00	**20.00**[c]
NE	5.82	4.00	3.28	4.36	2.54	0.72	0.18	0.18	**21.10**[c]
E	4.34	2.34	3.34	3.34	3.00	0.66	0.34	0.00	**17.34**[c]
SE	9.34	6.00	3.34	4.66	2.00	5.34	0.66	1.34	**32.66**[a]
S	9.00	7.00	2.00	4.00	4.00	1.00	0.00	2.00	**29.00**[a]
SW	9.00	4.34	5.34	8.00	7.34	4.34	1.34	3.00	**42.66**[a]
W	6.14	4.72	6.42	3.00	2.28	1.86	0.42	0.58	**25.42**[b]
NW	4.00	8.00	6.50	3.00	3.00	1.50	0.50	1.00	**27.50**[b]
Size Class Totals	**52.1**[d]	**41.9**[e]	**32.2**[f]	**32.4**[f]	**28.2**[g]	**16.9**[h]	**3.9**[i]	**8.1**[j]	

a-c values in rows with the same letter are not significantly different at $P \leq 0.05$.
d-j values in columns with the same letter are not significantly different at $P \leq 0.05$.

DISCUSSION

The saguaros on Pass Mountain were more abundant on the southern aspects just as Pierson and Turner (1998) found for populations in the northern part of the saguaro range. But unlike the study in Tucson where saguaros also favored east aspects (Pierson &Turner, 1998) the saguaros at Pass Mountain had a significantly larger presence on the western aspects than the eastern (Table 12, Figure 18).

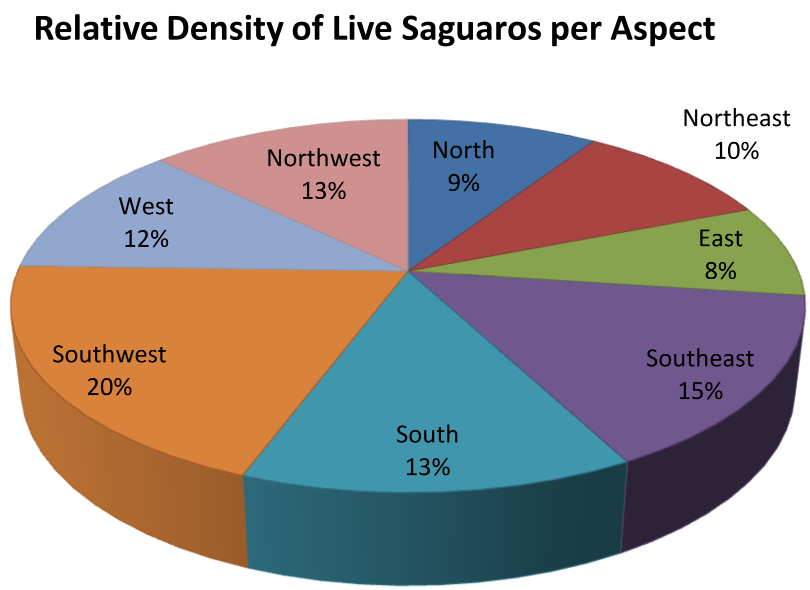

Figure 18. Relative Density (Saguaros/ha) of Live Saguaros per Aspect Within the Pass Mountain Study Area During 2009-2010.

In this study there is no significant variation among saguaro size classes by aspect, but the overall age structure of the Pass Mountain saguaro population suggests a growing populations with constant regeneration (Godinez-Alvarez et al, 2003). The relatively large numbers of saguaros recorded in the smaller size classes (Table 12) indicate recruitment is continuing in the Pass Mountain study area. Saguaro populations that show a large spike among the youngest individuals are considered healthy and growing (Drezner, 2004). Figure 19 illustrates the monotonic decrease of the size class distribution in the Pass Mountain saguaro population.

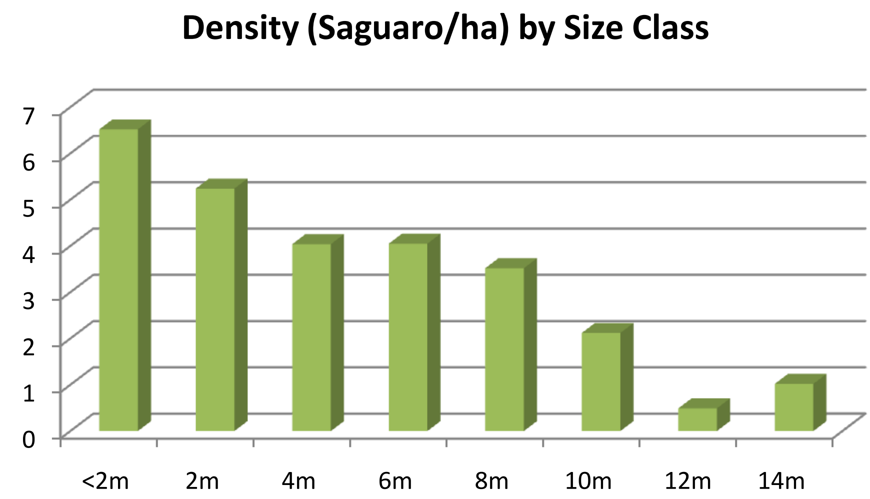

Figure 19. Saguaro Density (Saguaros/ha) by Size Class in the Pass Mountain Study Area 2009-2010.

At the Pass Mountain study area there are less than expected number of saguaros on the north facing aspects (Table 12). Yet, on the mountains further south around Tucson, Arizona it has been observed that the north facing aspects had significantly fewer saguaros than the north facing slopes of Pass Mountain. The distribution at Pass Mountain is similar to that expected from populations closer to the middle of the saguaro range rather than the northern part of the range which includes all populations in Arizona. For example, saguaros are visibly denser on the south slopes than on the north facing slopes of the mountains near Tucson, Arizona with an elevation around 732 m (2,400 ft) approximately 188 km (118 miles) south of the study area. The average lows in Tucson are in the 30 F^0

range from November through March with a minimum average annual temperature of 51.2^0 F (WRCC, Tucson #028796). Northern slopes would be more prone to prolonged freezing temperatures reducing the establishment of young saguaros. Saguaros are limited to elevations and latitudes where freezing temperatures do not persist for 24 hours (Nobel, 1980) and mean annual temperature typically declines with increased latitude (Molles, 2005). Although Pass Mountain is further north in latitude than Tucson, the lower elevation at the base of Pass Mountain of 549 m (1,800 ft) creates a milder climate with a minimum average annual temperature in the mid 50^0 F range. January is the only month to have a minimum average temperature in the 30^0 F range (Table 10) allowing the saguaro to germinate and survive on a larger variety of aspects than the study area near Tucson, Arizona.

The northern range of the saguaro was further considered by graphing the elevation of cities in Arizona from the border of the United States and Mexico north and noting the location and elevation of the study area (Figure 20). Cities were used because they are known locations and their elevations are easy to obtain. Just north from the border of the United States and Mexico Nogales is at 1,085 m (3,560 ft) then the elevation steadily decreases to approximately 372 m (1,220 ft) in Chandler, which located about 25 km (15 miles) southwest of the study area. At the southern base of Pass Mountain, elevation rises from the valley to 549 m (1,800 ft) then rise to 945 m (3,100 ft) at the peak of Pass Mountain. In Fountain Hills, approximately 20 km (12 miles) north of the study area, the elevation decreases to 489m (1,604 ft) then increases to approximately 1,150 m

(3,771 ft) in Sunflower which is located near the northern limit of the saguaro range. The variation of Arizona elevation could potentially produce a variation of habitat suitability based on the parameter of aspect among the northern saguaro populations.

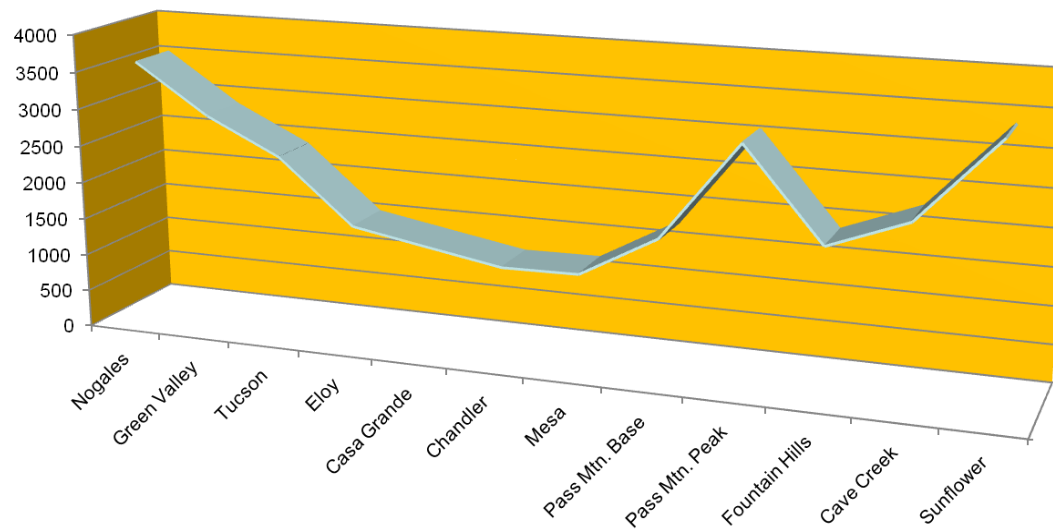

Figure 20. Elevation in Feet of Cities from the Border of the United States and Mexico North into Central Arizona.

The relative density, saguaros/hectare, of dead saguaro per aspect (Figure 21) closely matched the relative density of live saguaro per aspect (18) indicating that the distribution of the saguaro population by aspect has remained somewhat consistent on Pass Mountain for well over a hundred years. Dead saguaros are more abundant on the southern aspects but had a stronger presence on the eastern aspects than the current living population. Dead saguaros averaged an overall density of 2.20 in the Pass Mountain study area with the highest presence on southwest aspects at a density of 4.34 and the lowest presence on north aspects at a density of 0.50. Winter rains in the spring of 2010 saturated the ground and were followed by strong wind gusts after which I observed a number of large saguaros that went down in the study area during the spring of 2010.

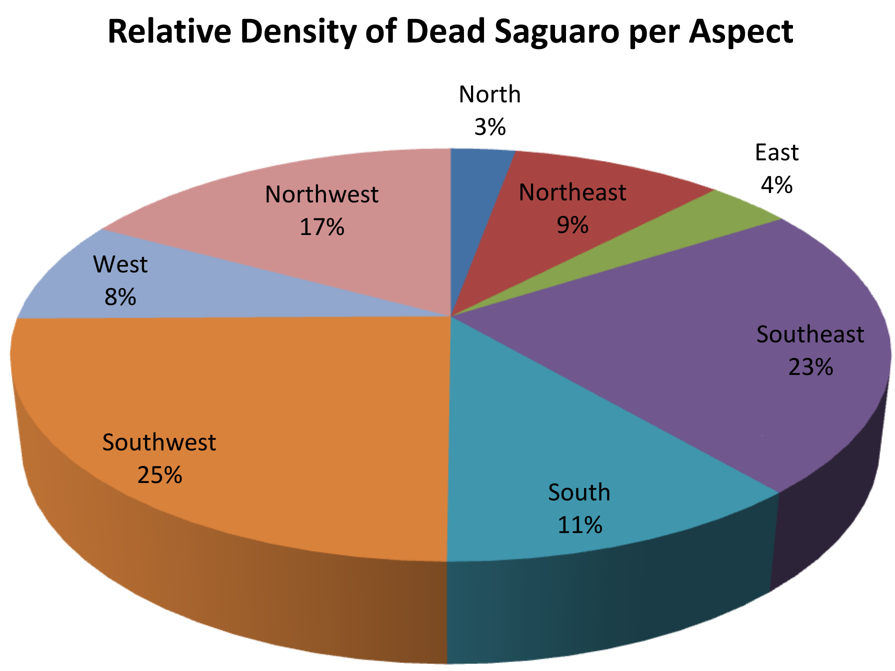

Figure 21. Relative Density (Saguaros/ha) of Dead Saguaros per Aspect Within the Pass Mountain Study Area During 2009-2010.

The aspect of a slope will impact the amount of solar energy that area will receive throughout the day. Aspect changes with topographical features such as mountains and valleys creating microclimates by shading parts of the landscape. In the northern hemisphere the south-facing aspects face the equator and receive more solar energy (Molles, 2005), however, the warmest and driest aspect is not south but southwest (Hasse, 1970). Although solar radiation is evenly distributed both before and after noon, morning heat primarily dries surfaces while afternoon solar energy heats up the soil (Hasse, 1970). In the current study at Pass Mountain, 20% of the saguaros were on southwest aspects with 13% on south aspects but saguaros with 16% on southeast slopes (Figure 18).

Directions for Future Research

Observations and data collected during this study have raised additional questions that would be of interest for further research. The 50 plots recorded for this study would be a good foundation for long term research of the saguaro population of Pass Mountain. A baseline formula has been established to estimate saguaro age for different populations by recording the growth rate of any size saguaro for two years within the population of interest (Drezner, 2003). This formula for estimating saguaro age was used by Drezner in an earlier study for a saguaro population close to the UMRP area (2008). This information would be interesting to match with the climate of the establishment time frame of the different size classes and to compare with the growth rate of other saguaro populations throughout its range.

Scars thought to be due to fire were recorded on saguaros within the plots and would be useful for mapping out the possible fire history of the area and comparing with the records of the Tonto National Forest. Most of the saguaros recorded with scars were in the larger size classes. The few smaller saguaros with scars may be older than their size would indicate, but perhaps their growth had been stunted by a fire due to the extent of the apparent damage.

The role of nurse plants is a widely discussed and debated topic that could be further analyzed with the data from this study and additional data. The nearest plant recorded for each may be the original nurse plant that particular saguaro established under, or a plant that grew years after for larger saguaros. I observed that some of the smaller saguaros apparently established next to boulders in this study area and were not located near or under the canopy a living nurse plant. The frequency of this situation could be quantified with greater sampling.

There is a distinct difference in soil properties and the rate of weathering of the granite, basalt and other parent materials with aspect. South-facing slopes were unstable with thin soils and decomposed granite and rocks that appeared solid crumbled on contact. North-facing slopes soils were deeper with more ground cover vegetation and rocks were stable. Soil analysis of the 50 plots examined in the current study to investigate the effect of aspect on soil development would be of interest for further research (Rob Wilson, NRCS pers. com.).

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APPENDIX A

CATALOGUE OF THE VASCULAR PLANTS OF USERY MOUNTAIN REGIONAL PARK AND PASS MOUNTAIN OF CENTRAL ARIZONA

Species are first arranged by the divisions Polypodiophyta and Magnoliophyta following the classification of Cronquist (1981). Magnoliophyta is further divided into the classes of Magnoliopsida (dicots) and Liliopsida (monocots). Taxa are then arranged alphabetically by families, genera, species and infraspecific taxa. Nomenclature follows the USDA PLANTS database, with synonyms from the Flora of North America (FNA, 1993) and the Arizona Flora (Kerney & Peeples, 1960). Common names are derived from the USDA PLANTS database. Each species is accompanied by the following information:

A. Common name

B. Synonyms from FNA and Kerney & Peebles

C. Plant duration:

  pr = perennial; ann = annual

D. Growth form (habit):

  grass – grass or grass-like; vine – twining, climbing plant; fern – lacks seed and flower, reproduces by spores; forb – without significant woody tissue; shrub – multi-stemmed woody plant; cactus – succulents with spines in place of leaves; tree – woody plant with trunk exceeding 4 meters in height (USDA, NRCS, 2011).

E. Abundance within the study area boundaries. Table 13 lists abundance terms and definitions used in this study.

F. Specimen information. Collections made during this study are listed by collection number. Species observed during this study but not collected are listed as, Not Col. For collections other than those made during this study, collection numbers are preceded by the initials of the collector (Table 14).

Table 13

Abundance Scale for Listed Species Found in the UMRP Study Area.

Density	Description
Abundant	Dominant or co-dominant throughout study area
Frequent	Easily found throughout study area but not dominant or co-dominant
Occasional	Widely scattered but not difficult to find
Infrequent	Only a few individuals but found in several locations
Rare	Limited to one or very few locations within the study area
Not Seen	Not found during this study but found in a previous survey from the same site

Table 14

Acronyms of Previous Collectors of the UMRP Study Area.

Name	Acronym
David J. Keil	DK
L. R. Landrum	LL
Elinor Lehto	EL
D.J. Pinkava	DP
Betty Walden	BW

Taxon	Duration	Habit	Origin	Abund.	Col. #
Division Gnetophyta					
Class Gnetopsida					
EPHEDRACEAE					
Ephedra trifurca Torr. ex S. Watson					
longleaf jointfir (EPTR)	pr	shrub	native	occasional	40,77
Division Pteridophyta					
Class Filicopsida					
PTERIDACEA K&P = Polypodiaceae					
Cheilanthes parryi (D.C. Eaton) Domin					
parry's lipfern (CHPA4)	pr	fern	native	infrequent	120
Notholaena standleyi Maxon					
star cloak fern (NOST)	pr	fern	native	occasional	129
Notholaena californica D.C. Eaton					
california cloak fern (NOCA)	pr	fern	native	infrequent	172
Division Magnoliophyta					
Class Lilliopsida - Monocotyledons					
LILLIACEAE					
Dichelostemma capitatum (Benth.) Alph. Wood					
bluedicks (DICA14)	pr	forb	native	infrequent	2,233
POACEAE K&P = Gramineae					
Aristida adscensionis L.					
sixweeks threeawn (ARAD)	ann	grass	native	frequent	17
Aristida purpurea Nutt. var. *parishii*					
parish's threeawn (ARPUP5)	pr	grass	native	frequent	68
K&P = *Aristida parishii*					
Avena fatua L.					
wild oat (AVFA)	ann	grass	invasive	rare	216
Bromus arizonicus (Shear) Stebbins					
arizona brome (BRAR4)	ann	grass	native	infrequent	42
Bromus diandrus Roth.					
ripgut brome (BRDI3)	ann/pr	grass	invasive	infrequent	357

Taxon	Duration	Habit	Origin	Abund.	Col. #
Bromus rubens L. red brome (BRRU2)	ann	grass	invasive	frequent	18, 24
Cynodon dactylon (L.) Pers. bermudagrass (CYDA)	pr	grass	invasive	rare	209
Dasyochloa pulchella (Kunth) Willd. ex Rydb. low woollygrass (DAPU7)	pr	grass	native	rare	187
Hilaria belangeri Steud.) Nash curly-mesquite (HIBE)	pr	grass	native	occasional	356
Leptochloa panicea (Retz.) Ohwi sspbrachiata(Steud.) N. Snow mucronate sprangletop (LEPA6)	ann/pr	grass	native	occasional	183
Muhlenbergia porteri Scribn. ex Beal bush muhly (MUPO2)	pr	grass	native	not seen	DK 828
Pennisetum ciliare (L.) Link bufflegrass (PECI)	pr	grass	invasive	infrequent	118, 208
Pennisetum setaceum (Forssk.) Chiov. fountaingrass (PESE3)	pr	grass	invasive	rare	69
Pleuraphis rigida Thurb. big galleta (PLRI3)	pr	grass	native	infrequent	119
Schismus arabicus Nees arabian schismus (SCAR)	ann	grass	invasive	frequent	25, 207
Schismus barbatus (Loefl. ex L.) Thell. common mediterranean grass (SCBA)	ann	grass	invasive	frequent	19
Sorghum bicolor (L.) Moench sorghum (SOBI2)	ann	grass	invasive	rare	188
Class Magnoliopsida - dicotyledons					
ACANTHACEAE					
Justicia californica (Benth.) D. Gibson belaperone (JUCA8)	pr	shrub	native	frequent	29,105

Taxon	Duration	Habit	Origin	Abund.	Col. #
AMARANTHACEAE					
Amaranthus fimbriatus (Torr.) Benth. ex S. Watson fringed amaranth (AMFI)	ann	forb	native	rare	65
Amaranthus obcordatus (A. Gray) Standl. trans-pecos amaranth (AMOB)	ann	forb	native	infrequent	165,167
Amaranthus palmeri S. Watson carelessweed (AMPA)	ann	forb	native	infrequent	186
Tidestromia lanuginosa (Nutt.) Standl. woolly tidestromia (TILA2)	ann	forb	native	rare	180
APIACEAE					
Bowlesia incana Ruiz & Pav. hoary bowlesia (BOIN3)	ann	forb	native	occasional	13,123
Daucus pusillus Michx. american wild carrot (DAPU3)	ann	forb	native	occasional	7,50
Spermolepis echinata (Nutt. ex DC.) A. Heller bristly scaleseed (SPEC2)	ann	forb	native	occasional	218
ARISTOLOCHIACEAE					
Aristolochia watsonii Woot. & Standl. watson's dutchman's pipe	pr	vine	native	not seen	DK 794
ASCLEPIADACEAE					
Asclepias subulata Decne. rush milkweed (ASSU)	pr	forb	native	occasional	57,179 355
Cynanchum arizonicum (A. Gray) Shinners arizona swallow-wort (CYAR12)	pr	vine	native	not seen	LL 5328
Funastrum cynanchoides (Decne.) Schltr. ssp. *Cynanchoides* fringed twinevine K&P = *Sarcostemma cynanchoides*	pr	vine	native	occasional	184
ASTERACEAE K&P = Compositae					
Adenophyllum porophylloides (A. Gray) Strother san felipe dogweed K&P = *Dyssodia porophylloides*	pr	subshrub	native	frequent	138,217

Taxon	Duration	Habit	Origin	Abund.	Col. #
Ambrosia ambrosioides (Cav.) Payne ambrosia leaf bur ragweed (AMAM2)	pr	shrub	native	occasional	48,199, 336
Ambrosia confertiflora DC. weakleaf bur ragweed (AMCO3)	pr	forb	native	infrequent	175
Ambrosia deltoidea (Torr.) Payne triangle bur ragweed (AMDE4)	pr	shrub	native	abundant	20
Ambrosia dumosa (A. Gray) Payne burrobush (AMDU2)	pr	shrub	native	occasional	349
Arctotis stoechadifolia P.J. Bergius african daisy (ARST2)	pr	forb	invasive	rare	236,352
Baccharis sarothroides A. Gray desertbroom (BASA2)	pr	shrub	native	frequent	74,75
Baileya pleniradiata Harv. & A. Gray ex A. Gray woolly desert marigold (BAPL3) K&P = *Baileya multiradiata*	ann/pr	forb	native	frequent	26
Bebbia juncea (Benth.) Greene sweetbush (BEJU)	pr	shrub	native	occasional	58
Brickellia coulteri A. Gray coulter's brickellbush (BRCO)	pr	shrub	native	frequent	45,131, 178
Chaenactis stevioides Hook. & Arn. esteve's pincushion (CHST)	ann	forb	native	not seen	DP 2-5
Encelia farinosa A. Gray ex Torr. brittlebush (ENFA)	pr	shrub	native	abundant	27
Eriophyllum lanosum (A. Gray) Rydb. white easterbonnets (ANLA7)	ann	forb	native	occasional	240,245
Eriophyllum pringlei A. Gray pringle's woolly sunflower (ERPR4)	ann	forb	native	infrequent	334
Isocoma acradenia (Greene) Greene var. *acradenia* alkali goldenbush (ISACA2)	pr	shrub	native	infrequent	173,191

Taxon	Duration	Habit	Origin	Abund.	Col. #
Lasthenia californica DC. ex Lindl. spp. *californica* california goldfields (LACAC2)	ann	forb	native	occasional	326
Layia glandulosa (Hook.) Hook. & Arn. whitedaisy tidytips (LAGL5)	ann	forb	native	occasional	310, 324,351
Logfia arizonica (A. Gray) Holub Arizona cottonrose (LOAR12) K&P = *Filago arizonica*	ann	forb	native	occasional	BW 27* 305
Machaeranthera juncea (Greene) Shinners rush bristleweed (MAJU)	pr	forb	native	frequent	343
Machaeranthera pinnatifida (Hook.) Shinners lacy tansyaster (MAPI)	pr	forb	native	not seen	DK 830
Monoptilon bellioides (A. Gray) H.M. Hall Mojave desertstar (MOBE2)	ann	forb	native	occasional	239
Oncosiphon piluliferum (L.F.) Källersjö stinknet (ONPI)	ann	forb	invasive	rare	338
Pectis papposa Harv. & A. Gray manybristle cinchweed (PEPA2)	ann	forb	native	infrequent	174
Perityle emoryi Torr. emory's rockdaisy (PEEM)	ann	forb	native	infrequent	344
Rafinesquia californica Nutt. California plumeseed (RACA)	ann	forb	native	occasional	309,320
Sonchus oleraceus L. common sowthistle (SOOL)	ann	forb	invasive	rare	328
Stephanomeria pauciflora (Torr.) a. Nelson brownplume wirelettuce (STPA4)	pr	shrub	native	occasional	189
Trixis californica Kellogg american threefold (TRCA8)	pr	shrub	native	frequent	11

*BW 27 – This sheet contained a mix collection that also listed *Filago californica* but specimen was not present (SEINet, 2011).

Taxon	Duration	Habit	Origin	Abund.	Col. #
Microseris lindleyi (DC.) A. Gray lindley's silverpuffs (MILI5) K&P = *Uropappus lindleyi*	ann	forb	native	infrequent	329
Viguiera parishii Greene parish's goldeneye (VIPA14)	pr	shrub	native	occasional	76,24
BORAGINACEAE					
Amsinckia menziesii (Lehm.) A. Nelson & J.F. Macb. var. *intermedia* (Fisch. & C.A. Mey.) common fiddleneck (AMME12) K&P = *Amsinckia intermedia*	ann	forb	native	frequent	202,223
Amsinckia tessellata A. Gray bristly fiddleneck (AMTE3)	ann	forb	native	not seen	DP 2
Cryptantha barbigera (A. Gray) Greene bearded cryptantha (CRBA5)	ann	forb	native	not seen	DK 821
Cryptantha decipiens (M.E. Jones) A. Heller gravelbar cryptantha (CRDE)	ann	forb	native	occasional	143
Cryptantha pterocarya (Torr.) Greene wingnut cryptantha (CRPT)	ann	forb	native	occasional	352
Plagiobothrys arizonicus (A. Gray) Greene ex A. Gray arizona popcornflower (PLAR)	ann	forb	native	occasional	244
Pectocarya platycarpa (Munz & I.M. Johnst.) Munz & I.M. Johnst. broadfruit combseed (PEPL)	ann	forb	native	occasional	147,229
Pectocarya recurvata I.M. Johnst. curvenut combseed (PERE)	ann	forb	native	occasional	38,111, 115,144
BRASSICACEAE					
Brassica tournefortii Gouan asian mustard (BRTO)	ann	forb	invasive	occasional	203
Lepidium virginicum L. var. medium (Greene) C. L. Hitchc. intermediate pepperweed (LEVIM)	ann/bi/pr	forb	native	occasional	10,201 315,316

Taxon	Duration	Habit	Origin	Abund.	Col. #
Lepidium lasiocarpum Nutt. var. *lasiocarpum* shaggyfruit pepperweed (LELAL)	ann/bi	forb	native	not seen	DP 5737
Lesquerella tenella A. Nelson moapa bladderpod (LETE3) K&P = *Physaria tenella*	ann	forb	native	infrequent	233
Sisymbrium irio L. london rocket (SIIR)	ann	forb	invasive	frequent	107,139
Thysanocarpus curvipes Hook. sand fringepod (THCU)	ann	forb	native	occasional	116,228
CACTACEAE					
Carnegiea gigantea (Engelm.) Britton & Rose saguaro (CAGI10)	pr	cactus	native	abundant	Not Col.
Cylindropuntia acanthocarpa (Engelm. & Bigelow) F.M. Knuth buckhorn Cholla (CYAC8) *K&P = Opuntia acanthocarpa*	pr	cactus	native	abundant	221
Cylindropuntia bigelovii (Engelm.) F.M. Knuth teddybear cholla (CYBI9) K&*P = Opuntia bigelovii*	pr	cactus	native	frequent	Not Col.
Cylindropuntia fulgida (Engelm.) F.M. Knuth jumping cholla (CYFU10) K&P = *Opuntia fulgida*	pr	cactus	native	frequent	Not Col.
Cylindropuntia leptocaulis (D.C.) F.M. Knuth christmas cactus (CYLE8) K&P = *Opuntia leptocaulis*	pr	cactus	native	occasional	220
Echinocereus engelmannii (Parry ex Engelm.) Lem. engelmann's hedgehog cactus (ECEN)	pr	cactus	native	occasional	DK 803
Mammillaria grahamii Engelm. graham's nipple cactus (MAGR9)	pr	cactus	native	occasional	DK 839
Opuntia englemannii Salom-Dyck ex Engelm. var. *engelmannii* cactus apple (OPENE)	pr	cactus	native	frequent	222

Taxon	Duration	Habit	Origin	Abund.	Col. #
CARYOPHYLLACEAE					
Silene antirrhina L. sleepy silene (SIAN2)	ann	forb	native	infrequent	15,300
CHENAPODIACEAE					
Atriplex canescens (Prush) Nutt. fourwing saltbush (ATCA2)	pr	shrub	native	rare	190
CRASSULACEAE					
Crassula connata (Ruiz & Pav.) A. Berger sand pygmyweed (CRCO34)	ann	forb	native	infrequent	301
CROSSOSOMATACEAE					
Crossosoma bigelovii S. Watson ragged rockflower (CRBI2)	pr	shrub	native	infrequent	109
CUCURBITACEAE					
Cucurbita digita A. Gray fingerleaf gourd (CUDI)	pr	vine	native	rare	342
EUPHORBIACEAE					
Argythamnia lanceolata (Benth.) Müll. Arg. narrowleaf silverbush (ARLA12)	pr	forb	native	infrequent	39,72, 132,136
Argythamnia neomexicana Müll. Arg. new mexico silverbush (ARNE2)	ann/pr	forb	native	infrequent	135,150
Bernardia myricifolia (Scheele) S. Watson mouse’s eye (BEMY)	pr	shrub	native	infrequent	164
Chamaesyce albomarginata (Torr. & A. Gray) Small whitemargin sandmat (CHAL11)	pr	forb	native	frequent	71
Chamaesyce ambramsiana (L.C. Wheeler) Koutnik abram’s sandmat (CHAB2)	ann	forb	native	frequent	154,177
Chamaesyce polycarpa (Benth.) Millsp. ex Parish smallseed sandmat (CHPO12)	ann/pr	forb	native	occasional	153
Euphorbia eriantha Benth. beetle spurge (EUER2)	ann	forb	native	infrequent	171,181

Taxon	Duration	Habit	Origin	Abund.	Col. #
FABACEAE K&P = Leguminosea					
Acacia greggii A. Gray var. *greggii* catclaw acacia (ACGRG3)	pr	shrub	native	frequent	60,137
Astragalus nuttallianus DC. smallflowered milkvetch (ASNU4)	ann/pr	forb	native	infrequent	234
Calliandra eriophylla Benth. fairy duster (CAER)	pr	shrub	native	frequent	21,36
Lotus humistratus Greene foothill deervetch (LOHU2)	ann	forb	native	not seen	BW 18
Lotus rigidus (Benth.) Greene shrubby deervetch	pr	forb	native	not seen	DK 836
Lotus strigosus (Nutt.) Greene var. *tomentellus* (Greene) Isely strigose bird's-foot trefoil (LOSTT)	ann	forb	native	occasional	200
Lupinus arizonicus (S. Watson) S. Watson arizona lupine (LUAR4)	ann	forb	native	infrequent	215,327
Lupinus sparsiflorus Benth. spp. *mohavensis* Dziekanowski & D. Dunn coulter's Lupine (LUSPM)	ann	forb	native	occasional	35,232
Marina parryi (Torr. & A. Gray) Barneby Parry's false prairie-clover (MAPA7)	pr	shrub	native	infrequent	46
Olneya tesota A. Gray desert ironwood (OLTE)	pr	tree	native	frequent	62
Parkinsonia microphylla Torr. yellow paloverde (PAMI5) K&P = *Cercidium microphyllum*	pr	tree	native	frequent	61
Parkinsonia florida (Benth. ex A. Gray) S. Watson blue paloverde (PAFL6) K&P = *Cercidium floridum*	pr	tree	native	infrequent	149,151
Senna covesii (A. Gray) Irwin & Barneby coues' cassia (SECO10)	pr	forb	native	frequent	33,66

Taxon	Duration	Habit	Origin	Abund.	Col. #
FOUQUIERIACEAE					
Fouquieria splendens Engel. ocotillo (FOSP2)	pr	shrub	native	frequent	Not Col.
GERANIACEAE					
Erodium cicutarium (L.) L'Hér. ex Aiton ssp. *cicutarium* redstem stork’s bill (ERCIC)	ann/bi	forb	invasive	frequent	308
Erodium texanum A. Gray texas stork’s bill (ERTE13)	ann/bi	forb	native	infrequent	232
HYDROPHYLLACEAE					
Emmenanthe penduliflora Benth. var. *penduliflora* whisperingbells (EMPEP)	ann	forb	native	rare	340
Eucrypta chrysanthemifolia (Benth.) Greene var. *bipinnatifida* (Torr.) Constance spotted hideseed (EUCHB)	ann	forb	native	frequent	14,100 194,304
Phacelia distans Benth. distant phacelia (PHDI)	ann/pr	forb	native	frequent	49
Phacelia neomexicana Thurb. ex Torr. new mexico phacelia (PHNE3)	ann	forb	native	occasional	106
Pholistoma auritum (Lindl.) Lilja blue fiestaflower (PHAU4)	ann	vine	native	infrequent	5
KRAMERIACEAE					
Krameria erecta Willd.ex Schult. littleleaf ratany (KRER)	pr	shrub	native	frequent	4
Krameria grayi Rose & Painter white ratant (KRGR)	pr	shrub	native	frequent	224
LAMIACEAE					
Hyptis emoryi Torr. desert lavender (HYEM)	pr	shrub	native	occasional	22
Salvia columbariae Benth. var. *columbariae* chia (SACOC)	ann	forb	native	occasional	9

Taxon	Duration	Habit	Origin	Abund.	Col. #
LOASACEAE					
Mentzelia involucrata S. Watson whitebract blazingstar (MEIN5)	ann	forb	native	rare	360
MALPIGHIACEAE					
Cottsia gracilis A. Gray slender janusia (JAGR) K&P = *Janusia gracilis*	pr	vine	native	frequent	70,110, 157,161
MALVACEAE					
Abutilon abutiloides (Jacq.) Garcke ex Hochr. shrubby Indian mallow (ABAB)	pr	forb	native	not seen	
Abutilon incanum (Link) Sweet pelotazo (ABIN)	pr	shrub	native	occasional	101,162, 182
Hibiscus denudatus Benth. paleface (HIDE)	pr	shrub	native	infrequent	108
Malva parviflora L. cheeseweed mallow (MAPA5)	ann/pr	forb	invasive	occasional	227
Sphaeralcea ambigua A. Gray desert globemallow (SPAM2)	pr	shrub	native	occasional	28
Sphaeralcea ambigua A. Gray ssp. *rosacea* (Munz & I.M. Johnst.) Kearney rose globemallow (SPAMR)	pr	shrub	native	rare	206,225
NYCTAGINACEAE					
Mirabilis laevis (Benth.) Curran var. *villosa* (Kellogg) Spellenb. wishbone-bush (MILAV)	pr	forb	native	frequent	31,312
OLEACEAE					
Menodora scabra A. Gray rough menodora (MESC)	pr	shrub	native	rare	113,133 354,358
ONOGRACEAE					
Camissonia californica (Nutt. ex Torr. & A. Gray) P.H. Raven California suncup (CACA32)	ann/pr	forb	native	occasional	47
Camissonia micrantha (Hornem.ex Spreng.) P.H. Raven miniature suncup (CAMI22)	ann	forb	native	occasional	30

Taxon	Duration	Habit	Origin	Abund.	Col. #
PAPAVERACEAE					
Argemone gracilenta Greene sonoran pricklypoppy (ARGR3)	pr	forb	native	not seen	DK 818
Argemone munita Durand & Hilg. ssp. *rotundata* (Rydb.) G.B. Ownbey flatbud pricklypoppy (ARMUR)	ann/pr	forb	native	infrequent	166
Argemone pleiacantha Greene southwestern pricklypoppy (ARPL3)	pr	forb	native	occasional	59
Eschscholzia californica Cham. california poppy (ESCA2)	ann/pr	forb	native	frequent	52
PLANTAGINACEAE					
Plantago patagonica Jacq. woolly plantain (PLPA2)	ann	forb	native	occasional	350
Plantago ovata Forssk. desert Indianwheat (PLOV)	ann	forb	native	infrequent	141,238
POLEMONIACEAE					
Eriastrum diffusum (A. Gray) H. Mason miniature woollystar (ERDI2)	ann	forb	native	occasional	54,142
Gila flavocincta A. Nelson ssp. *flavocincta* lesser yellowthroat gilia (GIFLF)	ann	forb	native	occasional	313,341
Linanthus bigelovii (A. Gray) Greene bigelow's linanthus (LIBI2)	ann	forb	native	occasional	227,306
POLYGANACEAE					
Chorizanthe brevicornu Torr. brittle spineflower (CHBR)	ann	forb	native	infrequent	148,323 339
Eriogonum fasciculatum Benth. var. *foliolosum* (Nutt.) S. Stokes ex Abrams Eastern Mojave buckwheat (ERFAF2)	pr	shrub	native	frequent	3,204
Eriogonum palmerianum Reveal Palmer's buckwheat (ERPA11)	ann	forb	native	not seen	DK 823
Eriogonum thomasii Torr. Thomas' buckwheat	ann	forb	native	not seen	DP 5720

Taxon	Duration	Habit	Origin	Abund.	Col. #
Pterostegia drymariodes Fisch. & C.A. Mey. woodland pterostegia (PTDR)	ann	forb	native	not seen	EL17561
PORTULACEAE					
Calandrinia ciliata (Ruiz & Pav.) DC. fringed redmaids (CACI2)	ann	forb	native	infrequent	117
Claytonia perfoliata Donn ex Wild. miner's lettuce (CLPE)	ann	forb	native	rare	335
RANUNCULACEAE					
Anemone tuberosa Rydb. tuber anemone (ANTU)	pr	forb	native	absent	EL 5772
Delphinium parishii A. Gray ssp. *parishii* parish's larkspur (DEPAP3) K&P = *Delphinium amabile*	pr	forb	native	rare	353
RUBIACEAE					
Galium stellatum Kellogg starry bedstraw (GAST)	pr	shrub	native	rare	114,330
SCROPHULARIACEAE					
Castilleja densiflora (Benth.) T.I. Chuang & Heckard ssp. *densiflora* Indian paintbrush (CADAD3)	ann	forb	native	occasional	322
Mabrya acerifolia (Pennell) Elisens brittlestem (MAAC3)	pr	vine	native	rare	103
SIMMONDSIACEAE					
Simmondsia chinensis (Link) C.K. Schneid. jojoba (SICH)	pr	shrub	native	abundant	43,73
SOLANACEAE					
Datura stramonium L. jimsonweed (DAST)	ann	forb	native	rare	not col.
Lycium exsertum A. Gray arizona desert-thorn (LYEX)	pr	shrub	native	frequent	160
Nicotiana obtusifolia M. Martens & Galeotti desert tobacco (NIOB)	ann/pr	forb	native	occasional	56

Taxon	Duration	Habit	Origin	Abund.	Col. #
Physalis crassifolia Benth. yellow groundcherry (PHCR4)	ann/pr	forb	native	infrequent	159
ULMACEAE					
Celtis ehrenbergiana (Klotzsch) Liebm. spiny hackberry (CEEH)	pr	shrub	native	occasional	145
Celtis laevigata Wild. var. *reticulata* (Torr.) L.D. Benson netleaf hackberry (CELAR)	pr	shrub	native	occasional	185
URTICACEAE					
Parietaria hespera Hinton var. *hespera* rillita pellitory (PAHEH)	pr	forb	native	frequent	193,196 318
VERBENACEAE					
Aloysia wrightii (A. Gray) A. Heller wright’s beebrush (ALWR)	pr	shrub	native	rare	163
VISCACEAE					
Phoradendron californicum Nutt. mesquite mistletoe (PHCA8)	pr	shrub	native	frequent	130,146
ZYGOPHYLLACEAE					
Larrea tridentata (DC.) Coville var. *tridentata* creosote bush (LATRT)	pr	shrub	native	abundant	32,226