A Preliminary Flora for Las Cienegas National Conservation Area and Studies on the Life History of the Endangered Huachuca Water Umbel

by

Jean-Philippe Solves

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

Approved April 2020 by the
Graduate Supervisory Committee:

Kathleen B. Pigg, Chair
Andrew Salywon
Elizabeth Makings

ARIZONA STATE UNIVERSITY

May 2020

ABSTRACT

Las Cienegas National Conservation Area (LCNCA), located in southeastern Arizona, is a place of ecological and historical value. It is host to rare native, threatened and endangered fauna and flora. as well as the site of the oldest operating ranch in the state. The first chapter of this thesis provides a preliminary flora of vascular plants at LCNCA assembled from field collections, photographs and herbarium specimens, and published through the online database SEINet. This preliminary flora of LCNCA identified 403 species in 76 families. Less than 6% of the flora is non-native, perennial forbs and grasses are the most abundant groups, and over a third of species in the checklist are associated with wetlands. LCNCA has been the target of adaptive management and conservation strategies to preserve its biotic diversity, and results from this study will help inform actions to preserve its rare habitats including cottonwood willow forests, mesquite bosques, sacaton grasslands, and cienegas. The second chapter investigates poorly understood aspects of the life history of the endangered Huachuca Water Umbel (*Lilaeopsis schaffneriana* subsp. *recurva.* Apiaceae) (hereafter HWU). This wetland species occurs in scattered cienegas and streams in southeastern Arizona and northern Sonora, Mexico. Three studies were conducted in a greenhouse to investigate seed bank establishment, seed longevity, and drought tolerance. A fourth study compared the reproductive phenology of populations transplanted at LCNCA to populations transplanted at urban sites like the Phoenix Zoo Conservation Center and the Desert Botanical Garden (DBG). Results from the greenhouse studies showed that HWU seeds were capable of germinating 15 years in a dormant state and that HWU seeds are present in the seed banks at sites where populations have been transplanted. Also, greenhouse

experiments indicated that colonies of HWU can tolerate up to 3 weeks without flowing water, and up to 2 weeks in dry substrate. Transplanted populations at LCNCA monitored in the fourth study produced a higher abundance of flowers and fruit relative to urban sites (i.e. DBG) suggesting that *in-situ* conservation efforts may be more favorable for the recovery of HWU populations. Findings from these studies aim to inform gaps in knowledge highlighted in USFWS recovery plan for this species.

ACKNOWLEDGMENTS

The author acknowledges the support of the United States Fish and Wildlife Service under Endangered Species Act Section 6 Grant Program (Segment 18 2014-2016-01) awarded to Dr. Julie Stromberg which provided funding for the Seed Bank, Seed Germinations, and Artificial Drought Study. The author would also like to recognize the Arizona Native Plant Society for the Doug Green Grant and the Arizona Research Grant which funded field work for the Phenology Study as well as collection trips to LCNCA. The author would like to thank the following individuals for their assistance in various aspects of this thesis: Jillian Cowles for incredible photographs of the HWU flower; Jeffery Simms, Peggy Monkemeier and the BLM Tucson Field Office for access to the LCNCA HWU population and help in conducting field work; Bradley Poynter, Dylan Church, Kevin Krahn, Whitney Heuring and the Phoenix Zoo Conservation Center for assistance in studying and monitoring the HWU population; Linda Howard and Kara Barron for developing and running the Seed Bank, Seed Germination, and Artificial Drought Studies; Brenton Scott for his work on early aspects of the study and for thoughtful discussion and guidance; volunteers at the Desert Botanical Garden for their assistance in monitoring the HWU population; Danika Setaro, Zachary Berry, and Cole Lawson-Whitaker for help and advice in identifying plant specimens; and the thesis advisory committee: Elizabeth Makings, Kathleen B. Pigg, and Andrew Salywon for guidance and advice on the organization of this project. The author would also like to particularly thanks Alison Willis for her incredible patience, understanding, and support exhibited throughout the completion of this difficult endeavor; as well as Remy, Florence, Jean Yves, Tammy, Yvan, Danielle Solves, and all members of the Martin family for their unconditional love, support, and guidance. Without them this project would not have been what it is today.

TABLE OF CONTENTS

CHAPTER Page

CHAPTER Page

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER 1

PRELIMINARY FLORA OF LAS CIENEGAS NATIONAL CONSERVATION AREA, PIMA COUNTY, ARIZONA

INTRODUCTION

Botanical inventories are a common approach to floristic research. Otherwise known as 'floras,' these lists vary widely with respect to their use and scale. Some floras cover broad geographical regions (e.g., Flora of North America Editorial Committee, eds. 1993+) and may include taxonomic treatments. Others may encompass smaller areas and serve as checklists for management and conservation purposes and provide referential material to identify specimens [e.g., Flora of the San Pedro National Conservation Area (Makings, 2006); Flora of Cienega Creek Preserve (Fonseca, 2013), or the Sonoita Creek Natural State Area (McLaughlin, 2006)]. Regardless of their scale, modern floras typically consist of species checklists supported by vouchered herbarium specimens and/or photographs that provide baseline observations of an area's taxonomic composition (Palmer et al., 1995; Funk, 2006).

Floras have numerous applications throughout a range of disciplines from systematics to resource management, to conservation biology and restoration ecology (Funk, 1993; Palmer et al., 1995). Vouchered material can serve to inform species distributions, geographic patterns of endemism, and floristic elements on a regional scale (Bowers & McLaughlin, 1982). When managed through herbaria, vouchers can also provide valuable material for land managers to reliably and accessibly identify local vegetation (Funk, 2006).

The process of undertaking a flora, however, is time intensive, and the number of individuals that are not only trained, but also financially supported is increasingly limited. Decreased funding in plant conservation and floristic studies has resulted in what is recognized as a "taxonomic impediment" by the United Nations Environment Program (UNEP) (Funk, 2006; Seastedt et al., 2008). Further challenges are posed by climate change and human disturbances which render the need for floristic studies even more urgent (Raven, 2019). Regions that are experiencing increasingly severe drought and extreme temperatures like the American Southwest (Waters et al., 2001; Melillo et al., 2014), are likely to also witness shifts in the composition of the local flora (Pyšek et al., 2004; Zhu et al., 2018). The composition of plant communities can gradually shift under drought conditions (Merlin et al., 2015) which can result in changes to the function and services of entire ecosystems (LaForgia et al., 2018). Biotic inventories, such as floras, document plant biodiversity at a moment in time, and therefore provide valuable data for comparative studies as baseline communities begin to shift (Seastedt et al., 2008; Turner et al., 2005).

Tools developed from the digitization of natural history collections are creating opportunities to address these challenges with novel solutions (Funk, 2006; Kress & Krupnick, 2006). Widely available bioinformatic platforms (e.g. Symbiota, http://symbiota.org,), digitizing tools, and online database networks [e.g. Southwest Environmental Information Network (SEINet) http://swbiodiversity.org/] are empowering taxonomists with improved means of accessing and processing biodiversity data globally (Gries et al., 2014). Current herbarium database management systems not only supply valuable geo-referencing tools (Funk, 2006), but also a means of assembling checklists from vouchers to evaluate the biodiversity of an area. For example, the ‘dynamic checklist’ tool available through the SEINet, allows users the opportunity to generate checklists of specimen data collected within a defined area and assess species occurrences. Tools such as the dynamic checklist from SEINet provide novel opportunities for occurrence data to support ongoing floristic research.

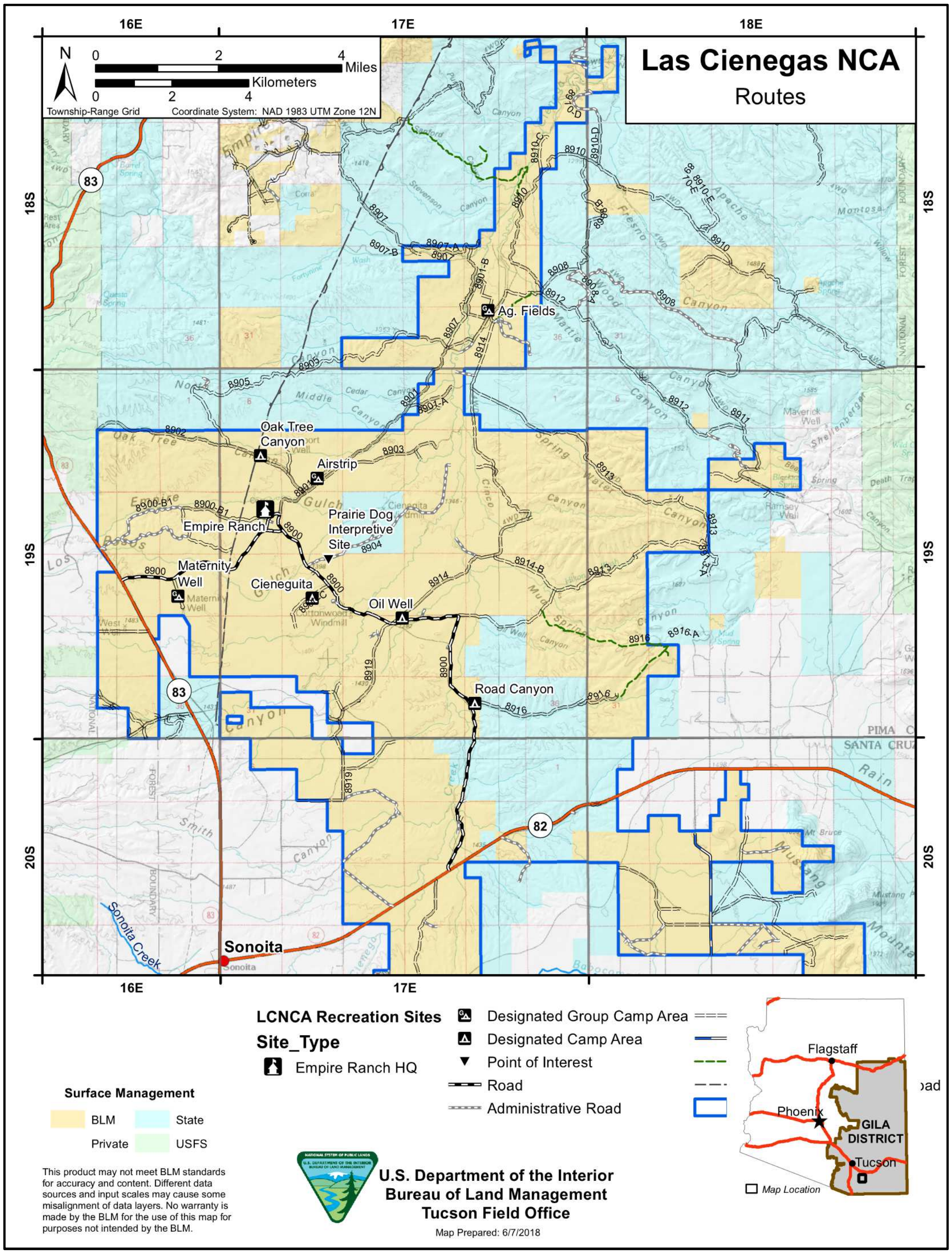

Fig. 1. Map of Las Cienegas National Conservation Area showing land ownership, routes and landmarks, courtesy of BLM Tucson Field Office, used with permission.

STUDY SITE

Las Cienegas National Conservation Area (LCNCA) is located approximately 70 kilometers southeast of Tucson, Arizona within the Sonoita Valley, north of the towns of Sonoita and Elgin, Arizona in Pima and Santa Cruz Counties. The boundaries of LCNCA include 16,985 hectares (ha) of public lands managed by the Bureau of Land Management (BLM) and 2,114 ha of Arizona State Trust lands (BLM, 2003; Gori & Schussman, 2005) (Fig. 1).

Las Cienegas NCA is dissected by Cienega Creek that flows from the south to the north with segments of perennial flow along the northern reach of the NCA. The main corridor of the creek through LCNCA is lined with lush forest galleries, while the upland banks are bordered by dense bosques with herbaceous understories. This corridor in the southern part of the NCA, meanders through vast grasslands and rolling alluvial hills. Perennial pools, remnant of once expansive marshlands, form near surface springs and headwaters and rich communities of wetland vegetation in an otherwise xeric landscape. Before being acquired by the BLM in 1988 and designated as a conservation area in 2000 (BLM, 2003), LCNCA was referred to by several different names depending on the source or time period, such as the Cienega Creek Basin, Sonoita Valley, Stock Valley, or Empire Valley (Huckell, 1995).

LCNCA harbors six federally listed species of native flora and fauna that are either threatened or endangered. LCNCA also borders the edge of the Apache Highlands ecoregion, a 323,000-ha territory of conservation interest which includes the Madraean Archipelago through southern Arizona, and into Sonora, Mexico. As a result of the unique landscape of the Madraean Archipelago LCNCA also holds exceptional biological value. In an assessment of conservation priorities across Arizona, The Nature Conservancy (TNC) ranked LCNCA first for biological uniqueness among other conservation areas identified in the state (Turner et al., 2005). For these reasons, LCNCA is a target for federal and county interagency collaboration. Various stakeholders, in collaboration with the BLM, have developed and implemented adaptive management pilot projects to support the conservation of the biotic diversity at LCNCA (Caves et al., 2013).

PHYSICAL GEOGRAPHY

Most of southeastern Arizona, below the escarpment of the Colorado Plateau, is located within the Basin and Range Physiographic Province, an area formed by folding, faulting, and volcanic activity (Keasey, 1974; Nations & Stump, 1981; Eaton, 1982). The interaction of geological processes has gradually sculpted a landscape marked by narrow mountain ranges separated by low, flat, rolling valleys and expansive grasslands (McClaran & Van Devender, 1997). In the southern portion of the Basin and Range Province, a unique geographic area referred to as the Madraean Archipelago or "Sky Islands" is defined by these tall narrow peaks and low valleys. The Sky Islands stretch across southeastern Arizona, southwestern New Mexico and northwestern Mexico, with its northern perimeter merging into the Mogollon Rim and White Mountains of eastern Arizona.

LCNCA lies at an elevation of 1200 – 1400 m above sea level, in a valley nestled between two Sky Island mountain ranges (Fig. 2). Along the western border are the Santa Rita Mountains which extend about 42 km north to south. The highest point on this range is Mount Wrightson with an altitude of 2881 m and is also one of the highest peaks in the broader Tucson area (Everson, 2010). To the east are the Whetstone Mountains which extend about 23 km north to south and have a peak of 2350 m known as Apache Peak. Both mountain ranges are geologically composed of a complex collection of conglomerate Precambrian granite, Paleozoic sedimentary rocks, and Cretaceous volcanic rocks (Hayes, 1970). Both the Santa Rita and Whetstone Mountains have layers of Cretaceous deposits near the southern end of their range which become gradually interspersed with outcrops of fossil-bearing marine limestone closer to the northern end (Hayes, 1970; Chronic, 1983; Nations & Stump, 1981). These outcrops have been commonly termed "the Narrows" and are located in the northern limits of LCNCA lining the channel of Cienega Creek. Along “the Narrows”, LCNCA boundaries extends into the foothills of the Empire Mountains which are composed of a mix of early to late Cretaceous volcanic rocks (Chronic, 1983).

The low, rolling Sonoita Valley in which LCNCA is situated contains much younger sedimentary deposits of mostly Pliocene to Pleistocene age. Soils are mostly alluvial with hillside formations derived from mixed sedimentary and volcanic parent materials (Bodner & Robles, 2017). Most of the territory of LCNCA encompasses a deep deposit of fertile, Pleistocene alluvium which becomes gradually mixed with older Pliocene soil. The plains near the southern end of the NCA sit atop of largely igneous alluvial deposits which form rounded hills, and locally prominent bluffs. Lowlands are dissected by gullies which carve through Pleistocene alluvium and transect vast floodplains. The younger mixed alluvium supports the native grasslands present along these lowland hills and drainages (McClaran & Van Devender, 1997). In comparison, the soils concentrated near the northern end of LCNCA, closer to the Empire Mountains, consist of older conglomerate deposits including mudstone, limestone, and gypsum. In the northern limits of LCNCA these deposits form into coarse piedmonts along large drainages (Hayes, 1970).

Fig. 2; Las Cienegas National Conservation Area lies between two “Sky Islands”. The Santa Rita Mountains to the west (top photo) and the Whetstones to the east (bottom photo).

CLIMATE

LCNCA experiences a semi-arid climate with a bimodal seasonal precipitation pattern. Precipitation and temperature at LCNCA are monitored from a weather station located at Empire Ranch HQ. Mean annual precipitation over the last century was 382.7 mm (15.07 in), with most of the rainfall occurring during the summer and winter months. Average summer precipitation over the last century was 234 mm (9.24 in), while the average winter precipitation was 92mm (3.63 in) (Abatzoglou et al., 2017) (Fig. 3). Historical records indicate that 62.5% (238.75 mm) of annual rainfall in the Sonoita Valley occurs during the summer season (July-September) (Huckell, 1995).

The mean annual temperature at LCNCA over the last century was 15.54 °C, with an average minimum of 6.62 °C in the winter from October to March and an average maximum of 24.4 °C in the summer from April to September (PRISM, accessed 2020). However, over the last two decades, mean annual temperature at LCNCA has been above average 16 out of the last 20 years, and winter precipitation has been below average for 14 out of the last 20 years. (Fig. 3) resulting in prolonged drought conditions (Abatzoglou et al., 2017). Increasing aridity in areas like Arizona, where water is already a limiting factor to plant growth, underscores the urgency of local botanical inventories.

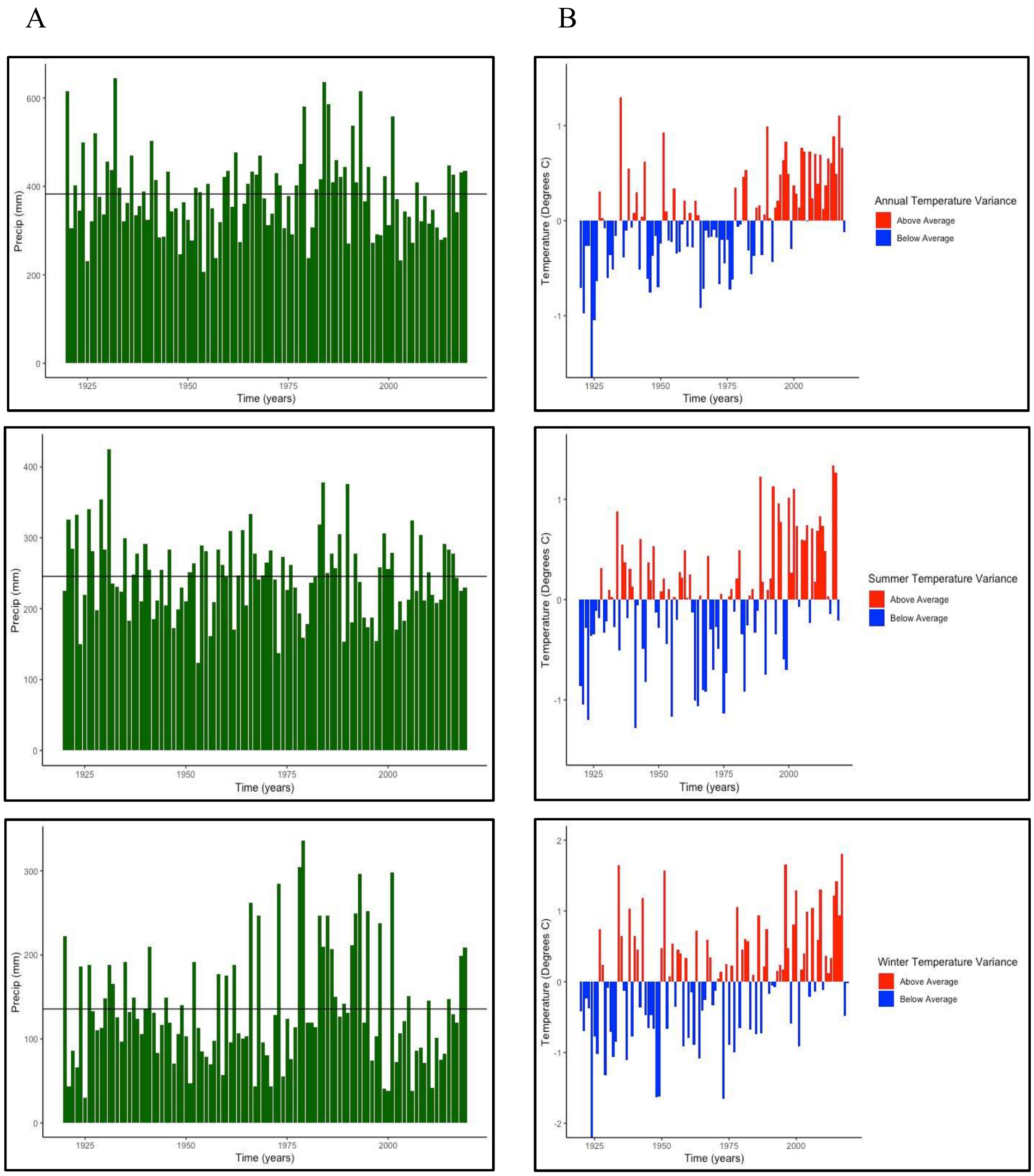

Fig. 3; Summary of Annual, Summer, And Winter Precipitation And Temperature at Las Cienegas National Conservation Area, graphs (A) show annual, summer, and winter precipitation, and graphs (B) show annual, summer, and winter temperature variations from average, measured at Empire Ranch HQ, time series data aquired from Westwide Drought Tracker, and graphs made in R version 3.6.0.

HYDROLOGY

Surface water in LCNCA is primarily drained by Cienega Creek which flows northeast towards the Empire Mountains. This watershed is ephemeral through most of the NCA but includes some perennial stretches in the northern limits. The broader Cienega Creek basin is divided into three subareas: upper Cienega Creek, lower Cienega Creek and Sonoita Creek (ADWR, 2003), of which only upper and part of lower Cienega Creek are present in the boundaries of LCNCA. More broadly, these features all contribute to the hydrology of the greater Santa Cruz watershed.

To the north of "The Narrows," the lower Cienega Creek subarea extends towards the northern section of the basin. Surface water along the creek here is mostly perennial, and groundwater follows surface water northeast along the eastern flank of the Empire Mountains. Here, Cienega Creek is one of the few remaining perennially flowing creeks in Arizona.

The upper Cienega Creek subarea extends through most of LCNCA. Along this subarea, surface water is ephemeral for a majority of the year. Cienega Creek forms a meandering channel which cuts through the alluvial floodplains in the southern parts of LCNCA. While the channel here may experience periodic flooding during years of high rainfall (ADWR, 2003) most portions of upper Cienega Creek in the southern part of LCNCA remain predominantly dry. Large arroyos and drainages are scattered along either banks of the main channel and some exhibit deep incision.

Two tributaries feed into Cienega Creek within LCNCA (Fig 4). Empire Gulch north of the Empire HQ flows west into Cienega Creek and includes some perennial segments which have been the site for the reintroduction for protected fauna (Andrew

Salywon, 2020, personal communication). Another tributary to Cienega Creek in LCNCA is Gardner Creek which is mostly ephemeral and connects to Cienega Creek further south below the Empire HQ.

Groundwater supply along most of the Cienega Creek watershed is derived from mountain block and mountain front recharge from high elevation precipitation in the Santa Rita and Whetstones (Tucci, 2018). These gradual processes allow water to percolate underground slowly to the valley bottom resulting in a slow recharge rate. Water dated from this source was found to be between 15,000 – 25,000 years old (Tucci, 2018), which would suggest that groundwater does not get recharged from local precipitation, even during wet years. This particular hydrology is important to consider when looking at the presence of specific vegetation on a landscape. As the climate in this region becomes increasingly dry (Waters et al., 2001; Melillo et al., 2014), managing the vegetation at LCNCA will become progressively contingent on the management of groundwater use on the Cienega Creek aquifer.

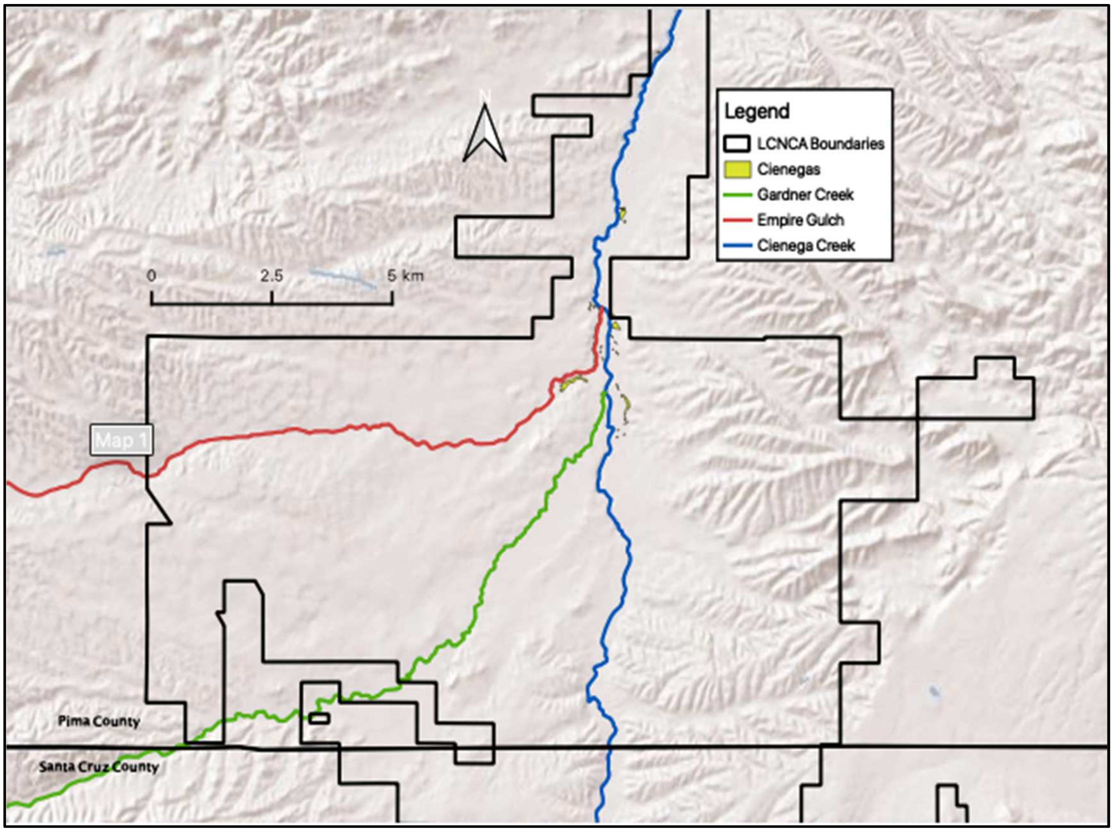

Fig. 4; Map of surface water flow at Las Cienegas National Conservation Area from the Nature Conservancy Freshwater Assessment, segment of Cienega Creek north of Cienegas experiences perennial flow, Empire Gulch is perennial only in small segments near the Empire Ranch HQ, and Gardner Creek is enitrely ephemeral in the national conservation area boudnaries, arrow indicates direction of surface and groundwater flow, map created with QGIS version 3.12.

WILDLIFE

Las Cienegas NCA provides a suite of habitats which support a diverse and unique fauna with 60 species of mammals, 230 species of birds, over 40 species of reptiles and amphibians, and 3 species of native fish some of which are endangered (MacFarland, 2013). Below broad groups of taxa will be mentioned and described, particularly those of conservation or management interest.

Ungulates such as the Mexican Pronghorn (*Antilocarpa americana mexicana)* as well as Mule Deer (*Odocoileus hemionus*), and White-Tailed Deer (*Odocoileus virginianus*) are common along the grasslands in the southern half the NCA. Populations of Pronghorn at LCNCA are some of few remaining in the state and have been actively monitored and protected throughout southern Arizona (Hervert et al., 2005). Smaller mammals like Jack Rabbits (*Lepu*s sp.), Kangaroo Rats (*Dipodomys* sp.), and Ground Squirrels (*Spermophilis* sp.) are likewise common in grasslands as well as along certain disturbed areas such as roadsides and campgrounds. White-Nosed Coati (*Nasua narica*) are occasional in the northern stretches of Cienega Creek, mainly along parts of the riparian corridor near the Narrows. Disturbance from off-highway vehicles and other human activity is reduced in this part of the channel as a result of the difficulty of access. Sections of LCNCA along the southern end of the site have also been designated as protected sites for reintroduction of the Black-Tailed Prairie Dog (*Cynomys ludovicianus*) (Hale et al., 2013).

As with many parts of southeastern Arizona, the Sonoita Valley and most of Las Cienegas NCA is a well-recognized birding area. Unique and rare habitat types (i.e. mesquite bosques, cienegas), play an important role in supporting a diverse suite of avian species. In 2011, the Arizona Important Bird Areas program recognized LCNCA as an important site for avian species of special status. Notably due to the presence of large numbers of the threatened chestnut collared longspur (*Calcarius ornatus*), as well as other species of concern such as the southwestern willow flycatcher (*Epidonax trailii*), western yellow-billed cuckoo (*Coccyzus americanus*) and gray hawk (*Buteo plagiatus*) that rely on the rare habitats found at LCNCA (Bodner & Simms, 2008; MacFarland, 2013; List, 2015).

Cienegas and perennial sections of Cienega Creek host wetland species like great blue herons (*Ardea herodias*) but are also among the few remaining refugia for populations of endangered and rare fish such as the Sonoran topminnow (*Poeciliopsis occidentalis sonoriensis)*. These same wetland habitats are also host to endangered reptiles such as the Chiricahua leopard frog (*Lithobates chiricahuensis*) and the Mexican garter snake (*Thamnophis eques*). In the mesquite terraces, understory grasslands, and tall bunchgrass habitats, birds such as vermillion flycatchers (*Pyrocephalus obscurus*), Bell's vireo (*Vireo bellii*), grasshopper sparrows (*Ammodramus savannarum*), loggerhead shrikes (*Lanius ludovicianus*) and various species of thrashers (*Toxostoma sp.*) can be spotted. Larger fauna such as wild turkey (*Meleagris gallopavo*) and javelina (*Pecari tajacu*) are common along dry segments of Cienega Creek and the bordering upland banks. Turkey vulture (*Catharte aura*) and hawks (*Falco* sp.) as well as mammals like coyotes (*Canis latrans*), kit foxes (*Vulpes macrotis*), and grey foxes (*Urocyon cinereoargenteus*) are common predatory species seen at LCNCA. Recently, wildlife cameras have even spotted large predators like mountains lions (*Felis concolor*) around the cienegas of LCNCA (Andrew Salywon, 2017, personal communication)

Additional information on the fauna of southeastern Arizona, including specific habitat and community types not discussed here can be found in the following references: Swarth, 1914; Hendrickson & Minckley, 1984, Brown, 1982; Brown & Makings, 2014.

CULTURAL HISTORY

The biotic diversity found at LCNCA, and throughout the greater Sonoita Valley has fostered a rich human presence. From periods of early agriculture by indigenous communities, to over a century of ranching on the native grasslands of LCNCA, the Valley has served as a valuable settlement sites for over 10,000 years (Stevens, 2001). Inevitably, this occupation has also influenced the distribution and occurrence of plant communities across the landscape.

During the late 1980's and 90's a series of archeological digs at two notable sites in the Sonoita Valley; Los Ojitos and Davidson Canyon (Upham, 1985) uncovered burial sites, shards of ceramic pottery, and plant remains dating back 4500 – 5000 years. (Huckell, 1995). Early human settlements in the Valley were largely thought to exhibit a hunting-gathering lifestyle, but evidence of cultivated plant remains also suggested that a more sedentary lifestyle through the practice of agriculture was developed by settled groups in the Valley (Huckell, 1995). Frequent burning was also common throughout the Valley during periods of early settlement by indigenous groups.

Recorded history in the Valley dates back to the turn of the 17^{th} century, when Spanish missionaries established a European presence in the New World. Around 1849 with the start of the California Gold Rush and the Gadsden Purchase in 1853, the first Anglo-American settlers arrived in the Sonoita Valley (Keasey, 1974). With their arrival came major changes in land-use. Roads and mail lines were developed through the region, resulting in the suppression of the established fire regime, and the expansion of mining and ranching operations (Dowell, 1978; Stevens, 2001). European settlers gradually modified a once fire-adapted wilderness into the grazed-and-settled landscape seen today. However, the human legacy at LCNCA is not defined only by early settlement activity, but also from over a century of livestock use at the Empire Ranch, the oldest continually working ranch in Arizona.

The Empire Ranch was established in 1876 as a 65-hectare homestead and has been grazing cattle in the Sonoita Valley for over 140 years (Fig. 5). Originally purchased and settled by William Wakefield and his brother-in-law Edward Nye Fish, the Ranch was quickly bought out by Fish and sold to two California businessmen, Walter Vail and Herbert Hilsop. In 1876, these two individuals started the Empire Land & Cattle Co, which marked the beginning of historic ranching at LCNCA. What followed was over a century of grazing, and land development such as channel incision and diversion of waterways for grazing allotments around Empire Gulch and Cienega Creek.

The Vail family operated the Empire Ranch for over 50 years, until 1928 when they sold the land to Frank and Charles Boice (Dowell, 1978; Vail, 2011). The era of the Boice family at the Empire Ranch saw the passage of the Taylor Grazing Act in 1934 which expanded grazing territory across the southern part of the homestead. In 1969, land rights to the Empire Ranch were sold to Gulf American Corporation, but a grazing lease was maintained by the Boice family until 1974, when the ranch was again sold off, this time to Anamax Mining Co. for water rights and mining potential. While no development was undertaken by Anamax, the historic value of the Ranch resulted in its listing in the

National Register of Historic Places in 1975 by Arizona historian Marjorie Wilson (https://www.empireranchfoundation.org/) for the cultural preservation of Western heritage.

Over a decade later in 1988, with the aim to preserve the historic and ecological value of the Valley, The Empire Ranch was purchased by the Bureau of Land Management (BLM). The new federal allotment, originally known as the Empire-Cienega Resource Conservation Area, was officially designated as a national conservation area by the Bush Administration in 2000. The eras of human activity at LCNCA from agriculture, to fire suppression, to decades of grazing, and land development have undoubtedly influenced the vegetation occurring at this site. Today, LCNCA is actively managed by the BLM to, not only protect, restore, and sustain the historic site as a symbol of Western legacy for generations to come, but also to preserve the remaining natural value of the surrounding landscape (BLM, 2003; Empire Ranch Foundation Website).

A

B

C

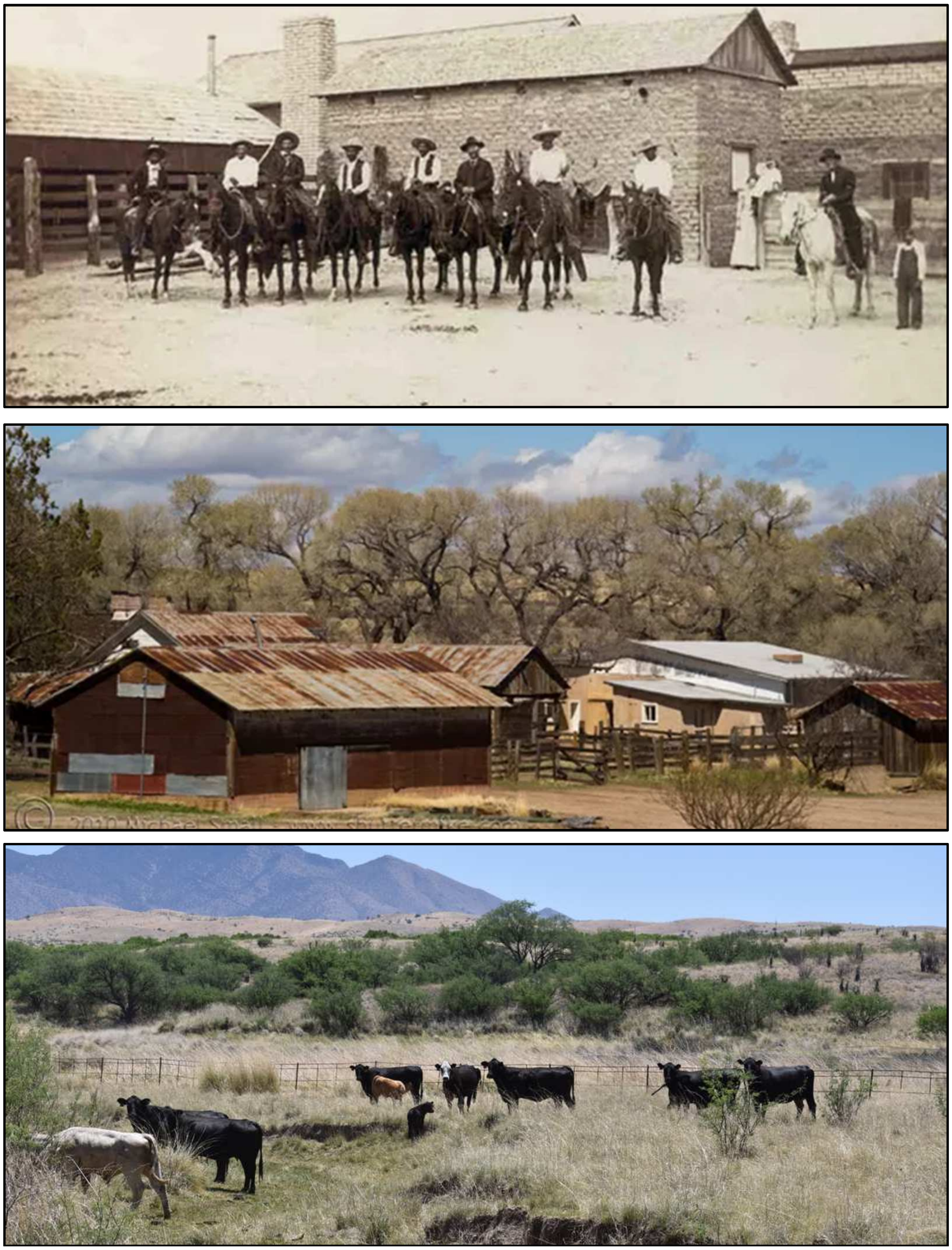

Fig. 5; Photos of ranching activity at Las Cienegas National Conservation Area, (A) ranch workers during the Vial era of ownership circa 19th century, photo courtesy of the Empire Ranch Foundation, (B) Empire Ranch house photographed by the author Fall 2017, (C) cattle grazing near Cieneguita photographed by the author Fall 2018.

METHODS

The checklist was assembled from vouchers collected in the field in addition to herbarium specimens databased in SEINet (2017, last accessed February 2020). Field vouchers were a mix of physical and photographed specimens collected over the course of the 2017-2019 season. Herbarium specimens added as vouchers from SEINet were examined as needed to verify proper geolocation and taxonomic identification. All specimen and landscape photographs were taken using a Nikon D3400 DSLR Camera (2020 Nikon Corporations, Melville, New York).

COLLECTIONS

The search and collection of plant specimens was performed between August 2017 and October 2019. The objective of each trip was to collect plant voucher material along with photos if possible. Habitat descriptions and a list of associated species were recorded for each specimen. A handheld Garmin unit was used to determine latitude/longitude and elevation. Specimens were identified at the Arizona State University Vascular Plant Herbarium (ASU). When enough material was available, duplicates were sent to the Desert Botanical Garden (DES) and the University of Arizona Herbarium (ARIZ).

A total of 535 specimens were collected over the course of 31 expeditions; four collecting trips were made during the last four months of 2017, nineteen over the course of 2018, and eight throughout 2019. Most expeditions lasted 1 – 3 days. Collectively, about 55 days were spent on collecting trips at LCNCA. Most of the collection activity took place between March and November and was mainly focused in parts of LCNCA north of the Pima/Santa Cruz county line (Fig. 6). Areas with surface water or access to near-surface ground water, such as the main channel of Cienega Creek, as well as around major features in LCNCA like Empire Gulch, Mattie Canyon, and Cieneguita were prioritized over roadsides and grazing allotments.

Areas that received minimal coverage would benefit from collecting efforts in the future including the grasslands and foothills that extend to the base of the Mustang Mountains near Elgin, Arizona, the piedmont of the Whetstone Mountains east of Cienega Creek, and some of the grasslands in the southwestern corner of LCNCA.

Collections targeted fertile plant material for ease of taxonomic identification included roots, shoot, flowers, and fruits whenever possible. LCNCA is host to one endangered plant species; *Lilaeopsis schaffneriana* subsp. *recurva* (A. W. Hill) Affolter (Huachuca Water Umbel). A wild population of this taxon was photographed but not collected due to its federal protection status. A digital checklist for LCNCA is publicly available via SEINet. An annotated version of this checklist including growth form, duration, and wetland status for each taxon can be found in Appendix B.

NOMENCLATURE AND IDENTIFICATION

The main sources used to identify specimen were *Arizona Flora* (Kearney et al., 1960), supplemented with recent treatments of the CANOTIA journal for the *Vascular Plants of Arizona Project* (Vascular Plants of Arizona, Editorial Committee, 1992), and Flora of North America (1993-2016). Fortunately, several areas around LCNCA had been previously inventoried and plant checklists of areas such as the San Pedro NCA (Makings, 2006), the Cienega Creek Natural Preserve (Fonseca, 2013), and the Sonoita

Creek Natural State Area (McLaughlin, 2006) provided helpful reference material for identification.

ANALYSIS OF FLORA

Many local floras in Arizona have been published, particularly around the southeastern part of the state, and the digitized occurrence data from these floras can be useful for assessing the completion of new assessments. LCNCA is located between three sites where previous floras were completed that share a similar elevational relief, precipitation, and annual temperatures (Table 5). [The San Pedro Riparian National Conservation Area (Makings, 2006), Cienega Creek Preserve (Fonseca, 2013), and Sonoita Creek Natural Area (McLaughlin, 2006)].

SEINet occurrence data from all three floras was compiled and first used to assess percent species overlap between compared sites to gauge the predictive value of this approach. Species overlap between individual sites and LCNCA was determined by comparing plant lists and tallying the number of shared species. Also, the percentage of species overlap between all four sites was determined by counting the number of shared species between all four sites and comparing it to the number of total species in the LCNCA flora.

Occurrence data from all three floras was then used to determine the average number of families, genera, and species and the standard error for a 95% confidence interval. A range of value two standard errors above and below the mean were rounded to the nearest whole number and used to represent the predicted diversity of plant families, genera, and species at LCNCA based on observed diversity at nearby sites.

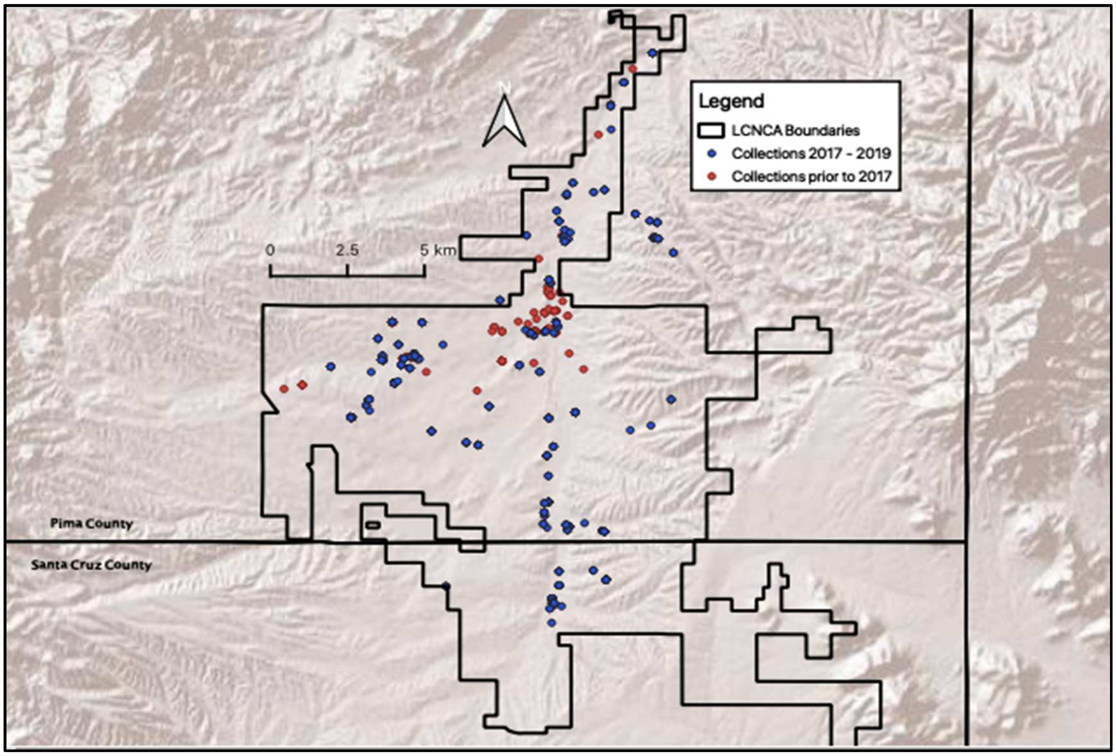

Fig. 6; Map showing the distribution of plant specimen collections at Las Cienegas National Conservation Area, collections prior to 2017 were concentrated north of the Pima/Santa Cruz county line, collections from 2017 - 2019 were more widespread across the conservation area, data aquired from SIENet, map created in QGIS 3.12.

RESULTS

The checklist of vascular plants for the Las Cienegas National Conservation Area contains 403 species (and 406 taxa) from 76 families. The most species rich families are the Poaceae (79 spp.), Asteraceae (70 spp.) and Fabaceae (35 spp.) which account for over 45% (184 / 403) of the species in the current flora. Other families represented by over 10 taxa include the Solanaceae (15 spp.), Euphorbiaceae (15 spp.) , Amaranthaceae, (12 spp.) and Cyperaceae (11 spp.) (Table 1). About 60% (45 / 76) of the current flora includes families with 3 or less taxa and of those, 34 are represented by only a single taxon (Table 1). Two-hundred and fifty-two genera were vouchered and the three most species rich were all in Poaceae (grass family): *Bouteloua*, *Muhlenbergia*, and *Eragrostis* (Table 2). An annotated version of the current plant checklist for LCNCA with vouchers and growth forms can be found in Appendix B.

A summary of plant life span and growth forms represented in the flora is provided in Appendix E . About 28% (116 / 403) of the species in the flora are annuals. Twenty-two species occur either as an annual, perennial, or biennial and were consequently omitted from calculating this total. Of the species which are exclusively annual, 91 were forbs (non-grass, herbaceous plants) with the remaining 25 divided amongst graminoid (19 spp.) and vines (6 spp.). The two most common life-forms were forbs (238) which account for 59% of the current flora, followed by graminoids (94) which account for another 20%. Twenty-one tree species were vouchered at LCNCA along with 12 succulent species which include cacti, agaves and yuccas (Table 3).

About 33% (134) of the species are associated with wetland habitats (Table 4). Just under 10% are facultative upland species, and another 10% are obligate or facultative wetland species (plants that occur > 66% of the time in wetlands). The Poaceae, Cyperaceae, and Asteraceae were among the families with the highest number of taxa in these wetland categories. Definitions of wetland indicator categories according to Lichvar et al., 2012 can be found in Appendix D, and a list of wetland taxa in the LCNCA flora can be found in Appendix A.

Species nativity was determined using the USDA Plant Database (https://plants.usda.gov/java/). Specific state level nativity for all species was not determined. Under 6% (23 / 403) of the flora of LCNCA is non-native to Arizona. However, of the 23 non-native species in the checklist, 60% (14/23) are grasses (Table 1).

Table 1. Most commonly represented plant families at Las Cienegas National Conservation Area, only families that are represented by over 10 species in the current flora were counted, top three families are also represented by the most genera.

Family	Genera	Native spp.	Non-Native spp.	Total spp.
Poaceae	35	65	14	79
Asteraceae	47	69	1	70
Fabaceae	20	32	3	35
Solanaceae	6	13	2	15
Euphorbiaceae	6	14	1	15
Amaranthaceae	7	11	1	12
Cyperaceae	4	10	1	11

Table 2. Genera with the most species represented in the Las Cienegas National Conservation Area flora, only genera represented by over 5 species in the current checklist were counted, top three genera all members of the Poaceae (grass) family.

Genera	**Total spp.**
Bouteloua	11
Muhlenbergia	8
Eragrostis	8
Euphorbia	7
Dalea	6

Table 3. Summary of growth form distribution of plants in the flora for Las Cienegas National Conservation Area, growth forms defined according to USDA Plant guidelines, specific definitions for each can be found in Appendix E.

Growth Form	Annual spp.	Perennial spp.	Ann/Per/Bi spp.	Total spp.
Forb	92	128	20	240
Graminoid	19	74	1	94
Shrub	0	58	0	58
Subshrub	0	28	0	28
Succulent	0	12	0	12
Tree	0	21	0	21
Vine	6	14	1	19

Table 4. Summary of wetland plant categories in the flora of Las Cienegas National Conservation Area, wetland indicator categories were in accordances with definitions given by Lichvar et al., 2012, specific definitions and characterisitcs of each category can be found in Appendix D.

Status	**Families**	**Genera**	**Total spp.**	**% of LCNCA Flora**
Obligate Wetland	14	24	27	6.0%
Facultative Wetland	13	18	24	5.9%
Facultative	15	30	31	7.6%
Facultative Upland	22	41	44	10.9%

HABITAT TYPES

COTTONWOOD-WILLOW RIPARIAN FOREST

An ecological survey of riparian areas conducted in 2000 estimated that there are about 291 ha of cottonwood-willow forest in LCNCA (Pima County, 2001). This is the largest contiguous area of cottonwood-willow forest in Pima County. In LCNCA, along the channel of Cienega Creek, these habitats form an almost uninterrupted stand stretching over 12 km (Fig. 7).

The most dominant and characteristic species is *Populus fremontii* (Fremont Cottonwood) which can grow over 30m in height and form tall canopies that highlight riparian channels with a deep green in contrast with the surrounding dry landscape. Stands of *P. fremontii* together with *Salix gooddingii* (Goodding's Willow) are common along the banks of Cienega Creek and tributaries like Empire Gulch (Fig. 7). Tree species diversity is generally low in these forests (Stromberg, 1997), but occasional species like *Juglans major* (Arizona Walnut) or *Fraxinus velutina* (Velvet Ash), and *Tamarix chinensis* (Tamarisk) have been found scattered in sparse populations around LCNCA. Some occurrences of *S. taxifolia* (Yew Willows) have been historically noted in Empire Gulch and along Cienega Creek (Bodner & Simms, 2008), but it has not been vouchered and consequently represented in this flora.

The communities of herbaceous vegetation in the understory of these riparian forests are organized along a moisture gradient, from the aquatic to semi-aquatic habitats in the main channel of the creek, along to the drier upland banks lining the outside of the riparian galleries. In parts of Cienega Creek where surface water is perennial, such as

Empire Gulch or along the Narrows, obligate aquatic species including *Hydrocotyle ranunculoides* (Floating Pennywort), *Lemma gibba* (Duckweed), *Nasturtium officinale* (Watercress), and *Veronica anagalis-aquatica* (Speedwell) are common. Other perennial, wetland species like *Cyperus sp.* (Sedges) and *Eleocharis palustris* (Common Spikerush) form intermixed stream-edge communities with occasional stands of *Equisetum laevigatum* (Smooth Scouring Rush) and *Schoenoplectus americanus* (Chairmaker's Wood Club-Rush). Such assemblages are common in the loamy, saturated shores of these mesic habitats. Less common species such as *Epipactis gigantea* (Stream Orchid) were found occurring along perennial segments of Cienega Creek, close to the northern limits of LCNCA.

Seasonal flooding and resultant scouring are important drivers in the composition of plant communities in riparian habitats (Boudell & Stromberg, 2008). Sections of riparian corridors where scouring has not occurred recently are dominated by annual and perennial grasses. Species like *Eriochloa acuminata* (Taper-Tip Cup Grass), *Hopia obtusa* (Vine-Mesquite), *Paspalum dilatatum* (Golden Crown Grass), and *Sorghum halpense* (Johnson Grass) are fairly common in more open segments of the channel where the cottonwood canopy is less dense. Shrub communities composed of species such as *Baccharis salicifolia* (Douglas' False Willow), *Brickellia floribunda* (Chihuahuan Brickellbush), and *Gymnosperma glutinosum* (Gumhead) are also more abundant in these areas. In contrast, forbs and graminoids are more predominant in corridors where scouring is more frequent. Perennial forbs like *Ambrosia psilostachya* (Perennial Ragweed), *Epilobium ciliatum* (Fringed Willowherb), *Lobelia cardinalis* (Cardinal-Flower), *Rivina humulis* (Rouge Plant), and *Persicaria bicornis* (Pink Knotweed) grow alongside annual grasses like *Echinocloa colona* (Jungle Rice) and *E. crus-galli* (Large Barnyard Grass).

Unfortunately, riparian forests are an increasingly threatened habitat in Arizona, and communities at LCNCA are no exception. *Populus fremontii* and *Salix goodingii* are shallowly rooted species and rely on saturation from near-surface ground water (Stromberg, 1993a). However, groundwater use in many parts of Arizona exceeds natural replenishment rate, and rural zones, such as around the towns of Sonoita or Elgin south of LCNCA, lack the same oversight assigned to metropolitan water sources (Jacob & Haloway, 2004). Rural communities rely more heavily on private groundwater, and as surface water sources become progressively more strained from climate change, managing the use of local aquifers in rural areas will be a growing challenge for Arizona policymakers (Jacob & Haloway, 2004). Simultaneously, land use operations such as the proposed Rosemont Mine in the Santa Rita Mountains also pose threats to the aquifer which sustains the hydrology at LCNCA (Powell et al., 2014). The uncertain future of groundwater in Arizona is problematic for cottonwood-willow forests that are reliant on the accessibility of shallow groundwater for their survival (Stromberg et al., 1996; Bodner & Simms, 2008). The future of these habitats in Arizona will hinge on the conservative use and management of finite groundwater sources.

Fig. 7; Photograph of a cottonwood-willow riparian forest habitat taken by the author on April 27th, 2018, photo taken in the ephemeral part of Cienega Creek facing south, this stretch of riparian corridor is located north of Cieneguita, the dark brown trunks in the foreground are *Populus fremontii*, an intermediate vegetative undestory is visibile in the background, a list of common species for this habitat can be found in Appendix C.

SEMI-DESERT GRASSLANDS

Throughout the southern portion of the LCNCA the channel of Cienega Creek cuts through a network of arroyos and low, rolling hills and, semi-desert grasslands spreads across hectares of the alluvial piedmonts of the Santa Rita and Whetstone Mountains (Fig. 8). These grasslands are the most abundant plant communities in the LCNCA, covering almost 94% of the total conservation area (Gori & Schussman, 2005).

Semi-desert grasslands (McClaran & VanDevender, 1997; Brown & Makings, 2014) can be distinguished from other habitats by elevation boundaries and tend to occur above desert scrublands, but below plains grasslands, or interior chaparral, from around 1100 – 1500 m elevation. Two diagnostic grass species for these grasslands are *Bouteloua eriopoda* (Black Grama) and *Hilaria mutica* (Tobosagrass) (Brown & Makings, 2014), both of which are have been vouchered for this checklist, confirming the presence of this habitat at LCNCA.

At LCNCA, a heterogenous mixture of early and late Pliestocene alluvium along with a bimodal rainfall regime support large stands of native, perennial grasses like *Bouteloua repens* (Slender Grama), *Digitaria californica* (California Crab Grass), *Heteropogon contortus* (Twisted Tanglehead), and *Hilaria belangeri* (Curly Mesquite). Outside of the floodplain, semi-desert grasslands reach up into the foothills east of Cienega Creek, with higher elevation grass species including *Bouteloua curtipendula* (Side-Oats Grama), *Eragrostis intermedia* (Plains Lovegrass), and *Setaria leucopila* (Streambed Bristle Grass).

Semi-desert grasslands also support a rich array of forbs, shrubs and succulent species including many from the Fabaceae (legume) family. Forbs such as *Dalea* sp.

(Prairie Clovers) and *Lupinus* sp. (Lupines) alongside shrub/subshrubs like *Acacia constricta* (Mescat False Acacia), *Calliandra eriophylla* (Fairy-duster), *Mimosa aculeaticarpa* var. *buinicifera* (Cat-Claw Mimosa) are common. Other forbs/subshrubs include species of *Boerhavia* sp. (Spiderling), *Eriogoum* sp. (Buckwheat), *Lepidium* sp.(Pepperweed), and *Sphaeralcea* sp. (Globe Mallow) are occasionally associated with more disturbed parts of these grasslands, near grazing allotments or roadsides.

Most succulent species in the LCNCA checklist such as *Agave palmeri* (Palmer's Agave), *Cylindropuntia spinosior* (Walking Stick Cactus), *Dasylirion wheeleri* (Sotol, *Nolina microcarpa* (Bear Grass), and *Yucca elata* (Soaptree Yucca) are characteristic of this habitat type along the bajadas and hills of LCNCA. Several noteworthy species of cacti were vouchered in these grasslands, including a tuber forming species of prickly pear cactus, *Opuntia pottsii* (Pott's Prickly Pear). This voucher represents the westernmost occurrence of the species in its range. Other noteworthy cacti species found in semi-desert grasslands include *Sclerocactus intertextus* (White Fishhook Cactus) and *Coryphantha viviprara* (Kaibab Spinystar). While not threatened or endangered, these low-growing, globular cacti were once common in LCNCA, but populations have since been greatly diminished because of illegal poaching (Andrew Salywon, 2020, personal communication).

Along parts of the LCNCA where semi-desert grasslands intersect the central floodplain, the loamy alluvium is carved out into wide arroyos. Dense colonies of *Ericameria nauseuosa* (Gray Rabbitbush) and *Isocoma tenuisecta* (Burroweed) with seasonal annuals like *Helianthus petiolaris* (Lesser Sunflower) are diagnostic.

Along more heavily grazed areas in LCNCA, semi-desert grasslands become increasingly dominated by stands of *Eragrostis lehmanniana* (Lehmann's Lovegrass) (Gori & Schussman, 2005). This South African species has spread across a sizable portion of the grasslands at LCNCA on either side of Cienega Creek and outcompetes a number of more palatable native forage species. Previous monitoring of *E. lehmanniana* at LCNCA indicated that this species spreads most readily on sandy loam ecological sites and has increased its spread since 1995 (Gori & Schussman, 2005). However, still more work is needed to determine the best treatment strategy for invaded areas.

Over the last century, grasslands in LCNCA have experienced changes in perennial grass cover as a result the spread of *E. lehmanniana*, and the suppression of a natural fire regime resulting in woody encroachment from mesquite (Humphrey, 1949; Stromberg 1993b, Gori & Enquist, 2003). Land managers have undertaken efforts to remove certain upland mesquite populations in order to improve grassland habitat for native fauna like Pronghorn antelope species.

Floras like this provide tools for land managers to distinguish valuable habitat type and identify problematic taxa like *E. lehmanniana* to subsequently manage their impact. Collective data from multiple local floras can even serve to identify broader populations of exotic/non-native species at the regional landscape scale and target management efforts accordingly.

Fig. 8. Photograph of a semi-desert grassland habitat taken by the author on August 15th, 2019, several *Agave palmeri* are visible in the foreground, photo taken in the sourthern end of the conservation area near the Pima/Santa Cruz county line, situated in the piedmont of the Whetstones facing south into the grassy drainage, a list of common species for this habitat can be found in Appendix C.

SACATON GRASSLANDS

Sporobolus wrightii (Giant sacaton) is a large, native grass that can measure up to 1m in diameter and up to 2m tall. It can grow under a wide range of conditions and form dense stands which host few woody species and are also referred to as sacaton "bottoms", "flats", or "seas". (Makings, 2006; Bodner & Simms, 2008;). These grasslands are common along floodplains, and low terraces around LCNCA (Fig. 9). Ecological site inventories have identified almost 1500 ha of sacaton flats at the NCA (Bodner & Simms, 2008; Tiller et al., 2012). Sacaton flats are sometimes considered as a variety of semi-desert grasslands (Brown & Makings, 2014), but for the sake of characterizing these within the LCNCA, they will be treated individually.

Giant sacaton grasslands are common along terraces, on the outskirts of the riparian corridors of Cienega Creek. They commonly form in fine, silty and/or loamy, alluvium deposits with access to near-surface groundwater no deeper than 4 m. Stands of *Sporobolus wrightii* are capable of temporarily persisting without groundwater after being established but do so at the cost of decreased in reproductive activity (Tiller et al., 2012). In parts of LCNCA where populations of *Sporobolus wrightii* are healthy, they can help effectively slow soil runoff, and provide a valuable buffer against erosion (Tiller et al., 2012; Bodner & Robles 2017).

Aside from these services, sacaton grasslands also provide habitat for a variety of understory grasses and forbs. In the summer months, annual forbs like *Acalypha ostryifolia* (Pineland Three-Seed Mercury), and *Portulaca umbraticola* (Wing-Pod Purslane) as well as multiple species of *Euphorbia* sp. (Sandmat), and *Ipomoea* sp. (Morning Glory) and are common below the tall panicle canopy. Annual graminoids like

Chloris virgata (Feather Windmill Grass) and *Eriochloa acuminata* (Taper-Tip Cup Grass) will grow in these shaded understories as well.

Vine-forming plants are also common among Sacaton grasslands in LCNCA. Climbing species such as *Phaseolus acutifolius* (Tepary Bean) will grow into the panicle canopy above and spread out across the top, while ground-dwelling species including *Apodenthera undulata* (Melon Loco) and *Cucurbita digitata* (Finger-Leaf Gourd) will root under the safety of the bunch grass stands and send out lengthy runners from the edges into more exposed parts. Other common perennial forbs associated with these grasslands include *Convovulus arvensis* (Field Bindweed), *Evolvulus sericeus* (Silver-Dwarf Morning-Glory), *Hoffmannseggia glauca* (Waxy Rush-Pea), *Hymenothrix wislizeni* (Trans-Pecos Thimblehead) and *Solanum elaeagnifolium* (Silver Leaf Nightshade). In disturbed patches of Sacaton grasslands, along certain roadsides where the bunch grass is less dense, weedy forbs like *Amaranthus palmeri* (Palmer's Amaranth) and *Salsola tragus* (Russian Thistle) are common.

Historically, sacaton grasslands were a dominant community along the Santa Cruz river and its tributaries (Tiller et al., 2012). Arroyo incision, increasing land conversion for agriculture, and groundwater pumping have all caused drastic drops in the local water table (Tucci, 2018). Accessing water at a depth greater than 3 m can be limiting for a stand of *Sporobolus wrightii* which do not produce very deep roots (Bryan, 1928; Tiller et al., 2012). Sacaton grasslands which are no longer able to access groundwater as a result of the lowered water table, heavily rely on precipitation and flooding to replenish soil moisture (Vivian et al., 2014). Unfortunately, as climate regimes become increasingly hotter and drier, the fate of these populations is of growing concern to management groups (Bodner & Simms, 2008; Tiller et al., 2012).

Similar to riparian forests, sacaton grasslands are well studied at LCNCA and are considered a prized community for their ecological, hydrological, and forage value. Several areas of sacaton grasslands in LCNCA have been designated and are regularly monitored to prevent further degradation. Also, restoration projects for giant sacaton in the Agricultural field and along closed-off roads have helped to study the recovery and groundcover trends of these rare communities (Gori & Schussman, 2005).

Fig. 9. Photograph of a sacaton floodplain habitat taken near Cieneguita, east of the cattle water hole, photo taken by author near evening on September 1st, 2018, dense stand of *Sporobolus wrightii* in the foreground streches all around the cienega and borders the channel of Cienega Creek further east, a list of common species for this habitat can be found in Appendix C.

MESQUITE BOSQUES

Prosopis juliflora (Mesquite) in Arizona can grow under a wide range of conditions (Stromberg, 1993b). Along upland habitats, *Prosopis juliflora* has become a problematic species as it encroaches upon native grasslands, particularly in areas where fire suppression is prevalent (Humphrey, 1949). Alternatively, along riparian corridors such as those along Cienega Creek at LCNCA, *Prosopis juliflora* can also form lush riparian habitats along streams channels, known as mesquite bosques (Fig. 10).

These bosques have been recognized as ecologically important and imperiled habitats (Minckley & Clark, 1984), and their dependence on groundwater makes them an increasingly threatened habitat in the Southwest (Stromberg, 1993b). The vegetative strata that form under the dense canopies of mesquite bosques can be distinguished by a unique suite of growth forms which can vary from vine/shrub understories to herbaceous ground cover (Stromberg, 1993b).

At LCNCA, mesquite bosques are most often found lining the upland terraces of riparian corridors. Previous surveys have identified approximately 235 ha of mesquite Bosque within LCNCA, most of which are concentrated along the dry upland banks of Cienega Creek and its tributaries (BLM, 2003; Bodner & Simms, 2008). Sometimes, mesquite bosques will form a narrow strip between the edge of cottonwood-willow galleries and sacaton grasslands which expand out along the floodplain. The overlap of habitat types is common at LCNCA, but the unique assemblage of species organized among the understory of *Prosopis* bosques distinguishes them from other riparian habitats such as Cottonwood-Willow Riparian Forests, and Sacaton Grasslands.

The woody understory is typically composed of sub-arborescent species including *Acacia greggii* (Catclaw Acacia), *Celtis reticulata* (Net-Leaf Hackberry), and *Sapindus saponaria* (Soaptree), as well as other large shrubs such as *Ziziphus obtusifolia* (Graythorn). Dense conglomerates of these shrub species are common among older stands of *Prosopis juliflora* (Mesquite), and contribute to the low, dense canopies in these habitats. Vines species like *Clematis drummondii* (Virgin's Bower) and *Matelea producta* (Texas Milkvine) are occasional among the canopies while shrub species such as *Anisacanthus thurberi* (Desert Honeysuckle), *Datura wrightii* (Jimson Weed), and *Rhus microphylla* (Small-leaf Sumac) form an intermediate stratum below. As with most habitats at LCNCA, species abundance and diversity following late-summer rains is dramatically apparent. Dry understories become lush with annuals including *Bidens leptocephala* (Few-Flower Beggarsticks), *Lepidium thurberi* (Thurber's Pepperwort), *Machearanthera tanacetifolia* (Takhoka Daisy), *Phacelia cearulea* (Sky-Blue Scorpion-Weed), and *Viguieria dentata* (Tooth-Leaf Goldeneye) along with species of *Chenopodium* sp. (Goosefoot) and *Ipomoea* sp. (Morning-Glory). A variety of graminoids like *Disakisperma dubia* (Green Sprangletop), *Eragrostis cilianensis* (Stink Grass), *Hopia obtusa* (Vine-Mesquite), *Setaria grisebachii* (Grisebach's Bristle Grass), and S. *leucopila* (Streambed Bristle Grass) are also common in the herbaceous understory of these bosque.

Mesquite bosques at LCNCA have not benefited from the same amount of management as other rare habitats like sacaton grasslands and cottonwood-willow forests. Nonetheless, they have been identified as one of the most ecologically valuable habitats at LCNCA (Bodner & Robles, 2017) and face similar threats from groundwater decline and climate change as other habitats at LCNCA (Stromberg et al., 1992). Future management of bosques at LCNCA will be dependent on the ability of land managers to reliably identify and monitor riparian groundwater sources at LCNCA (Stromberg et al., 1993), especially if annual precipitation and temperatures continue following .

Fig. 10. Photograph of a mesquite bosque habitat taken by the author on September 8th, 2018, photographed near the Empire Ranch HQ, on the outskirts of the riparian channel of Empire Gulch, photo taken facing east, *Prosopis juliflora* stand in the photo was well established, understory moslty vegetative, a list of common species for this habitat can be found in Appendix C.

CIENEGAS

The name of the Las Cienegas National Conservation area refers to the unique occurrence of a rare and vestigial type of wetland habitat. The term 'cienega' is used to describe a mid-elevation wetland found in the deserts of the Southwest around 1000 – 2000 m above sea level. These 'cienegas' (cien – hundred, agua – water) was first described by Spanish explorers was thought to refer to the localized abundance of water in an otherwise arid landscape (Hendrickson & Minckley, 1984). An overview of the distribution of these habitats across the southwest as well as a discussion on their ecology and hydrology is described by Hendrickson & Minckley (1984) in great detail.

Cienegas are primarily found throughout southeastern Arizona, New Mexico and north-western Mexico. These wetlands are commonly associated with springs and headwaters along vast floodplains which were historically abundant in southeastern Arizona (Hendrickson & Minckley, 1984). Cienegas are typically characterized by alkaline soils and are the product of freshwater springs which pool around build-ups of silt and organic matter. These can manifest differently on the landscape depending on water availability. They can range from permanently inundated pools, to more seasonally wet marshlands with semi-permanently saturated soils. Cienegas in southeastern Arizona often resemble seasonal marshlands and are populated primarily by grasses and low-growing riparian species (Hendrickson & Minckley, 1984). At LCNCA today, cienegas can be found along the floodplains bordering Cienega Creek, for example Cieneguita is a seasonal marshland located about 500 m west of Cienega Creek.

Cieneguita was once a wide, shallow seasonally inundated, wetland, however a series of three ponds to provide critical habitat for several species of conservation concern have been constructed at the western end of the wetland (BLM, 2003). The edges of the floodplain surrounding the ponds are dominated by *Sporobolus wrightii* (Giant Sacaton). Closer to the ponds, *Sorghum halspense* (Johnson Grass) forms dense stands in saturated soils, their understory is dominated by low-growing matted colonies of *Anemopsis californica* (Yerba Mansa). Mixed in are perennial forbs like *Berula erecta* (Cutleaf Water-Parsnip), *Ranunculus macranthus* (Large Buttercup), and *Rumex cirspus* (Yellow Dock).

Along one of the eastern most ponds in this marshland, large stands of *Schoenoplectus americanus* (Chairmaker's Wood Club-Rush) and *Typha latifolia* (Broad-Leaf Cattail) border the southern shoreline. The opposite shore is dominated by a mixed community of *Asclepias subverticillata* (Horsetail Milkweed), *Cuscuta campestris* (Field Dodder), *Eleocharis* sp. (Spikerush), and *Lythrum californica* (California Loosestrife). Various species of *Cyperus* sp. (Sedge) and *Juncus* sp. (Rush) are also abundant along saturated shorelines at all three of these ponds (Fig. 11).

Deposits studied from the confluence of Mattie Canyon and Cienega Creek indicate that these wetlands once covered expansive areas during wetter periods of the Pleistocene (Eddy & Cooley, 1983; Huckell, 1995) but have since been drastically reduced in size and number as a result of channelization and flow diversion. Some cienegas have been successfully preserved or re-restored, but a majority are dried up and the few remaining are of great conservation concern for the NCA (Hendrickson & Minckley, 1984; Bodner & Simms, 2008). Along with wetland plant communities, endangered species of flora and fauna are reliant on these habitats as aquatic refugia. Endangered taxa like the Chiricahua leopard frog (*Lithobates chiricahuensis*), the Gila topminnow (*Poeciliopsis occidentalis*), and the Mexican garter snake (*Thamnophis eques*) as well as populations of *Lilaeopsis schaffneriana* subsp. *recurva* (Huachuca Water Umbel) have been of conservation interest for agencies and management groups (Minckley et al., 2013). The second chapter of this thesis is dedicated to the conservation of the Huachuca Water and discusses the importance of recognizing cienega habitats for their role in the ongoing conservation of this species.

Fig. 11. Photograph of a cienega habitat taken by the author July 7th, 2018, photo taken facing west at one of three fenced wildlife ponds managed by the BLM located at Cieneguita, pond in the photograph is known as Crescent Pond, it is the further east of the three ponds from the cattle water hole, a list of common species for this habitat can be found in Appendix C.

DISCUSSION

The composition of this preliminary flora for LCNCA can be explained by the broad floristic diversity of the Sky Islands in tandem with the heterogeneity of local hydrological factors at LCNCA.

The Sky Islands represent a landscape with complex topography, large elevation gradients, and a bimodal annual precipitation regime which are all the result of numerous geographic, geologic, and climatic elements interacting over millions of years (Coblentz et al., 2005). As a result, the Sky Island region is host to a broad diversity of plant species and fosters high levels of endemism (McLaughlin, 1995) which are in turn reflected in local floras (Makings, 2006; Fonseca, 2013; McLaughlin, 2006) including LCNCA. Species such as *Astragalus thurberi*, *Agave palmeri, Bouteloua eludens,* and *Brickellia floribunda* are all examples of endemic plant species to the Sky Islands that are represented in the flora of LCNCA.

Another possible factor influencing the composition of the flora for LCNCA is the hydrology around Cienega Creek and throughout the conservation area. Over a 20% of the flora of LCNCA is represented by plants associated with wetland habitats (Table 4), and over 80% of the species in the flora of LCNCA are forbs or graminoids (Table 3). This representation is consistent with the vegetation type of riparian areas experiencing variable flow regimes (Stromberg et al., 2009; Vivian et al., 2014). The heterogeneity of perennial, intermittent, and ephemeral stream reaches paired with variable flow and flooding regimes are important drivers for wetland plant diversity (Pollock et al., 1998; Katz et al., 2012). Aquatic and semi-aquatic zones form their own suite of associated species while cienegas form another part of that heterogeneity with associated species guilds that are not found in river habitats (Hendrickson & Minckley, 1984).

Methods for assessing the observed diversity of a flora are varied. Bowers & MacLaughlin (1982) explored methods of calculating diversity with the goal of developing a predictive approach to floristics. Elevation range and collection time were assumed to contribute to over 75% of the number of species in a flora (absolute diversity). However, when equations used to predict absolute diversity and derived relative richness were modeled in the flora of the San Pedro Riparian National Conservation Area, predicted diversity (n = 177) was much lower than observed diversity (n = 625) indicating the shortcomings of relying on a small number of measurable factors (Makings, 2006).

Another approach for assessing diversity relies on the positive relationship between area size and species richness (Cain, 1938); large areas tend to foster a large number of species. A species-area curve can help illustrate predicted species diversity based on a given area. In the case of LCNCA, the area of the site is smaller than the area of the SPRNCA but greater than the area of CCNP and SCNSA (Table 5). Nonetheless, the observed diversity in the flora of CCNP and SCNSA rivals the diversity at SPRNCA (Table 7) which again suggests that area may not be principal factor responsible for plant diversity in this region.

The increased availability of digitized specimen data from local and regional checklists has provided alternative methods to assess plant diversity. As a growing number of floras become available digitally, their combined occurrence data can be assembled and compared to assess species overlap of nearby localities with similar environments. McLaughlin (2006) took this approach in comparing floras of 2 localities in southeastern Arizona before SEINet was available. Today, the same type of comparison can be achieved using digitized occurrence data and provide a predictive tool for floristic studies as well as a useful approach for predicting diversity at a given locality.

Following the analysis outlined in the methods, the checklists of LCNCA and three other nearby sites were compared to determine percent of species overlap. First, individual species lists were compared to that of LCNCA (Table 7). The percentage of species overlap varied between each site, but overall, between 30 – 50% of the species found in the flora of nearby locations like SPRNCA (47%) or CCNP (43%), were also found occurring at LCNCA (Table 1.X). Then the species overlap among all four sites was determined. A total of 168 species were shared between LCNCA and the three other floras which accounts for over 40% of the diversity observed in the current flora for LCNCA (168 / 403). For comparison, estimates proposed by Bowers & McLaughlin (1982) based on elevation and collection time alone only predicted 28% (177 / 625) of the diversity present in the San Pedro NCA flora.

Next, a range of values representing the predicted diversity of plant families, genera, and species at LCNCA was calculated (Table 6). In comparison to the range of values shown in table 7, the diversity of the flora for LCNCA (403 species, 252 genera, 76 families) falls below predicted levels of diversity (Table 8). Relative to predicted values more specifically, the current plant list for LCNCA represents about 83% (76 / 92) of families, 71% (252 / 356) of genera, and 66% (403 / 605) of species suggesting that this flora may only be a preliminary assessment of the plant diversity at LCNCA. Supplemental collecting trips would be worthwhile to further complete this flora.

\

Table 5. Summary of total area, elevation, relief & climate for sites nearby Las Cienegas National Conservation Area were floras have already been published, site information gathered from individual publications of each flora as well as from government or agency websites, site name abbreviations are as follows: Las Cienegas National Conservation Area (LCNCA), San Pedro Riparian National Conservation Area (SPRNCA), Cienega Creek Natural Preserve (CCNP), Sonoita Creek Natural State Area (SCNSA).

Site	**GPS**	**Area (ha)**	**Elevation Range (min-max)**	**Relief (m)**	**MAP (mm)**	**Mean Winter Temp (°C)**	**Mean Summer Temp (°C)**
LCNCA	31.82 -110.66	18,210	1203 - 1451	248	382	7.99	25.70
SPRNCA	31.67 -110.13	23,067	1109 - 1300	191	333	8.21	28.68
CCNP	32.017 -110.64	1,622	953 - 1077	124	355	10.31	30.20
SCNSA	31.500 -110.90	1,988	1008 - 1300	230	426	9.81	27.53

Table 6. Level of predicted diversity of plant families, genera, and species for Las Cienegas National Conservation Area based on observed diversity from other floras from nearby comparable sites, number of families, genera, and species for each site was averaged (n =3) and the standard error for a 95% CI was estimated, predicted diversity is represented by a range of values 2 SE's above and below the calculated average., site abbreviations are as follows: San Pedro Riparian National Conservation Area (SPRNCA), Cienega Creek Natural Preserve (CCNP), Sonoita Creek Natural State Area (SCNSA).

	SPRNCA	**CCNP**	**SCSNA**	**Predicted Diversity**
Families	91	89	97	80 - 100
Genera	363	346	360	330 - 370
Species	641	607	556	500 - 700

Table 7. Summary of species overlap between floras from nearby localities and Las Cienegas National Conservation Area, total species count was acquired from published plant lists on SIENet, species lists were manually compared to determine shared species, percent overlap represents the proportion of plants vouchered at nearby sites which were also vouchered for the flora of Las Cienegas National Conservation Area.

Flora	**Total Species**	**Shared Species with LCNCA**	**% Overlap with LCNCA**
SPRNCA	641	303	47.2%
CCNP	590	258	43.7%
SCNSA	669	238	35.5%

CONCLUSIONS

Las Cienegas National Conservation Area is a place of significant ecological and cultural value. It is host to some of the rarest habitat types in the American Southwest and provides valuable habitat for threatened and endangered taxa while also representing a landmark of Western heritage. The preservation of this unique place is of significance to a wide array of stakeholders and is strongly contingent not only on the work of land managers, but also the tools at their disposal. The flora provided in this chapter aims to provide the first preliminary assessment of plant diversity for this site in order to inform its ongoing management. The growing challenges that land managers face at LCNCA such as climate change, groundwater use, and invasive species rendered the need for a flora more pressing than ever. While the observed plant diversity in this preliminary assessment fell below predicted levels of diversity, percent of species overlap with other nearby sites suggest that a similar level of plant diversity can be expected at LCNCA. Further collections would be beneficial for expanding this flora and preserving the biodiversity found at LCNCA.

CHAPTER 2

STUDIES ON THE LIFE HISTORY TRAITS OF THE ENDANGERED HUACHUCA WATER UMBEL (*LILAEOPSIS SCHAFFNERIANA* SUBSP. *RECURVA,* APIACEAE)

INTRODUCTION

The Huachuca Water Umbel (hereafter HWU), *Lilaeopsis schaffneriana* subsp. *recurva* (A. W. Hill) Affolter (Apiaceae), is a rare, perennial, semi-aquatic plant that occurs in stream and wetland habitats of southeastern Arizona and northern Sonora, Mexico. This taxon primarily reproduces asexually via rhizomes (Fehlberg, 2017), and, infrequently sexually. It produces minute flowers less than 2.0 mm wide, with white petals and exerted nectaries; these are often organized in an umbel (Fig. 12) The cork-ribbed fruits are oblong and are borne on recurved pedicels. They contain buoyant seeds that are dispersed by water (USWFS, 2017). Populations of HWU naturally occur in widespread but scarce habitats (Affolter, 1985) that are threatened by human impact. Extensive habitat loss across the range of this species resulted in its federally endangered status in 1997 and continues to be the most prominent threat to its survival today (USFWS, 2014).

Wetland habitats in southeastern Arizona are increasingly threatened from growing human activity. Habitat degradation from channel incision and groundwater pumping has transformed vital riparian habitat for HWU from seasonal ponds and slow-flowing, perennial streams, into entrenched, ephemeral streambeds (Hendrickson and Minckley, 1984). More recently, threats to groundwater from land use operations like

Fig. 12. Photographs of buds, flowers, inflorescence, and fruit of the Huachuca Water Umbel, (A) top-view of flower, photo credit to Julian Cowles from Tucson, Arizona, (B) side-view of umbel inflorescence with two immature floral buds, (C) side-view of cork-ribbed fruit of the with recurved pedicel, all photos taken from transplanted populations occurring in ponds at Las Cienegas National Conservation Area managed by the Bureau of Land Management.

mines are compounded by the above average temperatures and below average precipitation regimes continue to reduce habitat quality and area for the HWU (Jacob & Haloway, 2004; Powell et al., 2014). Today, a few of the remaining wetlands and streams in southeastern Arizona have been designated as critical habitat for the HWU (USFWS, 2017). While rare, scattered, and often difficult to access, appropriate habitat conditions are crucial for maintaining extant populations. The scarcity of habitat paired with a diminutive growth form make the HWU a challenge to study and monitor *in situ*, which has resulted in a dearth of basic knowledge on the ecology of this plant. Conservation efforts, including habitat restoration, hinge on a better understanding of the life-history of the HWU.

Previous studies have already been successful at studying life history strategies for this species *ex-situ*. Reintroduction experiments of greenhouse colonies, transplant survivorships pilot studies, and short-term seed bank establishment monitoring (Titus & Titus, 2008b, c) have already provided vital information on the ecology of this rare plant. However, the factors and traits which influence the survival and persistence of the HWU *in-situ* is still poorly understood, and much remains to be learned to properly inform the conservation of this species. For example, HWU populations have been shown to establish persistent soil seed banks (Affolter, 1985; Titus & Titus, 2008a) and that the seeds may remain viable for up to ten years (unpublished data in Titus & Titus, 2008b). However, the seed banks and seed viability of the HWU have not been quantified from transplanted sites. As wild populations continue to decline, using greenhouse transplants to restore them will require a better understanding of their persistence in field conditions.

Evaluating the potential for HWU to persist undetected in a seed bank would also be helpful for informing monitoring efforts following periods of disturbance.

Similarly, studies on the drought tolerance of this species have found that factors like leaf density, and distance from surface water can influence the survival of a population (Malcom et al., 2017). In southeastern Arizona, many historically perennial streams have gradually become intermittent as a result of human and climate factors (Turner & Richter, 2011; Makings, 2006), which has contributed to the reported extirpation of HWU populations (USFWS, 2014). The duration of time that the HWU can persist in drought conditions has not been documented. This information has been directly identified as relevant to the conservation of this species by the USFWS (2017) in the recovery plan. Knowing the timeline of drought survivorship would be useful for assessing population health and actively managing during periods of drought.

Recent monitoring of transplanted colonies from *ex-situ* populations of HWU in urban settings observed a decrease in the production of flowers and fruits when plants were growing in standing water or submerged (Wells & Morrow, 2016). Since HWU populations tend to naturally occur in semi-aquatic conditions, it was notable that a colony would produce more flowers and fruits in drier conditions than it normally occurs in. Nonetheless, no similar studies have followed-up on this observation. The difference in phenology observed at this site highlights a need to better understand variations in living conditions for the HWU and how these conditions may impact its reproduction. Monitoring the phenology of different transplanted populations would help further investigate this aspect of its life history. Along with the habitat degradation and drier climates in the southwestern U.S., gaps in the life history of this species are imperative to address so as to implement the most efficient conservation practices for its recovery.

This aim of this study is to address four questions underlying several poorly understood aspects of the life history of the HWU using both greenhouse and field populations of HWU to inform land managers and scientists involved in the conservation of this rare plant. Questions were generated from previous research and monitoring efforts of extant populations and focused on basic aspects of the life history associated with persistence in different habitat conditions. 1) Are HWU seeds present in the seed bank at *ex situ* and *in situ* transplanted sites and/or extirpated sites? 2) How long do HWU seeds remain viable? 3) How long is the HWU capable of enduring artificial drought? 4) Do transplant site conditions influence the phenology of the HWU?

METHODS

SEED BANK STUDY

In order to determine the presence of HWU seeds in local seed banks, soil cores were collected from 10 sites across southern Arizona (Appendix F). Five sites had historical occurrences of HWU, which were extirpated at the time of monitoring. The five other sites hosted living transplanted colonies (Table 8). Soil cores were collected along a 10 m line transect from the upper 5 cm of soil. Each core was harvested using a metal cylinder at each of ten contiguous $1m^2$ plots along the stream or pond margin of each site. Two 100 cm^3 subsamples were also collected at each plot and combined in a plastic bag. GPS coordinates were taken at the beginning and end of each 10 m belt transect. If HWU was present at the site, the size of the population was estimated as ground cover percentage. Each study site was also photo documented to highlight site differences.

Soil cores for each site were grown out in a greenhouse using rectangular 25 cm x 50 cm planting trays containing six square inserts (total of 240 inserts). Each core was split between two inserts, to increase surface area. Each insert contained a coffee filter, a 1cm layer of sterile sand substrate, and the soil core was placed on top. The sand was prepped and autoclaved through a 10-hour sterilization cycle prior to use, and the collected soil layered on top of the sand remained refrigerated until use. Of the six inserts per tray, five contained soil cores and one contained only sand which served as a control. Every other day each tray was filled with 1000 mL of water to maintain constant soil saturation. The experiment was monitored for 12 weeks. Presence or absence of HWU was recorded twice a week, and presence of other plant taxa was recorded weekly. Following the 12 weeks growth period, all unidentified seedlings were verified under a dissecting scope to discern the HWU from other species.

SEED GERMINATION STUDY

The viability of HWU seeds of various ages was studied by using previously collected seeds from wild HWU populations across southern Arizona (dated between 1 to 15 years old). Seeds were generously donated by Jon and Priscilla Titus (State University of New York-Fredonia), and stored in paper packets under cool, dry conditions until used for this study. To test for percent germination, 20% of the seeds from each population were placed into petri dishes on moist filter paper. Ten petri dishes with up to ten seeds per dish, were placed into a germination chamber set to 25 ^{o}C with alternating 12-hour cycles of UV and full spectrum lighting. Germination was recorded weekly for the 12-week duration of the study. Water was added as needed to maintain a moist substrate.

ARTIFICIAL DROUGHT STUDY

To study the drought tolerance of HWU, a hydroponic watering system with controllable water flow was used to regulate the amount of water each colony received. Twelve colonies of HWU were obtained from the greenhouse stock grown at the Desert Botanical Garden (Phoenix, Arizona). Colonies were placed in standard 25 cm x 50 cm planting trays with six equal inserts containing rock-wool substrate and allowed to reproduce clonally to fill out the rock-wool slabs. Individual colonies were then moved into 46 cm x 61 cm x 15 cm tubs, and the rock wool was surrounded by a clay pebble growth medium to a depth of approximately 5cm. Water was brought into the tubs by a high-lift water pump (Ponics model PP8006, Cheyenne, Wyoming).

Periods of drought were induced artificially by cutting water flow to individual tubs for 1, 2, 3, 4, and 6-weeks respectively. The percent moisture of the peat moss slab was monitored weekly during drought conditions using a soil moisture meter (DSMM500, New York City, New York). Water was returned post-drought to observe recovery potential. Two replicate tubs were used per treatment along with two continuously watered controls. Colonies were photographed weekly and aboveground vegetative cover was estimated. Survivorship was determined by the number of colonies still capable of regrowth following drought conditions.

The pump initially ran for six fifteen-minute intervals every other hour each day. After 2 weeks, the watering frequency was increased to 15 minutes every hour to better mimic stream flow patterns. Water was delivered through a branching network of 1 cm flexible tubing. Each tub was fitted with 10 cm of tubing capped with a restrictor to stabilize the pressure throughout the network. The tubs also had 2.5 cm diameter drainage holes topped with 2.5 cm risers and filter caps. Gravity returned the water to a 136 L reservoir tank via two PVC tracks fed by 1cm flexible tubing attached to the drains in each tray. Aerators were used in the reservoir to increase available oxygen. The liquid fertilizer, *Floranova* (General Hydroponics, Santa Rosa CA), was added every third week. The solution has a 7-4-10 ratio of N, P_2O_5, K_2O, and micronutrients.

PHENOLOGY STUDY

In order to investigate how habitat conditions might influence the phenology of the HWU, two *ex situ* and two *in situ* transplant populations were monitored for 7 months. The location of each population was identified based on accessibility and locality difference (Appendix F). Two *ex situ* transplant populations were studied at the Phoenix Zoo Conservation Center (PZCC) and Desert Botanical Garden (DBG). HWU populations at these urban sites occur in artificially constructed wetlands or streams, in a large urban metropolitan area.

Two *in situ* transplant populations were studied in fenced ponds within LCNCA managed by the Bureau of Land Management. The HWU populations at this field site occur on the shores of inundated freshwater pools in mid-elevation floodplains.

Flowering of the HWU has been observed between March and October, peaking in July (USFWS, 2017), and greenhouse experiments have indicated that a HWU flower can persist for 2 – 5 days (Titus & Titus, 2008b). Also, transplants at the PZCC were found to take 6 – 8 days to mature from immature bud to fruit (Wells & Morrow, 2016). For these reasons, populations in this study were monitored every 6 – 8 days from January to July 2018. This timeline followed populations from a dormant state in the winter months, to peak flowering and fruiting in the summer, and avoided the possibility of counting any bud, flower, or fruit twice in the same location.

The number of immature buds, flowers, and fruit was counted and recorded for all plants within a 40 x 40 cm quadrat. A tool was constructed from PVC pipe and nylon rope to create 16 individual sampling areas for the quadrat. Pin flags were used to demarcate the precise location of each quadrats and were kept in place over the entire course of the study. Four quadrat points were set-up at both urban sites and the field site for a total of 12 quadrat points. The proportion of buds that matured into fruit over the course of the study was estimated for each site.

RESULTS

SEED BANK STUDY

HWU only germinated in the transplant site soil cores and was and did not germinate in the sample soils from any of the sites where the plant has been extirpated. More specifically, HWU germination was only observed in soil cores from the Desert Botanical Garden (4 out of 20 trays) and Las Cienegas National Conservation Area (1 out of 20 trays) for a total of 5 out of 212 trays or only 2.4% (Table 8). HWU seedlings were not detected in any soil cores from other transplant sites or from any of the 5 extirpated sites. Other species that emerged from the soil cores included *Eleocharis* (a wetland plant), grasses, and many young dicots. Control trays had no seedlings, an indication that no contaminating seeds were present in the experiment.

SEED GERMINATION STUDY

The number of HWU seeds that germinated in the experiment varied widely among populations, independent of age (Table 9). About 80% of the oldest seeds tested (15 yrs. old) germinated over the course of the study (48/60). One year old seeds from the Babocomari had a germination yield of 11% (1/9), whereas seeds from Scotia Canyon of the same age had a 100% germination yield (4/4). In contrast, all of the seeds from Bingham Cienega failed to germinate.

Germination was observed as soon as four days after moistening of the seeds. The seeds from the Scotia Canyon and Babocomari both germinated rapidly, with all germinants appearing during the first three weeks. The seeds from the DBG (15 years old) germinated throughout the course of the study until week ten. A few ungerminated seeds from all populations developed a fungal infection near the last week of the study and were removed to avoid contamination.

ARTIFICIAL DROUGHT STUDY

Huachuca Water Umbel colonies remained viable and capable of regrowth after up to 3 weeks without receiving flowing water. During drought treatments, moisture level in the peat moss substrate dropped by 50% during the first week and then completely dried out after two weeks. As a result of this, colonies which dried out for over 2 weeks also experienced n-1 week of dry substrate.

Colonies of HWU that experienced the 1 and 2-week drought treatments experienced 100% survivorship. Each pair of colonies for each treatment was capable of regrowth. Aboveground vegetative biomass for all four colonies dried out during the first week but showed signs of regrowth after a week of being rehydrated. Colonies were fully recovered with >50% aboveground cover two weeks after the end of the drought treatment.

Colonies of HWU that experienced the 3-week drought treatment, which included two weeks of dry substrate experienced 50% survivorship (1/2). Only one out of two colonies were capable of regrowth and recovered after the end of the treatment (Table 10). Colonies experiencing the 4-week and 6-weeks of drought conditions exhibited 0% survivorship. No colonies were capable of regrowth following these prolonged treatments.

PHENOLOGY STUDY

A difference in the abundance of immature buds, flowers, and fruit was observed between transplant localities. Transplanted *in situ* HWU populations from the LCNCA ponds produced 4067 buds and of those, 1586 matured to fruit (39%). Comparatively, the transplanted *ex situ* HWU populations from the DBG and Zoo produced 116 buds of which only 10 seemed to mature to fruit (8.6%) (Table 11). Overall, the populations observed in field sites produced 3951 more buds and 1576 more fruit than colonies observed in urban sites. For *in situ* transplanted colonies at field sites, about 39% (1586 / 4067) of observed buds matured to fruit. As for *ex situ* transplanted colonies at urban sites, about 8.62% (10/116) of observed buds matured to fruit (Table 11).

Table 8. Summary of Huachuca Water Umbel seedlings found in soil cores from extirpated and transplanted sites across Arizona, soil cores monitored for the seed bank study, extirpated populations were reported from recent monitoring efforts.

Population Sites Sampled	Population Status	Seedlings (# per tray)
Cienega Creek Preserve	Extirpated	0 / 20
San Pedro- Fairbanks	Extirpated	0 / 20
San Pedro- San Pedro H.	Extirpated	0 / 20
San Pedro- Charleston	Extirpated	0 / 20
San Bernadino	Extirpated	0 / 20
Finley Tank Springs	Transplanted	0 / 20
Horsethief Springs	Transplanted	0 / 20
Phoenix Zoo stream	Transplanted	0 / 20
Cieneguita (LCNCA)	Transplanted	1 / 20
DBG Pond	Transplanted	4 / 20

Table 9. Provenance, age, and number of Huachuca Water Umbel seeds which were tested and germinated per packet for the Seed Germination Study, seeds from Scotia Canyon, Babocomari, and Bingham populations were provided courtesy of John and Priscilla Titus from the State University of New York-Fredonia.

Seed Population	Age (years)	# in Packet	Seeds Tested	Seeds Germinated	% Germinated
Scotia Canyon	1	22	4	4	100 %
Babocomari	1	45	9	1	11 %
Bingham	14	25	5	0	0 %
Desert Botanical Garden	15	300	60	48	80 %

Table 10. Summary of the survivorship observed in the Huachuca Water Umbel during various lengths of artificial drought, treatment duration represents the total amount of time each colony spent without flowing water, the dry substrate column represents that specific amount of time the colony spent in desiccated substrate, survivorship is based on the recovery of both colonies experiencing each treatment.

Treatment Duration	Dry Substrate	Plant Survivorship
1 week	0 weeks	2/2 (100%)
2 weeks	1 week	2/2 (100%)
3 weeks	2 weeks	1/2 (50%)
4 + weeks	3 + weeks	0/2 (0%)

Table 11. Summary of bud and fruit count for transplanted populations of Huachuca Water Umbel at field and urban sites across Arizona, percent of bud to fruit represents the proportion of observed buds which matured into fruit over the course of the growing season, flower count for each site not included.

Population	Site	Buds	Fruits	% Bud/Fruit
Phoenix Zoo	Urban	41	5	12.19 %
Desert Botanical Garden	Urban	75	5	6.67 %
Total	-	116	10	8.62 %
LCNCA; Crescent Pond	Field	1057	312	29.52 %
LCNCA; Egret Pond	Field	3010	1274	42.33 %
Total	-	4067	1586	39.00%

DISCUSSION

The HWU is endemic to rare and increasingly threatened habitats and its reliance on habitat specific conditions for survival has brought scientists to consider its presence as an indicator of habitat health and diversity (Titus & Titus, 2008b). Findings from the presented studies highlight traits of the HWU that indicate this species is capable of enduring disturbance *in-situ* and recovering when conditions ameliorate. Proper habitat conditions are important for the conservation of the HWU and their role in the life history of the species merits further investigation. Studying the HWU *in-situ* may provide important context for addressing poorly understood aspects of its life history.

SEED BANK STUDY

This study confirmed the presence of HWU seeds in the seed bank at transplant sites (specifically the DBG and LCNCA), while no seeds were detected in seed banks from extirpated sites (Table 8). Previous work has illustrated the importance of seed banks for the management of riparian systems (Goodson et al., 2001, 2002) particularly for maintaining species diversity (Leck & Schütz, 2005; Capon & Brock, 2006). The composition of a seed bank can potentially influence the function of entire ecosystems based on the species present (Pakeman & Eastwood, 2013), and as such, seed banks are considered essential to restoration work (Bakker et al., 1996).

Seed banks are also one of the main methods through which plants can recolonize regularly flooded systems (McDonald et al., 1996), such as riparian zones, and may play a role in the observed diversity of habitats with intermittent flow (Katz et al., 2012). Past studies have suggested that the HWU may rely on an intermediate degree of disturbance (e.g. scouring from floods, drought, etc.), to persist amongst more competitive wetland plant communities (Stevenson, 1947; Affolter, 1985; Titus & Titus, 2008b, Malcom et al., 2017). Seed banks may be one manner through which this species manages to persist. Past studies have shown that wild populations of HWU are capable of establishing persistent seed banks (Affolter, 1985; Titus & Titus, 2008a). Also, HWU seeds are small, round and equipped for dispersal by water (Affolter, 1985) which is typical of xeroriparian diaspores and explains their presence in the seed bank (Stromberg, 2008). However, seeds had not yet been observed in the seed bank at sites where HWU populations had been transplanted.

This is important to consider when conserving the HWU *in situ*. When a population is founded at a new locality, establishing a seed bank not only helps the species persist, but it also has important implications for monitoring efforts. Sites where HWU populations are thought to be extirpated may in fact still have buried seeds in the soil capable of regrowth. For example, a HWU population at Cienega Creek Preserve was previously thought to be extirpated and was considered as such in this study. However, in 2018 this population was observed to have recovered aboveground vegetative growth (Peggy Monkemeier, personal communication, 2018.). The exact reason for the recovery of this population still remains to be investigated. Nonetheless, other sites where populations of HWU are thought to be extirpated may benefit from being revisited as seeds may still be present in the seed bank and allow for a delayed recovery.

In this study, the particular distribution of HWU seedlings observed may vary by conditions for each individual location. For example, seed banks of transplanted populations at urban sites may be differentially influenced by hydrology. Soil cores from the DBG were collected along the margin of an artificial pond, with no flowing water. Seeds from this site likely accumulated in the soil near the parent plants and were easily detected in soil cores. In contrast, colonies at the PZCC occur in a lotic habitat, downstream from several animal enclosures, and experience sporadic flood pulses and periods of temporary drought. While previous monitoring of this urban population indicated flowering and fruiting rates comparable to previous years (Well & Morrow, 2016), seeds were not detected from soil cores at this site. As the fruits of the HWU mature, both the infructescence and fruit axes recurve causing seeds to be dropped close to the plant base (Affolter, 1985). As a result of the dynamic hydrology at the PZCC site, it is possible that most seeds produced by this HWU population were carried downstream away from the sampling site before having a chance to be buried in the soil.

SEED GERMINATION STUDY

Seeds of the HWU harvested 15 years before this study were germinated, which indicates that seeds of this species are more long-lived than originally thought. Seeds of the HWU were previously found to remain viable for only up to 10 years (USFWS, 2017) and germinate rather quickly; often within one or two weeks after dispersal (Gori, 1995) and to germinate without cold stratification (Titus & Titus, 2008b).

Only 11% (1/9) of the seeds from the Babocomari populations germinated, whereas 100% (4/4) of seeds of the same age from the Scotia Canyon population germinated in this study. Titus & Titus (2008a) observed a high germination rate (90%) in a greenhouse study with seeds less than one year old, but findings from this study seem to suggest this high germination rate should not always be expected for different populations.

Most seeds in this study germinated within one to two weeks of initial watering which is typical for this species (Titus & Titus, 2008b), However, some of the 15 year old seeds sampled from the DBG took up to 8 weeks to germinate after initial watering. This prolonged germination rate is possibly due to the age of these seeds. Nonetheless 80% (48/60) of the 15 year old seeds actively germinated which would indicate that the observed viability is not anecdotal.

In general, seed viablility can vary among species depending on genetic differences as well as environmental conditions experienced by the parents (Kochanek et al., 2010). Plants that evolved in hot and dry climates tend to have greater seed longevity than those from cool and wet climates, and this longevity has been found to be influenced by a suite of abiotic factors (i.e. temperature, humidity, soil pH, and soil nutrient ratios) (Van Klinken et al., 2008; Pakeman et al., 2012; Long et al., 2015). Most wetland plants do not typically exhibit long-lived seeds, however findings from this study suggest that the HWU may be an exception.

The prolonged viability of seeds has important implications for the conservation of this species. For example, long-lived seeds stored in a soil seed bank may have played a role in the observed recovery of the Cienega Creek Preserve population discussed above. Long-lived, buoyant seeds also increase the chance of long-distance dispersal. Riparian species with a limited capacity to disperse terrestrially, such as the HWU, may greatly extend their range through traits like hydrochory (Boedeltje et al., 2004). The effect of this was noted in a related species, *Lilaeopsis masonii*, where dispersal and establishment of metapopulations showed persistence at the landscape scale, but not at the local scale (Grewell et al., 2013).

The possibility of long-distance dispersal of HWU colonies via seeds means that clonal establishment from flooding may not be the only important factor maintaining diversity in this taxon. Considering the low genetic diversity among extant populations of the HWU (Fehlberg, 2017), this would be a worthwhile avenue to investigate.

ARTIFICIAL DROUGHT STUDY

Greenhouse-grown colonies of HWU were dehydrated for varying lengths of time and were capable of recovery after 3-weeks without water. HWU colonies have been previously observed to tolerate short-term desiccation (Titus & Titus, 2008b, c; Malcom et al., 2017). *In-situ* tolerance to de-watering was found to be largely influenced by leaf density, colony life history, and distance from surface water. An established colony with enough above-ground vegetative growth is able to tolerate desiccation and still recover (Malcom et al., 2017). However, the length of time in which a HWU colony is capable of recovery following complete desiccation remains unknown.

This greenhouse study provides the first timeline of recovery for desiccation HWU colonies. Although, while most colonies in this experiment survived more than two weeks without flowing water, it is likely that this range will vary for *in-situ* populations. Nonetheless, a similar timeline was observed in certain field populations anecdotally (Titus & Titus, 2008c). This aspect of the life history of the HWU merits further investigation to better understand the conditions that maximize this plant's ability to recover from above-ground desiccation.

Drought and increased groundwater pumping are considerable threats to the habitat of the HWU. In turn, the diminished availability of proper habitat for this species is the greatest threat to its conservation. The reduced abundance of cienega habitats in the Southwest and the loss of flow in many stream habitats throughout the range of the HWU have both been the result of increased drought and groundwater use (Hendrickson & Minckley, 1984; USFWS, 2017). As the aridity of the surrounding landscape continues to increase, investigating the tolerance of HWU colonies to drought conditions *in-situ* will be a crucial next step.

PHENOLOGY STUDY

Over the course of a growing season, populations of HWU monitored *in-situ* at field sites produced over 3500 buds and 1500 fruits (Table 11) compared to *ex-situ* populations at urban sites. Also, the ratio of buds which matured into fruits was over 30% greater at field sites (39.0%) then urban sites (8.6%) (Table 11). This difference suggests that local factors may play an important role in the reproductive activity of the HWU.

Little is known about the reproduction and pollination biology of the HWU. Whether the HWU is self-compatible or an obligate outcrosser is largely unknown. Experiments suggest that most *Lilaeopsis* spp. are self-compatible (Affolter, 1985) but this has yet to be verified with the HWU. Also, this species is presumed to be insect pollinated due to the presence of floral features (USFWS, 2017), but again, this has yet to be corroborated. The low genetic diversity amongst extant populations in Arizona (Fehlberg, 2017) suggests that a better understanding of the reproductive biology of this species is crucial to its continued conservation.

This study provided a unique opportunity to observe differences in the phenology of multiple transplanted populations across Arizona. While the specific factors which influence the phenology of the HWU were not explored, this study still highlighted a notable difference in the phenology between *in-situ* and *ex-situ* populations.

The overall disparity in bud, flower, and fruit count was over an order of magnitude greater at field sites. While abundant flowering can occur irregularly in this species (USFWS, 2017), the magnitude of the difference observed between populations suggests that local factors such as site-specific habitat conditions or colony size may influence the reproduction of this species. For example, flooding is a common disturbance in riparian habitats and has been found to influence sexual reproduction in certain dicot perennials. Increased production of fruits and seeds helps to compensate for lower germination rates in flooded systems (Mony et al., 2010). Alternatively, the difference in colony size among monitored sites could have also contributed to the observed difference in phenology as clonal growth and dispersal were found to impact sexual reproduction in angiosperms (Barrett, 2015).

Regardless of the driving factor, the observed variation in phenology between HWU populations has important implications for the conservation of this species. Future studies should consider population parameters such as size and location when investigating the life history of this species. While studying the HWU *ex-situ* is less challenging, findings may vary from studies done *in-situ*. Specific differences, such as those observed in this study, can impact the outcome of conservation decisions and should be considered in future work on this taxon.

CONCLUSIONS

As of 2018 the US Fish & Wildlife Service has begun a period of information gathering to inform and update the recovery plan for the HWU (USFWS, 2017). Elucidating the poorly understood life history of this species can hopefully lead to continued success in conservation work. The four present studies addressed noted gaps in the understanding of the life history of this species by the USFWS in the current recovery plan. HWU seeds were found to remain viable for longer than originally thought, and these long-lived seeds were discovered in seed banks at two transplant sites. In greenhouse experiments, the HWU was capable of recovering from 3 weeks of desiccation, and a critical difference in the phenology of *in-situ* and *ex-situ* populations was highlighted. Findings from this chapter indicate that the fate of this wetland taxon will likely be contingent on efforts to not only restore, but also preserve suitable *in-situ* conditions for current and future populations.

REFERENCES

Abatzoglou, J. T., D. J. McEvoy, and K. T. Redmond, 2017. The West Wide Drought Tracker: Drought Monitoring at Fine Spatial Scales. Bulletin of the American Meteorological Society 98 (9): 1815-1820.

Affolter, J. M. (1985). A monograph of the genus *Lilaeopsis* (Umbelliferae). Systematic Botany Monographs 6: 1-140. doi: 10.2307/25027606.

Arizona Department of Water Resources (ADWR). (2003). Arizona Water Atlas. 3, Section 3.3 Cienega Creek. 36 p.

Bakker, J. P., Poschlod, P., Strykstra, R. J., Bekker, R. M., & Thompson, K. (1996). Seed banks and seed dispersal: important topics in restoration ecology. Acta Botanica Neerlandica 45(4):461-490.

Barrett, S. C. (2015). Influences of clonality on plant sexual reproduction. Proceedings of the National Academy of Sciences 112 (29): 8859-8866.

Bodner, G. S., & Robles, M. D. (2017). Enduring a decade of drought: Patterns and drivers of vegetation change in a semi-arid grassland. Journal of Arid Environments 136: 1-14.

Bodner, G., & Simms, K. (2008). State of the Las Cienegas National Conservation Area; Part 3: Condition and trend of riparian target species, vegetation and channel geomorphology. The Nature Conservancy.

Boedeltje, G. E. R., Bakker, J. P., Ten Brinke, A., Van Groenendael, J. M., & Soesbergen, M. (2004). Dispersal phenology of hydrochorus plants in relation to discharge, seed release time and buoyancy of seeds: the flood pulse concept supported. Journal of Ecology 92(5):786-796.

Boudell, J. A., & Stromberg, J. C. (2008b). Flood pulsing and metacommunity dynamics in a desert riparian ecosystem. Journal of Vegetation Science 19 (3): 373-380.

Bowers, J. E., & McLaughlin, S. P. (1982). Plant species diversity in Arizona. Madroño 29 (4): 227-233.

Brown, D. E., & Makings, E. (2014). A guide to North American grasslands. University of Arizona for the Boyce Thompson Southwestern Arboretum, Tucson.

Brown, D. E., Unmack, P. J., Brennan, T. C. (2007). Digitized map of biotic communities for plotting and comparing distributions of North American animals. The Southwestern Naturalist 52 (4): 610-616.

Brown, D. E. (Editor) (1982). Biotic communities: southwestern United States and northwestern Mexico. University of Utah Press, Salt Lake City.

Bryan, K. (1928). Change in Plant Associations by Change in Ground Water Level. Ecology. 9(4): 474-478.

Cain, S. A. (1938). The species-area curve. American Midland Naturalist, 573-581.

Capon S. J., & Brock M.A. (2006). Flooding, soil seed bank dynamics and vegetation resilience of a hydrologically variable desert floodplain. Freshwater Biology 51 (2): 206-223.

Caves, J. K., Bodner G. S., Simms K., Fisher, L. A., & Robertson, T. (2013). Integrating collaboration, adaptive management, and scenario-planning: Experiences at Las Ciénegas National Conservation Area. *Ecology and Society* 18 (3): 43-63.

Chronic, H. (1983). Roadside geology of Arizona. Mountain Press. Sevierville, Tennessee.

Coblentz, D. (2005). The tectonic evolution of the Madrean Archipelago and its impact on the geoecology of the Sky Islands. United States Department of Agriculture, Forest Service Proceedings, Rocky Mountain Research Station RMRS-P-36, 62-68.

Dowell, G. P. (1978). History of the Empire Ranch. MA Thesis, The University of Arizona, Tucson.

Empire Ranch Foundation, Retrieved 17 April 2020, from https://www.empireranchfoundation.org/

Eaton, G. P. (1982). The Basin and Range Province: Origin and tectonic significance. Annual Review of Earth and Planetary Sciences 10 (1): 409-440.

Eddy, F. W., & Cooley, M. E. (1983). Cultural and Environmental History of Cienega Valley, Southeastern Arizona. Anthropological Papers of the University of Arizona 43.

Everson, B. A. (2010). Rosemont Copper Project Environmental Impact Statement. Geological Society of America Annual Meeting, Denver, 31 October-3 November, 2010. Abstract

Fehlberg, S. D. (2017). Knowledge of Genetic Diversity informs Conservation of a rare, clonal Wetland plant Lilaeopsis schaffneriana subsp. recurva (Apiaceae). Journal of the Botanical Research Institute of Texas 11(2): 499-510.

Flora of North America Editorial Committee, eds. (1993+). Flora of North America North of Mexico. 19+ vols. New York and Oxford.

Fonseca, Julia, 2013, Cienega Creek Natural Preserve Flora, Retrieved 17 April 2020 from https://aznps.com/PAPAZ/Cienega_Creek/Cienega%20Creek.htm

Funk, V. A. (2006). Floras: a model for biodiversity studies or a thing of the past? Taxon 55(3): 581-588.

Funk, V. A. (1993). Uses and misuses of floras. Taxon 42(4):761-772.

Gries, C., Gilbert, M. E. E., & Franz, N. M. (2014). Symbiota–A virtual platform for creating voucher-based biodiversity information portals and communities. Biodiversity Data Journal, 2 (2): e1114.

Goodson, J. M., Gurnell, A. M., Angold, P. G., & Morrissey, I. P. (2002). Riparian seed banks along the lower River Dove, UK: their structure and ecological implications. Geomorphology 47(1): 45-60.

Goodson, J. M., Gurnell, A. M., Angold, P. G., & Morrissey, I. P. (2001). Riparian seed banks: structure, process and implications for riparian management. Progress in Physical Geography 25(3): 301-325.

Gori, D (1995). Monitoring plan for Huachuca water umbel Lilaeopsis schaffneriana ssp. recurva at Cottonwood Spring. Unpublished document., 12 pp.

Gori, D., & Schussman, H. (2005). State of the Las Cienegas National Conservation Area. Part I. Condition and trend of the desert grassland and watershed. The Nature Conservancy, Arizona Chapter, Tucson.

Gori, D. F., & Enquist, C. A. F. (2003). An assessment of the spatial extent and condition of grasslands in central and southern Arizona, southwestern New Mexico and northern Mexico. Nature Conservancy, Arizona Chapter, Tucson.

Grewell, B. J., Espeland, E. K., & Fiedler, P. L. (2013). Sea change under climate change: case studies in rare plant conservation from the dynamic San Francisco Estuary. Botany-Botanique, 91(5): 309-318.

Hale, S. L., Koprowski, J. L., & Hicks, H. (2013). Review of black-tailed prairie dog reintroduction strategies and site selection: Arizona reintroduction. In G. J.

Gottfried, P. F. Folliott,B. S. Gebow, L. G. Eskew, & L. C. Collins, eds. Merging science and management in a rapidly changing world: Biodiversity and management of the Madrean Archipelago III and 7th Conference on Research and Resource Management in the Southwestern Deserts; 2012 May 1-5; Tucson, AZ. Proceedings. RMRS-P-67. Fort Collins, CO: United States Department of Agriculture, Forest Service, Rocky Mountain Research Station. 67:310-315.

Hayes, P. T. (1970). Cretaceous paleogeography of southeastern Arizona and adjacent areas. USGS PP 658-B. U.S Government Printing Office. pp.1 -42.

Hendrickson, D. A., & Minckley, W. L. (1984). Cienegas--Vanishing climax communities of the American Southwest. Desert Plants 6 (3):131-176.

Hervert, J. J., Bright, J. L., Henry, R. S., Piest, L. A., & Brown, M. T. (2005). Home-range and habitat-use patterns of Sonoran pronghorn in Arizona. Wildlife Society Bulletin 33(1): 8-15.

Huckell, B. B. (1995). Of marshes and maize: preceramic agricultural settlements in the Cienega Valley, southeastern Arizona 59. University of Arizona Press, Tucson.

Humphrey, R. R. (1949). Fire as a means of controlling velvet mesquite, burroweed, and cholla on southern Arizona ranges. Rangeland Ecology & Management/Journal of Range Management Archives 2(4): 175-182.

Jacobs, K. L., & Holway, J. M. (2004). Managing for sustainability in an arid climate: lessons learned from 20 years of groundwater management in Arizona, USA. Hydrogeology Journal, 12(1), 52-65.

Katz, G. L., Denslow, M. W., & Stromberg, J. C. (2012). The Goldilocks effect: intermittent streams sustain more plant species than those with perennial or ephemeral flow. Freshwater Biology 57(3): 467-480.

Kearney, T. H., Peebles, R. H., Howell, H. T., & McClintock, E. (1960). Arizona flora. Univ of California Press.

Keasey, M. S. (1974) Gadsden's Silent Observers: An Introduction to the Natural History of Southern Arizona. Filter Press, Palmer Lake, Colorado

Kress, W. J., & Krupnick, G. A. (2006). The future of Floras: new frameworks, new technologies, new uses. Taxon 55(3): 579-580.

Kochanek J., Buckley, Y. M., Probert, R. J., Adkins, S. W., & Steadman, K. J. (2010). Pre-zygotic parental environment modulates seed longevity. Austral Ecology 35: 837–848.

LaForgia, M., Harrison, S. P., & Latimer, A. M. (2018). The indirect effects of exotic annual grasses on native annual forbs varies by drought strategy. Ecological Society of America Annual Meeting (August 5--10). .

Leck, M. A., & Schütz, W. (2005). Regeneration of Cyperaceae, with particular reference to seed ecology and seed banks. Perspectives in Plant Ecology, Evolution and Systematics 7(2): 95-133.

Lichvar, R. W., D. L. Banks, W. N. Kirchner, and N. C. Melvin. (2016). The National Wetland Plant List: 2016 wetland ratings. Phytoneuron 2016-30: 1-17. ISSN 2153 733x

Lichvar, R.W., Melvin, N. C., Butterwick, M. L., & Kirchner, W. N. (2012). National wetland plant list indicator rating definitions (No. ERDC/CRREL-TN-12-1). Cold Regions Research and Engineering Lab, Hanover NH.

List, I. R. (2015). The IUCN red list of threatened species. International Union for Conservation of Nature and Natural Resources. Online at: http://www. iucnredlist. org/(accessed 11 Oct 2015).

Long, R. L., Gorecki, M. J., Renton, M., Scott, J. K., & Colville, L. (2015). The ecophysiology of seed persistence: a mechanistic view of the journey to germination or demise. Biological Reviews 90: 31-59.

MacFarland, J. (2013). Important bird areas of the Madrean Archipelago: A conservation strategy for avian communities. In G. J. Gottfried, P. F. Folliott,B. S. Gebow, L. G. Eskew, & L. C. Collins, eds. Merging science and management in a rapidly changing world: Biodiversity and management of the Madrean Archipelago III and 7th Conference on Research and Resource Management in the Southwestern Deserts; 2012 May 1-5; Tucson, AZ. Proceedings. RMRS-P-67. Fort Collins, CO: United States Department of Agriculture, Forest Service, Rocky Mountain Research Station 67: 493-499.

Makings, E. (2005). Flora of the San Pedro Riparian National Conservation Area, Cochise County, Arizona. USDA Forest Service Proceedings 36: 92-99.

Malcom, J. W., Malcom, A. C., & Radke, W. R. (2017). Water (or the lack thereof), management, and conservation of an endangered desert wetland obligate, Lilaeopsis schaffneriana var. recurva (No. e2699v1). PeerJ Preprints.

McClaran, M. P., & Van Devender, T. R. (Eds.). (1997). The desert grassland. University of Arizona Press, Tucson.

McDonald, A. W., Bakker, J. P., & Vegelin, K. (1996). Seed bank classification and its importance for the restoration of species□rich flood□meadows. Journal of Vegetation Science 7(2): 157-164.

McLaughlin, S. P. (2006). Vascular floras of Sonoita Creek State Natural Area and San Rafael State Park: Arizona's first natural-area parks. *SIDA, Contributions to Botany*, 11 (661-704).

McLaughlin, S. P. (1995). An overview of the flora of the Sky Islands, southeastern Arizona: diversity, affinities, and insularity. Biodiversity and management of the Madrean Archipelago: the Sky Islands of southwestern United States and northwestern Mexico, 60-70.

Melillo, J. M., T. C. Richmond, & G. W. Yohe, eds. (2014) Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 p. doi:10.7930/J0Z31WJ2.

Merlin, A., Bonis, A., Damgaard, C. F., & Mesléard, F. (2015). Competition is a strong driving factor in wetlands, peaking during drying out periods. *PloS one*: 10(6):

Minckley, W. L., & Clark, T. O. (1984). Formation and destruction of a Gila River mesquite bosque community. *Desert Plants*, 6(1).

Mony, C., Mercier, E., Bonis, A., & Bouzille, J. B. (2010). Reproductive strategies may explain plant tolerance to inundation: a mesocosm experiment using six marsh species. Aquatic Botany 92(2): 99-104.

Nations, D., & Stump, E. (1981). Geology of Arizona. Kendall - Hall, Dubuque, Iowa.

Pakeman, R. J., & Eastwood, A. (2013). Shifts in functional traits and functional diversity between vegetation and seed bank. Journal of Vegetation Science 24(5): 865-876.

Pakeman, R. J., Small, J. L., & Torvell, L. (2012). Edaphic factors influence the longevity of seeds in the soil. Plant Ecology 213 (1): 57-65.

Palmer, M. W., Wade, G. L., & Neal, P. (1995). Standards for the writing of floras. BioScience 45(5): 339-345.

Pima County. 2001. Suitability analysis and representation goals for cottonwood-willow forest habitat. County Administrator's Office, Tucson AZ. 42p.

Pollock, M. M., Naiman, R. J., & Hanley, T. A. (1998). Plant species richness in riparian wetlands—a test of biodiversity theory. Ecology 79(1):, 94-105.

Powell, B., L. Orchard, J. Fonseca, and F. Postillion. (2014). Impacts of the Rosemont Mine on hydrology and threatened and endangered species of the Cienega Creek Natural Preserve. Pima County, Arizona. Pima County Flood Control District

PRISM. Retrieved 17 April 2020, from http://prism.oregonstate.edu.

Pyšek, P., Richardson, D. M., & Williamson, M. (2004). Predicting and explaining plant invasions through analysis of source area floras: some critical considerations. Diversity and Distributions 10(3): 179-187.

Raven, P. H. (2019). Saving plants, saving ourselves. Plants, People, Planet 1(1): 8-13.

Seastedt, T. R., Hobbs, R. J., & Suding, K. N. (2008). Management of novel ecosystems: are novel approaches required? Frontiers in Ecology and the Environment 6 (10): 547-553.

SEINet. Retrieved 17 April 2020, from http://swbiodiversity.org/

Stevens, M. N. (2001). Archaic and Early Agricultural period land use in Cienega Valley, southeastern Arizona . PhD. Thesis, The University of Arizona, Tucson.

Stevenson, G. B. (1947). The growth of a species of the genus *Lilaeopsis* in fresh-water reservoirs near Wellington. Transactions of the Royal Society of New Zealand, Botany 76 (4): 581-588.

Stromberg, J. C., Hazelton, A. F., White, M. S., White, J. M., & Fischer, R. A. (2009). Ephemeral wetlands along a spatially intermittent river: Temporal patterns of vegetation development. Wetlands 29 (1): 330-342.

Stromberg, J. C. (1998). Dynamics of Fremont cottonwood (*Populus fremontii*) and saltcedar (*Tamarix chinensis*) populations along San Pedro River, Arizona. Journal of Arid Environments 40 (2):133-155.

Stromberg J. C. (1997). Growth and Survivorship of Fremont Cottonwood, Goodding Willow, and Salt Cedar Seedlings After Large Floods in Central Arizona. Great Basin Naturalist 57(3): 198-208.

Stromberg, J.C., Tiller, R., & B. Richter. (1996). Effects of groundwater decline on riparian vegetation of semiarid regions: The San Pedro, Arizona. Ecological Applications 6 (1): 113-131.

Stromberg, J. C., J. A. Tress, S. D. Wilkins, & S. D. Clark. 1992. Response of Velvet Mesquite to Groundwater Decline. Journal of Arid Environments 23 (1): 45-58.

Stromberg, J. C. (1993a). Fremont cottonwood-Goodding willow riparian forests: a review of their ecology, threats, and recovery potential. Journal of the Arizona-Nevada Academy of Science 26(3): 97-110.

Stromberg, J. C. (1993b). Riparian mesquite forests: a review of their ecology, threats, and recovery potential. Journal of the Arizona-Nevada Academy of Science, 26(1):11-124.

Stromberg, J.C., S. D. Wilkins, and J.A. Tress. (1993). Vegetation-Hydrology Models: Implications for Management of Prosopis velutina (Velvet Mesquite) Riparian Ecosystems. Ecological Applications, 3(2): 307-314.

Swarth, H. S. (1914). A distributional list of the birds of Arizona. Cooper Ornithological Club.

Symbiota Overview. Retrieved April 17, 2020, from http://symbiota.org/docs/symbiota-introduction/symbiota-overview/

Tiller, R., M. Hughes, and G. Bodner. (2012). Sacaton Riparian Grasslands: Mapping Distribution and Ecological Condition using State-and-Transition Models in the Upper Cienega Creek Watershed. The Nature Conservancy, Tucson, Arizona. 45 pp + appendices.

Titus, J. H., & Titus, P. J. (2008a). Seedbank of Bingham Cienega, a spring-fed marsh in southeastern Arizona. Southwestern Naturalist 53 (3): 393-399.

Titus, J.H., & Titus, P. J. (2008b) Assessing the reintroduction potential of the endangered Huachuca water umbel in Southeastern Arizona. Ecological Restoration 26 (4): 311-321.

Titus P. J.,& Titus, J. H. (2008c) Ecological monitoring of the endangered Huachuca water umbel (Lilaeopsis schaffneriana ssp. recurva: Apiaceae). Southwestern Naturalist 53 (4): 458-465,

Tucci, R. 2018.Using Isotopes and Solute Tracers to Infer Groundwater Recharge and Flow in the Cienega Creek Watershed, SE Arizona. MS Thesis. The University of Arizona, Tucson.

Turner, D. S., & Richter, H. E. (2011). Wet/dry mapping: Using citizen scientists to monitor the extent of perennial surface flow in dryland regions. Environmental Management 47 (3): 497-505.

Turner, D., Marshall, R., Enquist, C., Gondor, A., Gori, D., Lopez, E., ... & Schwartz, S. (2005). Conservation priorities in the Apache Highlands ecoregion. Connecting Mountain Islands and Desert Seas: Biodiversity and Management of the Madrean Archipelago II. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, Tucson, AZ, 375-379.

Upham, S. 1983 Cultural and Environmental History of Cienega Valley Southeastern Arizona. Frank W. Eddy and Maurice E. Cooley, with sections by Paul S. Martin and Bruce B. Huckell. The University of Arizona Press, Tucson American Antiquity 50 (3):706-707.

U.S. Department of the Interior, Bureau of Land Management (USDI BLM). 1987. Riparian Area Condition Evaluation Handbook. Phoenix, AZ: BLM Phoenix District Field Office.

____2003. Approved Las Cienegas Resource Management Plan and Record of Decision. Arizona State office and Tucson Field Office.

U.S. Fish and Wildlife Service. 2017. Recovery plan for Lilaeopsis schaffneriana ssp. recurva (Huachuca water umbel). U.S. Fish and Wildlife Service, Arizona Ecological Services Field Office, Tucson, Arizona. 108 pp.

US Fish and Wildlife Service. 2014. Huachuca water umbel (Lilaeopsis schaffneriana ssp. recurva) 5-Year Review: Summary and Evaluation. https://www.fws.gov/southwest/es/arizona/Documents/SpeciesDocs/HuachucaWaterUmbel/Huachuca_Water_Umbel_5-Year_Review_2014_FINAL.pdf.

Vail, E. L. (2011). Diary of a Desert Trail. Vail Ranch Restoration Association 951: 552-3516.

Van Devender, T. R., & McClaran, M. P. (1995). Desert grassland history (pp. 68-99). The University of Arizona Press, Tucson, Arizona.

Van Klinken, R. D., Lukitsch, B., & Cook, C. (2008). Interaction between seed dormancy-release mechanism, environment and seed bank strategy for a widely distributed perennial legume, *Parkinsonia aculeata* (Caesalpinaceae). Annals of Botany102 (2): 255-264.

Vascular Plants of Arizona Editorial Committee. (1992). A new flora for Arizona in preparation. J. Arizona-Nevada Academy of Sciences, 26(1).

Vivian L, M,, Godfree R, C,, Colloff M, J,, Mayence C, E,, & Marshall D, J, (2014) Wetland plant growth under contrasting water regimes associated with river regulation and drought: implications for environmental water management. Plant Ecology 215 (9): 997-1011.

Waters, M. R., & Haynes, C. V. (2001). Late Quaternary arroyo formation and climate change in the American Southwest. Geology 29(5): 399-402.

Wells, S, & Morrow C. (2016). Habitat Conducive to Sexual Reproduction in L. s. recurva, Unpublished manuscript.

Zhu, W., Zheng, Z., Jiang, N., & Zhang, D. (2018). A comparative analysis of the spatio-temporal variation in the phenologies of two herbaceous species and associated climatic driving factors on the Tibetan Plateau. Agricultural and Forest Meteorology. (248): 177-184.

APPENDIX A

CHECKLIST OF WETLAND TAXA IN LAS CIENEGAS NATIONAL CONSERVATION AREA CHECKLIST

Appendix A. List of wetland plants for Las Cienegas National Conservation Area, organized alphabetically by family and species name, wetland ratings for each species is listed in accordance with the USDA Plant Database, specific indicator categories are defined in accordance with Lichvar et al., 2012, specific definitions can be found in Appendix D.

FAMILY *Species*	WETLAND CODE
AIZOACEAE	
Trianthema portulacastrum L.	FAC
AMARANTHACEAE	
Amaranthus palmeri S. Watson	FACU
Salsola tragus L.	FACU
APIACEAE	
Berula erecta (Huds.) Coville	OBL
Lilaeopsis schaffneriana subsp. recurva (A.W.Hill) Affolter	OBL
APOCYNACEAE	
Asclepias subverticillata (A. Gray) Vail	FACU
ARACEAE	
Lemna gibba L.	OBL
Lemna minor L.	OBL
ARALIACEAE	
Hydrocotyle ranunculoides L. f.	FACW
ASPARAGACEAE	
Dichelostemma capitatum (Benth.) Alph. Wood	FACU
ASTERACEAE	
Almutaster pauciflorus (Nutt.) A.& D. Love	FACW
Ambrosia psilostachya DC.	FACU
Ambrosia trifida L.	FAC
Baccharis salicifolia (Ruiz & Pav.) Pers.	FAC

Baccharis sarothroides A. Gray	FACW
Bidens aurea (Aiton) Sherff	OBL
Bidens frondosa L.	FACW
Bidens laevis (L.) Britton	OBL
Bidens leptocephala Sherff	FAC
Brickellia californica (Torr. & A. Gray) A. Gray	FACU
Conoclinium dissectum A.Gray	FACU
Erigeron flagellaris A. Gray	FACU
Helenium thurberi A. Gray	OBL
Helianthus annuus L.	FACU
Laennecia coulteri (A. Gray) G.L. Nesom	FAC
Pseudognaphalium canescens (DC.) Anderb.	FACU
Sonchus asper (L.) Hill	FAC
Symphyotrichum falcatum (Lindl.) G.L. Nesom	FACU
Symphyotrichum subulatum (Michaux) G. L. Nesom	OBL
Verbesina encelioides (Cav.) Benth. & Hook. f. ex A. Gray	FACU
Xanthium strumarium L.	FAC
Xanthocephalum gymnospermoides (A. Gray) Benth. & Hook. f.	FAC
BIGNONIACEAE	
Chilopsis linearis (Cav.) Sweet	FAC
BRASSICACEAE	
Lepidium thurberi Wooton	FACU
Nasturtium officinale W. T. Aiton	OBL
CANNABACEAE	
Celtis reticulata Torr.	FAC
CLEOMACEAE	
Polanisia dodecandra (L.) DC.	FACU

COMMELINACEAE	
Commelina erecta L.	FACU
CONVOLVULACEAE	
Convolvulus equitans Benth.	FACU
Ipomoea hederacea Jacq.	FACU
CUCURBITACEAE	
Echinopepon wrightii (A. Gray) S. Wats.	FAC
CYPERACEAE	
Carex praegracilis W. Boott	FACW
Carex thurberi Dewey	FAC
Cyperus esculentus L.	FACW
Cyperus fendlerianus Boeckeler	FAC
Cyperus odoratus L.	FACW
Eleocharis palustris (L.) Roem. & Schult.	OBL
Schoenoplectus acutus (Muhl. ex Bigelow) T. Love & D. Love	OBL
Schoenoplectus americanus (Pers.) Volk. ex Schinz & R. Keller	OBL
EQUISETACEAE	
Equisetum laevigatum A. Braun	FACW
EQUISETACEAE	
Chamaesyce hyssopifolia (L.) Small	FACU
FABACEAE	
Acacia greggii A. Gray	FACU
Amorpha fruticose L.	FACW
Hoffmannseggia glauca (Ortega) Eifert	FACU
Melilotus indicus (L.) All.	FACU
Prosopis juliflora (Sw.) DC.	FACU
Prosopis velutina Wooton	FACU

Senna hirsuta (L.) Irwin & Barneby	FACU
GENTIANACEAE	
Zeltnera calycosa (Buckley) G.Mans.	FACW
HYDROCHARITACEAE	
Najas guadalupensis (Spreng.) Magnus	OBL
IRIDACEAE	
Sisyrinchium demissum Greene	OBL
JUGLANDACEAE	
Juglans major (Torr.) Heller	FAC
JUNCACEAE	
Juncus acuminatus Michx.	OBL
Juncus balticus Willd.	FACW
Juncus mexicanus Willd. ex Schult. & Schult. f.	FACW
Juncus torreyi Coville	FACW
LAMIACEAE	
Marrubium vulgare L.	FACU
Mentha spicata L.	FACW
LOBELIACEAE	
Lobelia cardinalis L.	OBL
LYTHRACEAE	
Lythrum californicum Torr. & A. Gray	OBL
MALVACEAE	
Anoda cristata (L.) Schlecht.	FAC
MOLLUGINACEAE	
Mollugo verticillata L.	FACU
OLEACEAE	
Fraxinus velutina Torr.	FAC

ONAGRACEAE	
Epilobium ciliatum Raf.	FACW
Oenothera curtiflora W. L. Wagner & Hoch	FACU
ORCHIDACEAE	
Epipactis gigantea Douglas ex Hook.	OBL
OXALIDACEAE	
Oxalis stricta L.	FACU
PHRYMACEAE	
Erythranthe guttata (Fisch. ex DC.) G. L. Nesom	OBL
PHYTOLACCACEAE	
Rivina humilis L.	FAC
PLANTAGINACEAE	
Veronica anagallis-aquatica L.	OBL
POACEAE	
Chloris virgata Sw.	FACU
Cynodon dactylon (L.) Pers.	FACU
Distichlis spicata (L.) Greene	FAC
Echinochloa colona (L.) Link	FAC
Echinochloa crus-galli (L.) P. Beauv.	FACW
Elymus canadensis L.	FAC
Elymus elymoides (Raf.) Swezey	FACU
Elymus trachycaulus (Link) Gould ex Shinners	FACU
Eragrostis cilianensis (All.) Vignolo ex Janch.	FACU
Eragrostis pectinacean (Michx.) Nees ex Steud.	FAC
Eriochloa acuminata (J. Presl) Kunth	FACW
Heteropogon contortus (L.) Beauv. ex Roemer & J.A. Schultes	FACU
Hopia obtusa (Kunth) Zuloaga & Morrone	FACU

Muhlenbergia asperifolia (Nees & Meyen ex Trin.) Parodi	FACW
Muhlenbergia rigens (Benth.) A.S. Hitchc.	FAC
Pascopyrum smithii (Rydb.) Barkworth & D. R. Dewey	FAC
Paspalum dilatatum Poir.	FAC
Phleum pratense L.	FACU
Polypogon monspeliensis (L.) Desf.	FACW
Polypogon viridis (Gouan) Breistr.	FACW
Sorghum halepense (L.) Pers.	FACU
Sporobolus coromandelianus (Retz.) Kunth	FACU
Sporobolus cryptandrus (Torr.) A. Gray	FACU
Sporobolus wrightii Munro ex Scribn.	FAC
Tridens muticus (Torr.) Nash	FAC
POLYGONACEAE	
Persicaria amphibia (L.) Delarbre	OBL
Persicaria bicornis (Raf.) Nieuwl.	FACW
Persicaria lapathifolia (L.) Delarbre	FACW
Rumex crispus L.	FAC
PORTULACACEAE	
Portulaca halimoides L.	FAC
Portulaca oleracea L.	FAC
Portulaca umbraticola Kunth	FACU
POTAMOGETONACEAE	
Potamogeton foliosus var. foliosus Raf.	OBL
Zannichellia palustris L.	OBL
PRIMULACEAE	
Samolus parviflorus Raf.	OBL
RANUNCULACEAE	

Myosurus minimus L.	OBL
RUBIACEAE	
Diodia teres Walter	FACU
SALICACEAE	
Salix gooddingii Ball	FACW
SAPINDACEAE	
Sapindus saponaria L.	FACU
SAURURACEAE	
Anemopsis californica (Nutt.) Hook. & Arn.	OBL
SOLANACEAE	
Calibrachoa parviflora (Juss.) D'Arcy	FACW
Physalis pubescens L.	FACU
Solanum douglasii Dunal	FAC
TAMARICACEAE	
Tamarix chinensis Lour.	FAC
TYPHACEAE	
Typha latifolia L.	OBL
VITACEAE	
Vitis arizonica Engelm.	FACU

APPENDIX B

VASCULAR PLANT CHECKLISTS FOR LAS CIENEGAS NATIONAL CONSERVATION AREA, PIMA COUNTY, ARIZONA

Appendix B. Checklist of vascular plants for Las Cienegas National Conservation Area, assembled from field vouchers and herbarium specimen, organized alphabetically by plant family and species, each species represented by at least one herbarium voucher stored at the institution identified in brackets. A digital version of this checklist is available on SIENet (http://swbiodiversity.org).

FAMILY *Species*	Common Name	Life Form	Growth Form	Voucher(s)
ACANTHACEAE				
Anisacanthus thurberi (Torr.) A. Gray	Thurber's Desert-Honeysuckle		Shrub	Solves 248 [ASU]
Dicliptera resupinata (Vahl) Juss.	Arizona Foldwing	Per	Forb	Solves 210 [ASU]
ADOXACEAE				
Sambucus canadensis L.	Common Elderberry		Shrub/ Tree	Solves 283 [ASU]
AIZOACEAE				
Trianthema portulacastrum L.	Desert Horse-Purslane	Ann	Forb	Salywon 2018 [DES]
AMARANTHACEAE				
Amaranthus palmeri S. Watson	Careless Weed		Shrub	Solves 81 [ASU]
Atriplex canescens (Pursh) Nutt.	Four-Wing Saltbush	Ann	Forb	Solves 507 [ASU]
Atriplex elegans (Moq.) D. Dietr.	Wheelscale Saltbush	Ann	Forb	Solves 340 [ASU]
Atriplex wrightii S. Wats.	Wright's Saltbush	Ann	Forb	Salywon 2017 [DES]
Chenopodium berlandieri var. sinuatum (J. Murr) H.A. Wahl	Pitseed Goosefoot	Ann	Forb	Martin T-521 [ARIZ]
Chenopodium incanum (S. Watson) A. Heller	Mealy Goosefoot	Ann	Forb	Solves 117 [ASU]
Chenopodium pratericola Rydb.	Desert Goosefoot	Ann	Forb	Solves 438 [ASU]
Froelichia arizonica Thornb. ex Standl.	Arizona Snake-Cotton	Per	Forb	Solves 554 [ASU]
Gomphrena nitida Rothr.	Pearly Globe-Amaranth	Ann	Forb	Solves 437 [ASU]
Gomphrena sonorae Torr.	Sonoran Globe Amaranth	Ann/ Per	Forb	Solves 621 [ASU]

Guilleminea densa (Humb. & Bonpl. ex Willd.) Moq.	Small Matweed	Per	Forb	Solves 119 [ASU]
**Salsola tragus* L.	Prickly Russian-Thistle	Ann	Forb	Solves 2018-08-19 [SEINet]
AMARYLLIDACEAE				
Zephyranthes longifolia Hemsl.	Copper Zephyr-Lily	Per	Forb	Martin T-478 [ARIZ]
ANACARDIACEAE				
Rhus microphylla Engelm.	Little-Leaf Sumac		Shrub/ Tree	Solves 264 [ASU]
Rhus virens Lindh. ex A. Gray	Evergreen Sumac		Shrub/ Tree	Solves 459 [ASU]
APIACEAE				
Berula erecta (Huds.) Coville	Cut-Leaf Water-Parsnip	Per	Forb	Solves 531 [ASU]
Lilaeopsis schaffneriana subsp. *recurva* (A.W.Hill) Affolter	Schaffner's Grasswort	Per	Forb	Brewer 2010-10-27 [SEINet]
APOCYNACEAE				
Asclepias Asperula (Decne.) Woodson	Spider Antelope-Horns	Per	Forb	Solves 530 [ASU]
Asclepias brachystephana Engelm. ex Torr.	Short-Crown Milkweed	Per	Forb	Solves 566 [ASU]
Asclepias engelmanniana Woods.	Engelmann's Milkweed	Per	Forb	Solves 578 [ASU]
Asclepias nummularia Torr.	Tufted Milkweed	Per	Forb	Solves 569 [ASU]
Asclepias subverticillata (A. Gray) Vail	Horsetail Milkweed	Per	Forb	Solves 547 [ASU]
Matelea producta (Torr.) Woods.	Texas Milkvine	Per	Vine	Solves 284 [ASU]
ARACEAE				
Lemna gibba L.	Swollen Duckweed	Per	Forb	Solves 2018-05-28 [SEINet]
Lemna minor L.	Common Duckweed	Per	Forb	Wolkis 705 [ASU]

ARALIACEAE				
Hydrocotyle ranunculoides L. f.	Floating Marsh Pennywort	Per	Forb	Solves 542 [ASU]
ARISTOLOCHIACEAE				
Aristolochia watsonii Woot. & Standl.	Watson's Dutchman Pipe	Per	Forb	Solves 606 [ASU]
ASPARAGACEAE				
Agave palmeri Engelm.	Palmer's Century Plant		Succulent	Solves 561 [ASU]
Agave parryi var. *huachucensis* (Baker) Little	Huachuca Agave		Succulent	Hodgson 30818 [DES]
Dichelostemma capitatum (Benth.) Alph. Wood	Bluedicks	Per	Forb	Solves 223 [ASU]
Echeandia flavescens (Schult. & Schult. f.) Cruden	Torrey's Craglily	Per	Forb	Fagan 2009-07-28 [SEINet]
Milla biflora Cav.	Mexican Star	Per	Forb	Solves 180 [ASU]
Yucca baccata Torr.	Banana Yucca		Succulent	Solves 192 [ASU]
Yucca elata (Engelm.) Engelm.	Soaptree Yucca		Succulent	Clouse UAH-37 [ARIZ]
ASTERACEAE				
Acourtia nana (A. Gray) Reveal & R. M. King	Dwarf Desert Peony	Per	Forb	Solves 157 [ASU]
Ageratina wrightii (A. Gray) R. M. King & H. Rob.	Wright's Snakeroot		Shrub/ Subshrub	Solves 467 [ASU]
Almutaster pauciflorus (Nutt.) A.& D. Love	Alkali Marsh Aster	Per	Forb	Solves 311 [ASU]
Ambrosia confertiflora DC.	Weakleaf bur Ragweed	Per	Forb	Solves 412 [ASU]
Ambrosia psilostachya DC.	Cuman Ragweed	Per	Forb	Solves 474 [ASU]
Ambrosia trifida L.	Great Ragweed	Per	Forb	Solves 206 [ASU]
Ambrosia trifida var. texana Scheele	Texan Great Ragweed	Ann	Forb	Martin T-522 [ARIZ]
Baccharis salicifolia (Ruiz & Pav.) Pers.	Mule-Fat		Shrub	Solves 137 [ASU]

Baccharis sarothroides A. Gray	Rosin Bush		Shrub	Solves 2018-09-09 [SEINet]
Bahia absinthifolia Benth.	Hairy-Seed Bahia	Per	Forb	Solves 460 [ASU]
Berlandiera lyrata Benth.	Lyre-Leaf Greeneyes	Per	Forb	Solves 545 [ASU]
Bidens aurea (Aiton) Sherff	Arizona Beggarticks	Per	Forb	Solves 203 [ASU]
Bidens frondosa L.	Devil's Beggartick	Per	Forb	Solves 188 [ASU]
Bidens laevis (L.) Britton	Smooth Beggarticks	Ann/ Per	Forb	Solves 391 [ASU]
Bidens leptocephala Sherff	Few-Flower Beggarticks	Ann	Forb	Solves 419 [ASU]
Brickellia californica (Torr. & A. Gray) A. Gray	California Brickelbush		Subshrub	Solves 2018-10-19 [SEINet]
Brickellia floribunda A. Gray	Chihuahuan Bricklbush		Subshrub	Solves 472 [ASU]
Chaetopappa ericoides (Torr.) G.L. Nesom	Rose Heath	Per	Forb	Solves 485 [ASU]
Cirsium ochrocentrum A. Gray	Yellow- Spine Thistle	Bi/Per	Forb	Solves 2018-05-21 [SEINet]
Cirsium wheeleri (A. Gray) Petrak	Wheeler's Thistle	Per	Forb	Solves 292 [ASU]
Conoclinium dissectum A.Gray	Palm- Leaf Thoroughwort	Per	Forb	Mauz 110 [ARIZ]
Conyza canadensis (L.) Cronquist	Canadian Horseweed	Ann/ Bi	Forb	Solves 208 [ASU]
Ericameria nauseosa (Pall. ex Pursh) G. L. Nesom & G. I. Baird	Rubber Rabbitbrush		Shrub/ Subshrub	Solves 447 [ASU]
Erigeron arisolius G.L. Nesom	Arid Throne Fleabane	Ann	Forb	Solves 93 [ASU]
Erigeron concinnus (Hook. & Arn.) Torr. & A. Gray	Navajo Fleabane	Per	Forb	Solves 239 [ASU]
Erigeron divergens Torr. & A. Gray	Spreading Fleabane	Bi	Forb	Solves 620 [ASU]
Erigeron flagellaris A. Gray	Trailing Fleabane	Bi	Forb	Solves 499 [ASU]
Erigeron neomexicanus A. Gray	New Mexico Fleabane	Per	Forb	Solves 364 [ASU]

Gutierrezia microcephala (DC.) A. Gray	Threadleaf Snakeweed		Shrub/ Subshrub	Solves 345 [ASU]
Gymnosperm glutinosum (Spreng.) Less.	Gumhead		Shrub/ Subshrub	Solves 461 [ASU]
Helenium thurberi A. Gray	Thurber's Sneezeweed	Ann	Forb	Solves 244 [ASU]
Helianthus annuus L.	Common Sunflower	Ann	Forb	Wolkis 506 [ASU]
Helianthus petiolaris Nutt.	Prairie Sunflower	Ann	Forb	Solves 427 [ASU]
Heliomeris longifolia (Robins. & Greenm.) Cockerell	Longleaf False Goldeneye	Ann	Forb	Salywon 2101 [DES]
Heliomeris multiflora Nutt.	Showy Goldeneye	Per	Forb	Solves 434 [ASU]
Heliomeris multiflora var. nevadensis (A. Nels.) Yates	Nevada Goldeneye	Per	Forb	Solves 457 [ASU]
Heterosperma pinnatum Cav.	Wingpetal	Ann	Forb	Solves 202 [ASU]
Heterotheca subaxillaris (Lam.) Britton & Rusby	Camphorweed	Ann	Forb	Solves 626 [ASU]
Hymenothrix wislizeni A. Gray	Trans-Pecos Thimblehead	Ann/ Bi	Forb	Solves 339 [ASU]
Isocoma tenuisecta Greene	Burroweed		Subshrub	Solves 622 [ASU]
Laennecia coulteri (A. Gray) G.L. Nesom	Coulter's Horseweed	Ann	Forb	Solves 382 [ASU]
Machaeranthera tagetina Greene	Mesa Tansyaster	Ann	Forb	Solves 616 [ASU]
Machaeranthera tanacetifolia (Kunth) Nees	Tanseyleaf Tansyaster	Ann/ Bi	Forb	Solves 342 [ASU]
Malacothrix fendleri A. Gray	Fendler's Desert Dandelion	Ann	Forb	Clouse UAH-1 [ARIZ]
Melampodium strigosum Stuessy	Shaggy Blackfoot	Ann	Forb	Solves 357 [ASU]
Parthenium incanum Kunth	Mariola		Shrub	Salywon 2102 [DES]
Pectis cylindrica (Fern.) Rydb.	Sonoran Chinchweed	Ann	Forb	Solves 165 [ASU]
Pseudognaphalium canescens (DC.) Anderb.	Wright's Cudweed	Ann/ Bi/Per	Forb	Solves 618 [ASU]
Pseudognaphalium leucocephalum (A. Gray) A. Anderb.	White Cudweed	Ann	Forb	Solves 617 [ASU]
Pyrrhopappus pauciflorus (D. Don) DC.	Smallflower Desert-Chicory	Ann/P er	Forb	Wolkis 466 [ASU]

Sanvitalia abertii A. Gray	Abert's Creeping Zinnia	Ann	Forb	Solves 139 [ASU]
**Schkuhria pinnata* (Lam.) Kuntze ex Thell.	Pinnate False Threadleaf	Ann	Forb	Salywon 1856 [DES]
**Senecio flaccidus var. douglasii* (DC.) B.L.Turner & T.M.Barkley	Douglas' Ragwort	Per	Forb	Mauz 24-106 [ARIZ]
**Sonchus asper* (L.) Hill	Spiny Sowthistle	Ann	Forb	Wolkis 510 [ASU]
Stephanomeria pauciflora (Torr.) A. Nels.	Brownplume Wirelettuce		Subshrub	Clouse UAH-5 [ARIZ]
Stephanomeria tenuifolia (Raf.) Hall	Lesser Wirelettuce	Per	Forb	Solves 568 [ASU]
Stephanomeria thurberi A. Gray	Thurber's Wirelettuce	Per	Forb	Solves 251 [ASU]
Symphyotrichum falcatum (Lindl.) G.L. Nesom	White Prairie Aster	Per	Forb	Wolkis 981 [ASU]
Symphyotrichum falcatum var. falcatum (Lindl.) G.L. Nesom	White Prairie Aster	Per	Forb	Salywon 2205 [DES]
**Symphyotrichum subulatum* (Michaux) G. L. Nesom	Eastern Annual Saltmarsh Aster	Ann/ Bi	Forb	Solves 422 [ASU]
Symphyotrichum subulatum var. parviflorum (Nees) S.D. Sundberg	Southwestern Annual Saltmarsh Aster	Ann/ Bi	Forb	Solves 142 [ASU]
Thelesperma megapotamicum (Spreng.) Kuntze	Hopi Tea Greenthread	Per	Forb	Solves 297 [ASU]
Thymophylla pentachaeta (DC.) Small	Fiveneedle Pricklyleaf		Subshrub	Solves 385 [ASU]
Verbesina encelioides (Cav.) Benth. & Hook. f. ex A. Gray	Golden Crownbeard	Ann	Forb	Solves 358 [ASU]
Viguiera dentata (Cav.) Spreng.	Toothleaf Goldeneye		Subshrub	Solves 609 [ASU]
Xanthisma gracile (Nutt.) D.R.Morgan & R.L.Hartm.	Grassleaf Sleepy Daisy	Ann	Forb	Solves 625 [ASU]
Xanthisma spinulosum (Pursh) D.R. Morgan & R.L. Hartman	Lacy Tansyaster		Subshrub	Solves 490 [ASU]
Xanthium strumarium L.	Rough Cocklebur	Ann	Forb	Solves 592 [ASU]
Xanthocephalum gymnospermoides (A. Gray) Benth. & Hook. f.	San Pedro Matchweed	Ann	Forb	Solves 281 [ASU]
Zinnia acerosa (DC.) A. Gray	Desert Zinnia	Per	Forb	Solves 181 [ASU]
Zinnia grandiflora Nutt.	Rocky Mountain Zinnia	Per	Forb	Solves 624 [ASU]

BIGNONIACEAE				
Chilopsis linearis (Cav.) Sweet	Desert Willow		Shrub/ Tree	Solves 271 [ASU]
BORAGINACEAE				
Lithospermum cobrense Greene	Smooththroat Stoneseed	Per	Forb	Solves 572 [ASU]
Nama hispida A.Gray	Bristly Nama	Ann	Forb	Solves 260 [ASU]
Pectocarya recurvata I.M. Johnston	Curvenut Combseed	Ann	Forb	Solves 506 [ASU]
Phacelia arizonica A. Gray	Arizona Phacelia	Per	Forb	Solves 503 [ASU]
Phacelia caerulea Greene	Skyblue Phacelia	Ann	Forb	Solves 257 [ASU]
Phacelia crenulata Torr. ex S. Watson	Cleftlead Wild Heliotrope	Ann	Forb	Salywon 2123 [DES]
BRASSICACEAE				
Boechera perennans (S. Watson) W. A. Weber	Perennial Rockcress	Per	Forb	Solves 108 [ASU]
Descurainia pinnata (Walter) Britton	Western Tansymustard	Ann/ Bi/Per	Forb	Solves 217 [ASU]
Lepidium lasiocarpum Nutt.	Shaggyfruit Pepperweed	Ann/ Bi	Forb	Solves 115 [ASU]
Lepidium oblongum Small	Veiny Pepperweed	Ann/ Bi	Forb	Salywon 1876 [DES]
Lepidium thurberi Wooton	Thurber's Pepperweed	Ann/ Bi	Forb	Solves 528 [ASU]
**Nasturtium officinale* W. T. Aiton	Watercress	Per	Forb	Solves 252 [ASU]
**Sisymbrium irio* L.	London Rocket	Ann	Forb	Solves 501 [ASU]
CACTACEAE				
Coryphantha vivipara var. vivipara (Nutt.) Britton & Rose	Arizona Spinystar		Succulent	Solves 550 [ASU]
Cylindropuntia spinosior (Engelm.) Knuth	Walkingstick Cactus		Succulent	Solves 250 [ASU]
Echinocereus fendleri (Engelm.) Sencke ex J.N. Haage	Pinkflower Hedgehog Cactus		Succulent	Solves 2018-10-27 [SEINet]

Ferocactus wislizeni (Engelm.) Britton & Rose	Candy Barrelcactus		Succulent	Solves 182 [ASU]
Opuntia engelmannii Salm-Dyck	Cactus Apple		Succulent	Hodgson 30530 [DES]
Opuntia phaeacantha Engelm.	Tulip Pricklypear		Succulent	Solves 185 [ASU]
Opuntia pottsii Salm-Dyck	Twistspine Pricklypear		Succulent	Solves 184 [ASU]
Sclerocactus intertextus (Engelm.) N.P. Taylor	White Fishhook Cactus		Succulent	Solves 551 [ASU]
CANNABACEAE				
Celtis reticulata Torr.	Netleaf Hackberry		Shrub/ Tree	Solves 599 [ASU]
CELASTRACEAE				
Mortonia scabrella A. Gray	Rio Grande Saddlebush		Shrub	Solves 462 [ASU]
CLEOMACEAE				
Polanisia dodecandra (L.) DC.	Redwhisker Clammyweed	Ann	Forb	Solves 146 [ASU]
COMMELINACEAE				
Commelina dianthifolia Delile	Birdbill Dayflower	Per	Forb	Solves 571 [ASU]
Commelina erecta L.	Whitemouth Dayflower	Per	Forb	Solves 402 [ASU]
Tradescantia pinetorum Greene	Pinewoods Spiderwort	Per	Forb	Solves 570 [ASU]
CONVOLVULACEAE				
**Convolvulus arvensis* L.	Field Bindweed	Per	Forb/ Vine	Solves 287 [ASU]
Convolvulus equitans Benth.	Texas Bindweed	Ann/ Per	Forb/ Vine	Solves 483 [ASU]
Cuscuta campestris Yunck.	Fiveangled Dodder	Per	Forb/ Vine	Solves 308 [ASU]
Evolvulus arizonicus A. Gray	Wild Dwarf Morning-Glory	Per	Forb	Solves 255 [ASU]
Evolvulus nuttallianus Roem. & Schult.	Shaggy Dwarf Morning-Glory	Per	Forb	Solves 581 [ASU]
Evolvulus sericeus Sw.	Silver Dwarf Morning-Glory	Per	Forb	Solves 567 [ASU]

Ipomoea costellata Torr.	Crestrib Morning-Glory	Ann	Forb	Solves 455 [ASU]
Ipomoea cristulata Hallier f.	Trans-Pecos Morning-Glory	Ann	Forb/ Vine	Solves 456 [ASU]
**Ipomoea hederacea* Jacq.	Ivyleaf Morning-Glory	Ann	Forb/ Vine	Solves 426 [ASU]
CUCURBITACEAE				
Apodanthera undulata A. Gray	Melon Loco	Per	Forb/ Vine	Solves 546 [ASU]
Cucurbita digitata A. Gray	Fingerleaf Gourd	Per	Forb/ Vine	Solves 579 [ASU]
Cucurbita foetidissima Kunth	Missouri Gourd	Per	Forb/ Vine	Solves 245 [ASU]
Echinopepon wrightii (A. Gray) S. Wats.	Wild Balsam Apple	Ann	Forb/ Vine	Mauz 2006-55 [ARIZ]
Sicyos laciniatus L.	Cutleaf Bur Cucumber	Ann	Forb/ Vine	Solves 403 [ASU]
Sicyosperma gracile A. Gray	Climbing Arrowheads	Ann	Forb/ Vine	Solves 343 [ASU]
CUPRESSACEAE				
Juniperus coahuilensis (Martinez) Gaussen ex R.P. Adams	Redberry Juniper		Tree	Solves 2018-10-18 [ASU]
CYPERACEAE				
Carex praegracilis W. Boott	Clustered Field Sedge	Per	Graminoid	Solves 215 [ASU]
Carex thurberi Dewey	Thurber's Sedge	Per	Graminoid	Solves 393 [ASU]
Carex ultra Bailey	Cochise Sedge	Per	Graminoid	Salywon 2118 [ASU]
**Cyperus esculentus* L.	Yellow Nutsedge	Per	Graminoid	Solves 482 [ASU]
Cyperus fendlerianus Boeckeler	Fendler's Flatsedge	Per	Graminoid	Solves 388 [ASU]
Cyperus odoratus L.	Fragrant Flatsedge	Ann/ Per	Graminoid	Solves 132 [ASU]
Cyperus rusbyi Britt.	Rusby's Flatsedge	Per	Graminoid	Martin T-520 [ARIZ]
Eleocharis macrostachya Britton	Pale Spikerush	Per	Graminoid	Solves 541 [ASU]
Eleocharis palustris (L.) Roem. & Schult.	Common Spikerush	Per	Graminoid	Salywon 1884 [ASU]

Schoenoplectus acutus (Muhl. ex Bigelow) T Love & D. Love	Hard-Stem Bulrush	Per	Graminoid	Solves 532 [ASU]
Schoenoplectus americanus (Pers.) Volk. ex Schinz & R. Keller	Chairmaker's Bulrush	Per	Graminoid	Solves 309 [ASU]
EPHEDRACEAE				
Ephedra trifurca Torr. ex S. Watson	Longleaf Jointfir		Shrub	Solves 213 [ASU]
EQUISETACEAE				
Equisetum laevigatum A. Braun	Smooth Horsetail		Forb	Solves 274 [ASU]
EUPHORBIACEAE				
Acalypha neomexicana Muell.-Arg.	New Mexico Copperleaf	Ann	Forb	Salywon 1854 [DES]
Acalypha ostryifolia Riddell ex J. M. Coult.	Pineland Three-Seed Mercury	Ann	Forb	Solves 129 [ASU]
Acalypha phleoides Cav.	Shrubby Copperleaf		Subshrub	Solves 548 [ASU]
Croton pottsii (Klotzsch) Muell.-Arg.	Leatherweed		Subshrub	Solves 296 [ASU]
Euphorbia albomarginata Torr. & A. Gray	White-Margin Sandmat	Per	Forb	Solves 484 [ASU]
**Euphorbia dentata* Michx.	Toothed Spurge	Ann	Forb	Mauz 2006-39 [ARIZ]
Euphorbia dioeca Kunth	Royal Sandmat	Ann	Forb	Solves 204 [ASU]
Euphorbia exstipulata Engelm.	Square-Seed Spurge	Ann	Forb	Solves 123 [ASU]
Euphorbia florida Engelm.	Chiricahua Mountain Sandmat	Ann	Forb	Solves 452 [ASU]
Euphorbia hyssopifolia (L.) Small	Hyssopleaf Sandmat	Ann/ Per	Forb	Solves 326 [ASU]
Euphorbia revoluta (Engelm.) Small	Threadstem Sandmat	Ann	Forb	Salywon 1851 [DES]
Euphorbia stictospora Engelm.	Slimseed Sandmat	Ann	Forb	Solves 162 [ASU]
Euphorbia vermiculata Raf.	Wormseed Sandmat	Ann	Forb	Mauz 109 [ARIZ]
Jatropha macrorhiza Benth.	Ragged Nettlespurge	Per	Forb	Solves 263 [ASU]

Tragia nepetifolia Cav.	Catnip Noseburn	Per	Forb	Solves 415 [ASU]
FABACEAE				
Acacia constricta Benth.	White-Thorn Acacia		Shrub/ Tree	Solves 2018-05-20 [ASU]
Acacia greggii A. Gray	Catclaw Acacia		Shrub/ Tree	Solves 508 [ASU]
Amorpha fruticosa L.	False Indigo Bush		Shrub	Mauz 2006-56 [ARIZ]
Astragalus nuttallianus DC.	Small - Flower Milkvetch	Ann/ Per	Forb	Salywon 2126 [DES]
Astragalus thurberi A. Gray	Thurber's Milkvetch	Ann/ Per	Forb	Solves 495 [ASU]
Astragalus vaccarum A. Gray	Cow Spring Milkvetch	Per	Forb	Solves 406 [ASU]
**Caesalpinia gilliesii* (Hook.) Wallich ex D. Dietr.	Bird of Paradise		Shrub/ Tree	Solves 295 [ASU]
Calliandra eriophylla Benth.	Fairy-Duster		Shrub/ Subshrub	Solves 220 [ASU]
Chamaecrista nictitans (L.) Moench	Sensitive Partridge Pea	Ann/ Per	Forb	Solves 362 [ASU]
Crotalaria pumila Ortega	Low Rattlebox	Ann/ Per	Forb	Solves 430 [ASU]
Dalea brachystachya A.Gray	Fort Bowie Prairie Clover	Ann/ Bi	Forb	Mauz 2006-26 [ARIZ]
Dalea candida var. oligophylla (Torr.) Shinners	White Prairie Clover	Per	Forb	Solves 518 [ASU]
Dalea formosa Torr.	Feather-Plume		Shrub/ Subshrub	Solves 487 [ASU]
Dalea lachnostachys A. Gray	Glandlead Prairie Clover	Per	Forb	Solves 555 [ASU]
Dalea neomexicana (A. Gray) Cory	Downy Prairie Clover	Per	Forb	Salywon 2106 [DES]
Dalea pogonathera A. Gray	Bearded Prairie Clover	Per	Forb	Solves 298 [ASU]
Desmodium batocaulon A. Gray	San Pedro Ticktrefoil	Per	Forb	Solves 109 [ASU]
Desmodium retinens Schlecht.	Santa Rita Mountain Ticktrefoil	Per	Forb	Solves 341 [ASU]
Hoffmannseggia glauca (Ortega) Eifert	Indian Rush-Pea	Per	Forb	Solves 494 [ASU]

Lotus humistratus Greene	Foothill Deervetch	Ann	Forb	Salywon 2125 [DES]
Lupinus brevicaulis S. Watson	Short-Stem Lupine	Ann	Forb	Solves 486 [ASU]
Lupinus concinnus J.G. Agardh	Scarlet Lupine	Ann	Forb	Solves 225 [ASU]
**Macroptilium gibbosifolium* (Ortega) A. Delgado	Variable-Leaf Bush Bean	Per	Forb	Solves 576 [ASU]
**Melilotus indicus* (L.) All.	Annual Yellow Sweet Clover	Ann	Forb	Solves 267 [ASU]
Mimosa aculeaticarpa var. biuncifera (Benth.) Barneby	Cat Claw Mimosa		Shrub/ Tree	Solves 363 [ASU]
Mimosa dysocarpa Benth.	Velvet-Pod Mimosa		Shrub	Solves 557 [ASU]
Phaseolus acutifolius A. Gray	Tepary Bean	Ann	Vine	Solves 604 [ASU]
Prosopis juliflora (Sw.) DC.	Mesquite		Tree	Solves 597 [ASU]
Psoralidium tenuiflorum (Pursh) Rydb.	Slim-Flower Scurf Pea	Per	Forb	Solves 517 [ASU]
Rhynchosia senna Gillies ex Hook.	Texas Snout-Bean	Per	Vine	Solves 302 [ASU]
Senna hirsuta (L.) Irwin & Barneby	Woolly Senna	Per	Forb	Solves 99 [ASU]
Senna hirsuta var. leptocarpa Benth.	Woolly Senna	Per	Forb	Anderson 2003-42 [ASU]
FAGACEAE				
Quercus emoryi Torr.	Emory Oak		Tree	Solves 573 [ASU]
Quercus grisea Liebm.	Gray Oak		Tree	Solves 560 [ASU]
FOUQUIERIACEAE				
Fouquieria splendens Engelm.	Ocotillo		Shrub	Solves 2018-09-09 [ASU]
GENTIANACEAE				
Zeltnera calycosa (Buckley) G.Mans.	Arizona Centaury	Ann	Forb	Solves 275 [ASU]
HYDROCHARITACEAE				

Najas guadalupensis (Spreng.) Magnus	Guadalupe Water-Nymph	Ann	Forb	Mauz 2006-50 [ARIZ]
IRIDACEAE				
Sisyrinchium demissum Greene	Stiff Blue-eyed Grass	Per	Forb	Wolkis 710 [ASU]
JUGLANDACEAE				
Juglans major (Torr.) Heller	Arizona Walnut		Tree	Solves 601 [ASU]
JUNCACEAE				
Juncus acuminatus Michx.	Knotty-Leaf Rush	Per	Graminoid	Solves 398 [ASU]
Juncus balticus Willd.	Baltic Rush	Per	Graminoid	Solves 282 [ASU]
Juncus mexicanus Willd. ex Schult. & Schult. f.	Mexican Rush	Per	Graminoid	Anderson 2003-32 [ASU]
Juncus torreyi Coville	Torrey's Rush	Per	Graminoid	Solves 533 [ASU]
KRAMERIACEAE				
Krameria erecta Willd. ex J.A. Schultes	Small-Flower Ratany		Subshrub	Solves 562 [ASU]
Krameria lanceolata Torr.	Trailing Ratany		Subshrub	Solves 229 [ASU]
LAMIACEAE				
**Marrubium vulgare* L.	Horehound		Subshrub	Solves 256 [ASU]
**Mentha spicata* L.	Spearmint	Per	Forb	Solves 424 [ASU]
Salvia reflexa Hornem.	Lance-Leaf Sage	Ann	Forb	Solves 134 [ASU]
Salvia subincisa Benth.	Saw-Tooth Sage	Ann	Forb	Solves 477 [ASU]
Scutellaria potosina Brandegee	Mexican Skullcap	Per	Forb	Solves 164 [ASU]
Tetraclea coulteri A. Gray	Coulter's Wrinkle-Fruit		Subshrub	Salywon 2103 [DES]
LILIACEAE				

Calochortus kennedyi Porter	Desert Mariposa Lily	Per	Forb	Solves 231 [ASU]
LINACEAE				
Linum puberulum (Engelm.) Heller	Plains Flax	Ann	Forb	Solves 574 [ASU]
LOASACEAE				
Mentzelia albicaulis (Dougl.) Dougl. ex Torr. & A. Gray	White-Stem Blazing Star	Ann	Forb	Solves 497 [ASU]
Mentzelia asperula Woot. & Standl.	Organ Mountain Blazing Star	Ann	Forb	Solves 466 [ASU]
Mentzelia multiflora (Nutt.) A. Gray	Adonis Blazing Star	Per	Forb	Solves 470 [ASU]
LOBELIACEAE				
Lobelia cardinalis L.	Cardinal Flower	Per	Forb	Solves 396 [ASU]
LYTHRACEAE				
Lythrum californicum Torr. & A. Gray	California Loose-Strife		Subshrub	Solves 534 [ASU]
MALVACEAE				
Anoda cristata (L.) Schlecht.	Crested Anoda	Ann	Forb	Solves 454 [ASU]
Malvastrum bicuspidatum (S. Wats.) Rose	Shrubby False-Mallow	Per	Subshrub	Solves 448 [ASU]
Rhynchosida physocalyx (A. Gray) Fryxell	Buff-Petal		Subshrub	Solves 243 [ASU]
**Sida abutifolia* P. Mill.	Spreading Fan-Petal	Per	Forb	Solves 367 [ASU]
Sphaeralcea angustifolia (Cav.) G. Don	Cooper Globe-Mallow		Subshrub	Solves 523 [ASU]
Sphaeralcea laxa Woot. & Standl.	Caliche Globe-Mallow	Per	Forb	Solves 496 [ASU]
MARTYNIACEAE				
Proboscidea parviflora (Wooton) Wooton & Standl.	Devil's Claw	Ann	Forb	Solves 328 [ASU]
MOLLUGINACEAE				
Mollugo verticillata L.	Green Carpetweed	Ann	Forb	Solves 149 [ASU]

NYCTAGINACEAE				
Allionia incarnata L.	Trailing Four O'Clock	Per	Forb	Solves 232 [ASU]
Boerhavia coccinea P. Mill.	Scarlet Spiderling	Per	Forb	Solves 344 [ASU]
Mirabilis coccinea (Torr.) Benth. & Hook. f.	Scarlet Four O'Clock	Per	Forb	Solves 262 [ASU]
Mirabilis longiflora L.	Sweet Four O'Clock	Per	Forb	Solves 79 [ASU]
OLEACEAE				
Fraxinus velutina Torr.	Velvet Ash		Tree	Solves 100 [ASU]
Menodora scabra A. Gray	Rough Menodora		Subshrub	Solves 476 [ASU]
ONAGRACEAE				
Epilobium ciliatum Raf.	Fringed Willow-Herb	Per	Forb	Wolkis 501 [ASU]
Gaura hexandra Ortega	Harlequin Bush	Ann/ Per	Forb	Solves 529 [ASU]
Oenothera brachycarpa A. Gray	Short-Fruit Evening Primrose	Per	Forb	Solves 491 [ASU]
Oenothera cespitosa Nutt.	Tufted Evening Primrose	Per	Forb	Solves 504 [ASU]
Oenothera curtiflora W. L. Wagner & Hoch	Velvet-Weed	Ann	Forb	Solves 327 [ASU]
Oenothera primiveris A. Gray	Yellow Desert Evening Primrose	Ann	Forb	Salywon 1872 [DES]
ORCHIDACEAE				
Epipactis gigantea Douglas ex Hook.	Giant Helleborine	Per	Forb	Solves 514 [ASU]
OROBANCHACEAE				
Castilleja integra A. Gray	Whole-Leaf Indian Paintbrush	Per	Forb	Solves 458 [ASU]
OXALIDACEAE				
Oxalis alpina (Rose) Rose ex R. Knuth	Alpine Wood-Sorrel	Per	Forb	Solves 293 [ASU]
Oxalis stricta L.	Upright Yellow Wood-Sorrel	Per	Forb	Solves 294 [ASU]

PAPAVERACEAE				
Argemone pleiacantha Greene	Southwestern Prickly Poppy	Per	Forb	Solves 197 [ASU]
Corydalis aurea Willd.	Scrambled Eggs	Ann	Forb	Solves 500 [ASU]
PHRYMACEAE				
Erythranthe guttata (Fisch. ex DC.) G. L. Nesom	Blister-Leaf Monkey Flower	Per	Forb	Solves 512 [ASU]
PHYTOLACCACEAE				
Rivina humilis L.	Rouge-Plant	Per	Forb	Solves 605 [ASU]
PLANTAGINACEAE				
Maurandya antirrhiniflora Humb. & Bonpl. ex Willd.	Climbing Snapdragon	Per	Vine	Solves 603 [ASU]
Penstemon stenophyllus (A. Gray) T.J. Howell	Sonoran Beardtongue	Per	Forb	Solves 233 [ASU]
Plantago patagonica Jacq.	Wooly Plantain	Ann	Forb	Solves 521 [ASU]
**Veronica anagallis-aquatica* L.	Blue Water Speedwell	Per	Forb	Solves 513 [ASU]
POACEAE				
Aristida adscensionis L.	Six-Weeks Three Awn	Ann	Graminoid	Solves 444 [ASU]
Aristida californica Thurb.	California Three Awn	Per	Graminoid	Solves 565 [ASU]
Aristida schiedeana var. orcuttiana (Vasey) Allred & Valdos-Reyna	Single Three Awn	Per	Graminoid	Solves 588 [ASU]
Aristida ternipes Cav.	Spider Grass	Per	Graminoid	Solves 411 [ASU]
Aristida ternipes var. gentilis (Henr.) Allred	Spider Grass	Per	Graminoid	Solves 590 [ASU]
Aristida ternipes var. ternipes Cav.	Spider Grass	Per	Graminoid	Solves 334 [ASU]
Bothriochloa barbinodis (Lag.) Herter	Cane Beard Grass	Per	Graminoid	Solves 586 [ASU]
**Bothriochloa ischaemum* (L.) Keng	Turkestan Beard Grass	Per	Graminoid	Solves 374 [ASU]
Bouteloua aristidoides (Kunth) Griseb.	Neddle Grama	Ann	Graminoid	Solves 359 [ASU]

Bouteloua barbata Lag.	Six-Weeks Grama	Ann	Graminoid	Solves 376 [ASU]
Bouteloua chondrosioides (Kunth) Benth. ex S. Wats.	Spruce-Top Grama	Per	Graminoid	Solves 375 [ASU]
Bouteloua curtipendula (Michx.) Torr.	Side-Oats Grama	Per	Graminoid	Solves 591 [ASU]
Bouteloua eludens Griffiths	Santa-Rita Mountain Grama	Per	Graminoid	Solves 583 [ASU]
Bouteloua eriopoda (Torr.) Torr.	Black Grama	Per	Graminoid	Grass Guide [TNC]
Bouteloua gracilis (Kunth) Lag. ex Griffiths	Blue Grama	Per	Graminoid	Solves 614 [ASU]
Bouteloua hirsuta Lag.	Hairy Grama	Per	Graminoid	Grass Guide [TNC]
Bouteloua radicosa (Fourn.) Griffiths	Purple Grama	Per	Graminoid	Grass Guide [TNC]
Bouteloua repens (Kunth) Scribn. & Merr.	Slender Grama	Per	Graminoid	Grass Guide [TNC]
Bouteloua rothrockii Vasey	Rothrock's Grama	Per	Graminoid	Solves 432 [ASU]
Bromus carinatus Hook. & Arn.	Arizona Brome	Ann	Graminoid	Solves 423 [ASU]
Cenchrus spinifex Cav.	Coastal Sandbur	Ann	Graminoid	Solves 127 [ASU]
Chloris virgata Sw.	Feather Fingergrass	Ann	Graminoid	Solves 611 [ASU]
**Cynodon dactylon* (L.) Pers.	Bermuda Grass	Per	Graminoid	Wolkis 493 [ASU]
Dasyochloa pulchella (Kunth) Willd. ex Rydb.	False Fluff Grass	Per	Graminoid	Solves 372 [ASU]
Digitaria californica (Benth.) Henr.	Arizona Cottontop	Per	Graminoid	Solves 379 [ASU]
Digitaria cognata var. pubiflora Vasey ex L.H. Dewey	Hairy-Flower Crab Grass	Per	Graminoid	Grass Guide [TNC]
Digitaria insularis (L.) Mez ex Ekman	Sour-Grass	Per	Graminoid	Grass Guide [TNC]
Diplachne fusca subsp. fascicularis (Lam.) P. M. Peterson & N. Snow	Bearded Sprangletop	Ann	Graminoid	Solves 595 [ASU]
Disakisperma dubium (Kunth) P.M. Peterson & N.Snow	Green Sprangletop	Per	Graminoid	Solves 352 [ASU]
Distichlis spicata (L.) Greene	Salt Grass	Per	Graminoid	Salywon 2092 [DES]

**Echinochloa colona* (L.) Link	Jungle Rice	Ann	Graminoid	Solves 397 [ASU]
**Echinochloa crus-galli* (L.) P. Beauv.	Large Barnyard Grass	Ann	Graminoid	Solves 596 [ASU]
Elionurus barbiculmis Hack.	Wool-Spike Balsamscale	Per	Graminoid	Solves 174 [ASU]
Elymus canadensis L.	Nodding Wild Rye	Per	Graminoid	Solves 511 [ASU]
Elymus elymoides (Raf.) Swezey	Western Bottle-Brush Grass	Per	Graminoid	Solves 525 [ASU]
Elymus trachycaulus (Link) Gould ex Shinners	Slender Wheatgrass	Per	Graminoid	Solves 269 [ASU]
Enneapogon desvauxii Desv. ex Beauv.	Nine-Awn Pappus Grass	Per	Graminoid	Grass Guide [TNC]
**Eragrostis cilianensis* (All.) Vignolo ex Janch.	Stink Grass	Ann	Graminoid	Solves 610 [ASU]
**Eragrostis curvula* Stapf	Weeping Love Grass	Per	Graminoid	Grass Guide [TNC]
Eragrostis intermedia A.S. Hitchc.	Plains Love Grass	Per	Graminoid	Solves 575 [ASU]
**Eragrostis lehmanniana* Nees	Lehmann Love Grass	Per	Graminoid	Solves 619 [ASU]
Eragrostis pectinacea (Michx.) Nees ex Steud.	Purple Love Grass	Ann	Graminoid	Solves 330 [ASU]
Eragrostis pectinacea var. miserrima (Fourn.) J. Reeder	Desert Love Grass	Ann	Graminoid	Grass Guide [TNC]
Eragrostis pectinacea var. pectinacea (Michx.) Nees ex Steud.	Tufted Love Grass	Ann	Graminoid	Grass Guide [TNC]
**Eragrostis superba* Peyr.	Sawtooth Love Grass	Per	Graminoid	Grass Guide [TNC]
Eriochloa acuminata (J. Presl) Kunth	Taper-Tip Cup Grass	Ann	Graminoid	Solves 395 [ASU]
Eriochloa acuminata var. minor (Vasey) R.B. Shaw	Taper-Tip Cup Grass	Ann	Graminoid	Solves 353 [ASU]
Heteropogon contortus (L.) Beauv. ex Roemer & J.A. Schultes	Twisted Tanglehead	Per	Graminoid	Solves 584 [ASU]
Hilaria belangeri (Steud.) Nash	Curly Mesquite	Per	Graminoid	Solves 552 [ASU]
Hilaria mutica (Buckley) Benth.	Tobosa Grass	Per	Graminoid	Solves 335 [ASU]
Hopia obtusa (Kunth) Zuloaga & Morrone	Vine Mesquite	Per	Graminoid	Solves 585 [ASU]

Lycurus setosus (Nutt.) C.G. Reeder	Bristly Wolf's-Tail	Per	Graminoid	Salywon 2086 [DES]
Muhlenbergia arenicola Buckley	Sand Muhly	Per	Graminoid	Grass Guide [TNC]
Muhlenbergia asperifolia (Nees & Meyen ex Trin.) Parodi	Alkali Muhly	Per	Graminoid	Grass Guide [TNC]
Muhlenbergia emersleyi Vasey	Bull Grass	Per	Graminoid	Grass Guide [TNC]
Muhlenbergia fragilis Swallen	Delicate Muhly	Ann	Graminoid	Solves 163 [ASU]
Muhlenbergia porteri Scribn. ex Beal	Bush Muhly	Per	Graminoid	Solves 387 [ASU]
Muhlenbergia repens (J. Presl) A.S. Hitchc.	Creeping Muhly	Per	Graminoid	Mauz 109 [ARIZ]
Muhlenbergia rigens (Benth.) A.S. Hitchc.	Deer Grass	Per	Graminoid	Salywon 2116 [DES]
Muhlenbergia rigida (Kunth) Trin.	Purple Muhly	Per	Graminoid	Grass Guide [TNC]
**Panicum antidotale* Retz.	Blue Panic Grass	Per	Graminoid	Solves 473 [ASU]
Panicum hallii Vasey	Hall's Panic Grass	Per	Graminoid	Grass Guide [TNC]
Pascopyrum smithii (Rydb.) Barkworth & D. R. Dewey	Western Wheat Grass	Per	Graminoid	Anderson 2003-41 [ASU]
**Paspalum dilatatum* Poir.	Dallis Grass	Per	Graminoid	Anderson 2003-38 [ASU]
Paspalum distichum L.	Jointed Crown Grass	Per	Graminoid	Solves 400 [ASU]
**Phleum pratense* L.	Common Timothy	Per	Graminoid	Solves 536 [ASU]
**Polypogon monspeliensis* (L.) Desf.	Annual Rabbit's Foot	Ann	Graminoid	Solves 540 [ASU]
**Polypogon viridis* (Gouan) Breistr.	Beardless Rabbit's Foot	Per	Graminoid	Solves 279 [ASU]
Schizachyrium cirratum (Hack.) Wooton & Standl.	Texas Bluestem	Per	Graminoid	Grass Guide [TNC]
Setaria grisebachii Fourn.	Grisebach's Bristle Grass	Ann	Graminoid	Solves 205 [ASU]
Setaria leucopila (Scribn. & Merr.) K. Schum.	Streambed Bristle Grass	Per	Graminoid	Solves 613 [ASU]
**Sorghum halepense* (L.) Pers.	Johnson Grass	Per	Graminoid	Solves 598 [ASU]

Sporobolus cryptandrus (Torr.) A. Gray	Sand Dropseed	Per	Graminoid	Grass Guide [TNC]
Sporobolus coromandelianus (Retz.) Kunth	Target Dropseed	Per	Graminoid	Salywon 2061 [DES]
Sporobolus wrightii Munro ex Scribn.	Giant Sacaton	Per	Graminoid	Solves 607 [ASU]
Trachypogon montufari auct. non (Kunze) Nees	Spiked Crinkleawn	Per	Graminoid	Grass Guide [TNC]
Tridens grandiflorus (Vasey) Woot. & Standl.	Large-Flower Wooly Grass	Per	Graminoid	Grass Guide [TNC]
Tridens muticus (Torr.) Nash	Slim Triden	Per	Graminoid	Grass Guide [TNC]
Urochloa arizonica (Scribn. & Merr.) O. Morrone & F. Zuloaga	Arizona's Liverseed Grass	Ann	Graminoid	Solves 623 [ASU]
POLEMONIACEAE				
Eriastrum diffusum (A. Gray) Mason	Miniature Wooly Star	Ann	Forb	Solves 505 [ASU]
Eriastrum eremicum (Jepson) Mason	Desert Wooly Star	Ann	Forb	Solves 520 [ASU]
Gilia flavocincta A. Nels.	Lesser Yellow Throat Gily-Flower	Ann	Forb	Solves 237 [ASU]
Gilia transmontana (Mason & A. Grant) A.& V. Grant	Transmontane Gily-Flower	Ann	Forb	Salywon 2124 [DES]
Ipomopsis longiflora (Torr.) V. Grant	White-Flower Skyrocket	Ann	Forb	Solves 354 [ASU]
Ipomopsis thurberi (Torr. ex A. Gray) V. Grant	El Paso Skyrocket	Per	Forb	Solves 468 [ASU]
POLYGALACEAE				
Polygala alba Nutt.	White Milkwort	Per	Forb	Solves 556 [ASU]
Polygala barbeyana Chod.	Blue Milkwort	Per	Forb	Solves 553 [ASU]
POLYGONACEAE				
Eriogonum abertianum Torr.	Abert's Buckwheat	Ann	Forb	Solves 544 [ASU]
Eriogonum polycladon Benth.	Sorrel Buckwheat	Ann	Forb	Solves 147 [ASU]
Eriogonum wrightii Torr. ex Benth.	Wright's Buckwheat		Subshrub	Solves 439 [ASU]

Persicaria amphibia (L.) Delarbre	Water Smartweed	Per	Forb	Mauz 2006-43 [ARIZ]
Persicaria bicornis (Raf.) Nieuwl.	Pennsylvania Smartweed	Ann	Forb	Solves 409 [ASU]
Persicaria lapathifolia (L.) Delarbre	Dock-Leaf Smartweed	Ann	Forb	Mauz 2006-44 [ARIZ]
Persicaria punctata (Elliot) Small	Dotted Smartweed	Per	Forb	Wolkis 793 [ASU]
**Rumex crispus* L.	Curly Dock	Per	Forb	Solves 539 [ASU]
PORTULACACEAE				
Portulaca halimoides L.	Silk-Cotton Purslane	Ann	Forb	Salywon 2016 [DES]
Portulaca oleracea L.	Garden Purslane	Ann	Forb	Salywon 2019 [DES]
Portulaca suffrutescens Engelm.	Shrubby Purslane		Subshrub	Solves 365 [ASU]
Portulaca umbraticola Kunth	Wing-Pod Purslane	Ann	Forb	Solves 347 [ASU]
POTAMOGETONACEAE				
Potamogeton foliosus var. foliosus Raf.	Leafy Pondweed	Per	Forb	Mauz 2006-65 [ARIZ]
Zannichellia palustris L.	Horned Pondweed	Per	Forb	Mauz 2006-64 [ARIZ]
PRIMULACEAE				
Samolus parviflorus Raf.	Seaside Brookweed	Per	Forb	Anderson 2003-35 [ASU]
RANUNCULACEAE				
Clematis drummondii Torr. & A. Gray	Virgin's Bower	Per	Vine	Solves 211 [ASU]
Myosurus minimus L.	Tiny Mousetail	Ann	Forb	Salywon 1874 [DES]
Ranunculus macranthus Scheele	Large Buttercup	Per	Forb	Solves 304 [ASU]
RHAMNACEAE				
Ziziphus obtusifolia (Hook. ex Torr. & A. Gray) A. Gray	Graythorn	Per	Tree	Solves 141 [ASU]

RUBIACEAE				
Diodia teres Walter	Poor Joe	Ann	Forb	Solves 414 [ASU]
Houstonia rubra Cav.	Red Bluet	Per	Forb	Solves 543 [ASU]
RUSCACEAE				
Dasylirion wheeleri S. Watson	Common Sotol		Subshrub	Solves 2019-06-20 [SEINet]
Nolina microcarpa S. Watson	Bear Grass	Per	Forb	Solves 559 [ASU]
SALICACEAE				
Populus fremontii S. Watson	Fremont Cottonwood		Tree	Solves 103 [ASU]
Salix gooddingii C.R. Ball	Goodding's Black Willow		Tree	Solves 216 [ASU]
SAPINDACEAE				
Sapindus saponaria L.	Wing-Leaf Soapberry		Tree	Solves 522 [ASU]
SAURURACEAE				
Anemopsis californica (Nutt.) Hook. & Arn.	Yerba Mansa	Per	Forb	Solves 408 [ASU]
SOLANACEAE				
Calibrachoa parviflora (Juss.) D'Arcy	Seaside Petunia	Ann	Forb	Wolkis 507 [ASU]
Chamaesaracha coronopus (Dunal) A. Gray	Green-Leaf Five-Eyes	Per	Forb	Solves 324 [ASU]
Chamaesaracha sordida (Dunal) A. Gray	Hairy Five-Eyes	Per	Forb	Salywon 2236 [DES]
**Datura stramonium* L.	Jimsonweed	Ann	Forb	Salywon 1870 [DES]
Datura wrightii Regel	Sacred Datura	Per	Forb	Solves 78 [ASU]
Lycium pallidum Miers	Pale Desert-Thorn		Shrub	Solves 226 [ASU]
Physalis angulata L.	Cut-Leaf Ground-Cherry	Ann	Forb	Solves 175 [ASU]

Physalis hederifolia A. Gray	Ivy-Leaf Ground-Cherry	Per	Forb	Solves 463 [ASU]
Physalis hederifolia var. fendleri (A. Gray) Cronquist	Fendler's Ground-Cherry	Per	Forb	Solves 254 [ASU]
Physalis longifolia Nutt.	Long-Leaf Ground-Cherry	Per	Forb	Solves 535 [ASU]
**Physalis philadelphica* Lam.	Mexican Ground-Cherry	Ann	Forb	Salywon 2082 [DES]
Physalis pubescens L.	Ground Cherry	Ann	Forb	Wolkis 1002 [ASU]
Solanum douglasii Dunal	Green-Spot Nightshade	Per	Forb	Solves 106 [ASU]
Solanum elaeagnifolium Cav.	Silver-Leaf Nightshade	Per	Forb	Solves 524 [ASU]
Solanum rostratum Dunal	Horned Nightshade	Ann	Forb	Solves 289 [ASU]
TALINACEAE				
Talinum aurantiacum Engelm.	Orange Flame-Flower	Per	Forb	Solves 2018-07-27 [SEINet]
Talinum paniculatum (Jacq.) Gaertn.	Spoon-Leaf Flame-Flower	Per	Subshrub	Solves 131 [ASU]
TAMARICACEAE				
**Tamarix chinensis* Lour.	Saltcedar		Tree	Solves 224 [ASU]
TYPHACEAE				
Typha latifolia L.	Broad-Leaf Cattail	Per	Forb	Wolkis 979 [ASU]
VERBENACEAE				
Aloysia wrightii Heller ex Abrams	Wright's Beerush	Per	Shrub	Solves 471 [ASU]
Glandularia bipinnatifida (Nutt.) Nutt.	Dakota Mock Vervain	Per	Forb	Solves 101 [ASU]
Verbena gracilis Desf.	Fort Huachuca Vervain	Per	Forb	Solves 301 [ASU]
Verbena neomexicana (A. Gray) Small	Hillside Vervain	Per	Forb	Solves 261 [ASU]
VITACEAE				

Vitis arizonica Engelm.	Arizona Grape	Per	Vine	Solves 2019-06-20 [SEINet]
ZYGOPHYLLACEAE				
Kallstroemia grandiflora Torr. Ex. A. Gray	Orange Caltrop	Ann	Forb	Solves 443 [ASU]
Kallstroemia hirsutissima Vail ex. Small	Hairy Caltrop	Ann	Forb	Solves 417 [ASU]
Kallstroemia parviflora J.B.S. Norton	Warty Caltrop	Ann	Forb	Salywon 1852 [DES]

APPENDIX C

NOTEWORTHY HABITAT TYPES IN THE LAS CIENEGAS NATIONAL CONSERVATION AREA

Appendix C. Description of rare and threatened habitat types identified at Las Cienegas National Conservation Area, species lists represent the most common plants encountered in each habitat type in the conservation area.

Habitat Type	Reference	Description	Common Species for LCNCA
Cottonwood-Willow Riparian Forest	Stromberg (1993a)	Streamside woodlands composed of tall canopies with an understory of various sub-arborescent shrubs; ground cover dominated by herbaceous communities of forbs and grasses	*Populus fremontii, Salix gooddingii, Veronica anagallis-aquatica Fraxinus velutina, Sorghum halpense, Polypogon monspeliensis*
Mesquite Bosque	Stromberg (1993b)	Dense, *Prosopis*-dominated galleries with an herbaceous understory; occurring several meters above streambeds and intermittent rivers.	*Prosopis juliflora, Acacia greggii, Ziziphus obtusifolia, Clematis drummondii, Celtis reticulata, Anisacanthus thurberi*
Sacaton Grassland	Tiller et al. (2012)	Expansive monotypic grasslands along terraces occurring on or near floodplains of active channels, sometimes found associated with other habitat types	*Sporobolus wrightii, Cucurbita digitata, Phaseolus acutifolius, Eragrostis cilianensis, Ipomoea sp Atriplex elegans, Chenopodium sp.*
Semi-Desert Grassland	Brown & Making (2014)	Grasslands occurring around an elevation of 1100 – 1500 m, mostly discerned by a combination of perennial forage grasses with succulent plants like Yuccas or Agaves.	*Hilaria mutica, Agave palmeri, Yucca elata, Ipomopsis thurberi, Plantago patagonica, Bouteloua curtipendula, Eragrostis lehmanniana*

Cienega	Hendrickson & Minckley (1985)	Mid-elevation wetlands formed around headwaters or springs with dense vegetative communities; occurring along floodplains	*Anemopsis californica, Typha latifolia, Carex preagracilis, Muhlenbergia asperifolia, Rumex altissimus, Eleocharis palustris*

124

APPENDIX D

WETLAND PLANT INDICATOR RATINGS

Appendix D. Wetland plant indicator categories as defined by Lichvar et al., 2012, percentages identify the amount of time each species is found occurring in wetlands compared to other habitats.

Indicator Code	Indicator Status	% Occurrence in Wetlands	Ecological Description	Comment
OBL	Obligate Wetland	>99%	Always a hydrophyte	Always occurs in wetlands, rarely in uplands
FACW	Facultative Wetland	67% – 99%	Usually a hydrophyte; occasionally found in uplands	Occurs in wetlands, but may occasionally occur in non-wetlands
FAC	Facultative	34% – 66%	Commonly a hydrophyte or a non-hydrophyte	Equally likely to occur in wetlands and non-wetlands
FACU	Facultative Upland	1% – 33%	Occasionally a hydrophyte but usually occurs in uplands	Usually occurs in non-wetland habitat but occasionally found in wetlands
UPL	Obligate Upland	<1%	Rarely a hydrophyte, almost always occurs in uplands	Occurs almost always under natural conditions in non-wetland habitat, but may occur in wetlands in another region

APPENDIX E

PLANT GROWTH FORM CATEGORIES AND DEFINITIONS

Appendix E. Plant growth forms and definitions in accordance with the USDA Plants database (http://plants.usda.gov), some descriptions refer to species in specific families (i.e. Graminoids) while others describe broader categories of plant habits.

Growth Form	Description
Forb/Herb	Vascular plant without significant woody tissue above or at the ground. Forbs and herbs may be annual, biennial, or perennial but always lack thickening of secondary woody growth and have perennating buds borne at or below the ground surface.
Graminoid	Grass or grass-like plant, including grasses (Poaceae), sedges (Cyperaceae), and rushes (Juncaceae).
Shrub	Perennial, multi-stemmed woody plant, usually less than 4 to 5 meters (13 to 16 feet) tall. Typically have several stems ascending from or near the ground. Some may be taller than 5 meters or single-stemmed under certain environmental conditions.
Subshrub	Low-growing shrub usually under 0.5 m (1.5 feet) tall, not exceeding 1 meter (3 feet) tall at maturity.
Succulent	Vascular, xeric adapted plant with a tough cuticle, sometimes armed, with mucilaginous cells including cacti (Cactaceae), agaves (Asparagaceae), and yuccas (Asparagaceae).
Tree	Perennial, woody plant with a single stem (trunk), normally greater than 4 to 5 meters (13 to 16 feet) tall; under certain environmental conditions, some tree species may develop a multi-stemmed or short growth form (less than 4 meters or 13 feet in height).

Vine	Twining/climbing plant with relatively long stems, can be woody or herbaceous

APPENDIX F

MONITORED OR SAMPLED SITES USED IN HUACHUCA WATER UMBEL STUDIES

Appendix F. Summary of Huachuca Water Umbel populations that were monitored or sampled for individual studies, final column identifies which study the specific population was monitored or sampled in, (SG = Seed Germination, SB = Seed Bank, PS = Phenology Study).

Site Name	Habitat Type	Land Ownership	County	Study
Bingham Cienega*	Restored cienega	Pima Country	Pima	SG
Scotia Canyon*	Stream margin	U.S. Forest Service	Cochise	SG
Babocomari River*	Marshy stream margin	Private	Santa Cruz	SG
Cienega Creek Preserve	Marshy stream margin	Pima County	Pima	SB
San Pedro-Fairbanks	Stream margin	BLM	Cochise	SB
San Pedro-San Pedro House	Stream margin	BLM	Cochise	SB
San Pedro-Charleston	Stream margin	BLM	Cochise	SB
San Bernadino	Cienega	USFWS	Cochise	SB
Finley Tank Springs South	Spring-fed wetland	Audubon Research Ranch	Santa Cruz	SB
Cieneguita (LCNCA)	Restored cienega	BLM	Pima/Santa Cruz	SB / PS
Phoenix Zoo Stream	Constructed stream	Phoenix Zoo Conservation Center	Maricopa	SB / PS
DBG Pond	Constructed pond	Desert Botanical Garden	Maricopa	SB / PS / SG
Horsethief Springs	Marshy stream margin	BLM-SPRNCA	Cochise	SB