Desert Plants

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Svalbard Global Seed Vault
(N. Unklesbay)

Desert Plants
A journal devoted to broadening knowledge of plants indigenous or adapted to arid and sub-arid regions and to encouraging the appreciation of these plants.

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From the Editor...The Desert Legume Program deposited seed at Svalbard, a big accomplishment for our humble program. For twenty-three years DELEP has been collecting, storing and growing out legume seeds from all over the world. Matt Johnson and Ken Coppola have been employed by DELEP since R.P. Upchurch started the program in 1988. I was hired a few months later, in early 1990. Kirsten Lake joined us in 2007. The seed collection has grown steadily and much of it has been backed up in the National Center for Plant Genetic Resources in Fort Collins, Colorado beginning in 1996. To store our collection in this prestigious gene bank is indeed an honor that speaks to the value of the DELEP collection. DELEP has now gone one step further by depositing seed from its collection in the Svalbard Global Seed Vault and raising the stature of the program both nationally and internationally. The USDA and Seed Savers, a U.S. non-profit organization, are the only other U.S. depositors in Svalbard. We are all very proud of our program and its achievements.

The DELEP team: Ken Coppola, Margaret Norem, Kirsten Lake and Matthew Johnson (L. Unklesbay February 2011)

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Noteworthy Collections from Tempe Towne Lake Riverbed

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Tempe Towne Lake is a water body created by inflatable bladder dams that were constructed along the highly regulated and formerly-perennial Salt River in Phoenix, Arizona. The dam ruptured on 20 July 2010, exposing organic and clay-dominated lake bed sediments that had been submersed for approximately 10 years. A riverine marshland developed on the wet sediments, and during a site visit on 27 Sept 2010 twenty taxa were collected (Table 1). Below is a discussion of 3 species of interest.

Ammannia coccinea Rottb. (Lythraceae)

Significance: *Ammannia coccinea* has been popping up in the state flora occasionally for some 80 years, so it's presence in the Salt River is not remarkable. What is noteworthy, however, is that this plant was scarce in Arizona until around 2000, and has suddenly appeared in large numbers in this particular reach of the Salt River (Figures 1,2,3). *A. coccinea* was co-dominant in abundance with cattail (*Typha* sp.) in the community of wetland plants that we observed in September 2010. Why? And why now?

Ammannia L. is a cosmopolitan genus of about 25 species distributed in both temperate and tropical zones with a center of diversity in Africa (Graham 1985). *Ammannia coccinea*, variously referred to as scarlet Ammannia, scarlet toothcup, or valley redstem, is a native, annual, obligate wetland plant found throughout most of the US except for some northwestern states (USDA, NRCS 2010). The conservation status of this species varies from secure (IA, KY) to imperiled (NC, PA, WV), to critically imperiled (DC, DE) (NatureServe 2010). In Arizona, it is 'not ranked.'

Ammannia coccinea grows in a variety of riparian habitats, including marshy wetlands such as cienegas[1] and muddy flats along reservoirs, streams and playas. In New Mexico, *A. coccinea* occurs along the Rio Grande River wetlands in three general areas: greater Albuquerque; the Bosque del Apache National Wildlife Refuge, Soccoro New Mexico; and Elephant Butte Reservoir, near Truth or Consequences (SEINet 2010).

In Arizona, *A. coccinea* was collected for the first time in Arizona in 1936 by C. W. McLellan and L. L. Stitt, in "Papago Park Tempe Edge of Lake." It was not collected again until 1964, when E. Lehto documented it at Lake Pleasant Regional Park, "east shore of lower lake." There is a C. Irwin collection from Yuma County along the Colorado River in 1975, and then, in 1998, J. Boudell vouchered it from the Agua Fria River below New Waddell Dam (south of Lake Pleasant). She was investigating propagule (seed) banks from soil samples collected at various depths, and *A. coccinea* emerged in a growth chamber. There have been 5 more collections since 1998: L. McGill 7196 - north of the Willcox Playa, Cochise County, in 1999; E. Makings 1620 – St. David Cienega along the San Pedro River, Cochise County, in 2003; J. White 163 – Salt River at Price Drain under Loop 101 in Tempe, Maricopa County, in 2006; D. Jenke 164 – Salt River Bed at the Tres Rios Wetlands, Maricopa County, in 2007; and most recently, E. Makings et al. 3535 – in the river bed of Tempe Towne Lake, 9 weeks after the failure of the bladder dams.

In an e-mail communication, Shirley Graham, a Lythraceae expert from the Missouri Botanical Garden, confirmed the identity of this particular species, and had this to say regarding the genus: "A drying, previously flooded habitat is ideal for *Ammannia* and the irregular appearance of the genus at any one locality of this kind is absolutely typical. In Tanzania where *Ammannia* was in a rice field in great quantity one year according to collection data, when I visited the next year at the same place, same time, there was no sign of it. As for seed source, it might have been introduced by dispersal down river from rice cultivation or some previous local site. It floats nicely and is adapted to varying water levels, often starting in standing water and fully developing on dry mud flats."

The J. White collection in 2006 was just upstream of Tempe Towne Lake at a small wetland sustained in part by storm drain runoff. Considering the small size of the seeds (mass of 0.02 mg) (Royal Botanic Gardens Kew Seed Information Database, 2008) as well as the number of fruits on an individual plant (150-300 seeds/capsule) (Graham 1979, 1985), it is reasonable to assume that seed dispersal of only a few plants upstream could be responsible for establishment of the large population we observed. Alternatively, it may have been present in the soil seed bank of the lake bed, or even dispersed by waterfowl.

Figure 1. Habitat of *Ammannia coccinea*, abundant in this wetland among *Cyperus* spp., *Typha* sp., *et.al.*

Figure 2. *Ammannia coccinea* habitat nine weeks after the bladder dam failure. Soon after the riverbed was exposed, a cienega-type wetland emerged. Botanists/ecologists: Frankie Coburn, Lane Butler (background) Julie Stromberg.

Whether this *Ammannia* is from upstream water transport, a relict taxon in the seed bank, or a recent introduction by waterfowl, are topics of conjecture. Whatever the source, the potential for mass germination is well documented. *Ammannia* seeds retain viability for many years (vigorous up to 12 years) and are able to persist through prolonged dry periods (Graham 1979). Even after herbarium fumigation treatments, 5% of the seeds of *A. coccinea* from herbarium specimens 27 years old germinated (Graham 1985). The "boom and bust" nature of the genus was displayed in a spectacular way via the environmental conditions created at the Tempe Towne Lake site in September 2010.

Figure 3. *Ammannia coccinea*, aka "scarlet toothcup"

A taxonomic note: There are three species of *Ammannia* that have been identified in Arizona – *A. auriculata* Willd., *A. coccinea* Rottb., and *A. robusta* Heer & Regel. At the University of Arizona Herbarium (ARIZ), there are seven records of *A. robusta*, and duplicates of the Arizona State University (ASU) collections of *A. coccinea* from the Colorado River, San Pedro River, and the McClellan and Stitt specimen from Papago Park. Diagnostic characters of *A. coccinea* and *A. robusta*, such as peduncle length and fruit size, frequently overlap. Additionally, the species occupy identical habitats, are known to hybridize, and field characters that separate them such as flower and anther color may be impossible to discern from herbarium specimens (Graham 1979). Since the species are so weakly delimited, it is possible Arizona material is actually variation of a single taxon. Even if this is the case, the Salt River phenomenon is no less intriguing. '*Ammannia robusta*' was collected first by J. J. Thornber in 1905 in the Hooker Cienega in Sulpher Springs Valley, Cochise County. But collections that follow are similarly infrequent and far between, suggesting a previously marginal presence in the state.

Cyperus michelianus subsp. *pygmaeus* (Rottb.) Asch. & Graebn. (Cyperaceae). (Figure 4)

Significance: First confirmed North American collections of this taxon.

Cyperus michelianus subsp. *pygmaeus* was first collected in Arizona about the same time in two different localities. One of them was "Maricopa County; Agua Fria River; South of Lake Pleasant; below New Waddell Dam. Associated with *Tamarix ramosissima/ Salix gooddingii*. 33.8334999, 112.2756653, 400m. Propagule Bank Investigation with collections emerging from soil samples in growth chamber 1998-2000, soil depth=2-5cm; J. A. Boudell CG2-102, (ASU)." The other was "Gila County, Tonto National Forest; Roosevelt Lake; School House Point lake bottom. 33.6500493, -111.0101175, 645m, 21 October 1998, J. Hurja sn. (TEUI)." The date of the Hurja collection from Roosevelt Reservoir in 1998 is clear, but the date for Boudell is ambiguous as the plants may have emerged from the soil seed bank samples in either 1998 or 1999.

Figure 4. *Cyperus michelianus* subsp. *pygmaeus*

The soil was collected from the mostly-dewatered floodplain of the Agua Fria River below Lake Pleasant Reservoir, and the location of the parent plants and their year of production remain unknown (Boudell 2004).

C.yperus michelianus subsp. *pygmaeus* is an annual, typically of sandy or silty riverbanks and similar disturbed sites from hot (often arid) areas of the Old World (Anton Reznicek, personal communication). Specimen occurrence data from electronic databases accessed through the Global Biodiversity Information Facility (GBIF 2010) and the Missouri Botanical Garden's Tropicos website (TROPICOS 2010) suggest it is common in Australia, India, China, the Middle East, and Mediterranean. Other combinations/ synonyms for this taxon are *Cyperus pygmaeus* Rottb., *Dichostylis pygmaea* (Rottb.) Nees, *Juncellus pygmaeus* (Rottb.) C.B. Clarke (Tropicos 2010). The type specimen of *C. pymaeus* Rottb. is from Orillas del Sebú, Morocco, Africa (GBIF 2010). We chose to use the Tropicos taxonomy which lowers *C. pygmaeus* to the subspecific level, but also note the comments of Dr. Reznicek: "...*Cyperus pygmaeus* Rottb... is part of a taxonomic mess, and sometimes included in *Cyperus mechelianus* (as subsp. *pygmaeus*). *Cyperus michelianus*, however, differs in having more or less tristichous glumes and typically 2 stigmas. Your plant appears to have more or less distichous scales (hard to see however, in dried material) and many flowers with 3 stigmas".

In 2005 E. M. was given several sedges and other wetland plants from along the Salt River in the Phoenix area for identification on behalf of graduate students at ASU. This small *Cyperus* was among them. It resisted all available dichotomous keys so the inefficient and desperate technique of randomly thumbing through the ASU herbarium specimens of the genus in hopes of a lead was undertaken. There was one sheet of '*C. pygmaeus*' from Bharatpur, Rajasthan, India, collected in 1971 by M. Sing 68. It matched perfectly, and duplicates sent to Anton Reznicek at the University of Michigan were confirmed. The two previous collections of '*C. m. pygmaeus*' mentioned above were both originally misidentified as *Cyperus acuminatus* Torr. & Hook., but now with the recognition factor, annotations of these and several other sheets were made.

There is anecdotal evidence that the Roosevelt Reservoir population has increased since first collected. In July of 2009, a Tonto National Forest Service colleague collected it along the mouth of Tonto Creek at its confluence with Roosevelt Reservoir (the opposite end of the reservoir from the 1998 Hurja collection). It was growing in alluvium that had been submerged to a depth of at least 2 feet when the lake was higher in the spring (Debbie Cress, personal communication). She noted this population grew as a single-species patch covering about two acres. The lower Salt River populations are also on the rise as evidenced by more frequent collections: J. Poznick s.n., Salt River at Price Road (near the confluence with Indian Bend Wash) in 2005; D. Jenke 526, 708, 723, at the Tres Rios Wetlands (near the confluence of the Salt, Gila, and Agua Fria Rivers) in 2008 and 2009; and most recently E. Makings et al. 3542, in the river bed of Tempe Towne Lake, 9 weeks after the failure of the bladder dams (27 September 2010), where it was common (Figure 5).

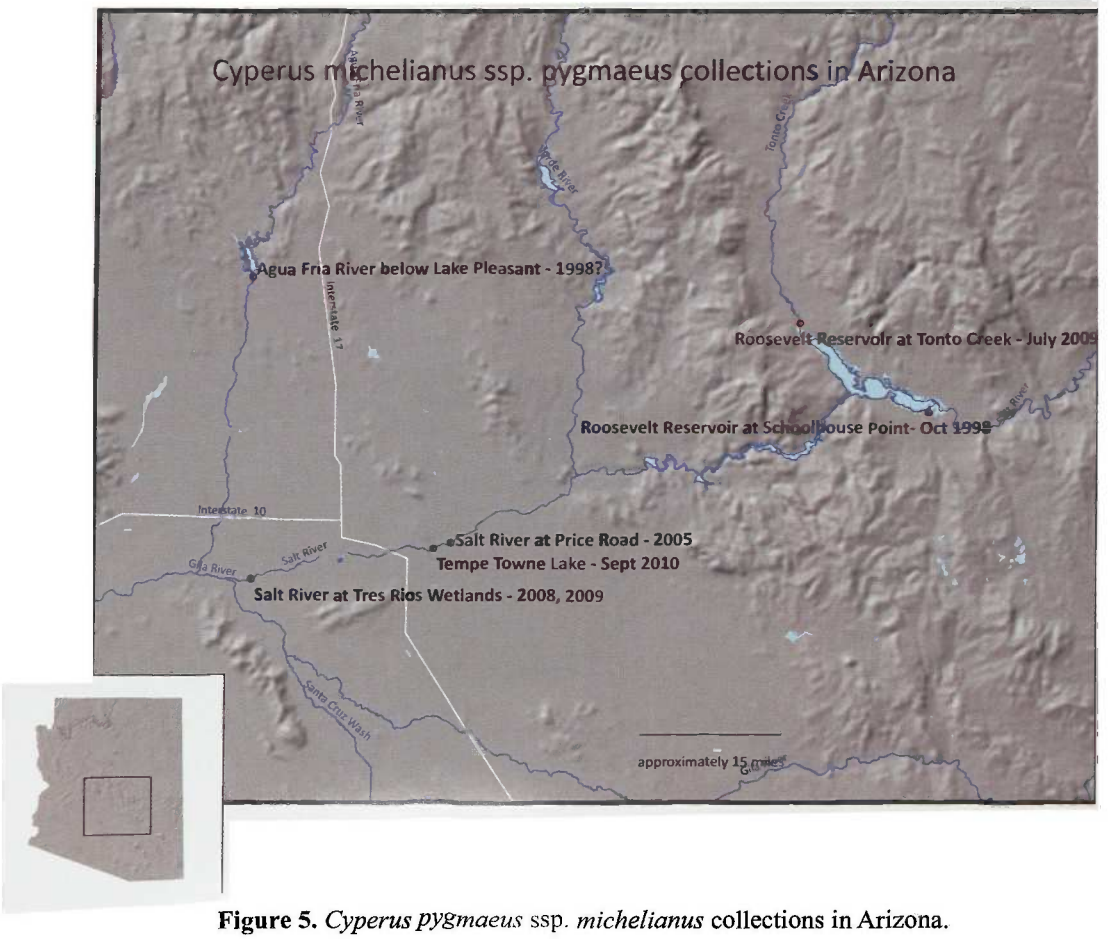

Figure 5. *Cyperus pygmaeus* ssp. *michelianus* collections in Arizona.

We may never know exactly how *C. m. pygmaeus* arrived at these rivers and reservoirs, but it's logical to assume it was introduced by people (vs. birds or wind). Migrating birds are occasionally blown by storms off their north/south trending migration corridors, but it is improbable that the seeds would have been carried across oceans. Most likely it was recreation related – in the tackle box of a visitor from Australia, or the dried mud on the boot of a Gulf War veteran. Tempe Towne Lake was not the first collection of *C. m. pygmaeus* in Arizona, but the site was notable for its abundance of this particular plant. Watercourses are ideal corridors for dispersal of plants, and the Salt River riparian zone is providing suitable habitat for *C. m. pygmaeus*. We will likely see expansion of its range throughout the larger Colorado River system in the near future.

Ludwigia erecta (L.) H. Hara (Onagraceae) yerba de jicotea

Significance: First collection for Arizona.

Ludwigia erecta is an obligate wetland species (USFW 1988) distributed in tropical regions of South America, Central America, central Mexico, and the Caribbean. In "A Flora of Tropical Florida," (Long & Lakela 1971) it is described as "pan tropical." In the United States, *L. erecta* occurs in southern Florida, with scattered collections in the Florida Panhandle, and one somewhat disjunct collection from Hinds County, Mississippi (GBIF 2010; USDA, NRCS. 2010).

Ludwigia erecta was collected during the 27 September 2010 excursion to the Tempe Towne Lake bottom. It was scattered, but not uncommon, and conspicuous because of its height – several plants were 4-5 feet tall (Figures 6,7). Having some experience with the wetland flora of the state, it was exciting to see something unfamiliar. After some research, nothing in the known state flora was a candidate, so duplicates were sent to experts at Missouri Botanical Garden for determination. Drs. Peter Hoch and Peter Raven were gracious and prompt with their response: "We agree that your material is *Ludwigia erecta* (L.) H. Hara. Based on known distributions, this is somewhat surprising (it seemed more likely to be *L. decurrens* based on its wider distribution), since this species is currently known in the USA only from southern Florida. However, it ranges widely across South America, the Caribbean, Central America at least to central Mexico, and – probably naturalized – in Africa, so it is not unexpected that it should show up in Arizona, and we might look for more occurrences in northern Mexico... I think your collection warrants some sort of published note, since this is a significant range extension, and will be of interest to many, especially those working on invasive plants (some Ludwigias in California have become serious problems) and on the predicted spread of species northward in association with climate change...." Indeed, using the Google Earth "ruler" tool, the distance to the nearest collections of *L. erecta* in the US is approximately 1,200 miles (Mississippi, Hinds County), and in Mexico, 950 miles (Nayarit).

Ludwigia erecta was "discovered" and "extirpated" within two weeks time from Tempe Towne Lake, but it's reasonable to assume it will persist. There are several plants upstream of the Lake that were vouchered on a botanical visit 24 November 2010. Those that remain are afforded a limited, yet suitable habitat in the shallows of the Salt River, and seeds from the Tempe Towne Lake population may have been washed downstream. To verify this, summer 2011 explorations of ephemeral and permanent wetlands along the urban reaches of the River bed should be undertaken.

Overview

In conclusion, the temporary wetland at Rio Salado and Rural Road in Tempe contrasted sharply with the lake environment that the City decided to construct 10 years ago. Policy makers marketed the area as 'lake front' and were obligated to repair the dam and return the property to the landscape they promised. Public sentiment seemed to agree. The mainstream media wrote of mostly negative perceptions of the site and a desire to restore the lake as soon as possible, including such quotes from local newspapers "...a muddy swamp hazardous to our health," "...odor and decay rising from the marshy water," "...smell of standing water and fish," and that "the lake is like the symbol of Tempe." The habitat is, of course, gone now – herbicide was applied to the vegetation in order to control

Figure 6. *Ludwigia erecta* – habit and stature contrast with surrounding graminoid vegetation.

Figure 7. *Ludwigia erecta*, aka "yerba de jicotea"

the growth of cattail, the bladder dams were replaced, and the Lake refilled in early October 2010.

In some ways, it's not surprising that this area produced novelties given the surrounding influences – there are several storm drains, it is immediately downstream from the confluence of Indian Bend Wash, which empties a large urban watershed, and there are two major freeways that pass over the river. However, considering the flora that emerged was remarkably "native" or at least "non-horticultural" given the number of potential non-natives available from the perimeter, something else is going on here.

Ironically, the formation of the Lake inadvertently created the substrates suitable for the establishment of this specialized suite of wetland plants. At the time of its construction, Tempe Towne Lake was lined with clay to reduce water infiltration. The lake bed sediments we sampled were anaerobic, and had an abundance of clay, silt, and organic matter (Estella Ruth personal communication) and our hypothesis is this created a habitat reminiscent of cienega wetland soils that historically blanketed many rivers in the region, quite different from the sandy soils that typify many of our rivers today. The Salt River will continue to be a "managed system," but what some saw as "muddy swamp" was actually a rare glimpse of the resilience of a desert riparian ecosystem, with its self-assembling diversity, evidence that our rivers and their connection to cienegas is not lost (Figures 8, 9).

The restoration implications of these plant findings are important. The Salt River in the Phoenix area seems to have a particular wetland flora that is persisting (or re-assembling) despite all the regulation, and restorationists need to become aware of this. Restoration of riparian habitats often includes constructed wetlands with the "re" introduction of native species incorporating active techniques such as plantings and earth moving. These tend to be costly and even temporary given high mortality rates of transplants, and the tendencies of rivers to redirect themselves. In light of the remarkably short amount of time it took for this particular wetland to emerge, restoration emphasis toward more "passive" techniques may be more expedient and economical. Seed banks of former wetlands are time sensitive, but effective management tools to be considered.

Citations

Boudell, J. A. 2004. Propagule banks as refugia for plant diversity in Southwestern riparian ecosystems. Ph. D. Dissertation, Arizona State University.

GBIF. 2010. Global Biodiversity Information Facility. Version 1.3.1. (data.gbif.org, accessed 20 October 2010, 15 November 2010).

Graham, S. A. 1979. The Origin of *Ammannia* x *coccinea* Rottboell. Taxon, 28(1):169-178.

Graham, S. A. 1985. A revision of *Ammannia* (Lythraceae) in the Western Hemisphere. Journal of the Arnold Arboretum 66:395-420.

Long, R. W. & O. Lakela 1971. A Flora of Tropical Florida – A Manual of the Seed Plants and Ferns of Southern Peninsular Florida. 962 pp.

NatureServe. 2010. NatureServe Explorer: An online encyclopedia of life. Version 7.1. NatureServe, Arlington, Virginia. (http://www.nature.org/explorer, (http://www.natureserve.org/explorer, accessed 18 October 2010).

Royal Botanic Gardens Kew Seed Information Database. 2008 (http://data.kew.org/sid/) release 7.1, May 2008, accessed 10 December 2010.

SEINet. 2010. Southwest Environmental Information Network (http://swbiodiversity.org/seinet/index.php, accessed 19 October 2010).

Tropicos.org. Missouri Botanical Garden. 21 Oct 2010 (http://www.tropicos.org/Name/9909398).
2010 Missouri Botanical Garden - 4344 Shaw Boulevard - Saint Louis, Missouri 63110

USDA, NRCS. 2010. The PLANTS Database (http://plants.usda.gov, accessed 18 October 2010). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

U.S. Fish and Wildlife Service. 1988. *National list of vascular plant species that occur in wetlands.* U.S. Fish & Wildlife Service Biological Report 88 (26.9).

[1]Cienega- a marsh or wetland. Cienegas can form where layers of rock or impervious clay hold water at the surface or through the continuous upwelling of numerous small springs and seeps. These conditions produce a rare plant community of sedges, grasses, reeds, and cattails because the soil is permanently saturated see: http://www.blm.gov/az/st/en/prog/recreation/hiking/stdavid.html

All photographs by Elizabeth Makings in September, 2010.

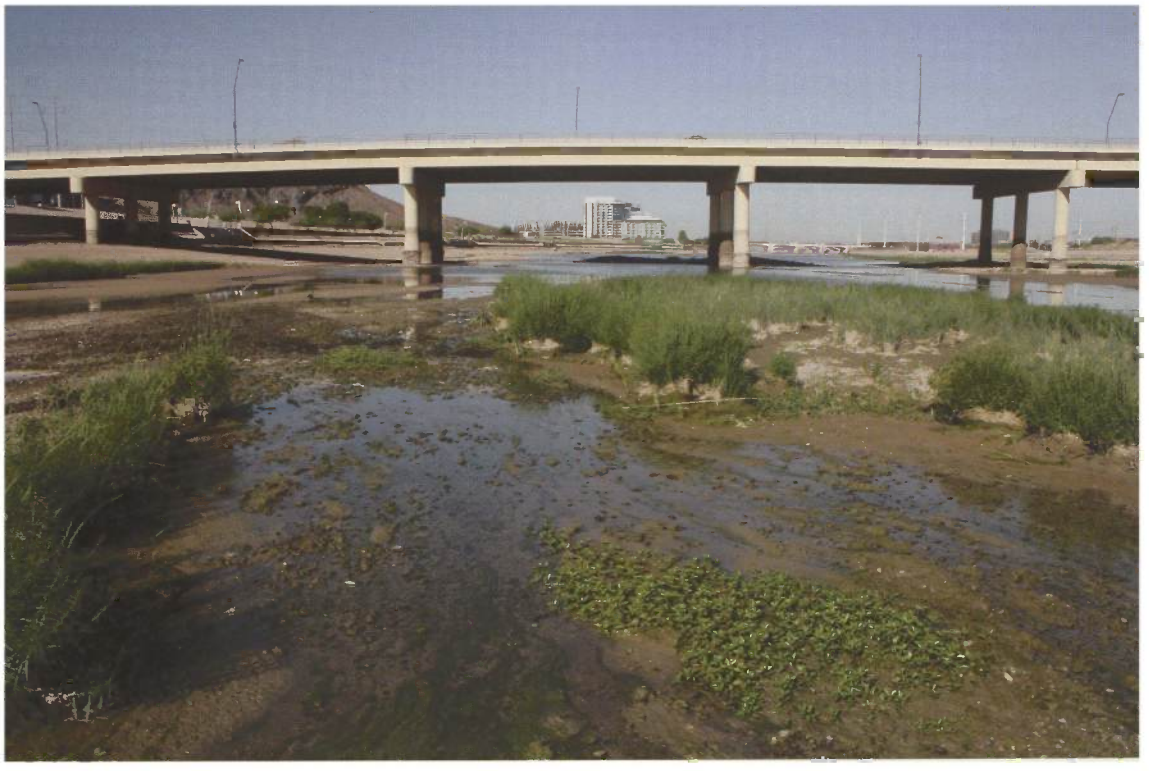

Figure 8. Tempe Towne Lake temporary wetland at Rural Road: 33. 4309,-111.925; 1160 ft. Low sprawling species in the foreground is *Ludwigia peploides*.

Figure 9. Looking west from Rural Road. Birds identified in photo by Matt Chew: **Great egret** (*Ardea alba*, **snowy egret** *Egretta thuls*, **cattle egret** *Bubulcus ibis*, **great blue heron** *Ardea herodias*, **blacknecked stilt** *Himantopus mexicanus*, **great-tailed grackle** *Quiscalus mexicanus*; two unidentifiable ducks in the distant puddle that are probably **mallards**. Other birds that made appearances during low water (not pictured): **turkey vultures** *Cathartes aura*, **ospreys** *Haliaeetus leucocephalus*, **mallards** *Anas platyrhynchos*.

Table 1. Species collected at Salt River, Tempe Towne Lake. September 2010

Family	**Species**	**Wetland indicator status#**
Amaranthaceae	**Amaranthus albus*	FACU
Asteraceae	*Eclipta prostrata*	FAC
Asteraceae	*Pluchea odorata*	OBL
Asteraceae	*Xanthium strumarium*	FAC
Boraginaceae	*Heliotropium curassavicum*	OBL
Cyperaceae	**Cyperus difformis*	OBL
Cyperaceae	*Cyperus erythrorhizos*	OBL
Cyperaceae	*Cyperus odoratus*	FACW
Cyperaceae	**Cyperus pygmaeus*	No information
Cyperaceae	*Eleocharis geniculata*	FACW,OBL
Cyperaceae	*Schoenoplectus maritimus*	OBL
Lythraceae	*Ammannia coccinea*	OBL
Onagraceae	*Ludwigia erecta*	OBL
Onagraceae	*Ludwigia peploides*	OBL
Poaceae	**Echinochloa colona*	FACW
Poaceae	*Leptochloa fusca ssp. uninervia*	FACW
Poaceae	*Leptochloa viscida*	FACU
Polygonaceae	*Persicaria lapathifolia*	OBL
Portulacaceae	**Portulaca oleracea*	FAC
Typhaceae	*Typha* sp.	OBL

*introduced

#Indicator Code Wetland Type (USFW 1988)

OBL Obligate Wetland occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW Facultative Wetland usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC Facultative equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU Facultative Upland usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
UPL Obligate Upland occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified.

DELEP Seed Arrive in Svalbard

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Scientists work to collect and store seeds of plant species in order to utilize the seed material in plant breeding efforts and also to conserve biodiversity. In addition to collecting seeds of wild species of plants, crop seeds are collected and stored. As the efforts to collect plant seeds from all over the world increase, the methodology for storing these seeds long term in seed banks under proper conditions has advanced. Researchers study seeds to determine their long term viability and the best storage conditions for maintaining that viability. It has been determined that storing the seeds in a cold dry location can preserve them for longer periods.

Nicolay I. Vavilov, a Russian scientist, is recognized as the "father of seed banking". In the period between 1916 and 1940 he traveled to five continents to search for new agricultural plants and to confirm his theories on plant genetic diversity. He amassed the largest seed collection of cultivated plants in the world, collecting 200,000 species from five continents by 1940. (Vavilov 1997, book published posthumously) Vavilov was arrested, tortured and imprisoned under the Stalin regime. He was starved to death in prison and died in 1943.

The importance of backing up a seed bank cannot be overstated. In February 2011, the Egyptian Deserts Gene Bank located on North Sinai, was badly damaged by looters. Equipment was stolen, the cooling system damaged and data destroyed. The bank specialized in desert plants including medicinal plants and fruit trees and was not backed up elsewhere. Fortunately, the seeds themselves were not damaged. (nature.com 2011) Seed banks in Afghanistan have been destroyed by war. (Ralof 2002). In 2006 a seed bank in the Philippines was damaged when a typhoon knocked down a seed bank wall (NYTimes 2006).

The Global Seed Vault in Svalbard, Norway was built to conserve food crop seeds from around the world, thus ensuring genetic diversity of the world's food crops. The location was selected based on climatic conditions. In case of a cataclysmic event on earth, the intent is there would still be a supply of crop seeds from this vault for farmers to "start over". This seed vault is a safety storage facility designed for the preservation of duplicate seed collections. Unlike conventional gene banks, the Global Seed Vault does not make seeds available to plant scientists. The storage procedure is referred to as the "black box" method meaning only the depositing institution has the right of ownership and disposition. The depositor is also responsible for seed replacement at the end of the seed viability period.

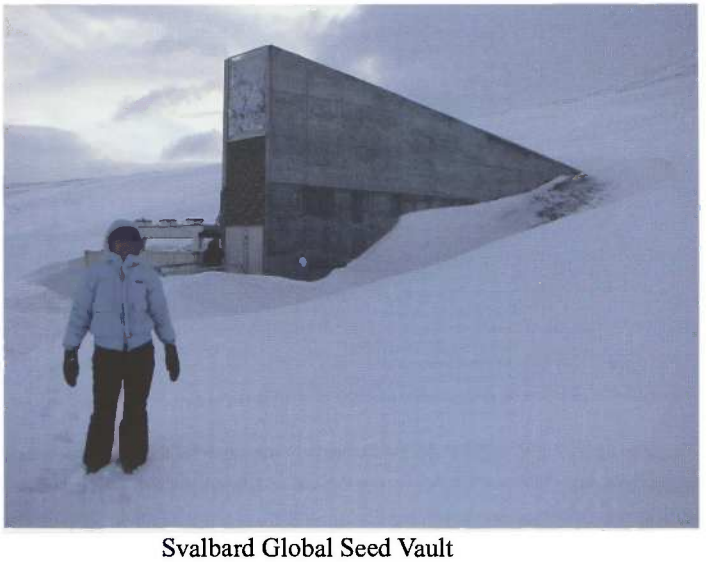
The Global Seed Vault which opened in February 2008, is entirely underground except for the entrance. The vault was blasted out of the permafrost (-3 to -4 degrees C) and is located very deep in a mountain. The seed vault was constructed by Norway at a cost of 45 million NOK (8 million dollars). Svalbard is a Norwegian territory located at 74-81 degrees N. Three partners manage the seed vault:

Royal Norwegian Ministry of Agriculture and Food
Nordic Genetic Resource Center (NordGen)
Global Crop Diversity Trust

An access tunnel 100 m long connects the brushed steel entrance to the storage vault. The vault consists of three chambers each with the capacity to store 1.5 million different seed samples at a constant temperature of -18 C. Seeds are stored in aluminum foil packages placed within boxes and stored on shelves. The seeds are stored free of charge however shipping costs are the depositor's responsibility.

The Desert Legume Program was established within the University of Arizona, College of Agriculture and research arm of the Boyce Thompson Arboretum, in June 1988. Legumes were targeted because they are the most important human food source after cereal grains. The use of legumes extends beyond nutrition as many are grown for animal forage, medicinal purposes and forestry products. The DELEP seed bank is a unique and valuable collection and an important resource for preserving seeds of thousands of desert legume species. The seed bank currently includes 3523 accessions, 1356 species and 221 genera from 57 countries and 6 continents and is located at the Desert Legume Program offices in Tucson, Arizona. DELEP has a long affiliation with USDA-ARS National Plant Germplasm System. A back-up collection of a portion of the DELEP collection is maintained at the National Center for Plant Genetic Resources in Fort Collins, Colorado.

DELEP submitted a list of desert legume species to the Svalbard Global Seed Vault program for possible deposition in the vault. In due course the list was approved for deposit. To date, 25 national and international institutions have deposited more than 400,000 unique seed samples from 198 countries in the Svalbard Global Seed Vault. The National Plant Germplasm System (USDA) and Seed Savers Exchange were the sole U.S. organizations having deposits at Svalbard. Thus DELEP is the third U.S. organization represented in Svalbard, an opportunity that significantly raises the profile of DELEP both nationally and internationally.



Svalbard Global Seed Vault

The DELEP seed list represents seeds originating from ten countries and includes: twenty-five accessions of 18 genera of *Acacia*, five accessions of *Parkinsonia*, four of *Prosopis* and three of *Lupinus*, *Phaseolus* and *Senna*. Eleven other legume species are represented by two accessions each and nine legume genera are represented by one accession each. The species in the DELEP collection have been used historically by indigenous people for food (vegetables and flour), forage, honey, gum and medicine. Additionally, some of the wood is used in construction and as firewood for cooking. Currently, Native Americans still use *Parkinsonia microphylla*, *Phaseolus filiformis* and *Phaseolus acutifolius* pods for vegetables. The Aborigines in Australia still use *Acacia kempeana* pods for flour and vegetables. *Acacia greggii* and *Acacia wrightii* are used for honey production. *Vigna unguiculata* (cowpea) is commonly consumed by people around the world. *Medicago sativa* (alfalfa) is grown for forage worldwide and *Leucaena leucocephylla* is used as forage in parts of Africa. *Lupinus angustifolius* is also grown for forage for sheep in Australia. Scientists are analyzing plant parts of some of these species, e.g. *Acacia victoriae* and *Sutherlandia frutescens* for medicinal properties.

Prior to sending the DELEP seed to Svalbard, a seed blessing was conducted at the Boyce Thompson Arboretum. Traditional Navajo words were spoken as the blessing pipe was circulated among the group gathered for the seed sendoff. The box of seeds was positioned in the center of the blessing ceremony. The words gave all a moment to reflect on the action of sending our desert seeds to a far away and very exotic locale for long term storage.

Navajo Seed Blessing at Boyce Thompson Arboretum
(L. Unklesbay February 2011)

In February 2011, I had the unique opportunity of traveling to Svalbard to deposit the seeds. My daughter, Nancy Unklesbay, who studies at the University of Oslo, traveled to Svalbard with me. Ola Westengen, a NordGen employee from Oslo in charge of depositors, accompanied us to the vault.

Photography was difficult because of the cold and the blowing snow but we did manage a few photos at the vault entrance. Once inside we proceeded down a 100 m tunnel and entered a side room which contained a computer and a guest book. We were able to add our names to a long list of dignitaries who had previously visited the vault. We dressed in special clothing provided by the vault before entering the actual seed storage section. Entry to the shelving section of the vault is for depositors only.

The employees of the seed vault had not anticipated and were not prepared for the global interest in the project. Journalists and scientists worldwide make requests to enter the vault. Since seed submissions are scheduled three to four times a year, the journalists try to schedule visits during the submission time and hope for entry. I was fortunate in that I was able to visit the vault a second time with Roland von Bothmer, the scientist from NordGen in charge of public relations for the vault.

The DELEP contribution was one box, a small contribution compared with the hundreds of boxes that bigger organizations deposit. However, this box symbolizes the importance of the DELEP program in its efforts to preserve seeds of a specific plant group. This single box also signifies the beginning of a collaboration with the global seed vault that hopefully will continue for many years.

Literature Review

New York Times. February 29, 2008. Near Arctic, Seed Vault is Fort Knox of Food.
Raloff, Jante. 2002. Afghanistan's Seed Banks Destroyed. Science News.
Vavilov, N.I. 1997. Five Continents. International Plant Genetic Resources Institute. Rome.
http:blogs.nature.com/news/the great beyond/2011/02/genebank.html

Margaret Norem and Ola Westengen entering the seed vault
(N. Unklesbay February 2011)

One hundred meter tunnel to the vault
(N. Unklesbay February 2011)

Entries to vaults 1 and 2. Note permafrost on the walls.
(M.Norem, February, 2011)

Margaret Norem and Nancy Unklesbay in the Arctic
(Ola Westengen, February 2011)

Ola Westengen and Margaret Norem entering Vault 2 with DELEP box. (N. Unklesbay February 2011)

Ola Westengen shelving the DELEP box
(N. Unklesbay February 2011)

Boyce Thompson Arboretum and the Global Strategy for Plant Conservation

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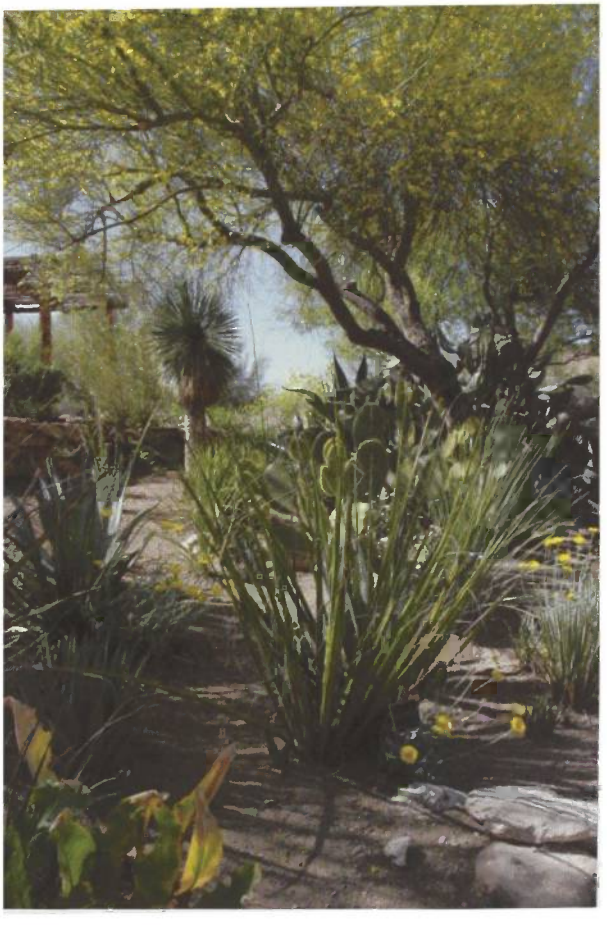
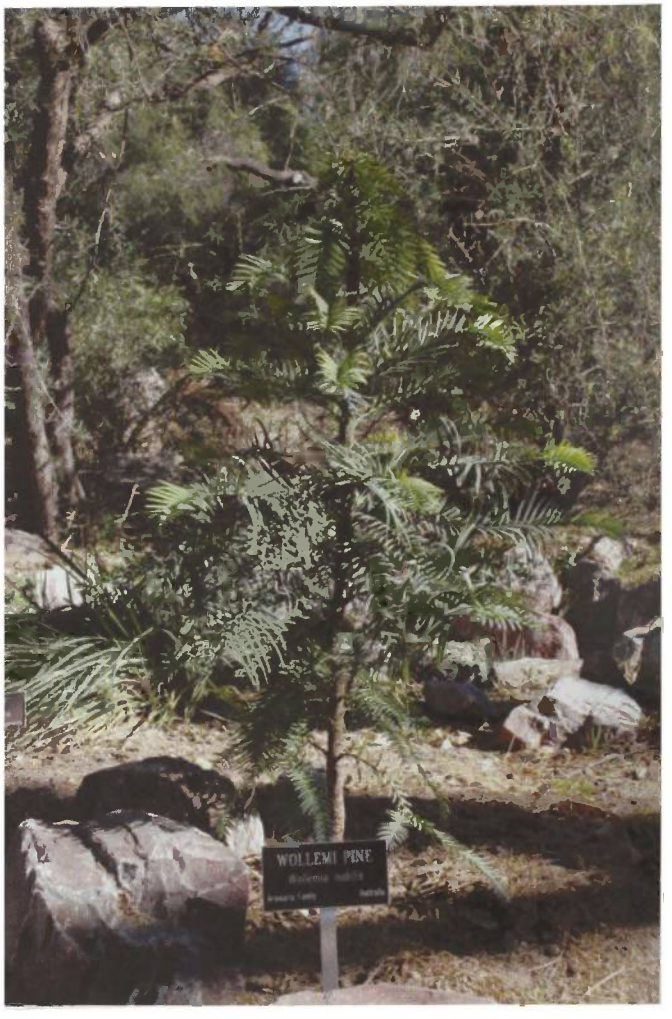
What would you do if you found out that maybe a third of plant species would be extinct in your lifetime? Assuming your first step might be finding out what plant experts were doing, the following article will bring you up to date and give you some background on current efforts to prevent this from happening. (As well as explain the alphabet soup that is frequently employed when discussing this topic).



Which plants would you be willing to sacrifice? (M. Siegwarth)

What is Plant Conservation

Simply put, the ultimate aim of plant conservation is to maintain viable growing plant communities in the wild in sufficient numbers to protect the genetic diversity of a species and to allow it to survive. This is often referred to as *in situ* conservation or on site conservation. *Ex situ* conservation or off site conservation has become popular as native habitat disappears. This loss of habitat frequently changes the number of plants listed as rare, threatened or endangered. As the number of viable communities in the wild decreases, so do the odds of the species surviving. In addition, the loss of native plant communities represents a loss of some genetic diversity as each community, although of the same species, may contain some genetic differences.



Arboreta may soon have more than the 100 Wollemi Pines existing in the wild. (M. Siegwarth)

Many arboreta and botanical gardens have embraced *ex situ* conservation as they are uniquely suited for it. Already, some species currently exist only at these institutions and no longer grow in the wild. *Ex situ* conservation bears with it a heavy responsibility. Seeds must be maintained not only as a backup for the institutions current collection but also to share with other institutions. A grow out plan is required as seeds, even in optimum storage conditions, have a finite life. In other words, as seeds begin to lose their viability, they need to be propagated so that these new plants will yield fresh, viable seeds of their own. For research purposes and documentation, live plants and plant specimens stored in herbariums are also critical to research efforts. Even with a large supply of seed, if propagation, growth information, and data on seed origin is lost, the seeds become essentially useless.

Plant conservation at arboreta and botanical gardens aims to practice *ex situ* conservation until the time is ripe for the restoration of a species through *in situ* conservation.

Why is Plant Conservation Important

I was somewhat hoping that stating "losing up to a third of plant species in our lifetime" is in and of itself, sufficient rationale to embrace plant conservation efforts. However, when people responded that a few less flower varieties is not necessarily cataclysmic, I decided to beef up this section of the article.

Plants supply us with food, shelter, medicines and clothing and it is hard for me to imagine a world without them. However, this does not address the need for diversity nor the fact that "virtually all human food comes directly or indirectly from plants, with just 103 species supplying over 90 percent of the calories we consume" (Raven 1999). This assumes we are willing to embrace a more monotonous diet over time. I personally could not forgo the joys of heirloom tomatoes or the pleasure of comparing the various scents of heritage roses. As history has taught us, the over reliance on just a few species carries great risk. The Irish potato famine in the 1800s is probably the most famous example but the spread of soybean rust in 2004 is probably a better example of why plant conservation is so important. Scientists screened more than 20,000 varieties of soybeans and their relatives looking for genetic resistance to rust that could be bred into this important crop (Scientific Collections 1999). Sadly, as with many things, we will not know what we have lost until it is gone.

The Heritage Rose Garden at Boyce Thompson Arboretum. (M. Siegwarth)

The Arboretum on its own

Since its founding, Boyce Thompson Arboretum (BTA) has always had a global outlook. At its dedication in 1929, University of Arizona President Dr. Homer Shantz marveled at the opportunity before him. Whereas most horticultural efforts were focused on the mere 12.5 percent of the earth's surface that was deciduous, BTA would draw on the neglected 50 percent of the earth's surface that was arid or semi-arid. In fact, he noted that with supplemental irrigation, BTA's reach would extend beyond 50 percent. Immediately, plants from around the world were gathered at this unique place that could provide a hospitable climate for them to grow and be studied (Desert Plants 2009).

At the time, the mission of BTA was primarily research and education. Recreation, although not explicit in the mission, was a natural part of any visit to the Arboretum. Conservation and the green movement were not yet prominent in the psyche of the 1920s. However, restoring and making land productive after the demise of the mining and timber industries was certainly in the Colonel's thoughts.

The 1940s reinforced the research focus of the Arboretum as the nation dealt with shortages and disruption of supplies of needed plant material from around the world. The partnership with the University of Arizona in the 1960s further reinforced the research and education focus of the Arboretum. The partnership with Arizona State Parks in the 1970s made explicit the recreational aspect of the Arboretum's mission.

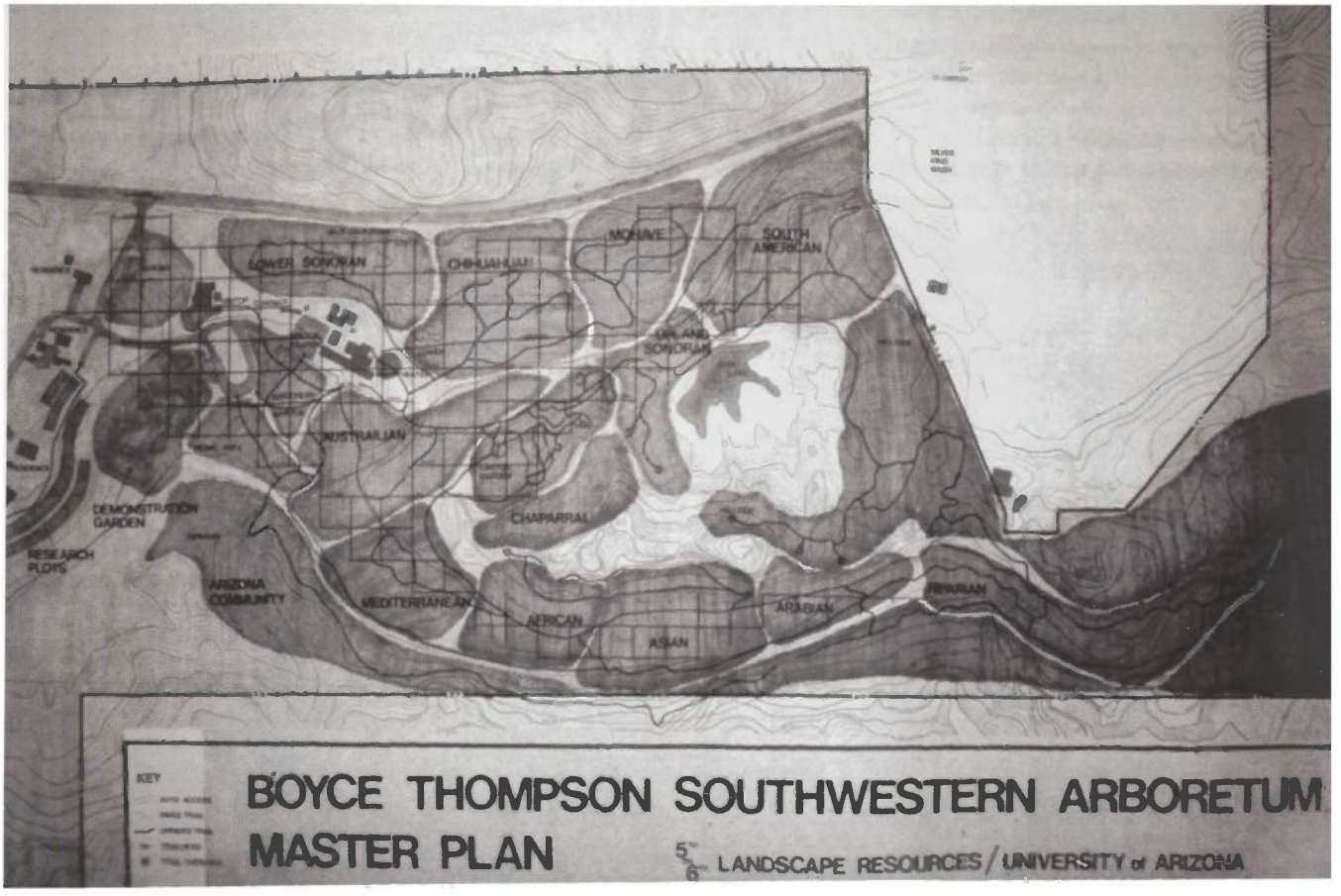
In 1979, the Master Plan was changed to move the focus of our exhibits from either a type, i.e. cactus garden or use, i.e. economic trees to a geographic, i.e. Chihuhuan Desert. By creating a geographic focus, this allowed BTA to create plantings in a natural setting and in effect, create a natural biotic community where the interplay of plants could function. This change not only reinforced our research and educational opportunities but the recreational aspect of the Arboretum as well. It has become one of the defining characteristics of the Arboretum.

Australian shrubby woodland plant community at Boyce Thompson Arboretum. (M. Siegwarth)

In the late 1990s, the Board added three words to the mission statement. The mission statement became "The purpose of the Boyce Thompson Arboretum is to instill in people an appreciation of plants through the fostering of educational, recreational, research and **conservation** opportunities associated with **the world's** arid land plants". These changes made explicit our global focus and the importance of conservation to our mission. In looking at the national and global efforts in this area, we were right there in the forefront.

Beginning of the Global Effort

In 1999, at the XVI International Botanical Congress, in St. Louis, Missouri, Dr. Peter Raven, Director of the Missouri Botanical Garden made a call for action for Plant Conservation. His concern



Boyce Thompson Arboretum master plan (M. Siegwarth)

was as many as 100,000 of the estimated total 300,000 species may be gone or on the way to extinction by the middle of the next century.

The first of the 7 steps he recommended was:
"(1) Establish a new coordinating body, presumably sponsored by the United Nations directly, possibly managed by one of its constituent organizations, to monitor the status of plants throughout the world, detect those in most danger, and take steps to conserve them in nature, in botanical gardens, or in seed banks or preferably a combination of these strategies."

This was followed up by another call to action by the Gran Canaria Declaration in April 2000. The Gran Canaria Group is an *ad hoc* group drawn from national and international organizations, institutions and other bodies involved in biodiversity conservation. The first meeting of this group ultimately led to the development and adoption of the Global Strategy for Plant Conservation.

In 2002, the Global Strategy for Plant Conservation (GSPC) was unanimously agreed to by all parties to the United Nations Convention on Biological Diversity at the Hague. The GSPC listed 16 targets to be achieved by 2010 in order to significantly reduce the loss of plant biodiversity. Grouped into five categories, some of these 16 targets are beyond the reach of Boyce Thompson Arboretum and would lead to an advocacy role in areas that many might find uncomfortable. The following broad categories currently fit squarely in the mission of BTA:

(1) Understanding and documenting plant diversity
(2) Conserving plant diversity
(3) Using plant diversity sustainably
(4) Promoting education and awareness about plant diversity
(5) Building capacity for the conservation of plant diversity

Within these categories is Target 8. The goal of Target 8 is to have 60 percent of threatened plant species in accessible *ex situ* collections, preferably in the country of origin, and 10 percent of the plant species included in recovery and restoration programs.

In 2010, it was realized that even though arboreta and botanical gardens in North America were making significant strides individually, there was no data collectively on the progress in meeting Target 8. Botanic Gardens Conservation International (BGCI) is a facilitating agency for the Global Implementation of Target 8. BGCI – USA, The United States Botanical Garden and the Arnold Arboretum at Harvard University conducted the first ever assessments of which threatened North American species were actually held *ex situ*. Boyce Thompson Arboretum and its Desert Legume Program participated in this assessment, listing both their living and germplasm (or seed) collections.

Also, in 2010, at the 10th Conference of the Parties to the Convention on Biological Diversity in Japan, it was agreed to revise the GSPC and its targets for work through 2020. Specifically Target 8 was increased to 75 percent of the worlds threatened species would be in *ex situ* collection. The above documents are available at http://www.bgci.org/ourwork/policytools/.

The Efforts of the United States within this framework

Even though the United State is not a party to the Center for Biological Diversity, many U.S organizations still work within its convention, especially if they are working with the global community. Although there are many conservation based groups in the United States, the Plant Conservation Alliance (PCA), the North American Plant Conservation Consortium (NAPCC) and the Center for Plant Conservation (CPC) are worth singling out in relationship to BTA.

The PCA, founded in 1994 as the Native Plant Conservation Initiative, is a consortium of ten federal government Member agencies and over 270 non-federal Cooperators representing various disciplines within the conservation field. PCA Members and Cooperators work collectively to solve the problems of native plant extinction and native habitat restoration, ensuring the preservation of our ecosystem.

PCA embodies the axiom "think globally, act locally." Federal plant conservation resources are pooled at the national level to provide a focused, strategic approach to plant conservation at the local level on public and private lands, eliminating duplication of effort and increasing the effectiveness of these programs. Each year, PCA awards thousands of dollars for on-the-ground conservation and restoration projects through a matching funds grant program administered by the National Fish and Wildlife Foundation.

The PCS came up with a national framework for plant conservation in 1995, which is similar in many ways to the GSPC. To read this framework, go to http://www.nps.gov/plants/strategy.htm.

In the early 1990s, the American Public Gardens established the North American Plant Collections Consortium (NAPCC). The NAPCC is a network of botanical gardens and arboreta working to coordinate a continent-wide approach to plant germplasm preservation, and to promote high standards of plant collections management. NAPCC Collections may serve as reference collections for plant identification and cultivar registration. Collection holders make germplasm available for taxonomic studies, evaluation, breeding, and other research. Participating institutions compare holdings with others to identify duplications and gaps. This makes efficient use of available resources, strengthening collections through combined collaborative activities. (http://www.publicgardens.org/) The NAPCC collections can be either single site, one institution or multi-site, several institutions joining together to conserve a particular genus.

Another U.S. organization is the Center for Plant Conservation (CPC). The CPC is dedicated solely to preventing the extinction of U.S. native plants. The Center was one of the first organizations created to meet this need. The Center is a network of 36 leading botanic institutions. Founded in 1984, the Center operates the only coordinated national program of off-site (*ex situ*) conservation of rare plant material. This conservation collection ensures that material is available for restoration and recovery efforts for these species. CPC also works in research, restoration, technical assistance, education and advocacy through the efforts of the network and the national office.

The cooperative CPC network maintains the National Collection of Endangered Plants. Believed to be the largest living collection of rare plants in the world, the collection contains more than 700 of America's most imperiled native plants. Live plant material is collected from nature under controlled conditions and then carefully maintained as seed, rooted cuttings or mature plants. Network institutions conduct horticultural research and carefully monitor these materials so that imperiled plants can be grown and returned to natural habitats. Several CPC institutions are also involved in restoration projects in the field (*in situ*). Scientists are stabilizing current populations of imperiled plants and reintroducing new populations in appropriate habitats. (CPC website http://www.centerforplantconservation.org/About/Mission/Mission.asp)

Boyce Thompson Arboretum Current Efforts

With over 3,200 species at the Arboretum and another 1,356 maintained by the Desert Legume Program, BTA continues to be part of the global conservation effort. Not only are DELEP seed backed up at the National Center for Plant Genetic Resources in Fort Collins and the Global Seed Vault in Svalbard Norway, its holdings are also listed on the national Germplasm Resources Information Network (GRIN) and the BGCI Plant Database, so that researchers worldwide can have access to their holdings. In the last two years, DELEP has honored over 100 seeds requests to 21 states and 21 foreign countries. With our new listings in the BGCI database and resultant publicity on our program, we expect these numbers to grow.

Svalbard Global Seed Vault (M. Norem)

Simply put, maintaining a seed bank, which includes growing them out occasionally to replenish the seed, maintaining a live plant collection for researchers and others, providing specimens for herbaria and maintaining detailed records on the plants and techniques of propagation is already quite an effort that few visitors ever see. Add to that, recovery and restoration projects, and you can see why the staff at BTA and DELEP are already pretty busy. However, there is so much more to do.

Even though this is a global effort and BTA has much to offer globally, there is much to be done right here in our backyard. BTA has been working with the Arizona Department of Transportation and the U.S. Forest Service on recovering and studying the propagation and transplant of the endangered *Echinocereus triglochidiatus* var. *arizonacus* or Arizona Hedgehog Cactus. With this partnership, BTA also hopes to be involved in several restoration projects as well.

Although DELEP's collection is considered a treasure, DELEP still needs 188 species to complete its collection of the approximately 370 legumes species in Arizona. The USDA's plant database lists 22 legumes for Arizona in their threatened and endangered list, of which four have federal threatened or endangered status. DELEP has some holdings of threatened/endangered species but not all. DELEP is hoping to acquire 90 new Arizona species over the next year if sufficient funding becomes available to conduct seed gathering efforts. If successful, working with BTA to maintain a live plant collection and a seed grow out plan will be required.

Arizona hedgehog cactus (M. Siegwarth)

BTA is considering applying for membership in the NAPCC both as a single site for Fabaceae (legumes) and as part of the multi-site *Quercus* (oak) group. DELEP already has a unique collection and may be appropriate for entry. The multi-site *Quercus* group has 13 members but none in the Southwest. BTA has been busy expanding its oak collection with plants that have been grown from wild seed and has the requisite collection data.

BTA will be joining the PCA so that it may apply for grants related to our efforts to conserve and restore native plants to the wild. With the help of the CPC, BTA will improve its handling of the rare, threatened and endangered species it has or may acquire over the next few years.

Conclusion and Next Steps

I hope I have established that there is much going on at the state, national and global level and that BTA is part of that. There is also a great deal that still needs to be done. If BTA is to continue to be part of the solution, collaboration with the PCA, NAPCC and CPC will be critical. Just as critical is our ability to perform such work.

Other institutions have offered us seed because of our unique location and mission. But the acceptance of this seed comes with great responsibility, as I stated at the beginning of this article. BTA needs to upgrade its seed storage, propagation and greenhouse facilities, as well as its collection data management tools. I hope you can help us meet these needs through our annual Research, Collection and Education appeal, as well as a future capital campaign to meet the challenges ahead.

Literature Cited

1. Raven, Peter H. 1999. Plants in Peril: What Should We Do? XVI International Botanical Congress. August 1-7, 1999. St. Louis, Missouri.
2. Scientific Collections: Mission-Critical Infrastructure for Federal Science Agencies. 1999. Interagency Working Group on Scientific Collections (IWGSC) Page 23.
3. Shantz, Homer L. 2009. World Vegetation in Relation to the Boyce Thompson Southwestern Arboretum. Desert Plants 25(2). page 17

Jeff Payne gathering seed for the Desert Legume Program. (M. Johnson)

Which plants would you be willing to sacrifice? (M. Siegwarth)

Plants Found Along the Effluent Dominated Stretch of the Middle Santa Cruz River

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Introduction

Water was sustainably harvested from the Santa Cruz River before European settlement by the native Hohokam peoples in what is now southern Arizona for hundreds of years. These people cultivated edible crops utilizing carefully engineered mud lined irrigation canals (Logan 2002). During this time the Santa Cruz River ran perennially and supported an abundant and vast riparian ecosystem. This riparian forest system contained such regionally extinct species as the muskrat, wild turkey, beaver as well as a variety of native fish. In addition its waters supported abundant and vast cottonwood, mesquite, and willow forests. Unsustainable water harvesting, deforestation, overgrazing, introduction of plant cultivars and their accompanying insect communities, erosion, and desertification begun in the middle 1800's by new Spanish urban settlers marked the start of the decline of the Santa Cruz River ecosystem (Logan 2002). By 1940 groundwater pumping from the Tucson basin's aquifers had lowered water tables past the reach of even the great cottonwood's massive root systems and the river's remaining riparian vegetation began to die (Figure 1).

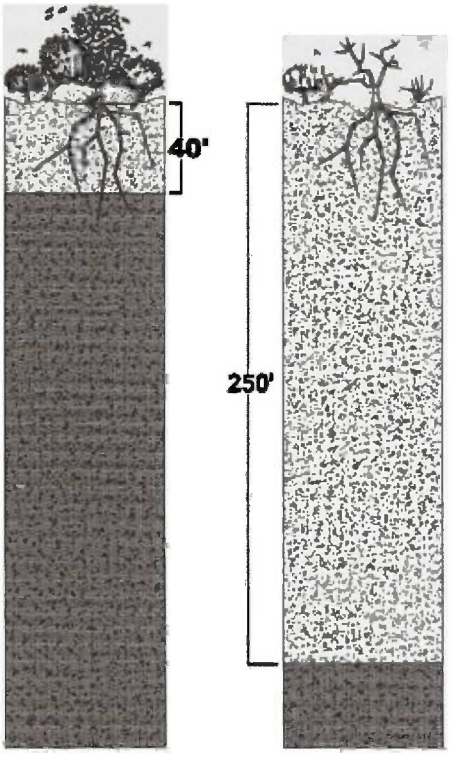


Figure 1. Two hundred years ago the groundwater table was less than 50 feet below the surface. By 1923 groundwater usage rates had surpassed recharge rates (Nabhan 1999). Today the groundwater table is 200 - 250 feet below the surface (Fabre 2009).

In 1977, in an effort to recycle reclaimed wastewaters and to partially re-charge the Tucson basin aquifer, Pima County began releasing treated wastewater or effluent waters into the Santa Cruz at Roger and Ina Roads. These running waters led to the partial rehabilitation of over 30 miles of the Santa Cruz starting at Roger Road. As a result a unique, effluent dependent, riparian ecosystem has developed with high biological diversity and a complex vegetation mosaic. This article is an attempt to identify and describe the plant life in the area. Although not comprehensive this article is the most complete collection of the vegetation which exists describing this unique ecosystem known to the author. It describes just over 100 species identified by the author during graduate research and casual observations or by others for catalogue in the University of Arizona Herbarium.

As part of thesis work in April and May of 2002, vegetation data was collected in 23 belt transects selected randomly along 4 different river type environments of the greater, middle Santa Cruz River. The purpose of this research was to gather enough plant data to be able to show, with statistical significance, the effects of the release of effluent waters on the vegetation of the severely debilitated Santa Cruz River. This was done using such biological measures as density, richness, diversity, cover, even-ness, and nativity (Figure 2). The results of this initial study were published in a thesis entitled, "Changes in Riparian Vegetation Following Release of Reclaimed Effluent Water into the Santa Cruz River: As a Corollary, the Effects of Channelization on the Vegetation in the Santa Cruz". One aspect of the work of this initial study was to count and identify individual plant species. A total of 60 plant species were identified in study transects along the effluent dominated stretches of the middle Santa Cruz during this initial thesis work.

The purpose of this report is; 1) to provide a photographic and written description of the vegetation identified and recorded in the effluent dominated middle Santa Cruz River by the author and others as recorded at the University of Arizona Herbarium, 2) to identify and describe predominant species of the area 3) to describe some of the unique attributes of the plants in this unique ecosystem, 4) to signify poisonous plants and occasionally identify their active secondary compounds, 5) to signify plants which were also identified and recorded by J.J. Thornber in the Santa Cruz watershed over 100 years ago, 6) to distinguish between nativity and dependence on effluent waters in an effort to describe plant life which might be termed as restored to the area as a result of effluent release and Thornber's identification prior to 1910, 7) to identify additional riparian native plants which can be assumed to be restored to the area.

Materials and Methods

As part of the work of the original study transect locations were randomly selected in 4 designated study areas; 1) areas with effluent waters, 2) areas without effluent, 3) channelized areas with effluent and 4) channelized areas without effluent. (Figure 3). A total of 23 transects were randomly selected and data was meticulously gathered in each. In total over 14,000 individual plants were identified and counted and a total of 71 different plant species named. Ten of the original 23 transects were in areas which contained effluent waters as were 60 of the original 71 identified plant species.

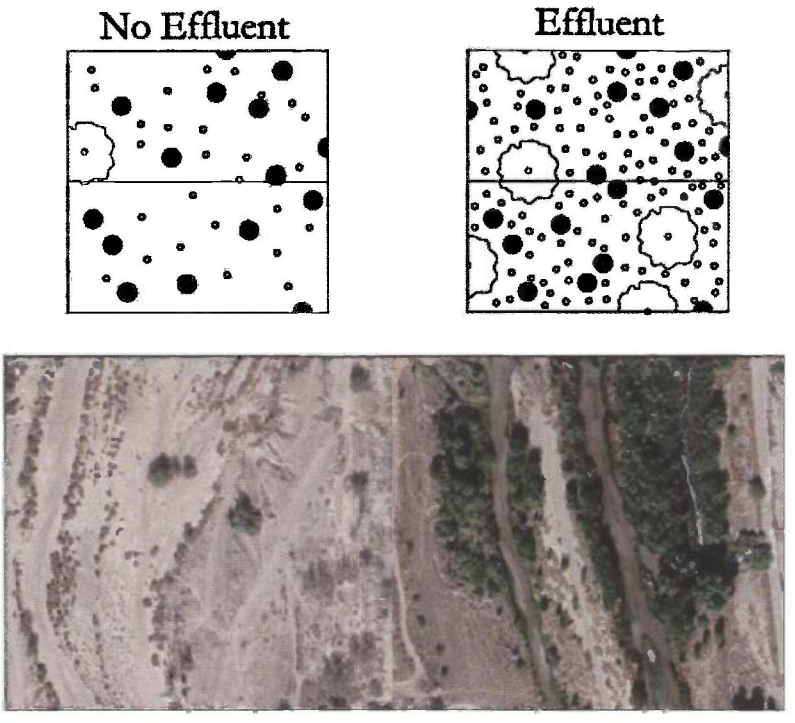


Figure 2. Santa Cruz River: Vegetative cover in the effluent affected stretch. (Gormally, 2002)

Figure 3. River Transects: Transects 25.5 feet wide bank to bank. See dirt road right of river effluent water for a sense of scale. (Aerial image courtesy of Google Earth.)

The data was collected in belt transects which were just over 25 feet wide and as long as the river was wide. In one case this was greater than the length of two football fields put end to end. Not surprisingly, the transect with the highest plant density occurred in an effluent dependent reach of the river and contained just under 936 individual plant specimens in an approximately 7,300 square foot belt transect. The transect with the highest number of plants was located in an especially wide river section containing effluent. This transect had over 1900 plants in an area just under 19,000 square feet. The transect with the least plants, a count of 88, was located in an un-channelized and severely debilitated river section located south of downtowne Tucson approximately 250 feet upstream of the Irvington Road bridge.

Plants identified and recorded at the University of Arizona Herbarium in the middle effluent dominated stretch of the Santa Cruz are also listed. An original plant list from the Herbarium's Santa Cruz River database of 736 plants was filtered based on a number of criteria developed by the author in order to distinguish between those found in the lower effluent dependent plant ecosystem. These plants from the UA Herbarium Santa Cruz database were cross referenced for date of identification, latitudinal and longitudinal location, descriptive location, and presence of effluent. The author identified forty three plants catalogued in the herbarium as effluent dependent under the above guidelines and they are included here.

Plants found in non-effluent dependent stretches of the river will not be covered in this manuscript. The plants of this ecosystem were covered in "Desert Plants", Volume 18, Number 1, entitled "Plants of the Santa Cruz Valley at Tucson" by Kathryn Mauz June 2002. Another related "Desert Plants" article entitled "Herbaceous Exotics in Arizona's Riparian Ecosystems", Volume 13, Number 1, June 1997, describes 70 common native and exotic plants found in Arizona's riparian areas. Interestingly, only 25 of these 70 have been found in the lower effluent dependent Santa Cruz plant ecosystem to date.

Describing the Area

The stretch of the Santa Cruz River located in and around the Tucson basin is generally referred to as the middle stretch as it is in the approximate middle of the river's course. The area containing flowing effluent may then be termed the effluent dominated middle Santa Cruz river. There are two major flows of effluent in the Santa Cruz River. One is from the towne of Nogales and the other further downstream is from the Tucson area. For this reason vegetation in the middle Santa Cruz in areas containing effluent might be referred to as the lower effluent dependent Santa Cruz vegetation.

Symbols Legend

NT = Native Tree, **ET** = Exotic Tree, **NW** = Native Woody Shrub, **EW** = Exotic Woody Shrub, **NH** = Native Herbaceous, **EH** = Exotic Herbaceous.

P signifies a predominant species.

SpecSig signifies a plant marked for recognition by Phil Jenkins, University of Arizona Herbarium Plant Specialist.

:X: marks a highly poisonous or deadly poisonous plant species.

T-1909 represents plants which Thornber identified in the Santa Cruz watershed prior to 1909, (Mauz 2002). Thirty two of these plants were identified in the lower effluent dependent reach. Of these 32, 10 can be said to be native plants dependent upon the additional water supplied by effluent.

RTA signifies a native species which might be assumed as "restored to area" due to its dependence on supplemental water for survival. Of 103 species identified in this article 24 are assumed to be RTA.

IFS denotes those plants which have traditionally served as a food source to Native American peoples.

OIU denotes other indigenous uses such as medicinal and tactile.

CLP indicates a commonly used landscape plant. Due to the high water availability in the area, various native and exotic landscape plant species occur in the area.

ARIZ ###### signifies a plant specified as found in the effluent dependent lower Santa Cruz River by the University of Arizona Herbarium, (***ARIZ***) and its corresponding specimen number (######). If the specimen number is followed by an * the plant was also identified and recorded by the author.

Plants found in the lower effluent dependent Santa Cruz river ecosystem: Alphabetical by plant type.

Trees

Acacia constricta, Whitethorn Acacia, **NT, CLP**

This desert native is a common tree in the Sonoran Desert landscape. Its yellow balls are very fragrant and abundant pollinating sources. When pruned this tree has a very attractive appearance and is a common choice in designed landscapes (Bowers 1993).

Acacia greggii, Catclaw Acacia, **NT, :X:, T-1909, IFS, OIU**

Like the whitethorn, the catclaw acacia is a southwestern United States desert native. Also called the catclaw mesquite, tear blanket, Gregg's catclaw, devil's claw, paradise flower, wait-a-minute, wait-a-moment, and wait-a-bit tree, the *Acacia greggii* has unique and extremely sharp cat claw-like thorns. The genus name Acacia means thorny and the species name of greggii is derived from the root name of Josiah Gregg, an amateur naturalist of the early 1800's. This tree is normally a smaller one in comparison to other desert natives however mature trees sometimes reach heights up to 50 feet. Like the whitethorn, its flowers are puffy yellow balls which are a favorite of nectar collecting insects. The fragrant yellow puff balls appear April through October (Leake 1993). The seeds have been ground into flour and the pods eaten raw or cooked by native peoples for centuries. Its very dense wood has traditionally been used for stock in home and tool construction (Petrides 2005).

Cercidium floridum or *Parkinsonia florida*, Blue Palo Verde, **NT, IFS, CLP**

Named after the Greek word, kerkidion, for weaver's comb, plants in the genus *Cercidium* produce seeds with a unique segmented shape resembling these historically common tools, (Lamb 1975). Another unique attribute of the blue palo verde is the fact that it contains chlorophyll in its bark allowing it to conduct photosynthesis along its trunk and branches as well as its leaves. The chlorophyll gives trees in the Cercidium family a greenish, greenish yellow or greenish blue color (Yetman 2009). As the name implies the blue palo verde has a bluish color to its bark. It is a common Sonoran Desert tree most often found in and near riparian areas. Like its relative below, the *C. floridum* has a dense, low growth pattern and is twiggy with an unusually abundant spring bloom which often covers the entire tree (Jones 2000). Trees in full bloom often appear to be made of solid yellow leaves and stems until inspected up close and found to be covered in thousands of tiny yellow flowers. After pollination there is an abundance of seeds which were a food source for indigenous Native American people, (Petrides 2005).

Cercidium microphyllum or *Parkinsonia microphylla*, Foothills Palo Verde, **NT, IFS, CLP**

Also called yellow palo verde, this predominant native tree, is more likely to be found, as its common name implies, on higher and drier ground. The scientific name of *microphyllum* describes prolific and tiny leaves. It is a hardy, slow growing plant, found below 4000 feet (Duffield & Jones 1981), native to the Sonoran Desert in the United States (Jones 2000). It has an impressive yellow spring bloom. The flowers from this bloom are a good nectar food source for many insects (Leake 1993). Like the Blue Palo Verde, its seeds were an important native food source, and their preparation included roasting, grinding, and soaking (Yetman 2009). Both the blue and foothills palo verde trees are excellent native landscaping trees as they are sculpturally attractive, uniquely colored, prolific flowering plants, which provide habitat and food for native wildlife.

Nicotiana glauca, Tobacco Tree, **ET, :X:, T-1909, OIU**

This smaller tree has smooth white bark and large dark blue-green leaves. The plant is a close relative to the common tobacco plant and contains many of the same toxic chemicals such as nicotine and other alkaloids which makes plants in this familyextremely poisonous. Although not predominant, the plant is relatively common along the effluent dependent lower Santa Cruz and its large darkly colored leaves make it easily distinguishable from other vegetation in the area. Like the common tobacco plant, all parts of the plant can be deadly if ingested (Schmutz 1979). Several deaths were recorded when young plants were mistaken for spinach, cooked, and then consumed. This deadly exotic plant is a native of Argentina. Among over a dozen symptoms of ingestion are nausea, severe vomiting, cold sweats, convulsions and death due to respiratory failure (Schmutz 1979, Wink 2008).

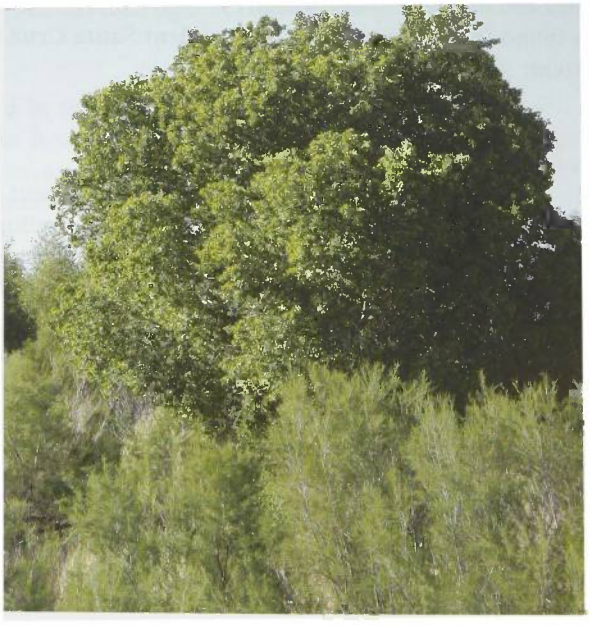
Nicotiana glauca

Olneya tesota, Ironwood, **NT, IFS, OIU**
Ironwood has one of the strongest, densest, and heaviest woods of any tree in the world. This unique tree is thought to live as long as 900 years. Its trunk can survive decomposition another 1000 years after plant death (Yetman 2009). Due to their slow growth and unique wood, ironwoods cannot be dated using the traditional tree ring method. Their age is calculated using carbon dating methods. Although not as common as the velvet mesquite and native palo verdes, it can often be found as a predominant tree in various regions around Tucson and in the Sonoran Desert. One such area is the Ironwood National Monument west of Tucson. Its seeds can be roasted and eaten (Lamb 1975) and they were an important food source for many indigenous desert people (Yetman 2009). The wood was used to make very hot fires and load bearing beams in home construction. *Olneya tesota* can be found in Arizona, California, and northern Mexico (Yetman 2009).

Parkinsonia aculeata, Mexican Palo Verde, **ET, IFS**
Considered an invasive weedy species by many Southwest plant experts, the exotic Mexican palo verde tree is a common occurrence in the landscapes of the City of Tucson. This aggressively invasive species can be distinguished from its relatives the blue and foothills palo verdes, by its long willow-like leaves and associated abundant litter. This tree has now naturalized into many disturbed and urban areas. Like the other palo verdes found in the area, its seeds were a food source of indigenous peoples of its range (Yetman 2009).

Populus fremontii, Fremont Cottonwood, **NT, T-1909, RTA, IFS, OIU** Also called Fremont poplar, Arizona cottonwood, MacDougal cottonwood, and the alamo, the *Populus fremontii* is an extremely large riparian tree. It was once abundant along most of the Santa Cruz River in a vast and prolific riparian forest which contained wild turkey, beaver, and muskrat. In the desert Southwest it is always a sight to see due to its sheer size, bright green leaves, and assumed proximity to water. The cottonwood uses relatively large amounts of ground and surface water and is habitat to many bird species including large raptors such as hawks and owls. Cottonwoods can grow to 100 ft. tall with a trunk 5-6 feet in diameter and with a comparably vast and deep root structure (Vines 1960). It is a source of foraging food for herbivores such as mule deer, sheep and elk and was used by Native American people as a food source, for medicinal purposes, and as construction material for baskets and other tools, (Vines 1960). The trees buds or catkins are edible and its bark is thought to have curative powers for healing bruises, sprains, and broken bones (Yetman 2009). Cottonwoods grow at elevations lower than 6000 ft. (Duffield and Jones 1981).

The forests of cottonwood and willow that thrived along the Santa Cruz prior to European settlement disappeared in the early 20th century as surface waters disappeared and water tables dropped. Along the now barren stretches of the Santa Cruz southeast of the I-19 crossing and San Xavier Cathedral all that is left of their existence are large holes in the ground which are the voids left after the death and decomposition of the their great root systems. Although not predominant, cottonwood trees are beginning to thrive in the lower effluent dependent Santa Cruz. They serve as valuable nesting habitat to various raptor species and as a hint of the former riparian forests of the Santa Cruz.



Populus fremontii

Voids where cottonwoods once grew

Prosopis hybrid, South American Hybrid, **ET, CLP**
Unlike its Sonoran Desert relative the velvet mesquite, the South American hybrid is a non-native, semi-aggressive, invasive, species. Introduced for its fast growth rate and favorable size the South American mesquite has begun to naturalize into disturbed and urban areas. Along the effluent dominated lower Santa Cruz it can be found alone or in groups of two or three. Unfortunately, this plant has been used frequently in the desert landscape as it grows rapidly with relatively little water. Drawbacks to its use and maintenance are its large and sharp thorns, its likelihood of falling over in heavy storms due to its fast and often top heavy growth and its less favorable habitat value to native bird species.

Prosopis velutina, Velvet Mesquite, **NT, T-1909, IFS, OIU, CLP**
Commonly known as velvet mesquite, this tree is one of the most important trees of the Sonoran Desert. '*Velutina*' refers to the velvety quality of its leaves. It is one of the most predominant in the region and serves as habitat for its own unique fauna. Its seeds have been used as a food source by wildlife and native peoples for thousands of years and it is an excellent native landscaping tree. It is often found in and near riparian areas in large groupings called mesquite bosques. These riparian ecotopes serve as unique habitat for many types of birds and small mammals of the region (Lamb 1975). Bosques were a common phenomenon along the Santa Cruz prior to the riparian ecosystem collapse in the late 19th and early 20th century, the result of unsustainable water harvesting.

The mesquite bean was the foundational starch food source in the diet of many native peoples and the sap which oozes from the tree is sweet and edible. It was considered a treat or natural candy by many indigenous groups. It also served a functional role as an adhesive, filler, and as an all-purpose resin. The roots, bark, sap, and leaves all served medicinal roles in traditional Southwest medicine. These plant parts were used to cure conjunctivitis, intestinal parasites, acne, and dandruff (Yetman 2009). The wood of mesquite releases a favorable smell and flavor when smoked and has therefore been used in the smoking of meats. Unfortunately, there has been little restoration of the historical mesquite bosques which once existed along the water course due to effluent release into the Santa Cruz and its occurrence here is relatively low when compared to its abundance in other Sonoran Desert regions.

Salix gooddingii, Goodding Willow, NT, P, SpecSig, T-1909, RTA, OIU, ARIZ 193844*
The Goodding willow is the most common tree species found in the effluent dependent reach of the lower Santa Cruz. It can be found lining the stream course in most areas where there is effluent. Like the Fremont cottonwood, the Goodding willow was a predominant and integral part of the once prolific riparian forests of pre-Spanish colonization. As an integral and predominant species it provided food and habitat for many animal species. It was a common food source of locally extinct beavers and would have been utilized often for dam building along the pre-settlement Santa Cruz River ecosystem (Allen 1983, Glinski 2002). This native tree species seems to have benefited the most from the release of effluent into the lower Santa Cruz River as thin riparian forests of Goodding willow can be seen along its banks for miles. There were an average of 12 trees per effluent study transect easily making it the most common effluent dependent tree. If effluent release is continued and barring any major flood events, 50 foot Goodding willow trees will dominate much of this stretch of river ecosystem in less than 10 years providing a substantial partial river restoration and considerable riparian habitat.

In some areas the trees are often as tall as 30- 40 ft. and are habitat for owls, hawks, and song birds in addition to the endangered willow flycatcher (Yetman 2009). They can grow as tall as 50 ft. with trunks as wide as 2-3 ft. in diameter, (Lamb 1975). This willow is a natural source of acetylsalicyclic acid or aspirin, and was therefore a favorite painkiller of Native American healers (Yetman 2009). *S. gooddingii* can be found in California, Arizona, Nevada, Texas, Colorado, New Mexico, and Utah, (USDA).
Spec Sig: According to Phil Jenkins Goodding willow is perhaps the most important plant in southern Arizona that indicates the presence of a permanent water source. Its presence is an indicator of a habitat that is suited for such fauna as flycatchers, vireos and warblers.

Salix gooddingii

Tamarix ramosissima, Salt Cedar, **ET, P**
Also known as Manna-Bush, Athel, Eshel, Asul, Athul, and Atle, this is the second most predominant tree in the effluent dependent region. This aggressive and often un-desirable invader from Africa and the Middle East, out-competes many native trees for vi-

tal riparian waters not only in this area but across the Southwest (Duffield and Jones 1981). It is a large tree easily reaching heights of 40 feet and greater. It was originally cultivated as an ornamental, erosion, and wind break plant in Texas and the Southwest, but now chokes many southwestern riparian areas (Vines 1960). One positive to its occurrence in the area is that its dense foliage and large size serves as excellent plant cover and bird habitat. Another drawback to the salt cedar is the fact that it has allelopathic properties which prevent understory growth.

Woody Shrubs

Ambrosia aptera, Ragweed, **NW, RTA**

Plants in this genus are commonly found in desert regions and are often uniquely adapted for dry climates. The ragweed is somewhat of an exception as its relatively large leaves require more water than other plants in the genus (Bowers 1993). Therefore it prefers and can often be found in riparian areas. The pollen from these plants are known allergens. *Ambrosia aptera* contains sesquiterpenes and sesquiterpene lactones which are moderately hazardous secondary compounds causing neurotoxicity and allergic reactions (Wink 2008).

Arundo donax, Giant Reed, **EW, P, T-1909, IFS, OIU**

Also known as canegrass, this grass has competitively pushed the native canegrass, *A. phragmites*, out of Sonoran riparian areas (Yetman 2009). The two plants closely resemble each-other with tall 8 – 12 foot vertical structures similar to bamboo. *Arundo donax* so closely resembles its native counterpart that the two plants can only be distinguished by the most skilled plant expert (Yetman 2008). The young shoots of both plants were an early food source of indigenous peoples. Its roots were used to make healing teas for various ailments and its hollow stems to make musical wind instruments. Its dense thickets offer shelter, food, and protection to many wildlife species (Yetman 2009). It also contains bufotenin, tryptamines and tyramines which are moderately hazardous hallucinogenic and mind altering compounds (Wink 2008). This plant often dominates along the banks of the lower Santa Cruz effluent dependent ecosystem in thick and tall stands.

Arundo donax

Atriplex canescens, 4-Wing Saltbush, **NW, T-1909, IFS, OIU**

Also known as wingscale, this plant is unique for its color and texture. It is a silvery grey and covered with small scales. It is a popular foraging plant for deer, sheep, and other large herbivores. Along the effluent dependent water course it is most commonly found as an edge species. It has also been used as a preservative, yellow dye, salt flavored seasoning and as medicine by indigenous peoples of the region. It was said to heal stomach pain, infections, and toothaches (Yetman 2009). Its seeds can be ground into an edible meal and it roots and flowers, when combined with saliva, into a healing ointment for insect bites (Leake 1993).

Atriplex cf. lentiformis, Saltbush, **NW**

This plant, also known as quail bush, big saltbrush, big saltbush, quailbrush, lenscale, len-scale saltbush and white thistle is most commonly found along coastal Californian landscapes but is native to the Sonoran Desert (USDA, Calfora).

Baccharis salicifolia, Seepwillow, **NW, *SpecSig*, T-1909, OIU, *ARIZ 191266****

Also called pursh, this is a native stream bank shrub with willow-like leaves and long straight stems. Native American people used the plant's branches to make arrows and its leaves as odor absorbers and deodorants. The leaves were also used to make a contraceptive tea for women (Yetman 2009). The plant flowers from February through May. Its range is from sea level to 5000 ft. in West Texas, New Mexico, Arizona, California, and South America reaching as far southward as Chile (Vines 1960).

Spec Sig: According to Phil Jenkins, seepwillow is a shrub or small tree that indicated the presence of underground water.

Baccharis sarathroides, Desert Broom, **NW**

This common desert shrub can be found predominating almost every disturbed piece of land in the Tucson area. Its unique leafless structure allows it to begin all-out photosynthesis through its stems immediately after rains, beating most traditional plants which must first produce new leaflets prior to beginning photosynthesis (Bower 1993). Another mechanism which assists the plant to outcompete others is its abundant and feathery seed pods which distribute themselves readily and by large numbers through the air.

Caesalpinia gilliesii, Yellow Bird of Paradise, **EW, CLP, T-1909**

This relatively common landscape plant native to South America has a showy yellow and red flower (Duffield and Jones 1981). Interestingly, Thornber identified this plant prior to 1909, making it one of a number of historical ornamentals.

Celtis pallida, Desert Hackberry, **NW, T-1909, IFS, CLP**

This unique desert native is a valuable plant with many important ecological roles in the desert ecosystem. Its edible fruits are eaten by coyote, javelina, rabbit, and bird species. Its leaves food for differing butterfly larva and mule deer. Its size, thickness and spiny nature afford ideal nesting cover for desert quail and dove. The Sonoran Desert represents the northernmost reach of this plants home range as it is a sub-tropical and tropical plant stretching southward into Central America and Argentina (Bowers 1993). Due to its many favorable qualities this plant makes an ideal desert native landscaping choice.

Cupressus species (unidentifiable)
Plants in this genus are evergreen trees or shrubs with dense foliage and coned fruits (USDA).

Cylindropuntia leptocaulis x. spinosior, *Opuntia leptocaulis*, Desert Christmas Cactus, **NW, IFS, *ARIZ 124747, 126350***
This native cactus derives its common name from its green branches and red fruits which are on display around Christmas time (Kearney 1960). Native peoples of the region have traditionally harvested and eaten the fruits from this spiny cactus (USDA).

Cyclindropuntia spinosior or *Opuntia spinosior*, Cane Cholla, **NW, *ARIZ 126328***
This common and widely distributed Sonoran Desert cholla species, like all chollas, provides cover to songbirds from predation. It also supplies a valuable fruiting food source to many animal species (Bower 1993).

Encelia farinosa, Brittlebush, **NW, CLP, OIU**
This small flowering shrub is often planted for its attractive and hardy nature as a low water landscape plant and as a seed plant in seed mixes for revegetation efforts in southwest Arizona. It is native to the Sonoran and Mojave Deserts and displays beautiful abundant yellow flowers in the spring and at other times (Jones & Sacamano 2000). The gum which oozes from the stems of this plant can be used to make incense. It was used by Catholic priests for this purpose for centuries. Native American peoples chewed and heated the plant's gum to be applied as a pain-killing and healing ointment (Leake 1993). Care should be taken as it is poisonous and contains dangerous sesquiterpenes which are moderate cell and neuro-toxins (Wink 2008).

Hymenoclea momogyra, Burrobush, **NW, :X:**
Also known as romerillo, cheeseweed and jecota, this plant has a cheesy smell when its leaves are disturbed. This bright green desert shrub is often clustered together in thickets and occurs in the Southwest below 4,000 ft. It can be found from western Texas to southern California and down into northern New Mexico (Dodge 1985). It contains moderately dangerous cell toxins, neurotoxins, and allergens (Wink 2008).

Isocuma tenuisecta, Burroweed, **NW**
This is a hardy and poisonous pioneering species which cattle will avoid. As a result the plant often dominates grazed areas. It can often be found along parking lots and in other disturbed areas. This desert native has tiny yellow flowers which make for a somewhat showy display in late summer and early fall (Bowers 1993).

Larrea tridentata, Creosote, **NW, CLP, :X:, OIU**
The most widespread desert plant (Leake 1993), also known as chaparral leaf, greasewood, hedionilla, gobernadora, and guamis, creosote has numerous unique uses and qualities. It can survive on very little water and often predominates an ecosystem, almost to the point of being a monoculture. When this occurs, often in flat, poor soil and low water areas, the resulting biome is called a creosote flat. The plant itself emits a very strong smell after rain which permeates the air. Its body is covered with a sticky resin and its fruits are covered in white hairs. It is home to multiple insect species including a midge which makes leafy galls on its limbs (Lamb 1975). It has many indigenous uses as paint, dye, medicine for rheumatism and burns, food flavoring, and as a perfume (Leake 1993). Creosote is poisonous and contains lignans such as nordihyroguajaretics which are cytotoxic and can cause nausea, vomiting, diarrhea, and abdominal pain if consumed (Wink 2008). Yetman (2009) claims that some plants may be as old as 12,000 years, which could make creosote the oldest living plant on earth.

Lycium andersonii, Anderson Wolfberry, **NW, T-1909, *ARIZ 211464***
Known as Anderson thornbush, Anderson lycium, Anderson desert thorn, Anderson boxthorn, Tomatillo, and desert tomato, this Sonoran Desert native plant can form thickets in riparian washes. Unique in its form with spiked branches which get larger further from the main stem, this plalnt provides an almost impenetrable wall of thorns which sometimes prevents birds from entering. Fruits which are sometimes prolific are very bitter and have been used as a food source by indigenous peoples (Kearney 1960).

Opuntia x. tetracantha, ***ARIZ 126264***

Panicum antidotale, Blue Panicgrass, **EW, *ARIZ 108811***
This plant is classified as a noxious weed by the California Department of Food and Agriculture (USDA).

Penisetum ciliare, Buffelgrass, **EW, P**
This highly invasive and aggressive large grass species from Africa, Asia, India and the Middle East can quickly out-compete native plants in the Sonoran Desert. It is a threat to ecosystems across southern Arizona. Recently, community and government groups have banded together to remove buffelgrass from various ecosystems including the study area. Since data was gathered in 2002 buffelgrass numbers have increased significantly in effluent and non-effluent sections of the middle Santa Cruz (USDA, Gormally 2002).

Typha domingensis, Southern Cat-tail, NW, P, RTA
Also known as cumbungi, this native aquatic plant can be found in dense thickets at the edge of flowing and standing waters. It is a predominant species among the lower effluent dependent Santa Cruz vegetation and forms long and dense thickets up to four feet tall (USDA).

Typha domingensis

Herbaceous Plants

Apium leptophyllum or Cyclospermum leptophyllum, Marsh Parsley, **EH,** ***ARIZ 193857***
This small herb is a member of the celery family and is notable as a common garden weed as well as for its similarity in appearance to parsley (Munz 1974).

Argemone ochroleuca, Sweet Pale, **NH, RTA,** ***ARIZ 193849***
Also known as Mexican pricklypoppy, this plant is a native annual with thorny thistle-like leaves and showy flowers (USDA).

Asteraceae species (unidentifiable)
Commonly referred to as the Sunflower family, plants in the Asteraceae are generally herbaceous and flowering. (Calflora)

Bidens cernua, Spanish Needles, NH, RTA
This small native herb has a sparse and vertical form and displays yellow, daisy-like flowers (USDA).

Bothriochloa barbinodis, Herter Cane Bluestem, **NH, RTA**
This native grass is a whispy bluish low-lying grass (USDA).

Bouteloua artistidoides, Needle Grama, **NH, RTA**
This native grass is very long and fine (USDA).

Brassica species (unidentifiable)
Plants in the genus *Brassica* are often utilized as a food and seasoning source and are commonly grown as mustard seed crop. They are thought to originate from Europe and Asia (Wink 2008). Some species are sometimes called "Black Mustards" and can be poisonous. These "black" species sequester dangerous amounts of nitrate and may produce goiter and anemia in those ingesting their seeds and roots which contain the highest doses of the toxin (Schmutz 1979).

Bromus catharticus, Rescue Grass, **EH, T-1909,** ***ARIZ 196700***
This grass which grows 2 to 3 feet high is sometimes grown for foraging and is a native of South America (Bailey 1949).

Calibrachoa parviflora, D'Arcy Seaside Petunia, **NH, T-1909, RTA**
This native herb produces thin, branching stems which grow along the ground rooting as they go. The vertical branches are leafy and their showy purple flowers are large and colorful giving the plant the appearance of an ornamental (USDA).

Chenopodium sp., Goosefoots, ***ARIZ 62604****
The big green leaves of some species of plants in the *Chenopodium* genus are often edible as leafy stock however other species in the genus can be poisonous (USDA).

Chenopodium murale, Nettle Leaf Goose Foot, **EH, :X:, T-1909**
This poisonous plant contains oxalic acid, oxalates, other organic acids and cytotoxins which are moderately to highly hazardous. Symptoms of ingestion include, necrosis, inflammation of the eyes, burning mouth and throat, gastrointestinal disorder, and spasms (Wink 2008).

Conium maculatum, Poison Hemlock, **EH, :X:, ARIZ** ***165857*, 62885****
This is perhaps the most poisonous and deadly plant in the area. Also called spotted hemlock, or poison parsley, *Conium maculatum* is a forb of the parsley or carrot family. The plant was introduced from Eurasia and is frequently found in meadows, along roads and in drainage-ways throughout the U.S. and southern Canada (Schmutz 1979). This plant, growing to 9 ft. tall, is one of the most poisonous plants of the world (Foxx 1985). All parts of the plant are poisonous. Like the mustard, it contains the highest levels of toxic and deadly compounds in its seeds and roots. Poison Hemlock was commonly used by Greeks and Romans in murders and suicides. It was used to execute Socrates in 399 BC for teaching of Greek gods in a blasphemous way (Wink 2008). Symptoms of *Conium maculatum* ingestion are burning of the mouth and mucus membranes, nervousness, trembling, loss of coordination, dilation of the pupils, general weakness, coldness, convulsions, coma, and death due to respiratory paralysis. As little as 2-4 kg of dried leaves can kill a grown cow if ingested (Schmutz 1979).

Conium maculatum

Conyza canadensis, Horseweed, **NH, T-1909, RTA**
Also known as Canadian horseweed, Canadian fleabane, coltstail, marestail, and butterweed, this plant is generally considered a weedy species. It is unique however in its extremely thin, vertical, and dense form (USDA).

Cryptantha angustifolia, Narrow Leafed Forget-Me-Not, **NH**
This fatter leafed *Cryptantha* has white flowers and like others of this genus, it is covered in stiff hairs which lay flat along its body. It is a good food source for harvester ants (Leake 1993).

Cynodon dactylon, Bermuda Grass, **EH, P, T-1909**
Bermuda grass is a predominant exotic grass species along the

Santa Cruz. It is perhaps one of the most predominant and problematic invasive exotic species in the Southwest next to buffelgass. It was introduced as a hardy grass in the early 1900's and has been problematic ever since, finding its way to most disturbed and urban areas. Once your yard is infested its absolute removal is next to impossible without the regular treatment of herbicides to the infected areas. It is also a cyanogenic glucoside producer and can cause gastrointestinal problems in forging livestock (Wink 2008).

Cyperus sp., **CLP, *ARIZ 63237 ****
The *Cyperus* genus is comprised of around 600 sedge plants, most of which are aquatic and exotic however some natives do exist. These plants have a unique form and can often be found as ornamentals in local aquatic gardens and ponds (USDA).

Dactyloctenium radulans, Buttongrass, **EH, *ARIZ 187719***
This is a native grass species (USDA).

Datura meteloides, Sacred Datura, **NH, :X:, T-1909, RTA, OIU**
Also called Indian-apple, Tolguaca, Jimson weed and moonflower, this plant is in the nightshade family and is easily identifiable by its round, golf ball sized, spiked, green seed pods and large tissue paper-like silky flowers. The plant has been used by native peoples for centuries in the prevention of miscarriages and as a link to the spirit world. The plant contains hallucinogenic toxins (Schmutz 1979). The Aztecs are one people which used the plant for this purpose as well as medicinally to treat multiple ailments (Wink 2008). Some native healers believe its leaves can be heated and placed on bruises, sprains, and broken bones in order to ease pain and aide in the healing process (Yetman 2009). Many people have unwittingly taken it upon themselves to experiment with this plants hallucinogenic properties and have temporarily lost their sanity, experiencing bouts of visual and auditory hallucinations for periods lasting 12 to 24 hours. Ingesting as little as half the contents of one seed pod can bring about these psychotic effects. Ingestion can also lead to death. Interestingly it derives one of its common names, Jimson weed, as a corruption of Jamestowne where in 1676 soldiers ate the plant and suffered terribly(Foxx 1985).

Descurainia pinnata subsp. ochroleuca, Detling Western Tansymustard, **NH, T-1909, *ARIZ 1938***
This small native herb has a vertical form terminating in a yellow cluster of flowers (USDA).

Echinochloa colonum, Jungle Rice, **EH, T-1909**
This exotic wild grass from Asia is often used as a famine food source. Its seeds are mashed and made into a flour for bread or porridge (USDA).

Eichhoria crassipes, Water Hyacinth, **EH, OT**
Commonly known as water hyacinth, this plant is a floating, aggressive, invading species which can quickly overcome a standing water source and choke out its oxygen dependent aquatic life by smothering the aquatic system. I came across it only once at one specific location a few years after completing my initial thesis work and was amazed by its sheer numbers. It had completely over-taken the surface of a large standing effluent pond just upstream of the Ina road outlet. The plant has been frequently used as a pond plant, however its use has been outlawed due to its voracious and dominating nature over riparian areas.

Eriochloa aristata, Bearded Cupgrass, **NH, T-1909, *ARIZ 165866***
This grassy plant is an annual to Arizona, California and northern Mexico, (Kearney 1951).

Gaura parviflora, Velvet Weed, **NH, RTA**
Also known as velvety guara, downy guara, and smallflower guara, this plant grows to 6 ft. with lance shaped leaves, pink flowers, rose colored stamens, and red anthers, (Foxx 1985).

Gnaphalium wrightii, Cud Weed, **NH, RTA**
Also known as everlasting, this is a weedy native plant. Based on its common name one might assume it plays a role in the feeding of livestock (USDA).

Hedypnois cretica, Creteweed, **EH, *ARIZ 30508***
Also known as Cretanweed, this plant is native to the Mediterranean basin and is a noxious weed in the Southwest (USDA).

Heterotheca subaxillaris, Camphor Weed, **NH, RTA**
Also known as telegraph plant and golden aster, this native herb has a delicate form with yellow daisy-like flowers. Leaves of the plant wreak of camphor and will leave a pungent oil on your hands or clothing (USDA).

Hydrocotyle ranunculoides, Water Pennywort, **NH, T-1909, RTA**
Known as floating pennywort, this aquatic is native to the Americas but an invasive exotic in the United Kingdom (USDA).

Lappula redowskii, Stickseed, **NH, RTA, *ARIZ, 300428, 193846***
This small herbaceous plant grows across Arizona from 1,000 to 8,500 feet in areas with ample sun and disturbed soils (Kearny 1951).

Lathryus oderatus, California Common Sweet Pea, **EH, *ARIZ 208816***
This herbaceous and showy flowering annual is a native to the Meditteranean (Munz 1974).

Lepidium oblongum, **EH, *ARIZ 193855***
This is a delicate and uniquely shaped low lying native (USDA).

Lepidium virginicum, Virginia Pepper Weed, **EH, *ARIZ 193856***
This herbaceous plant with clustering yellow flowers was listed by Munz as a US native but Arizonan exotic. It is commonly found in disturbed areas (Munz 1974).

Linaria canadenis, L. texana, Toad Flax **EH, *ARIZ 193848***
Also known as blue toad flax, this California native is often found on scorched landscapes (Munz 1974, Calflora).

Ludwigia palustris, Marsh Purslane, **NH, RTA**
This native aquatic plant can be found intermitantly along the effluent dominated stretch of the Santa Cruz. It is unique in its delicate form and ornamental flower structure. It represents one of a number of delicate and showy aquatic stream edge groundcovers which can be found in the area (USDA).

Ludwigia palustris

Malva neglecta, Mallow, **EH**
Also known as cheeseweed, *Malva neglecta* has white to blue flowers and grows low to bushy. This annual growing to 1 ft. tall has fruits which resemble a small round of cheese. These fruits are edible when young, (Foxx 1985).

Matthiola longipetala, Night-Scented Stock, **EH, *ARIZ 128339, 128340***
Also known as the evening stock, this plant, a native from Eurasia, is grown for its showy purple flower clusters whose fragrant scent permeates its surroundings during the evening hours (USDA).

Melilotus indicus, Sour Clover, **EH, :X:, T-1909, *ARIZ 66797****
This plant contains anticoagulating compounds which are sometimes used medicinally. They are also harmful if taken improperly and cause internal bleeding. The plant can cause sudden death in cattle (Wink 2008).

Melilotus species (unidentifiable) Sweet Clover, **EH, :X:**
Plants in the genus *Melilotus* are also called melilots. They are native to Europe and Asia, emit a pleasureable fragrance, and contain coumarin, a common perfume additive (USDA).

Mimulus floribundus, Manyflowered Monkeyflower, **NH, RTA, *ARIZ 42232***
This small native riparian herb is a low lying plant with alternating leaves and showy yellow flowers (USDA).

Mimulus guttatus, Monkey Flower, **NH, P, RTA, *SpecSig*, IFS**
The stems and leaves of this edible plant can be used as greens in salads (Leake 1993). This plant was found in just under 30% of transects. When it occurred it numbered from 20 – 30 individuals. This plant served as a common food plant of indigenous peoples (Foxx 1985).
Spec Sig: According to Phil Jenkins, Monkeyflower indicates water being present, even surface ephemeral water after rains.
Monolepis nuttalliana, **NH, T-1909, *ARIZ 19385***
This plant occurs frequently in southern Arizona at elevations of 3000 ft. and lower. Native peoples made pinole from its seeds and it has served as a fairly strong pasture food for cattle (Kearney 1951).

Muhlenbergia microsperma, Littleseed Muhly, **NH, *ARIZ 106414***
This native grass has a delicate clumping form (USDA).

Nama hispidum, Grey Bristly Nama, **NH, T-1909, RTA, *ARIZ 43359***
This low lying herbaceous forb has showy purple flowers and delicate green stems.

Nasturtium officinale, Water Cress, **EH, T-1909, *SpecSig, ARIZ 193847***
Formerly known as *Rorippa nasturtium-aquaticum,* this plant grows submersed and above calm waters with a dense and low-lying spread of green foliage and white flowers. Its terminal leaves are larger than its laterals and they have a mild pepper taste. They have been used around the world as greens and as a seasoning in soups. The plant is naturalized from Europe (Foxx 1985).
Spec Sig: According to Phil Jenkins, watercress is a plant that is dependant on permanent water, with at least some parts of the plants submerged.

Nasturtium officinale

Nicotiana trigonophylla or *N. obtusifolia*, Desert Tobacco, NH, :X:, T-1909, RTA, ARIZ 43739*
Also called coyote tobacco, this Sonoran Desert native riparian plant was used for smoking by the Yuma and Havasupai tribes.

Desert tobacco's scientific name was coined by a sixteenth-century French ambassador to Portugal, Jean Nicot, who introduced the plant in France (Leake 1993).

Panicum stramineum, **NH, T-1909, RTA, *ARIZ 16588***
This is a mid-sized native grass.

Parietaria hespera, Pelitory, **EH, *ARIZ 193845***
Also known as pellitory, Rillita pellitory, and western pellitory, this annual herb is a native of California (Calflora).

Petunia parviflora or *Calibrachoa parviflora,* Wild Petunia, **NH, RTA, *ARIZ 193858, 62081***
This California native annual herb can be found in sandy riparian habitat (Calflora).

Phalaris minor, Littleseed Canary Grass, **EH, :X:**
This is a medium sized grass with large clumping fruits (USDA). It is commonly observed in patches in the study area.

Polanisia doderandra, Clammy Weed, **NH, RTA**
Also known as redwhisker clammyweed, this plant is an annual native of much of the United States (USDA).

Polygonum argyrocoleon, **EH,** ***ARIZ 117341***
This herbaceous annual is a native of Asia (Munz 1974).

Polygonum aviculare L., **EH, T-1909,** ***ARIZ 193853***
This herbaceous plant is frequently dispersed throughout North America and is naturalized from Eurasia (Kearny 1951).

Polygonum lapathifolium, Curly Top Knotweed, **EH, P, T-1909, RTA,** ***ARIZ 165888, 68400*** This herbaceous plant is frequently dispersed throughout North America and is native to many parts of North American but not Arizona (Calflora, Munz 1974). It is commonly found in the study area occurring in large patches.

Polygonum lalpathifolium

Polygonum pensylvanicum, Lady's Thumb, **NH, RTA**
Also called knotweed and smartweed, these plants contain slightly hazardous anthraquinones and naphthodianthrones which are cell toxic and mutagenic, (Wink 2008).

Polygonum species (unidentifiable) Knotweed, **NH, RTA**
Also often called smartweed, knotgrass, bistort, tear-thumb, and mile-a-minute, plants of the polygonum are unique in that they often have reddish or reddish speckled stems and clustering flowers of pink, white, or green (USDA).

Ranunculus sceleratus var. *multifidus*, Cursed Buttercup, **NH, RTA,** ***ARIZ 193843***
This native herb is a very light green in color with big yellow flowers (USDA).

Rumex crispus or *R. hymenosepalus*, Curly-Leaf Dock., **NH, P, :X:, RTA**

Rumex crispus grows to 3 ft. tall with lanced to oblong leaves, large with many margins. It has yellow flowers and triangular shaped fruit (Foxx 1985). All parts of the *Rumex crispus* are poisonous containing tannins, physcion, aloe-emodin (anthroquinones), and high levels of oxalates. These secondary compounds can cause gastro-intestinal tract disorder, nausea, vomiting, and abdominal pain. Poisonings usually occur in animals (Wink 2008).

Rumex dentatus L., Toothed Dock, **EH**
This native of Eurasia and Africa can be found growing in disturbed moist areas. It is an allelopathic plant producing compounds which prohibit the growth of other plants in its vicinity (USDA).

Salsola kalivar, Russian Thistle, **EH**
Also known as white man's plant, the *Salsola kalivar* has branched, reddish stems growing to 6 ft. It is a Russian annual native whose seeds were brought to the U.S. in flax seed. It is a very prolific weed, (Foxx 1985).

Sinapsis arvensis or *Brassica arvensis*, Wild Mustard, **EH**
Also known as charlock, this European native has become a common exotic weed in much of North America. This plant is highly invasive and is poisonous to livestock (USDA).

Sisymbrium orientale, Indian Hedgemustard, **EH**
Also known as Oriental hedgemustard, this non-native plant has naturalized itself into many regions across the United States West and Southwest (USDA).

Sisymbrium irio, London Rocket, **EH**
This invasive species from Europe thrives in the desert wherever there is high amounts of water. The plant grows in winter and spring and dies back during hot months. The tips of this plant are topped with small yellow flowers, (Leake 1993).

Solanum nigrum or *S.americanum*, Nightshade, **NH, :X:, IFS, RTA,** ***ARIZ 80797****
Known as black nightshade, common nightshade, and poisonberry, its leaves and un-ripe berries contain high concentrations of the glycol-alkaloid, solanine which is extremely toxic. When ripe and boiled however, the berries may be used to make pies and jellies. Symptoms of solanine ingestion include headache, vomiting, diarrhea, dilated pupils, shock, and paralysis (Schmutz 1979).

Solanum rostratum, Buffalo Bur, **NH, RTA,** ***ARIZ 69834***
Also known as spiny nightshade and Texas thistle, this native weedy plant of the Nightshade family has a unique flower which exhibits the rare trait if heteranthery, meaning it has two distinct anthers of different size (USDA).

Sonchus oleraceus, Common Sow Thistle., **EH**
This exotic species also known as sow thistle, smooth sow this-

tle, annual sow thistle, hare's colwort, hare's thistle, milky tassel, and swinies, is a medicinal and food plant from Europe and Asia (USDA).

Sorghum halepense, Johnson Grass., **EH, T-1909**
This invasive mid-large sized grass can be found throughout much of the United States and parts of Canada (USDA).

Suaeda moquinnii, Seep Weed., **NH, T-1909**
This native to California is also known as the inkweed, Mojave seablite, bush seepweed, quelite, and salado. It favors salty areas along the coast of California (Calflora).

Teucrium cubense, Small Coastal Germander., **NH, T-1909, RTA**
This desert native is commonly found in wetland communities in the southern United States (USDA, Calflora).

Veronica anagallis-aquatica, Speedwell, **P, NH, RTA, *SpecSig*, :X:, *ARIZ 73825****
This is a predominant low lying stream edge plant which has ornamental purple flowers (USDA). It can be found along most of the study area.
Spec Sig: According to Phil Jenkins, like watercress, this plant is partly submerged, and is therfore an indicator of permanent water. It frequents slow flowing streams.

Veronica anagallis-aquatica

Veronica perigrina L. *xalapensis*, Neckweed, **EH, *ARIZ 193860***
This simple annual is often found in areas which have suffered fire damage and is commonly found below 9000 feet in Arizona (Munz 1974, Kearny 1951).

Veronica species (unidentifiable)
The genus *Veronica* contains over 500 flowering species and are often food sources to various butterfly species (USDA).

Xanthium strumarium, Cocklebur., **NH, :X:, P, T-1909 , RTA**
Known as cocklebur, it is a native plant which is naturalized all over the world (Wink 2008). It is commonly found along most of the study area. The plant is deadly poisonous and can be a cause of sudden death in livestock and other grazing animals. Animals die 10 to 15 minutes after ingestion of this plant and others like it in the cyanogenic plants category. In comparison, *Conium maculatum* or poison hemlock, can take up to one hour to cause death after ingestion (Burrows 1989). Cyanogenic plants are those containing cyanogenic glucosides. These glucosides are present in more than 2500 plant species comprising the cyanogenic plant group. These secondary compounds are an evolutionary defense mechanism by which these plants protect themselves from herbivory. Upon plant tissue damage, hydrogen cyanide is released killing or deterring the herbivores. Three people died in China after they mis-identified the buds from this plant as food (Wink 2008).

Xanthium strumarium

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References

Allen, A. W. 1983. Habitat suitability index Mildl. Serv. FWS/OBS-W10.30 Revised. 20 pp. models: Beaver. U.S. Fish

Bailey, L.H. 1949. Assorted Staff of the Bailey Hortorium at Cornell University, The Manual of Cultivated Plants. MacMillan Company, New York.

Bowers, Janice Emily & Brian Wignall. 1993. Shrubs and Trees of the Southwest Desert. Southwest Parks and Monuments Association. Tucson, AZ

Burrows, George E. & Ronald J. Tyrl. 1989. Plants Causing Sudden Death in Livestock. Clinical Toxicology, Vol. 5, No. 2, July 1989.

Calflora, http://www.calflora.org

Dodge, Natt N. 1985. Flowers of the Southwest Deserts. Southwest Parks and Monuments Association. Tucson, AZ.

Duffield, Mary Rose, & Warren Jones. 1981. Plants for Dry Climates. H.P. Books Publishing, Tucson, AZ.

Gormally, Josh Fiora. 2002. Changes in Riparian Vegetation Following Release of Reclaimed Effluent Water Into the Santa Cruz River: As a Corollary, the Effects of Channelization on Vegetation in the Santa Cruz River. M.S. Thesis. University of Arizona, Tucson, AZ.

Fabre, Julia & Claire Cayla. 2009. Riparian Restoration Efforts in the Santa Cruz River Basin. Water Resources Research Center, University of Arizona, Tucson, Arizona, March 2009.

Foxx, Teralene S. & Dorothy Hoard. 1985. Flowers of the Southwestern Forests and Woodlands. Los Alamos Historical Society, Los Alamos, NM.

Glinski, Richard. 2002. Life of the Santa Cruz River Exhibit. Old Tucson, Tucson, AZ.

Jones, Warren. & Charles Sacamano. 2000. Landscape Plants for Dry Regions. Fisher Books.

Kearny, Thomas H., & Robert Peebles. 1951. Arizona Flora. University of California Press, Berkeley & Los Angeles, CA.

Lamb, Samuel H. 1975. Woody Plants of the Southwest. The Sunstone Press, Santa Fe, NM.

Leake, Dorothy Van Dyke, John Benjamin Leake & Marcellotte Leake Roeder. 1993. Desert and Mountain Plants of the Southwest. University of Oklahoma Press, Norman and London.

Logan, Michael F. 2002. The Lessening Stream: An Environmental History of the Santa Cruz River. University of Arizona Press, Tucson, AZ.

Lynn F. James, Dale R. Gardner, Stephen T. Lee, Kip E. Panter, James A. Pfister, Michael H. Ralphs & Brian L. Stegelmeier. 2005. Important Poisonous Plants on Rangelands, Management strategies based on toxin level in the plant, animal susceptibility, and grazing behavior can reduce the risk of poisoning.

Mauz, Kathryn. 2002. Plants of the Santa Cruz Valley at Tucson, Desert Plants. Volume 18, Number 1. University of Arizona. Tucson, AZ.

Mika Zagrobelnya, Søren Baka, Anne Vinther Rasmussena, Bodil Jørgensen, Clas M. Naumann & Birger Lindberg Møllera. 2004. Cyanogenic glucosides and plant–insect interactions, Phytochemistry 65: 293–306.

Munz, Phillip A. 1974. California Flora. UC Berkeley Press, Berkeley, CA.

Nahban, Gary Paul. & Andrew R. Holdsworth. 1999.State of the Desert Biome: Uniqueness, Biodiversity, Threats and the Adequacy of Protection in the Sonoran Bioregion. Wildlands Project, 2nd edition, Arizona-Sonora Desert Museum, Tucson, AZ.

Petrides, George A. 2005. Trees of the American Southwest. Stackpole Books, PA, www.stackpolebooks.com.

Raven, Peter H., Ray F. Everet, & Susan E. Eichhorn. 1992. Biology of Plants, Fifth Edition, Worth Publishers.

Schmutz, Ervin M. & Lucretia Breazeale Hamilton. 1979. Plants That Poison: An Illustrated Guide for the American Southwest.Northland Press, Flagstaff, AZ.

USDA, NRCS. 2011. The PLANTS Database (http://plants.usda.gov, 28 February 2011). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Vines, Robert A. 1960. Trees, Shrubs, and Woody Vines of the Southwest. University of Texas Press, Austin and London.

Wink, Michael. & Ben-Erik Van Wyk. 2008. Mind Altering and Poisonous Plants of the World.Timber Press, London.

Yetman, David. 2009. 50 Common Edible and Useful Plants of the Southwest. Western National Parks Association. Tucson, AZ.

Great blue heron and other water fowl

Svalbard morning (M. Norem)