U.S. Fish & Wildlife Service

Recovery Plan for Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*)

Pima pineapple cactus (*Coryphantha scheeri* var. r*obustispina*).
Photograph by the U.S. Fish and Wildlife Service

August 2018
Southwest Region
United States Fish and Wildlife Service
Arizona Ecological Services Field Office
Tucson, Arizona

This document was prepared by Julie Crawford, Plant Ecologist, USFWS Arizona Ecological Services Field Office, with review by Scott Richardson, USFWS Arizona Ecological Services Field Office and Sarah Rinkevich, Stacey Stanford, and Julie McIntyre, USFWS Regional Office. Valuable input was provided through public comment.

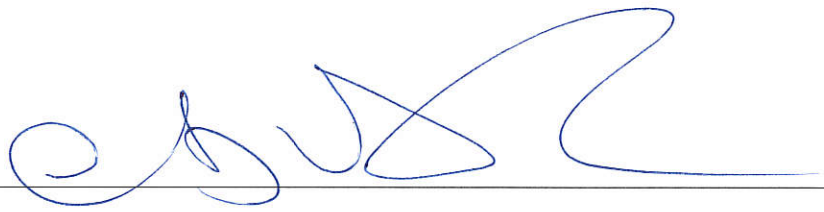
Suggested reference:

U.S. Fish and Wildlife Service. 2018. Recovery plan for Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*). U.S. Fish and Wildlife Service, Southwest Region, Tucson, Arizona. 76 pp + 2 Appendices.

Recovery Plan for Pima pineapple cactus
(*Coryphantha scheeri* var. *robustispina*)

2018

Region 2
U.S. Fish and Wildlife Service
Arizona Ecological Services Field Office
Tucson, Arizona

Approved: 

Regional Director, Southwest Region, Region 2, U.S. Fish and Wildlife Service

Date: August 27, 2018

Disclaimer

Recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. Plans are published by the U.S. Fish and Wildlife Service (Service), sometimes prepared with the assistance of recovery teams, contractors, State agencies and others. Recovery plans do not necessarily represent the views, official positions or approval of any individuals or agencies involved in the plan formulation, other than Service. They represent the official position of Service only after they have been signed by the Regional Director. Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

An electronic copy of this final recovery plan will be made available at: *http://www.fws.gov/endangered/species/recovery-plans.html* and at *http://www.fws.gov/southwest/es/arizona/pima.htm*.

Executive Summary

Current Species Status

Coryphantha scheeri var. *robustispina* (=*Coryphantha robustispina* (Schott ex Engelm.) Britton and Rose ssp. *robustispina*, Pima pineapple cactus) was listed as endangered under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.) on September 23, 1993 (58 FR 49875); critical habitat was not designated. The taxon inhabits Lower Sonoran desert-scrubland, desert-grassland, and the ecotone (transition area) between desert-scrubland and desert-grassland, and has been documented between 728 and 1,280 meters (m) (2,388 and 4,200 feet [ft]) elevation in southeastern Arizona and northern Sonora, Mexico. We consider all *C. scheeri* var. *robustispina* individuals as components of a single population and we are currently aware of fewer than 8,000 extant *C. scheeri* var. *robustispina* individuals across the range of the taxon. In addition, 1,837 are known to no longer exist, primarily due to development and mining.

Habitat Requirements and Limiting Factors

Coryphantha scheeri var. *robustispina* are sparsely distributed on the landscape. In compiling data from 72 separate surveys of over 40,500 ha (100,000 ac) of habitat, 71 percent contained fewer than 1 cactus per ha (85 percent contained fewer than 1 cactus per ac; see Appendix 1). The taxon is long-lived (can reach over 30 years in age) and self-incompatible (incapable of self-fertilization and thus requiring outcrossing). Research indicates areas with higher density of *C. scheeri* var. *robustispina* plants have greater pollination and thus more fruit production than areas where plants are more widely dispersed.

Typical *C. scheeri* var. *robustispina* associates include an assortment of other cactus species such as *Opuntia engelmannii* (Engelmann prickly pear), *O. fulgida* (jumping cholla), and *Ferocactus wislizeni* (Arizona barrel cactus), and native bunch grasses. Collectively, cacti within the habitat provide enough pollen to provision the nests and support survivorship of their shared pollinator, *Diadasia rinconis* (no common name), which is a cactus specialist bee. Preservation of *C. scheeri* var. *robustispina* necessarily also requires preservation of pollinator habitat and pollination corridors. Research also indicates that given the loss of individual *C. scheeri* var. *robustispina* to drought in recent years, topographic diversity among preserved habitats may provide microclimate differences important for long-term *C. scheeri* var. *robustispina* survival.

There has been success in germinating seedling *C. scheeri* var. *robustispina* in captivity, as well as *in situ* in cages in the field. Several botanical gardens maintain seedlings, as well as larger plants. We are unaware if any germinated seedlings have been cultivated in captivity to an adult life stage. There has been mixed success in transplanting this species into natural habitat.

Recovery Priority

The recovery priority number for *C. scheeri* var. *robustispina* is 3C, meaning that the listed entity is a subspecies (or in this case, a plant variety), the level of threat is high, there is a conflict with some form of economic activity (urbanization), and recovery potential is high.

Recovery Strategy

The principal recovery strategy is to preserve and restore quality *C. scheeri* var. *robustispina* habitat to protect individuals and their seedbanks within two recovery units representing the entire population and range of the taxon. The two recovery units center on the Altar and Santa Cruz valleys of southeastern Arizona. The major threats within the Altar Valley Recovery Unit, which is managed primarily for livestock grazing, include the spread of invasive, nonnative grasses and the resultant altered fire regimes and increased competition. Urbanization is the major threat within the Santa Cruz Valley Recovery Unit, which includes Tucson, Nogales, and the urban areas between. Throughout the entire range, *C. scheeri* var. *robustispina* is stressed by drought conditions, as well as predation by mammals and insects. The conservation and restoration of habitat within these two recovery units will allow a stable, self-sustaining population to persist with some level of connectivity between individuals throughout the range, and provide opportunities for population expansion.

We define a self-sustaining population as one that is stable or shows positive population growth for 10 years over a 15-year period, with evidence of natural reproduction and establishment. The recovery strategy entails minimizing or ameliorating the most significant long-term threats to the continued existence of the species, which are: 1) habitat loss due to commercial and residential development and 2) competition with nonnative plants, such as *Cenchrus ciliaris* (=*Pennisetum ciliare*, buffelgrass), *Eragrostis lehmanniana* (Lehmann's lovegrass), and other *Eragrostis* species, and alteration of fire regimes. Additional efforts will focus on improving our understanding of *C. scheeri* var. *robustispina* ecology, distribution, and threats, as well as, reducing the impacts of stressors such as recreation and border activity, and potentially, the presence of livestock.

Recovery Goal

The ultimate goal of this recovery plan is to outline specific actions that, when implemented, will sufficiently reduce the threats and stressors to *C. scheeri* var. *robustispina*, ensure its long-term viability in the wild, and allow for its removal from the list of threatened and endangered species.

Recovery Objectives

1) Threat and Habitat-based objective: Conserve, restore, and properly manage the quantity and quality of habitat needed for the continued survival of *C. scheeri* var. *robustispina* and its pollinators. This includes the reduction or mitigation of habitat loss and degradation; spread of invasive, nonnative plant species and the resultant altered fire regimes and increased competition; and other stressors.

2) Population-based objective: Conserve, protect, and restore existing and newly discovered *C. scheeri* var. *robustispina* individuals their seedbanks (approximately 10 meters radius from plants), and habitat for pollinators (approximately 900 meter radius from plants) in each recovery unit to ensure survival of the taxon. Maintaining and increasing successful seed set into the seedbank is important because seed availability must coincide with wet years for germination and initial seedling survival. The population must be self-sustaining, of

sufficient number to endure climatic variation, stochastic events, and catastrophic losses, and must represent the full range of the species' geographic and genetic variability.

Recovery Criteria

Downlisting of *Coryphantha scheeri* var. *robustispina* to threatened status may be considered when all of the following conditions have been met to address the threats and stressors to the species:

1) Threats and Habitat Criterion: At least 8,094 hectares (ha) (20,000 acres [ac]) of *C. scheeri* var. *robustispina* habitat per recovery unit are documented to be of optimal quality and remain that way through successful habitat conservation and land management planning. At least 24,281 ha (60,000 ac) of *C. scheeri* var. *robustispina* habitat per recovery unit are documented to be of good quality and remain that way in perpetuity. Habitat is considered optimal quality when it: is protected for conservation purposes; is managed in a manner that promotes the long-term survival of *C. scheeri* var. *robustispina*; has less than 20 percent cover of *C. ciliaris*, *E. lehmanniana*, or other invasive nonnative plant species that alter ecosystem function; contains contiguous habitat and corridors for pollinators; and the *C. scheeri* var. *robustispina* population is observed to be stable or increasing. Habitat is considered good quality when the cover of *C. ciliaris*, *E. lehmanniana*, or other nonnative plants that alter ecosystem function remains between 20 and 35 percent; the land is managed in such a way that promotes the continued existence or expansion of long-term survival of *C. scheeri* var. *robustispina*.

2) Population-based Criterion: Conserve, protect, and restore mature *C. scheeri* var. *robustispina* individuals, their seedbanks (approximately 10 meters radius from plants), and habitat for pollinators (approximately 900 meter radius from plants) in each recovery unit through resource management, land conservation, and restoration techniques such as *in situ* germination. Quantitative monitoring, using a standardized monitoring protocol, of established plots across a variety of land ownerships and land management scenarios, with landowner support, is conducted within each of the two recovery units every 3 to 5 years. Plots demonstrate that the population is stable or increasing a minimum of 10 years over a 15-year period.

To delist *C. scheeri* var. *robustispina*, the first two criteria for downlisting must be met or surpassed, and monitoring must demonstrate that the population is increasing for a minimum of 20 years over a 30-year period. The additional time necessary to achieve delisting ensures continued population viability. Additionally, it will allow land managers to continue to reduce threats to *C. scheeri* var. *robustispina* from nonnative species invasion achieved during downlisting and track the long-term effectiveness of management. The additional time will also allow land managers to develop methods to reduce anticipated cost and effort needed to maintain habitat and population viability absent the protections of the Act.

Actions Needed

1) Conserve existing and newly discovered *C. scheeri* var. *robustispina* and associated habitat, including unoccupied areas that provide habitat and connectivity for pollinators.

2) Restore quality *C. scheeri* var. *robustispina* habitat in the U.S. and Mexico.

3) Develop range-wide standardized long-term monitoring of individuals in established plots, as well as their habitats, threats, and stressors.

4) Encourage scientific study to improve our understanding of *C. scheeri* var. *robustispina* biology, ecology, abundance, status, threats, stressors, viability, propagation, restoration of individuals and of habitats, distribution, and genetics in the United States and Mexico.

5) Maintain plants in captivity at botanic gardens and seeds at seed storage facilities; encourage research into propagation, *in situ* seed planting, and transplanting methods.

6) Develop public outreach, collaborative partnerships, and agreements with private landowners in the United States and Mexico that encourage *C. scheeri var. robustispina* conservation.

Estimated Time and Cost of Recovery

The estimated cost to implement this plan for the first 20 years, the minimum time anticipated to recover the species, is $62,925,460. If recovery is not achieved within the first 20 years, we assume an additional cost of $1,173,230 over the subsequent 10 years to recovery (from 2038 to 2048) for a total cost to recovery of $64,098,690.

Resumen Ejecutivo

Estado Actual de la Especie

Coryphantha scheeri var. *robustispina* (Biznaga-partida de Espinas Gruesas) fue listada como en peligro de extinción bajo el Acta de Especies en Peligro de Extinción (Acta) el 23 de septiembre de 1993 (58 FR 49875); no se designó hábitat crítico. El taxón habita matorral desértico de Sonora bajo, la pradera desértica, o el ecotono entre matorral desértico y pradera desértica, y se ha documentado entre 728 y 1,280 metros (m) (2,388 y 4,200 pies) elevación en el sureste de Arizona y el norte de Sonora, Mexico. Consideramos todos los individuos de *C. scheeri* var. *robustispina* como componentes de una población única y actualmente conocemos menos de 8,000 individuos existentes por el rango de distribución del taxón. Además, sabemos que 1,837 individuos ya no existen, principalmente debido a proyectos de desarrollo y minería.

Requisitos de Hábitat y Factores Limitantes

Coryphantha scheeri var. *robustispina* (=*C. robustispina* subsp. *scheeri* (Lemaire) N. P. Taylor, cactus de piña Pima) se considera escasamente distribuido en el paisaje. En la recopilación de datos de 72 muestreos distintos de más de 40,500 ha (100,000 ac), 71 porciento contenía menos de 1 cactus por ha (85 porciento contenía menos de 1 cactus por acre; ver apéndice 1). El taxón es longevo (puede alcanzar una edad mayor de 30 años) y es auto incompatible (no es capaz de auto fertilización y así requiere cruzas externas). Las investigaciónes indica áreas con más alta densidad de plantas de *C. scheeri* var. *robustispina* tienen más polinización y así más producción de fruta que áreas donde las plantas están más dispersas.

Los asociados típicos de *C. scheeri* var. *robustispina* incluye una variedad de otras especies de cactus como *Opuntia engelmannii, O. fulgida,* y *Ferocactus wislizeni*, tal como gramas nativas. Colectivamente, los cactus dentro del hábitat proveen suficiente polen para proporcionar los nidos y apoyar sobrevivencia del polinizador compartida, *Diadasia rinconis*, la abeja especialista de cactus. La preservación de *C. scheeri* var. *robustispina* también requiere de una protección del hábitat y corredores de los polinizadores. Las investigaciones también indica que dado la perdida de individuos de *C. scheeri* var. *robustispina* a sequía en años recientes, la diversidad topográfica entre los hábitats preservadas puede proveer diferencias micro climáticas importantes para la sobrevivencia de *C. scheeri* var. *robustispina* a largo plazo.

Han tenido éxito en germinar plantones de *C. scheeri* var. *robustispina* en cautiverio, tal como in situ en jaulas en el campo. Varios jardines botánicos mantienen plantones, tal como plantas más grandes. No sabemos si plantones germinados han sido cultivados en cautiverio hasta una etapa de vida de adulto. Han tenido éxito variable con trasplantar esta especie en su hábitat natural.

Prioridad para la Recuperación

El número de prioridad para la recuperación de *C. scheeri* var. *robustispina* es 3C, el cual significa que la entidad listada es un subespecie (o en este caso, una variedad de planta), el nivel de amenaza es alta, hay conflicto con algún forma de actividad económica (desarrollo), y la potencial para recuperación es alta.

Estrategia para la Recuperación

La estrategia principal para la recuperación del *C. scheeri* var. *robustispina* es proteger individuos y sus bancos de semillas dentro de dos unidades de recuperación las cuales representan toda la población y el rango de distribución del taxón. Las dos unidades de recuperación se centran en las valles Altar y Santa Cruz en el sureste de Arizona. Las amenazas mayores dentro de la Unidad de Recuperación de Valle Altar, la cual se maneja principalmente para ganadería, incluye la propagación de gramas invasores, no-nativas, y el resultante alteración del régimen de incendios y aumento de competencia. Urbanización es la amenaza mayor dentro de la Unidad de Recuperación de Santa Cruz, la cual incluye Tucson, Nogales, y las áreas urbanas entre ellos. Por todo el rango de distribución, *C. scheeri* var. *robustispina* está estresada por sequía tal como depredación por mamíferos e insectos. La conservación y restauración de hábitat dentro de estas dos unidades de recuperación dejará que una población estable y auto sostenible persiste con algún nivel de conectividad entre individuos por todo el rango de distribución y proveerá oportunidades para expansión de la población.

Definimos una población estable y auto sostenible como uno que muestra crecimiento positivo de población durante un periodo de 15 años, con evidencia de reproducción y establecimiento natural. La estrategia de recuperación involucra minimizar y reducir las amenazas más importantes a largo plazo a la existencia seguida de la especie, las cuales son: 1) perdida de hábitat debido al desarrollo comercial y residencial, y 2) competencia con plantas no-nativas, tales como *Cenchrus ciliaris* (=*Pennisetum ciliare*), *Eragrostis lehmanniana*, y otras especies de *Eragrostis*, y alteración de regímenes de incendios. Esfuerzos adicionales enfocará en mejorar nuestro entendimiento de la ecología, distribución, y amenazas de *C. scheeri* var. *robustispina*, tal como reducción de los impactos de estresores como recreación y actividades fronterizas, y potencialmente la presencia de la ganadería.

Meta de Recuperación

La meta esencial de este plan de recuperación es perfilar acciones específicas que, cuando implementadas, reducirán las amenazas y estresores de *C. scheeri* var. *robustispina* suficientemente así que asegurará su viabilidad a largo plazo en el silvestre y deja que se remueve de la lista de especies amenazadas y en peligro de extinción.

Objetivos de Recuperación

1) Objetivo basado en amenazas y hábitat: Conservar, restaurar, y maneja apropiadamente la cantidad y calidad de hábitat necesaria para la seguida sobrevivencia de *C. scheeri* var. *robustispina* y sus polinizadores. Esto incluye la reducción o mitigación de la perdida y degradación de hábitat, la dispersión de especies no-nativas, y la alteración del régimen de incendios y el aumento de competencia resultantes y otros estresores.
2) Objetivo basado en población: Conservar, proteger, y restaurar existentes y recién descubiertos individuos de *C. scheeri* var. *robustispina* y sus bancos de semillas (un radio de aproximadamente 10 metros de las plantas) y hábitat para polinizadores (un radio de aproximadamente 900 metros de plantas) en cada unidad de recuperación para asegurar la

sobrevivencia del taxón. Mantener y aumentar la exitosa formación de semillas en el banco de semillas es importante porque la disponibilidad de semillas debe coincidir con años lluviosas para germinación y sobrevivencia de los plantones. La población debe estar auto sostenible, de suficiente números para aguantar variación climática, eventos estocásticos, y pérdidas catastróficas, y debe representar el rango completo de la variabilidad geográfica y genética de la especie.

Criterios de Recuperación

Cambiar el estatus de *Coryphantha scheeri* var. *robustispina* a amenazada puede considerarse cuando cumplen todas las siguientes condiciones dirigidas a las amenazas y estresores a la especie:

1) Criterio de amenaza y habitat: Por lo menos 8,094 hectáreas (20,000 acres) de hábitat de *C. scheeri* var. *robustispina* por unidad de recuperación están documentadas en condición optima y quedan así. Por lo menos 24,281 hectáreas (60,000 acres) de hábitat de *C. scheeri* var. *robustispina* por unidad de recuperación están documentadas en condiciona buena y quedan así por medio de exitosa conservación y planificación de manejo de tierras. Hábitat se considera de calidad óptima cuando: está protegida para propósitos de conservación; se maneja de manera que promueva la sobrevivencia de *C. scheeri* var. *robustispina* a largo plazo; tiene menos de 20 por ciento de cobertura de *C. ciliaris, E. lehmanniana*, u otras especies de plantas no-nativas que alteran las funciones de la ecosistema; contiene hábitat contiguo y corredores para polinizadores; y donde se observa números estables o creciendo de *C. scheeri* var. *robustispina*. Hábitat se considera de calidad buena cuando la cobertura de *C. ciliaris, E. lehmanniana*, u otras plantas no-nativas que altera las funciones de la ecosistema queda entre 20 y 35 por ciento; y el terreno se maneja de tal manera que promueve la existencia continua o expansión de la sobrevivencia a largo plazo de *C. scheeri* var. *robustispina*.

2) Objetivo basado en población: Conservar, proteger, y restaurar individuos maduros de *C. scheeri* var. *robustispina* y sus bancos de semillas (un radio de aproximadamente 10 metros de las plantas) y hábitat para polinizadores (un radio de aproximadamente 900 metros de plantas) en cada unidad de recuperación por medio de manejo de recursos, conservación de tierras, y técnicas de restauración como germinación in situ. Monitoreo cuantitativo, usando un protocolo de monitoreo estandarizado, de parcelas establecidas en una variedad de tipos de tenencia de tierra y escenarios de manejo, con el apoyo de los propietarios, se lleva a cabo dentro de cada una de las dos unidades de recuperación cada 3 a 5 años. Las parcelas demuestran que la población está estable o creciendo por un mínimo de 10 años durante un periodo de 15 años.

Para remover *C. scheeri* var. *robustispina* de la lista, los primeros dos criterios para cambiar el estatus a amenazada deben cumplirse o superarse, y el monitoreo debe demostrar que la población está creciendo por un mínimo de 20 años durante un periodo de 30 años. El tiempo adicional necesario para remover la especie de la lista asegura la continuidad de la viabilidad de la población. Además, permitirá a los administradores continuar reduciendo las amenazas a *C. scheeri* var. *robustispina* de la invasión de especies no nativas lograda durante la reclasificación a amenezada y monitorear la efectividad a largo plazo de la gestión. El tiempo adicional también permitirá a los administradores desarrollar métodos para reducir los costos y esfuerzos anticipados para mantener el hábitat y la viabilidad de la población en ausencia de las protecciones del Acta.

Acciones Necesarias

1) Conservar existentes y recién descubiertos individuos de *C. scheeri* var. *robustispina* y su hábitat asociado, incluyendo áreas desocupados que proveen hábitat y conectividad para sus polinizadores.

2) Restaurar la calidad de hábitat de *C. scheeri* var. *robustispina* en los Estados Unidos y México.

3) Desarrollar monitoreo estandarizado de individuos a largo plazo por todo el rango de distribución en parcelas establecidas, tal como sus hábitats, amenazas, y estresores.
4) Fomentar investigación científico para mejorar nuestro conocimiento dela biología, ecología, abundancia, estado actual, amenazas, viabilidad, propogacion, restauración de individuos, y genetice de *C. scheeri* var. *robustispina* en los Estados Unidos y México.

5) Mantener las plantas en cautiverio en jardines botánicos y semillas en las instalaciones para almacenar semillas; fomentar investigaciones de métodos propagación, siembra in situ, y trasplantación.

6) Desarrollar materiales para divulgación al público, asociaciones colaborativas, y acuerdos con los propietarios de terrenos en los Estados Unidos y Mexico que fomentan conservación de *C. scheeri* var. *robustispina*.

Fecha Estimada y Costo de Recuperación

El costo estimado para implementar este plan por los primeros 20 años, el tiempo mínimo anticipado para recuperar la especie, es de $62,925,460. Si no se logra la recuperación dentro de los primeros 20 años, presumimos un costo adicional de $1,173,230 en los siguientes 10 años hasta la recuperación (del 2038 al 2048) por un costo total de la recuperación de $64,098,690.

Table of Contents

Acknowledgements
The recovery planning process has benefitted from the advice and assistance of many individuals, agencies, and organizations. We thank the following individuals for providing information and insight; we apologize to anyone whose name was omitted inadvertently from this list:

Marc Baker, Southwestern Botanical Research
Ann Chenevert-Steffler, Buenos Aires National Wildlife Refuge
Katie Cline, formerly of Natural Resources Conservation Service
Dan Cohan, formerly of Buenos Aires National Wildlife Refuge
Pat King, Altar Valley Conservation Alliance and King Anvil Ranch
John Kraft, Coronado National Forest
Christopher Jarchaw, United States Geological Survey
Brian Powell, Pima County Office of Sustainability and Conservation
Iris Rodden, Pima County Natural Resources, Parks and Recreation
Sue Schuetze, Arizona Game and Fish Department
Kathryn Thomas, United States Geological Survey
Sabra Tonn, Arizona Game and Fish Department

The primary author of this recovery plan is Julie Crawford, Plant Ecologist, Arizona Ecological Services Field Office, Flagstaff, Arizona. Some information and photographs used in this document are from an earlier draft recovery plan written by contractor Marc Baker in 2012. Jennifer Smith-Castro translated the Executive Summary into Spanish. Additional thanks go to the following for their technical assistance and review and editing of this document: Julie McIntyre, Sarah Rinkevich, Scott Richardson, and Stacey Stanford, all of the U.S. Fish and Wildlife Service.

Part I. Background

1. Overview

On July 1, 1975 (40 FR 27824), *Coryphantha scheeri* var. *robustispina* (Pima pineapple cactus) was included among 3,000 plant species under status review by the Service. The review, based on a report provided by the Smithsonian Institution, considered *C. scheeri* var. *robustispina* a threatened candidate species. On December 15, 1980 (45 FR 82480, p. 82499), *C. scheeri* var. *robustispina* was identified under the Endangered Species Act (Act) as a category 1 candidate species. Candidate species are those fish, wildlife, and plants for which we have on file sufficient information on biological vulnerability and threats to support preparation of a listing proposal, but for which development of a listing regulation is precluded by other higher priority listing activities. The taxon remained a category 1 until it was proposed for listing on April 20 1992 (57 FR 14374). *Coryphantha scheeri* var. *robustispina* was listed as endangered under the Endangered Species Act of 1973 (Act), as amended (16 U.S.C. 1531 et seq.) on September 23, 1993. Threats identified in the 1993 *C. scheeri* var. *robustispina* listing document include: illegal collection; habitat degradation and destruction resulting from recreation, historical and present overuse of the habitat by livestock, mining, agriculture, road construction, and urbanization; and range management practices to increase livestock forage (58 FR 49875). Critical habitat for the taxon was not designated at the time of listing because publication of critical habitat maps could make the taxon more vulnerable to collection.

The first 5-year status review (5-Year Review) for *C. scheeri* var. *robustispina* was completed by the Service and signed on February 8, 2007 (Service 2007a, entire). Based on the static or declining status of the species across its range and continued threats and stressors, it was recommended in the 5-Year Review that the taxon remain listed as endangered. A second 5-Year Review was initiated on April 15, 2015 (80 FR 20241). The recovery priority number for *C. scheeri* var. *robustispina* is 3C, meaning that the listed entity is a subspecies, the level of threat is high, there is a conflict with some form of economic activity (urbanization), and the potential for recovery is high. A draft recovery plan, written by a contractor, was sent for review to the Service on March 28, 2012. Due to other higher priorities, it was not finalized at that time. We have utilized some information and photographs from that document. On June 26, 2016, a Notice of Availability for the Draft Recovery Plan for *Coryphantha scheeri* var. *robustispina* (Recovery Plan) was published in the Federal Register, with request for public comment (82 FR 28875). This document finalizes the Recovery Plan and addresses threats to the species identified at the time of listing and other threats and stressors such as predation and drought exacerbated by climate change.

2. Description

Individuals of *C. scheeri* var. *robustispina* are small, hemispheric to cylindrical, stem succulent perennials of the Cactaceae (cactus family) (Figure 1). Individual stems reach 5 to 46 centimeters (cm) (1.9 to 18.1 inches (in)) in height and 5 to 21 cm (1.9 to 8.3 in) in diameter, are comprised primarily of tough, fleshy pulp, and are protected by a leathery outer skin (Arizona Rare Plant Guide Committee 2001, unpaginated). Stems may be singular or form clumps. The surface of the stems is covered in 2 to 3 cm (0.8 to 1.2 in) long rounded projections called tubercles, each of which is grooved along the upper surface and contains one to several extra-floral nectaries (place that secretes nectar to attract pollinators) along the groove (Figure 2)

(Roller 1996a, p. 9; Baker 2011, p. 17). At the tip of each tubercle, arising from small bumps called areoles, are groupings of 7 to 20 straw-colored spines that darken with age (Roller 1996a, p. 9; Parfitt and Gibson 2004, p. 226). There is an average of two thick central spines, one of which is generally hooked and averages 1.7 millimeters (mm) (0.07 in) thick and 3 cm (1.2 in) long (Baker and Butterworth 2013, p. 996). There are 6 to 16 thinner radial spines about 1.1 to 3.5 cm (1.43 to 1.38 in) long (Parfitt and Gibson 2004, p. 226). The young areoles are densely covered with deciduous wool (Benson 1969, p. 195; Benson 1982, p. 818).

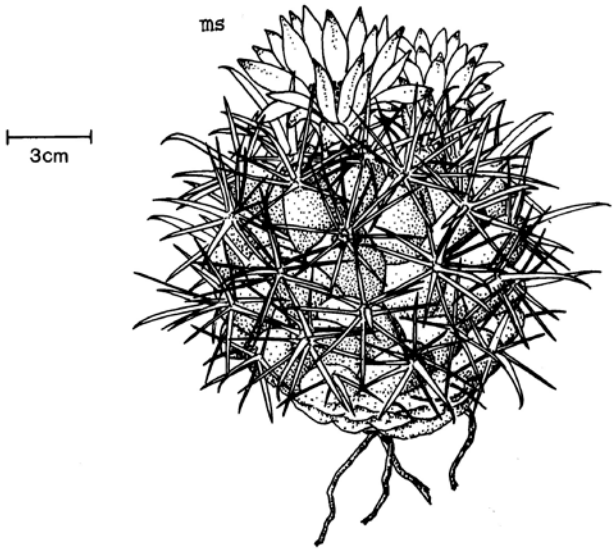


Figure 1. Illustration of *Coryphantha scheeri* var. *robustispina* (Arizona Rare Plant Guide Committee 2001).

Figure 2. *Coryphantha scheeri* var. *robustispina* extra-floral nectaries with visiting ants. Photo by Marc Baker.

The stems of *C. scheeri* ssp. *robustispina* arise from taproots that are deeper than most Sonoran Desert cacti (Roller 1996b p. 1) at about 15 cm deep (Schmalzel 2000a, p. 2). Lateral roots are found between 2 and 5 cm below the soil surface and extend approximately 1 m (3.28 ft) in

length (Schmalzel 2000a, p. 2; Schmalzel 2000b, p. 8). SWCA Environmental Consultants (SWCA) (1999, p. 16) reported observing a lateral root extending 3 to 4 m (9.8 – 13.1 ft) in the direction of coppice mounds (piles of fine surface materials). Schmalzel (2000a, pp. 16-17) observed that 9 of 37 individual *C. scheeri* ssp. *robustispina* plants in the Altar Valley had roots that appeared to grow, along gradients of moisture, particularly toward coppice mounds. Although this was not scientifically tested, it was hypothesized that this may allow faster penetration of the soil by rain and reduce surface evaporation.

The flowers of *C. scheeri* ssp. *robustispina* average 6.5 cm (2.6 in) long with pale yellow tepals (petals and sepals) that are variously tinged with red pigments (Figure 3). Flowers generally open early to mid-July following summer rains; fruit matures a few weeks later (Roller 1996a, p. 54). The pale green fruits are narrowly ellipsoid, 3.2 to 5.7 cm (1.25 to 2.25 in) long and 1.3 to 1.9 cm (0.5 to 0.75 in) wide, with a soft rind and juicy sweet pulp surrounding a mass of brown to black seeds (Benson 1969, p. 195).

Figure 3. *Coryphantha scheeri* var. *robustispina* in flower. Photo by Marc Baker.

3. Taxonomy

Arthur Schott originally described the taxon as *Mammillaria robustispina* from a collection he made from near El Sásabe, Sonora, Mexico (holotype MO 2017438) and the name was published by George Engelmann in 1856 (*M. robustispina* Schott ex Engelmann). Britton and Rose (1923, pp. 33-34) transferred the species to *Coryphantha* (*C. robustispina*). The name of the taxon was recombined by Benson (1982, p. 820) to *C. scheeri* var. *robustispina* and then again to *C. robustispina* (Schott ex Engelm.) Britton & Rose ssp. *robustispina* by Taylor (1998, pp. 17-18). According to Taylor, the species name C. *robustispina* has priority over the epithet C. *scheeri*. This view is accepted by Anderson (2001, p. 196). Within this document, however, we refer to the taxon as *C. scheeri* var. *robustispina*, the name in use when the taxon was listed as endangered under the Act in 1993 and how the taxon has been referred to in Service documents since that time.

A morphometric study in 2004 suggested that a taxonomic cline exists between all *C. robustispina* occurring between Arizona and Texas and therefore no varieties are valid (Schmalzel et al. 2004, p. 553). Three varieties; *robustispina*, *uncinata* and *scheeri*, have been investigated recently and were shown to be geographically isolated (Baker 2005, p. 6), significantly different morphologically (Baker 2003, p. 17), and significantly different genetically (Butterworth 2010, p. 14; Baker and Butterworth 2013, p. 996), warranting subspecific division. We accept this varietal differentiation in this document.

4. Distribution

In the United States, *C. scheeri* var. *robustispina* is found across roughly 152,920 ha (377,873 ac) of land within the Altar and Santa Cruz Valleys in Pima and Santa Cruz Counties, Arizona, including some lands that connect the two valleys. Plants are found on lands owned or managed by the Federal government (approximately 16 percent), State government (approximately 50 percent), Tribal government (approximately 5 percent), and private entities (approximately 29 percent; Figure 4).

There is no indication that the historical range of the taxon differs widely from the current known distribution. The type specimen was collected on the Sonoran side of the United States - Mexico border, just south of the Baboquivari Mountains (Benson 1982, p. 820); surveys indicate that this specimen was collected at the extreme southwestern edge of its range (Baker 2005, p. 6). *Coryphantha scheeri* var. *robustispina* occurs within two subbasins of the Santa Cruz Watershed: Brawley Wash and the Upper Santa Cruz (Figure 5). These subbasins face largely differing threats and stressors and are subjected to different land uses. Therefore, we are using these subbasins as the basis for our recovery units, which we describe later in this document. Because less than 2 percent of the known plants occur more than 900 m (2,952.8 ft) apart, (the distance where individual *C. scheeri* var. *robustispina* are likely to be genetically isolated; McDonald 2005, p. 3), we consider all *C. scheeri* var. *robustispina* individuals as components of a single population.

5. Abundance

Between 2004 and 2005, Baker conducted a study in Arizona and Sonora that was designed to estimate the geographic distribution and relative densities for individuals of *C. scheeri* var. *robustispina*. Surveys took place in the following general areas: south of Sásabe, Sonora; south of Nogales; from north of Benson, Arizona; south to the United States - Mexico border; north of Douglas, Arizona; and southeast of Tucson, Arizona. Within the Benson and Douglas areas, no individuals were located, although most habitats surveyed were similar to known *C. scheeri* var. *robustispina* sites in elevation, topography, vegetation type, and plant cover (Baker 2005, p. 1). Surveys conducted south of the international border focused on three areas that had not been formally surveyed, which were geographically intermediate between known localities of var. *robustispina* and var. *uncinata*. These surveys resulted in a total of five individuals (one per 54 ha surveyed) now known for Sonora, all less than 10 kilometers (km) (6.2 miles (mi)) from the international border. As potential habitat appears unlikely farther south, it is unlikely that there are significant populations of *C. scheeri* var. *robustispina* in Sonora or elsewhere in México (Baker 2005, p. 6).

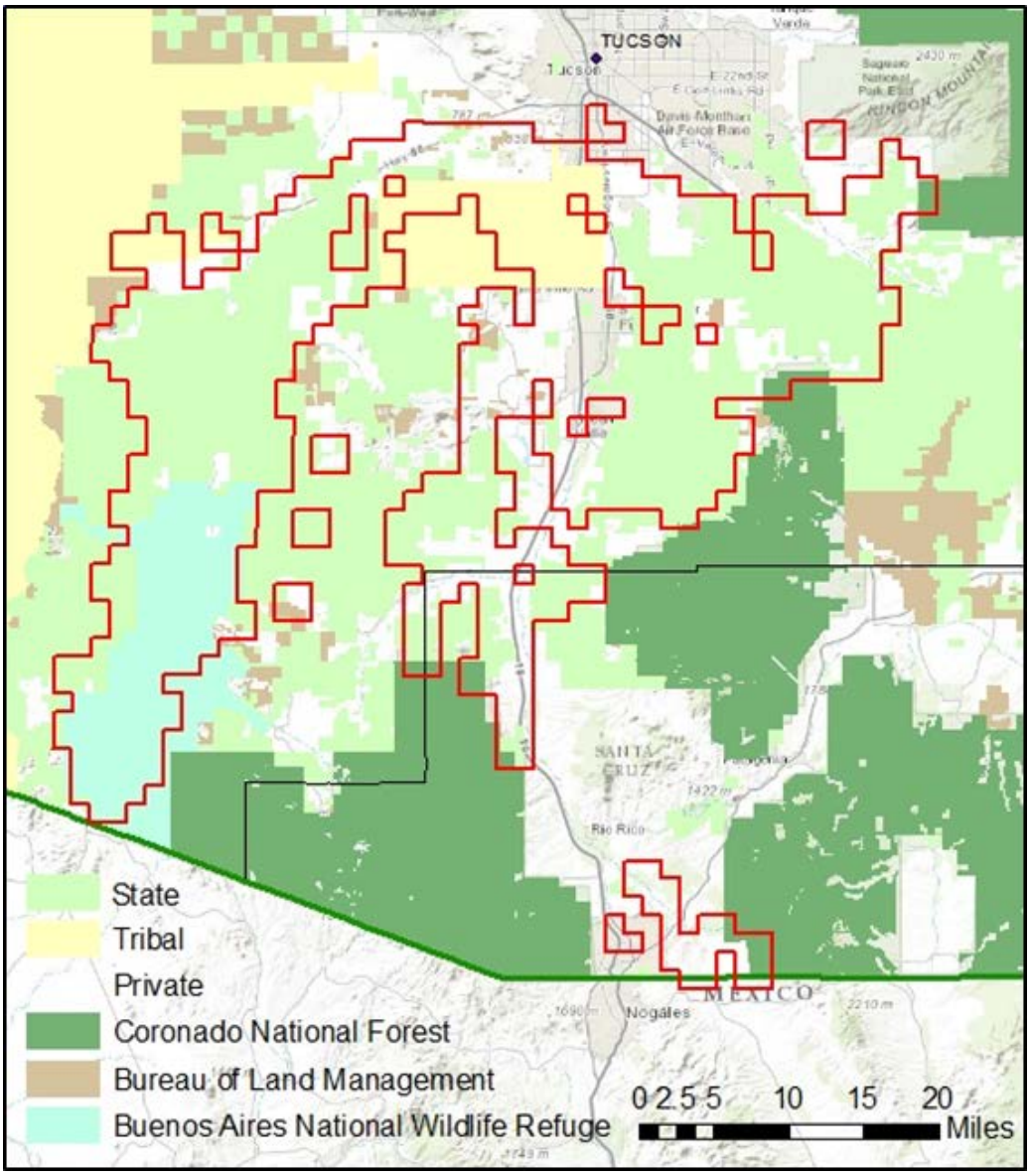


Figure 4. Land ownership within the *Coryphantha scheeri* var. *robustispina* general population range, southern Arizona (red polygon).

Coryphantha scheeri var. *robustispina* is typically found widely spaced in the landscape. In a 1992 study intended to better define the range of the species, Ecosphere Environmental surveyed over 809 ha (2,000 ac) of habitat with characteristics that could support *C. scheeri* var. *robustispina*, finding 195 clumps (an estimated 649 individuals) total on roughly 101 ha (250 ac; pp. 9-10). They concluded that the plants were scattered within moderate sized areas in "favorable habitats" and widely dispersed in "less optimal habitat" (Ecosphere Environmental Services Inc.1992, p. 3). They did not however, provide definitions of favorable or less optimal *C. scheeri* var. *robustispina* habitat.

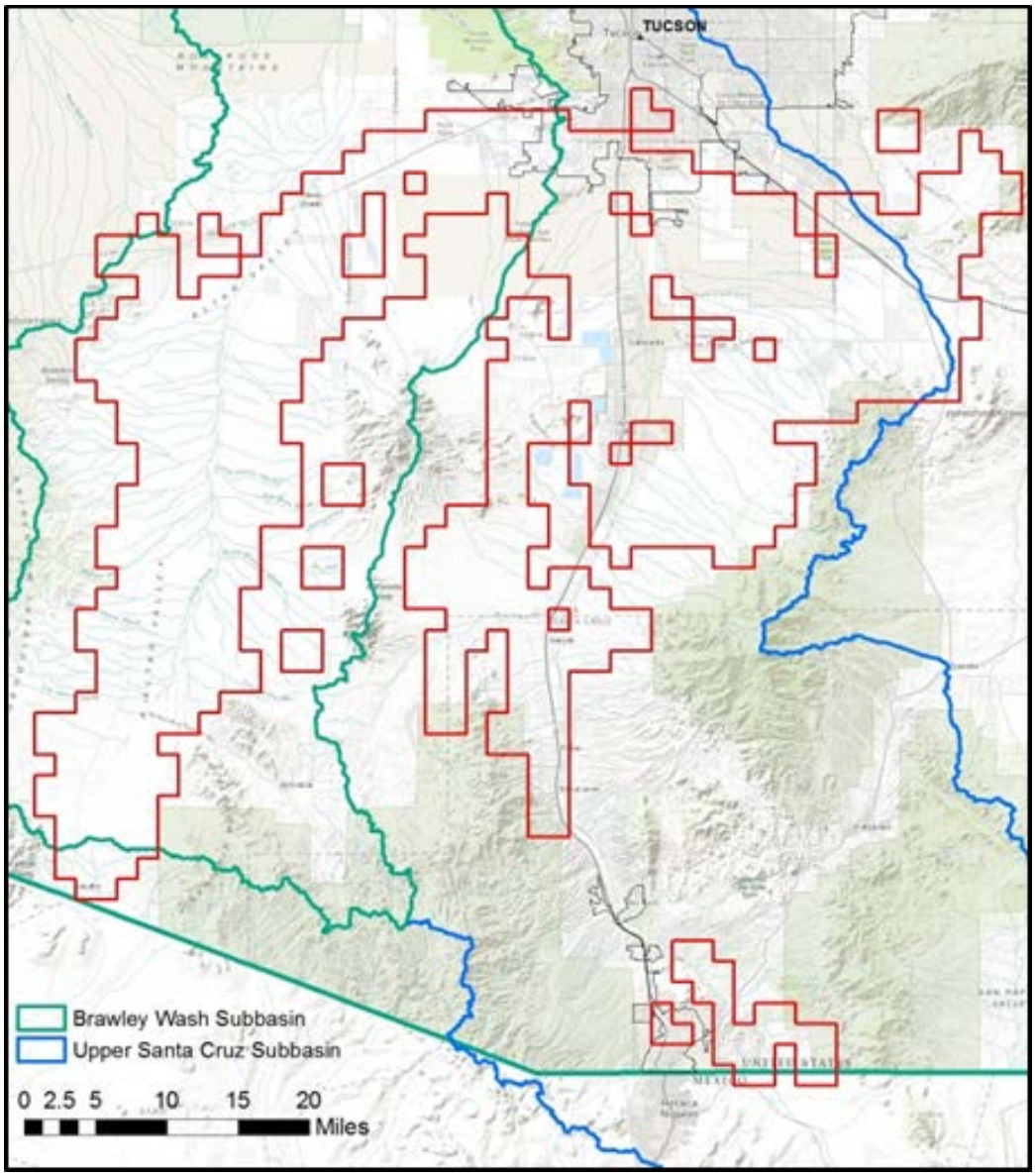


Figure 5. Subbasin division within the *Coryphantha scheeri* var. *robustispina* general population range of southern Arizona (red polygon). The Brawley Wash Subbasin is equivalent to the Altar Valley Recovery Unit. The Upper Santa Cruz Subbasin is equivalent to the Santa Cruz Valley Recovery Unit.

There have been attempts to estimate the number of individual *C. scheeri* var. *robustispina* plants across the range of the taxon based on a sampling of field surveys and extrapolation (Westland Resources, Inc 2004, entire; Baker 2012, p. 19). These estimates however, do not account for the variability in density that occurs, for land use, or for habitat suitability. For example, within the Buenos Aires National Wildlife Refuge (BANWR) in the Altar Valley, 612 plants (living and dead) have been found on over 20,234 ha (50,000 ac) of potential habitat (Chenevert-Steffler pers. comm. January 29, 2015). In contrast, 477 individuals were found during surveys of 723.2 ha (1,787 ac) of potential habitat on State Trust and Santa Rita Experimental Range lands in the Santa Cruz Valley (Ecosphere Environmental Services Inc. 1995, p. 1). Appendix 1 demonstrates the number of individuals and acres of suitable habitat surveyed from the vast majority of surveys conducted for the species since 1985. A total of 6,131individuals have been

documented in our files from these surveys of 42.49 ha (105,786 ac) of suitable habitat from 1985 to the present. Similarly, as of the summer of 2015, the Arizona Natural Heritage Program database of locations for this taxon consisted of approximately 8,000 records of living cacti individuals, in addition, 1,837 are known to no longer exist, primarily due to development and not natural causes (Tonn pers. comm. July 13, 2018).

Relatively few studies have been conducted where portions of the *C. scheeri* var. *robustispina* population was monitored over time. In 1997, Robert Schmalzel established a permanent plot to study *C. scheeri* var. *robustispina* growth and age structure on the King Anvil Ranch in the Altar Valley; this plot was revisited in 1998, 1999, and 2000 (Schmalzel 2000b, p. 6). In this study, 139 individuals were followed, of which 15 died between 1997 and 2000 (Schmalzel 2000b, p. 7). During a follow-up study by Marc Baker and Rafael Rouston initiated in 2002, it was reported that "many" of the 139 plants measured by Schmalzel were dead, with no apparent cause of death discovered (Dimmit and Brusca 2004, p. 5). In this follow-up study, long-term plots were established at six locations within the Altar Valley, including the area previously studied by Schmalzel (Dimmit and Brusca 2004, p. 2). In 2003, a total of 260 individuals were located on the 6 plots; these plants were evaluated on 6 additional occasions through 2012, when 93 plants remained (Baker 2013, p. 4; Table 1). Rodent and insect predation, drought, and poor habitat quality are commonly associated with *C. scheeri* var. *robustispina* death (Phillips et al. 1981, p. 10; Mills 1991, p. 5; Schmalzal & McGibbon 2010, pp. 3, 10-11; Baker 2011, pp. 6; Baker 2013, p. 4; Service 2015a, p.1; Service 2015b, p. 2), though it is unknown what the cause of death was on these plants. In 2017, these plots were once again visited and 113 plants were located; researchers indicate the increase in individuals since 2012 is likely due to recruitment from the seedbank (Molano-Flores pers. comm. February 2, 2018; Table 1). In each year of study, some recruitment was noted; however, recruitment has not exceeded mortality in any year (Baker 2013, p. 9; Molano-Flores 2018, p. 14).

Year	Total Original Plants
2003	260
2005	180
2006	184
2007	171
2008	160
2009	150
2010	137
2011	94
2012	93
2017	*113

Table 1. Year of survey and total number of *Coryphantha scheeri* var. *robustispina* within 6 Altar Valley plots. * Researchers indicate increase since 2012 is likely due to recruitment from the seedbank (Molano-Flores pers. comm. February 2, 2018)

Between 1995 and 2007, 45 individual *C. scheeri* var. *robustispina* were monitored in an exclosure on Coronado National Forest land in the Santa Cruz Valley. In 2010, no living plants were found (Coronado National Forest 2010, entire), however, in a partial survey of this area in 2015, some *C. scheeri* var. *robustispina* were found both within and outside of this exclosure (Service 2015b, entire). Similarly, plants are monitored regularly on the Pima County and Palo

Alto Pima Pineapple Cactus Conservation Bank properties. On one portion of the County-owned Conservation Bank property in 2006, 67 plants were mapped; when last counted in 2014, 13 of the original 67 plants remained alive and 11 new plants had been found (Pima County 2015, p. 1). Within or adjacent to the Palo Alto Conservation Bank property, 49 plants were found in 2001; as of September, 2015, 9 of the original individuals remained alive and 11 new plants were discovered, for a total of 24 known *C. scheeri* var. *robustispina* (Westland 2015, p. 2).

6. Habitat

Coryphantha scheeri var. *robustispina* is typically found in open areas within the Sonoran Desert-scrub and desert-grassland vegetation types and in areas transitional between these vegetation communities (Figure 6; Roller and Halverson 1997, pp. 267-268). Routson (2003, p. 3) found that individuals of *C. scheeri* var. *robustispina* within the Altar Valley occurred most frequently in disclimax (displaced climax due to disturbance) desert-grassland among woody vegetation on well-drained soils. Many studies describe the subshrubs *Zinnia* species (desert zinnia), *Gutierrezia sarothrae* (snakeweed), *Isocoma tenuisectus* (burroweed), and *Eriogonum* spp. (buckwheat) as common associates (Schmalzel 2000c, p. 1; McPherson 2002, p. 3; McDonald 2005, p. 58; Service 2007a, p. 9). Schmalzel (2000c, p. 2) noted greater rates of mortality among *C. scheeri* var. *robustispina* occurring under the canopies of *Prosopis velutina* (velvet mesquite). Similarly, Kidder (2014, entire) found occupied sites were characterized by overall high incoming solar radiation (Kidder 2015, p. 110). McPherson (2002, p. 3), however, found individuals occur more frequently under the canopy of perennial plants than at a distance of at least 1 m (3.28 ft) from the canopy edge.

The taxon is generally found on deep, silty and gravely, alluvial soils at elevations between 728 and 1,280 m (2388 and 4,200 ft) (Ecosphere Environmental Services Inc., 1992, p. 11; Roller and Halverson 1997, p. 267; McPherson 2002, p. 2; Kidder 2015, p. 110; Tonn pers. comm. March 16, 2016). Although *C. scheeri* var. *robustispina* have been located on early (Holocene) and late (Pleistocene) Quaternary, as well as Cenozoic period soils, individuals appear to be more abundant on the younger (Quaternary) alluvia and less abundant on older, nutrient-poor alluvia (SWCA 1999, p. 6; Figure 7). Schmalzel (2000b, p. 10) suggests both Holocene and Pleistocene surfaces are needed for the persistence of *C. scheeri* var. *robustispina*, with the younger, more nutrient-rich Holocene soils where *C. scheeri* var. *robustispina* grow more quickly, but can perish in more frequent fire, and the older and nutrient-poor Pleistocene soils acting as refugia where vegetation and fire are sparse. Figure 7 illustrates the affinity of the taxon for Quaternary soils throughout its range.

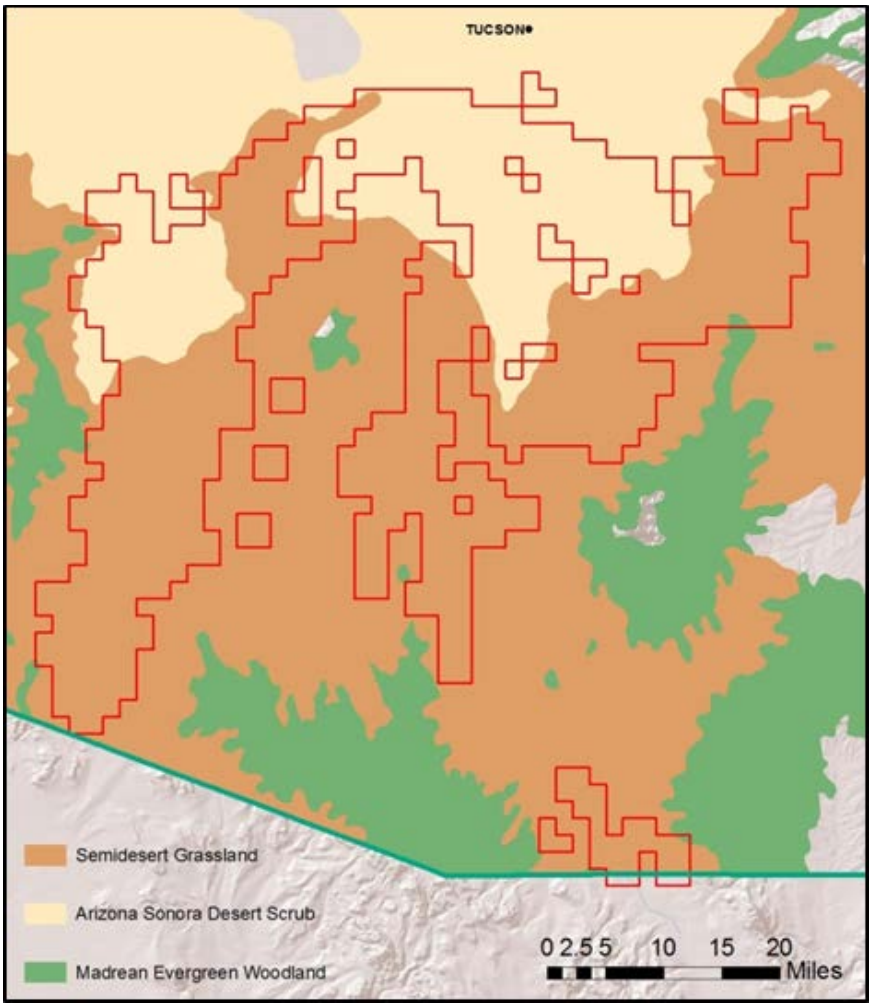


Figure 6. General southern Arizona *Coryphantha scheeri* var. *robustispina* general population range (red polygon) and associated vegetation communities.

McPherson (2002, p. 2) also noted that individuals of *C. scheeri* var. *robustispina* are associated with coppice mounds about 70 percent of the time and may be creating the mounds when small particles of silt, sand, and organic matter are blown into the spines of the cactus and drop to the base. McDonald (2005, p. 58) noted that 93 percent of 374 individual *C. scheeri* var. *robustispina* found in burned and unburned areas of the Altar Valley were on coppice mounds. SWCA (1999, p. 16) reported that some of the highest densities of *C. scheeri* var. *robustispina* individuals occur within 10 m (32.8 ft) of banner-tailed kangaroo rat (*Dipodomys spectabilis*) mounds. SWCA suggested that *C. scheeri* var. *robustispina* individuals access nutrients from *D. spectabilis* feces by sending out long lateral roots (SWCA 1999, p. 16). However, Schmalzel (2000b, p. 9) noted that of 154 plants studies on a permanent plot in the Altar Valley, only two plants were growing directly on banner-tailed kangaroo rat mounds.

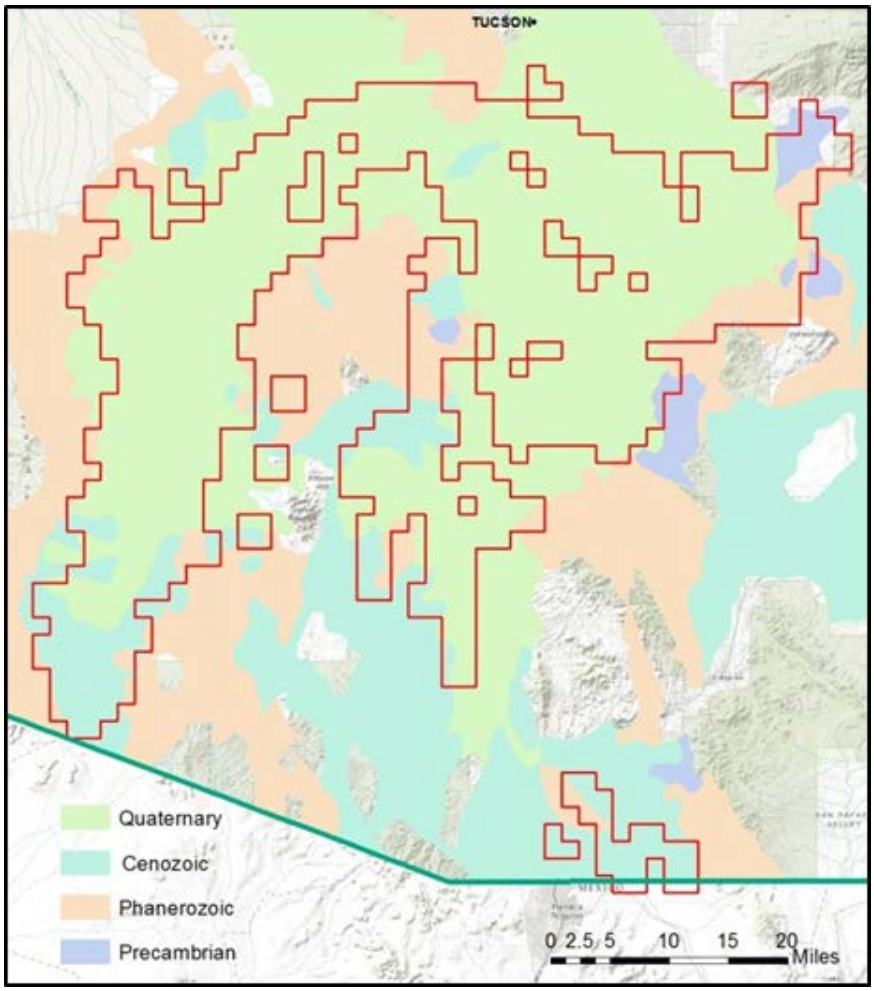


Figure 7. Geology within general southern Arizona *Coryphantha scheeri* var. r*obustispina* general population range (red polygon), by Geologic Time Period, illustrating the preference for Quaternary (Holocene and Pleistocene) substrates.

7. Life History and Ecology

Lifespan

Coryphantha scheeri var. *robustispina* is a perennial shrub with succulent stems, which, along with the flowers, fruits, and seeds, are palatable to some degree to animals. Although individuals can have a longevity of 30 or more years (Roller 1996a, pp. 38, 41; Schmalzel pers. comm. May 22, 2000), in some areas, such as the BANWR, they have a much shorter lifespan, possibly due to competition with invasive nonnative grasses (Cohan pers. comm. June 19, 2015). Schmalzel (2000a, p. 20) hypothesized that competition with grass, both native and nonnative, is inversely correlated to *C. scheeri* var. *robustispina* growth, seed output, and longevity, though this has not been tested.

Flowers

Flower buds begin to appear in mid-May and the timing is related to photoperiod and rainfall (Roller 1996a, p. 58). Flowering usually occurs in early to mid-July or five to seven days after the first summer rains of at least 3 mm and continues through the monsoon season (Kearney and Peebles 1951, p. 577; Roller 1996a, p. 58; Kidder 2014, entire). Flowers persist for a single day,

yet the timing of flowering may assist with pollination, as there are few cactus species which bloom at this same time, resulting in a greater potential for pollination success (McDonald and McPherson 2005, p. 531). Schmalzel (2014, p. 4) suggests that plants do not reach maturity and begin to flower until they are more than 12 years of age and likely between 20 and 25 years of age.

Pollination

Pollinators of *C. scheeri* var. *robustispina* are fairly well known. Flowers of the taxon are morphology typical for the subgenus Cactoideae and exhibit characteristics considered generalized with respect to pollination, that is, the pollen being easily accessible to many different types of pollinators. Known pollinators include both native insects and the nonnative European honeybees (*Apis mellifera*) (Roller 1996a, p. 63). Schmalzel (2000c, p. 2) reported collecting and identifying from *C. scheeri* var. *robustispina* in the Altar Valley the following flower visitors: *Diadasia rinconis* (no common name; Apidae), and the halictid bees; *Agapostemon melliventris* and *A. cockerelli* (Halictidae)). Schmalzel (2000d, p. 8) and a 2005 pollination study (McDonald 2005, p. 17) conclude that the primary pollinator of *C. scheeri* var. *robustispina* is *D. rinconis*. Though *D. rinconis* feeds on nectar from a variety of cactus flowers, it collects pollen primarily from *Opuntia* sp. (prickly pear) (Ordway1987, p. 15). *Diadasia rinconis* is a solitary anthophorid that nests in dense aggregation in open ground, and is one of the most common native bees on cactus flowers from April to June in southern Arizona. *Diadasia* spp. move nesting sites yearly to shed parasites, therefore requiring the continued availability of sandy, well-drained bare ground avilabe to create nests (Buchmann per. comm., March 13, 2012). Although most pollen transfer occurs within a few hundred meters of *C. scheeri* var. *robustispina* individuals, *Diadasia rinconis* is capable of transporting pollen 1.2 km (0.7 mi) or more (McDonald 2005, p. 29). *Coryphantha scheeri* var. *robustispina* become isolated from potential pollination after 600 m (1,968.5 ft) and since the taxon is not able to self-pollinate (Service 2000a, p. 4), they are likely to be genetically isolated or inbred after 900 m (2,953 ft; McDonald 2005, p. 30). Pups (offsets of the parent cactus that are genetically identical) produced vegetatively will not increase genetic diversity of the population.

Fruits and Seed Dispersal

Fruit and seed dispersal for the taxon is probably facilitated, for the most part, by rodents and, perhaps less so, by ants. It has also been hypothesized that jack rabbits (*Lepus* spp.) may play a key role in fruit and seed dispersal (Westland 2005, p. 33; Schmalzel and McGibbon 2010, p. 11). In 2001, Westland (2005, p. 33) examined jackrabbit dung and discovered intact *C. scheeri* var. *robustispina* seeds within. They noted that dung increased around plants at the time fruits are maturing. A study conducted by Baker and Routson beginning in 2002 documented that ants were mostly associated with extrafloral nectaries, however there were multiple cases of ants eating the fruits and transporting seeds (Baker 2013, p. 21). This study also documented the presence of a single seed in jackrabbit feces, which supports the jackrabbit dispersal hypothesis (Baker 2013, p. 33). In a study of antelope jackrabbit (*Lepus alleni*) habitat structure and vegetation characteristics, Altemus (2016, p. 10) did not detect a spatial association between the jackrabbits and the presence of *C. scheeri* var. *robustispina*, but suggested further study was warranted, as this was a habitat selection study for the herbivore and did not emphasize the distribution of fruits. Additionally, Harris' antelope squirrels (*Ammospermophilus harrisii*),

desert cottontails (*Sylvilagus audubonii*), and birds have been observed feeding on fruits and may play a part in seed distribution (Roller 1996a, p. 64; Baker 2011, pp. 23-24).

In 2010 and 2011, a study by Baker (2011, p. 4) placed cameras in *C. scheeri* var. *robustispina* habitat to investigate animal fruit dispersal. Using motion sensors, the cameras captured photographs of Harris' antelope squirrels 114 times (excluding photos taken within 15 minutes of each other). Individual desert cottontails were photographed 31 times, kangaroo rats (*Dipodomys* sp.) 19 times, and jackrabbits 9 times (Baker 2011, pp. 23-24). Harris antelope squirrels were the only animals caught in the act of eating fruits (Figure 8) and marking cacti. Westland (2005, p. 33) hypothesized that pronghorn (*Antilocapra americana*) may have historically provided long distance dispersal and gene flow across the range of *C. scheeri* var. *robustispina*. Baker (2013, p. 33) hypothesized that roadrunners, doves, and other birds may be long distance seed dispersers.

Figure 8. Harris' antelope squirrel eating fruit of *C. scheeri* var. *robustispina* in the Altar Valley, Arizona.
Photo by Marc Baker, with permission.

Seed Production

Coryphantha scheeri var. *robustispina* produce an abundance of seeds. Baker (2012, p. 21) reported that over a 6-year period, 32 percent of the individuals among 6 sites in the Altar Valley produced mature fruits, with an average of 2.37 fruits per fruit-bearing individual. Mills (1991, p. 5) reported that the average *C. robustispina* ssp. *robustispina* fruit contains nearly 120 seeds. Thus, each year, on the average, each *C. scheeri* var. *robustispina* individual produces 91 seeds (120 seeds/fruit × 2.37 fruits per fruit-bearing plant × 0.32 fruit-bearing plants/ total plants). Similarly, Roller (1996a, p. 72) studied seed at 5 sites spread across the taxon's range and found the average number of seeds produced per fruit was 89. Mills (1991, p. 4) noted an average of 114 seeds per fruit on 21 fruits collected from 17 plants on the west side of the Sierrita Mountains. Schmalzel (2002, p. 4) in a study of hand pollinated plants in a greenhouse situation found the mean number of seeds produced per fruit was 87, with a large range from 19 to 156 seeds per fruit. He notes that other cacti have disproportionate seed production among individual

plants and that seed size varied greatly between plants as well, with a median seed mass of 5.32 milligrams (sd = .94 mg).

Seed Germination

Ample seed production, however, does not necessarily equate to persistant seedbanks or recruitment (e.g. see Godinez-Alvarez et al. 2003, p. 183; Aragon and Lasso 2018, p. 1). One field study reported the results of two trials where 200 or more *C. scheeri* var. *robustispina* seeds were planted in close proximity to *in situ C. scheeri* var. *robustispina* adult plants and germination was followed (Schmalzel 2002, p. 7). In the first trial, 16 of 220 seeds germinated in the first year and none in the second. In the second trial, 35 of 200 seeds germinated; 30 in the first year and 5 in the second year of study (Schmalzel 2002, p. 7). In another study, field germination testing from 5 study sites found that *C. scheeri* var. *robustispina* seeds had high germination rates of 88 percent (Roller 1996a, p. 75). Observations from laboratory and shadehouse over a 22-month period showed continuous germination indicating that there is no set dormancy period for the seeds (Roller 1996a, p. 72). The study also found that seeds from *C. scheeri* var. *robustispina* that were transplanted into a controlled shadehouse require at least 96 hours of high water saturated soil in order to imbibe and temperatures above 19 degrees Celsius (66 degrees Fahrenheit) and below 38 degrees Celsius (100 degrees Fahrenheit) in order to germinate (Roller 1996a, pp. 65-66). Byrd (pers. comm. July10, 2017) noted germination only from seed from freshly collected vs. desiccated fruit. We are not aware of any tests of seedbank viability over time.

8. Reasons for Listing and Current Threats and Stressors

In determining whether to list, delist, or reclassify a species under section 4(a) of the Act, we evaluate the threats to the species based on the five categories outlined in section 4(a)(1) of the Act: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; and (E) other natural or manmade factors affecting its continued existence. Threats identified in the 1993 *C. scheeri* var. *robustispina* listing document include: habitat loss due to mining, agriculture, road construction, and urbanization and range management practices to increase livestock forage (Factor A); habitat degradation due to historical and present overuse of the habitat by livestock (Factor A); and illegal collection (Factor B). In addition, threats and stressors identified through research and section 7 consultations that could potentially impact *C. scheeri* var. *robustispina* include invasive nonnative plant competition and alteration of the fire regime (Factor A); recreation and border activities (Factor A); predation by small mammals and insects (Factor C); inadequacy of existing regulatory mechanisms (Factor D); the effects of drought and climate change (Factor E); and small population size and isolation (Factor E). All of these threats and stressors are discussed below; a list of threats and stressors and associated recovery objectives, criteria, and actions can be found in Table 2.

		Recovery		
ESA Listing Factors	Threats and Stressors	Objectives	Criteria	Recovery Actions
A	Habitat loss due to mining, agriculture, road construction, and urbanization*	1.1, 1.3, 1.7, 1.8, 2.1, 2.2, 2.3, 2.4, 3.1, 3.2, 3.3, 3.5, 3.6, 3.8	1, 2, 3	1a-d, 3a-c, 4a-c, 5a-c, 6a-c
A	Historical range management*, nonnative plant invasion, and altered fire regimes	1.2, 1.7, 1.8, 2.2, 2.4, 3.1, 3.2, 3.3, 3.5, 3.6, 3.8	1, 2, 3	2a-b, 3b-c, 4a, 4c, 5a-c, 6a-c
A	Habitat degradation due to historical and present overuse of the habitat by livestock*	1.1, 1.2, 1.3, 1.7, 1.8, 2.2, 2.4, 3.1, 3.2, 3.3, 3.5, 3.6, 3.8	1, 2, 3	2a-b, 3b-c, 4a, 4c, 5a-c, 6a-c
A	Recreation and border activity	1.1, 1.2, 1.3, 1.7, 1.8, 2.2, 2.4, 3.1, 3.2, 3.3, 3.5, 3.6, 3.8	1, 2, 3	2a-b, 3b-c, 4a, 4,c, 5a-c, 6a-c
B	Illegal collection*	1.3, 1.7, 1.8, 3.2, 3.8	1, 3	5a-c, 6a-c
C	Predation by small mammals and insects	1.4, 1.5, 2.4, 3.1, 3.2, 3.3, 3.6	1, 2, 3	3b, 4a, 4c, 5a-c,
D	Inadequacy of existing regulatory mechanisms	1.6, 1.7, 1.8, 3.3, 3.8	1, 2, 3	6a-c
E	Drought and climate change	1.1, 2.2, 2.3, 3.1, 3.2, 3.3, 3.5, 3.7	1, 2, 3	1a-d, 4b-c, 5a-c
E	Small population size and isolation	1.1, 1.3, 2.1, 2.2, 2.3, 3.1, 3.2, 3.3, 3.4, 3.5, 3.7	1, 2, 3	1a-d, 3c, 4a-c, 5a-c, 6a-c

Table 2. Threats and stressors tracking table for *Coryphantha scheeri* var. *robustispina*
* indicates threat identified at time of listing

Factor A: Present or Threatened Destruction, Modification or Curtailment of Habitat or Range

Habitat loss due to commercial development

The primary habitats of *C. scheeri* var. *robustispina* are open areas on flat ridge tops or areas with less than 10 percent slope, which are also areas very well suited for human development. Urban and suburban development in the areas south and west of Tucson, Green Valley, and Nogales, Arizona, and mining in the Sierrita Mountains and Green Valley, threats first recognized in the 1980s (Phillips et al. 1981, p. 11; Mills 1991, p. 7; Reichenbacher 1985, p. 21; Service 2000a, p. 7), are responsible for complete and permanent modification of lands that previously supported *C. scheeri* var. *robustispina* and its pollinators. By 2000, the Service estimated that 43 percent of the total habitat surveyed to date had been modified or destroyed due to urbanization (Service 2001a, p. 6). For example, 143 ha (353 ac) of habitat and 47 individual plants were lost to a single housing development project in 1998 (Service 1998c, p. 16). In 2014, 197 ha (487 ac) of suitable *C. scheeri* var. *robustispina* habitat and 99 individual plants were lost to a single infrastructure development project (Service 2014a, p. 33).

Since its listing in 1993 through February, 2018, there have been 81 formal section 7 consultations under the Act involving *C. scheeri* var. *robustispina* in southern Arizona. This has resulted in the direct mortality (e.g. removal for construction activities) of more than one thousand individual *C. scheeri* var. *robustispina* and the loss of 3,238 ha (8,000 ac) of suitable habitat. Consultations under the Act only occur for projects with a Federal nexus, either occurring on Federal lands or using Federal dollars or needing a Federal permit. Therefore,

many projects that occur within the range of *C. scheeri* var. *robustispina* do not undergo section 7 consultations, and the Service does not typically receive information regarding the status or loss of plants or habitat associated with those projects.

In summary, *C. scheeri* var. *robustispina* occur on relatively flat land that is well suited for human development. Habitat loss to mining and urbanization has been and continues to be a major threat to *C. scheeri* var. *robustispina*. Thousands of acres of suitable habitat and more than a thousand individuals have been lost to this threat since the taxon was listed. This threat remains high.

Habitat loss due to nonnative plant invasion and altered fire regimes

Coryphantha scheeri var. *robustispina* occur in both the desert-grassland and desert-scrubland plant communities, especially in the ecotone of the two (Roller 1996a, p. 9). Invasive nonnative grasses in both communities compete with native plants for water and nutrients, reduce community composition and structure, and alter fire frequency and intensity.

Semi-desert-grassland

Healthy desert grasslands are dominated by native bunchgrasses, such as *Bouteloua eriopoda*, (black grama), *Bouteloua hirsuta*, (hairy grama), *Bouteloua rothrockii*, (Rothrock's grama), *Bouteloua curtipendula* (sideoats grama), *Bouteloua gracilis* (blue grama), *Muhlenbergia porteri* (bush muhly), *Muhlenbergia setifolia* (curlyleaf muhly), *Pleuraphis jamesii* (James' galleta), *Pleuraphis mutica* (tobosagrass), and *Sporobolus airoides* (alkali sacaton). Other kinds of plants also occur in the desert grassland, such as *Yucca* spp. (yucca), *Agave* spp. (century plant), *Acacia* spp. (acacia), *Opuntia* spp. (prickly pear and cholla), and other cacti, including *C. scheeri* var. *robustispina*. These different lifeforms have different shaped and sized canopy and root systems and create heterogeneity of form, height, and open patches that provide a refuge from competition and fire and are essential to the survival of *C. scheeri* var. *robustispina*.

Occurring roughly every 10 to 20 years and following periods of adequate moisture, large-scale low-severity fire defined historical disturbance regimes of desert-grassland plant communities of southern Arizona and northern Mexico (McPherson and Weltzin 2000, p. 5; Brooks and Pyke 2002, p. 6; McDonald and McPherson 2011a, p. 385; Fryer and Leunsmann 2012, entire). Through heavy livestock grazing historically (beginning in the 1820s) and improved fire-suppression techniques thereafter, the fire return interval increased to 50 years or more by the late 1800s (Thomas 1991, p. 13). Due to these changes in grazing and fire regimes, *P. velutina* became less vulnerable to mortality and began encroaching into these native grasslands (Parmenter and Van Devender 1995, p. 214; Van Auken 2000, p. 205; Sayre 2007, p. 42; Lindsay et al. 2011, p. 3252).

Efforts initiated several decades later to control *P. velutina* invasion included mechanical removal and high intensity prescribed fire. In addition, by the 1930s, invasive nonnative grasses such as *Eragrostis lehmanniana* (Lehmann's lovegrass) were intentionally planted into southern Arizona grasslands to revegetate degraded landscapes, decrease erosion, and increase forage production for livestock (Anable et al. 1992, p. 181; Sayre 2007, p. 42; McDonald and McPherson 2011a, p. 385).

Eragrostis lehmanniana, a nonnative grass from South Africa, has numerous competative advantages over native grasses in southern Arizona. The taxon resprouts from roots and tiller nodes not killed by hot fire, is not hampered by the reduction in mycorrhizae associated with fire and erosion, is able to respond to winter precipitation when natives grasses are dormant, is able to produce copious seed earlier than native grasses, maintains larger seedbanks than native grasses, and has higher seedling survival and establishment than native grasses during periods of drought (Anable 1990, p. 49; Anable et al. 1992, p. 182; Robinett 1992, p. 101; Fernandez and Reynolds 2000, pp. 94-95; Crimmins and Comrie 2004, p. 464; Geiger and McPherson 2005, p. 896; Schussman et al. 2006, p. 589; O'Dea 2007, p. 149; Archer and Predick 2008, p.26; Mathias et al. 2013, entire). This species outcompetes native grasses for water, light, and nutrients, forming nonnative dominated grasslands that have reduced structural, species, and spatial diversity and produce two to four times the biomass of native grasslands (D'Antonio and Vitousek 1992, p. 70; McPherson 1995, pp. 136-137; VanDevender et al. 1997, p. 4; Huang et al. 2009, pp. 903-904; Figure 2.4).

Within the BANWR, it is thought that competition from *E. lehmanniana* has reduced longevity of individual *C. scheeri* var. *robustispina* to less than one-third the typical lifespan of the species (Schmalzel 2000a, p. 20; Cohan pers. comm. June 19, 2015). In addition, Thomas et al. (2017, p. 204) found that sites on BANWR with low vegetation cover in the immediate vicinity of *C. scheeri* var. *robustispina* had greater survival in both control and treatment areas, thus providing additional evidence that, due to competition, *E. lehmanniana* negatively impacts *C. scheeri* var. *robustispina*. Similarly, at the Appleton-Whittell Research Ranch in southern Arizona, Bock et al. (1986, p. 459) determined that *E. lehmanniana* negatively impacted ten native plant species.

The unnaturally dense and evenly spaced canopies of invasive nonnative grass dominated communities (as compared to more open and heterogeneous native dominated grasslands) have higher fuel loads of highly lignified (long-lasting through slow decomposition) litter that result in more frequent fires that have longer flames, faster rates of spread, and higher intensity and frequency than historical low-intensity burns of native desert grasslands (Anable et al. 1992, p. 186; Williams and Baruch 2000, p. 128; Crimmins and Comrie 2004, p. 464). Because of this, coupled with more frequent fire starts from cross-border violators, fires are now more frequent and intense (Anable et al. 1992, p. 186; D'Antonio and Vitousek1992, p. 75; Williams and Baruch 2000, p. 128; Crimmins and Comrie 2004, p. 464; Emerson 2010, pp. 15, 17). In addition, *E. lehmanianna* dominated grasslands recover quickly from fire, as fires scarify the ample seeds and remove canopy allowing for high seedling emergence (Cable 1965, p. 328; Anable 1990, p. 15; Roundy et al. 1992, p. 81; McPherson 1995, p. 137; Biedenbender and Roundy 1996, p. 160). In many locations in southern Arizona in recent decades, repeat fires have occurred within short periods of time, aided by the dominance of invasive nonnative grasses in the landscape (BAER 2017).

This results in the reduction of structural and spacial diversity of habitats, alteration of wildfire patterns, and increases competition with native plants, including *C. scheeri* var. *robustispina*, for water, light, and nutrients. Between 1932, when *E. lehmanniana* was introduced into southern Arizona, and 1991, 145,000 ha (358,303 ac) of desert- grassland had been impacted by this nonnative, of which 69,000 ha (170,503 ac) were directly seeded (Anable et al. 1992, p. 181; Slaughter 2014, p. 7). By 2003, Gori and Enquist (p. 10) suggest that the nonnative grasses *E.*

lehmanniana and *E. curvula* (Boer lovegrass), were common or dominant on 566,560 ha (1,400,000 ac) of land in southeastern Arizona. There are no current estimates on the number of hectares infested, however it is likely far greater than that of the 2003 estimate 15 years ago. The Forest Service estimates that up to 75 percent of *C. scheeri* var. *robustispina* habitat has been infested by *E. lehmanniana* (ADA 2010, entire). Figure 9 demonstrates our best estimate of the distribution of native, nonnative, and shrub invaded grasslands within and nearby *C. scheeri* var. *robustispina* habitat (The Nature Conservancy 2004, entire).

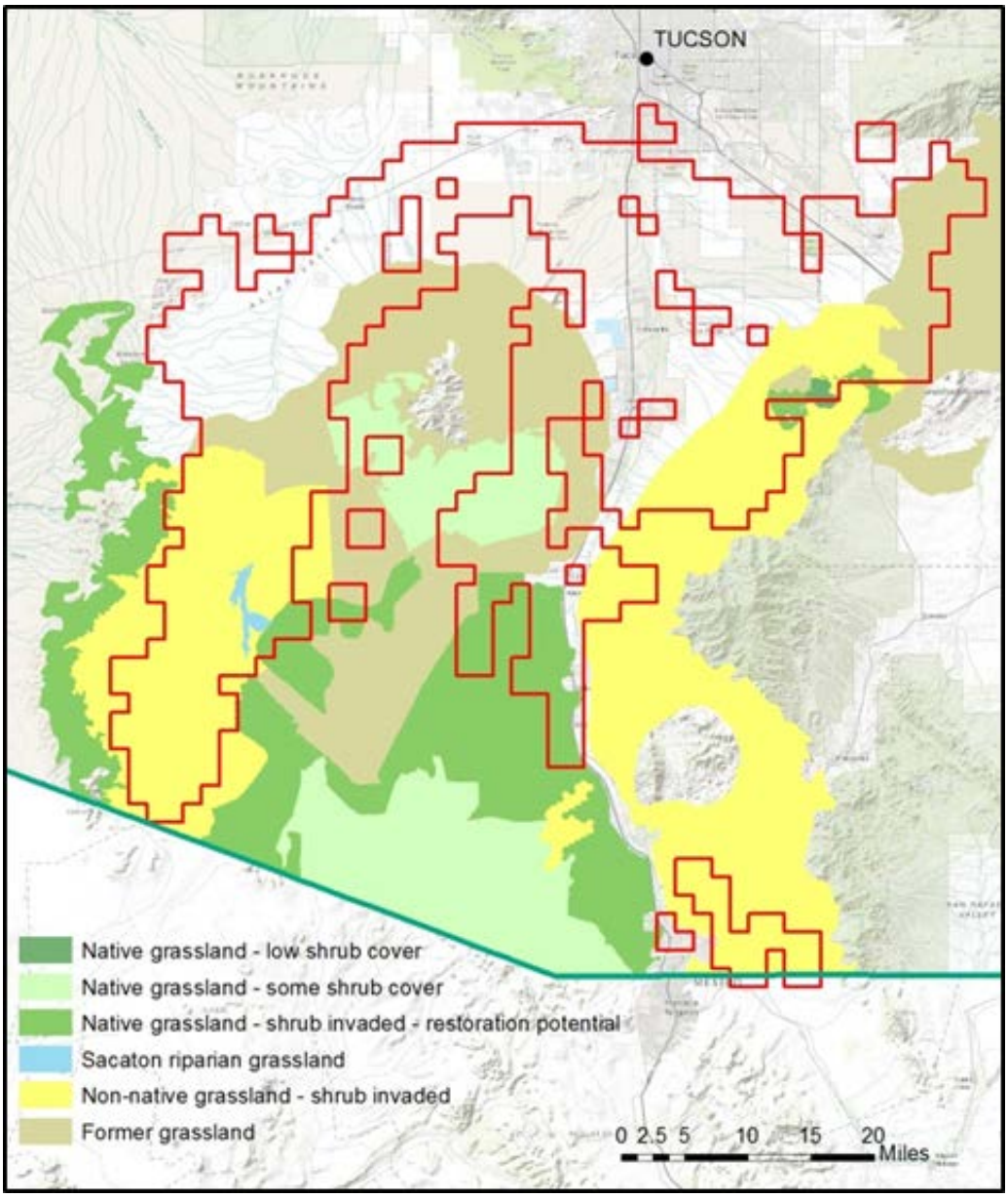


Figure 9. Grassland condition within general locations of *C. scheeri* var. *robustispina* of southern Arizona (red polygon), illustrating the condition of the desert-grassland habitat of the taxon. Geospatial data from TNC, 2004.

Within a single fire event in native grassland, some patches may burn at high temperatures, while others burn lightly or do not burn at all. Fire-free refugia for *C. scheeri* var. *robustispina* may be small (Figure 10) or non-existent (Figure 11) in grasslands infested with invasive nonnatives grasses. The number of individual cacti in habitat infested with invasive nonnative grasses may decrease over time if recruitment does not keep up with losses due to fire and other threats or stressors. Deserts invaded by invasive nonnative grasses have a new dynamic whereby soil processes may also become permanently altered (Allen et al. 2011, p. 451).

Desert-scrubland

Desert-scrubland, where there is decreased annual precipitation compared to desert-grasslands, is typically characterized by low and discontinuous plant fuels, plants that lack fire-adapted characteristics, and fire return intervals that may have historically been greater than 250 years (McLaughlin and Bowers 1982, p. 246; Thomas 1991, p. 11; Alford et al. 2005, p. 451; Brooks and Pyke 2002, p. 5; Brooks and Chambers 2011, p. 433). Fine fuels, typically only at adequate densities following wet winters or in a few areas with perennial grasses, allowed for small, low severity fires (Schmidt and Rogers 1988, p. 437; Brooks and Chambers 2011, p. 433; Esque et al. 2013, p. 223). In contrast, desert-scrubland invaded by invasive nonnative grasses have continuous fuels that alter fire regimes and these grasses compete with native plants for space, nutrients, and water.

The invasive nonnative African grass, *Cenchrus ciliaris*, was brought to the United States for agricultural experimentation as early as 1889, and was utilized for revegetating degraded rangelands in the southwest from 1902 through the 1940s (Tellman 1997, p. 7; Brenner 2011, p. 91; Lyons et al. 2013, p. 65). There were many strains of the plant brought by the Soil Conservation Service from Africa to the Texas Experimental Station and these were released throughout the southwestern United States by 1949, with introduction to Mexico during the 1950s (Martin-R. et al. 1995, p. 60, Brenner 2011, p. 91). Several varieties of *C. ciliaris* s were planted in test fields in southern Arizona in the 1960s, with one of these strains, T-4464, that established the best and has since escaped from the test fields (Saguaro National Park 2018, entire). Until recently, Texas A&M University was conducting agricultural research on *C. ciliaris* to develop more robust and cold-hearty strains. These varieties have been released in Texas and Mexico. In Arizona, efforts are made to control this species and it is not intentionally planted for forage. This species now impacts millions of acres of lands in the region (Martin-R. et al. 1995, p. 60; Van Devender et al. 1997, p. 3; Lyons et al. 2013, p. 66).

Fires occurring on lands infested by *C. ciliaris* are more severe and frequent than fires in surrounding ecosystems, even in communities with comparable fuels (McDonald and McPherson 2011b, p. 1152). *Cenchrus ciliare* can resprout within days of fire; however, native plants not adapted to fire suffer greater losses in cover and species richness (McDonald and McPherson 2011b, pp. 1152-1153). Increases in invasive nonnative grass cover in deserts can also increase habitat for rodents (Olsson et al. 2012, p. 18). Rodents consume cacti for water, especially in times of drought (Riegel 1941, p. 96; Orr et al. 2015, p. 1058). Rodents have been shown to preferentially cache native grass seed under the dense and protective canopy of *C. ciliare*, thus further depleting deserts of native species able to outcompete *C. ciliare* (Sommers and Chesson 2016, p. 7). In addition, invasive nonnative grasses in deserts may be detrimental to the survival

of ground nesting native bee species that require sparsely vegetated habitat (Lindsay et al. 2011, p. 3262), which in turn may impact *C. scheeri* var. *robustispina* pollination and survival.

Figure 10. Example of small *C. scheeri* var. *robustispina* refugia habitat (bare soil) within *E. lehmanniana*-dominated grassland.

Figure 11. Example of *C. scheeri* var. *robustispina* without refugia from nonnative *E. lehmanniana.*

Fire and cacti

Although succulents can be severely damaged or destroyed by fire, they may survive burning by: a) occupying open microsites characterized by low fuel abundance, especially on rocky ridgetops, b) plants being missed by the fire due to the mosaic burn pattern of fires, c) seedlings shrinking into the soil at certain times of the year when fire may be present, d) evolving morphological or physiological fire tolerance, e) producing thick callous tissue following damage which may protect plants in subsequent fire, or f) production of offsets after injury or death (Thomas 1991, pp. 13 and 20; Tolley 1992 p. 6; Roller 1996a, pp. 17, 34, 39, 77; Roller and Halverson 1997, p. 5; McDonald and McPherson 2006, pp. 54, 56, 66; 58 FR 49875, p. 49876). Invasion of *C. ciliaris* in desertscrub and *E. lehmanniana* in desert grasslands, among other nonnative invaders, has altered the structure of those landscapes and reduced or removed bare ground niches used by *C. scheeri* var. *robustispina* and other cacti as fire evasion. In general, *C. scheeri* var. *robustispina* do not appear to be well-adapted to the more frequent and hotter fires more typical of today's invaded desert grasslands and desert scrublands.

Although cacti typically do not burn, they do scorch and blister, damaging epidermal and mesophyll tissue (Figure 12), and spines can be burned off, leaving plants unprotected from predation and more vulnerable to killing frost (Figure 13; Thomas 1991, pp. 14 and 17; Robinett 1996, entire; McDonald and McPherson 2011b, p. 1151). Responses of cacti to alterations in fire frequency and intensity have been studied to some extent and some insight can be gleaned from short-term fire response studies of other cacti species. In a study of grasslands in southern Arizona, Humphrey and Everson (1951, p. 266) found greater mortality of three *Opuntia* species on burned vs. unburned areas one year following high intensity fire. In a study of *C. ciliaris* infested Sonoran Desert, McDonald and McPherson (2011, p. 1152) found that nearly 90 percent

of cacti photosynthetic tissue was damaged by high severity fire. In addition, flowers, fruits, and seeds that are burned halt sexual reproduction temporarily, even if the cactus is not killed; disruption of seed entering the seedbank may impact future recovery. Although some cacti seed are able to withstand extremely high temperatures, seeds are not stimulated to grow due to fire, as in other plants that are adapted to fire (Thomas 1991, p. 19).

Figure 12. Example of *Coryphantha scheeri* var. *robustispina* killed by fire. Photo by BANWR, with permission.

Figure 13. Example of *C. scheeri* var. *robustispina* damaged by fire. Photo by Katie Cline, with permission.

In another study of frequent Sonoran Desert fires, mortality of cacti species was reduced due to their presence in rocky outcrops which provided refuge from fire (Thomas 1991, p. 19).

Similarly, Thomas and Goodson (1991, entire) followed four species of small globular cacti after grassland fires on the Applleton-Whittell Research Ranch and BANWR of southeastern Arizona. They found that immediately after fire, there was no significant difference in the number of dead individuals between burned and unburned areas across all four species studied. However, 1 year after the fire, 30 to 50 percent of burnt plants had died compared to less than 20 percent of unburned plants. After 4 years, 80 percent of the burnt cacti had died. For two of the cacti species, this was significantly greater mortality than unburnt plants, however, for a third species, unburnt and burnt plant mortality was more-or-less equal. For the fourth species, mortality of control plants exceeded those burnt, possibly due to old age of the unburnt plants, or release from competition plus a nitrogen pulse in those that had burnt.

In another cactus study from southern Arizona, Thomas and Goodson (1992, p. 99) found that repeated or intense fires resulted in reduced cactus survivorship; fewer post-fire survivors result in long-term decline, as frequent fires do not allow time for seedling establishment and population recovery. In a 16 year study of *Coryphantha*, *Echinocereus*, *Echinomastus*, and *Mammilaria* cacti, Thomas (2006, p. 9) found that within 2 years of a grassland fire, less than 25 percent of 50 tagged cacti perished. All plants however, died within a 16 year period (less than half the typical lifespan of *C. scheeri* var. *robustispina*) and a new cohort replaced the original plants (Thomas 2006, p. 9).

Fire and *Coryphantha scheeri* var. *robustispina* in the Altar Valley

In 1986, there was a prescription burn in the north portion of East San Pedro pasture and in Valley Pasture. In 1987, there were prescription burns in the East San Pedro and West Mill pastures which was described as hot and extensive (Schmalzel 2014, p. 1). In 2012, Schmalzel et al. surveyed roughly a quarter of the East San Pedro and the West Mill pastures via belt transect and located 73 individual *C. scheeri* var. *robustispina*; these were almost all in the southwest quarter of East San Pedro pasture (Schmalzel 2014, p. 3).

In 1991, surveys prior to a prescribed fire in the Altar Valley revealed 83 *C. scheeri* var. *robustispina* pre-burn (Maender pers. comm. April 19, 1991). Associated species included 12 native cacti, shrubs, and herbaceous plants, but no grasses were among the inventoried associated plants. A follow-up check of a sample of these individuals revealed a mix of completely burned and killed individual *C. scheeri* var. *robustispina*, as well as, some plants appearing to be fine; the difference being a matter of how much fuel was in close proximity to individual plants (Maender pers. comm. March 4, 1992). There is indication that at least some of the burned individuals survived through resprouting (Robinett pers. comm. June 23, 1992). In addition, of 16 individual *C. scheeri* var. *robustispina* studied 2 years post-burn, Maender (1993, entire) found fire damage as follows: a single plant with no damage, 2 plants with slight damage, 2 plants with moderate damage, 10 plants with severe damage, and 1 plant that had died. He noted that the unharmed or slightly damaged plants may not have had available fuels associated with them.

In 1994 - 1995, survivorship of *C. scheeri* var. *robustispina* was studied at fires on BANWR (wildfire) and the nearby Kind Anvil Ranch (prescription). Results indicate presence of fuels was a strong indicator of *C. scheeri* var. *robustispina* survival. At the BANWR site, 31 percent *C. scheeri* var. *robustispina* survived after fires in areas with high densities of *E. lehmanniana*,

whereas, 70 percent survived in areas with low *E. lehmanniana* densities on the King Anvil Ranch (Roller and Halvorson 1997, p. 12). Halverson and Roller (1997, p. 12) note that *C. scheeri* var. *robustispina* does not show a pattern of basal resprouting in vegetation types dominated by heavier fuels following fire (p. 12). In addition, apical resprouting was also lower at BANWR (31 percent) as compared to the King Anvil Ranch (55 percent). The details of the King Anvil fire are presented below.

One year following the 1995 prescription burn in the West San Pedro Pasture, Robinett (1996, entire) revisited these same *C. scheeri* var. *robustispina* individuals and reported roughly equal mortality (20 to 30 percent) of *C. scheeri* var. *robustispina* on and off the prescription burn area, stating mortality was likely due to drought. He also noted some of the burned plants were eaten by small mammals, presumably due to loss of protective spines. Schmalzel (2000b, pp.8- 9) noted that within the Diaspar soils (young sandy loam) of this pasture, which support higher grass cover than the associated Caralampi and Sasabe-Caralampi soils (older gravelly sandy loam), the grassland had not burned in 50 to 100 years and had the potential for fairly dense stands of perennial grasses and *Bouteloua barbata* (sixweeks grama) under the right rainfall conditions. Schmalzel (2000b, p. 8) stated that most of the *C. scheeri* var. *robustispina* on this pasture occurred on the Caralampi and Sasabe-Caralampi which were sparsely vegetated and with small mesquite. Within the Diaspar soils on this pasture where grasses were more dense and mesquites grow large, nearly all *C. scheeri* var. *robustispina* were killed by the fire. Schmalzel (2000b, p. 9) notes that the low productivity and fewer fuels of the Caralampi soils act to make fire discontinuous to nonexistant.

Roller and Halverson (1997, p. 11) also looked at this pasture post-fire and found that 27% of 37 individuals sampled showed evidence of burning and of those 70% survived past the first rainy season post-fire. Survival included through resprouting (80 percent of the plants in burned areas resprouted, vs, no plants resprrouted in unburned areas). It is not known if their sample was from plants from the Caralampi soils or the Diaspar soils. In 2014, Schmalzel, pp. 2-3) noted that roughly 200 plants were identified prior to the 1995 West Mill pasture prescription burn and that in 1997 and 1998 he revisited a small portion of the plants and found 127 living individuals stating that he found 3-4 unreported plants in proximity to any plant located in 1994 before the burn. It is unknown if he visited plants on Calarampi or Diaspar soils.

In 2005, McDonald revisited this and other nearby burned and unburned pastures. He found the overall post-fire demography and density of *C. scheeri* var. *robustispina* both on and off of burned areas did not differ (McDonald 2005, p. 61). He noted that some *C. scheeri* var. *robustispina* may have escaped fires in microsites with little fuel, but that it is possible that most of the plants examined in this study established after the fire (2005, p. 61). McDonald feels that the distribution and abundance of *C. scheeri* var. *robustispina* may ebb and flow based on regional rainfall patterns, grass production, and fire dynamics. McDonald also noted that the burned areas of his study, which included the 1995 fire, did not have high amounts of *E. lehmannii* or other nonnative species. He warned that caution should be taken when restoring fire in areas outside of historic conditions (e.g. with increasing *E. lehmannii*), as this could profoundly change community composition and possibly decrease *C. scheeri* var. *robustispina* survival (McDonald 2005, p. 75).

In July 2015, another prescription fire was monitored for effect to 26 *C. scheeri* var. *robustispina* individuals in the Altar Valley. Cline (2015, p. 4) found a significant decrease in the health and survival of the cacti in both control and burn areas. Of the three healthy individuals that did burn, post-fire monitoring found that one was scorched from radiant heat, one had slight yellowing with charred spines, and a third was dead, but had eight healthy pups. Cacti in the control area also showed significant decrease in health and survivorship, primarily due to frost, drought, and predation.

In summary, historically, low severity fires that occured every 10 to 20 years in grasslands (McPherson and Weltzin 2000, p. 5; Brooks and Pyke 2002, p. 6; McDonald and McPherson 2011a, p. 385; Fryer and Leunsmann 2012, entire), or every 250 years in deserts (McLaughlin and Bowers 1982, p. 246; Thomas 1991, p. 11; Alford et al. 2005, p. 451; Brooks and Pyke 2002, p. 5; Brooks and Chambers 2011, p. 433), likely posed no threat to the long-term survival of *C. scheeri* var. *robustispina* individuals. When invaded by invasive nonnative grasses, fire frequency and intensity increase, leading to the deterioration of both natural grassland and desert communities (Olsson et al. 2012, p. 10; Steidel et al. 2013, p. 529). Invasive nonnative grasses produce more fine fuels than native vegetation, allowing for a more uniform and higher intensity burn compared with the discontinuous fuels of some native grasslands and deserts, thus reducing the number of microsite refuges safe from fire (58 FR 49875, p. 49876; Maender 1993, entire; Roller and Halvorson 1997, p. 12; McPherson and Weltzin 2000, p. 7; Brooks and Pyke 2002, p. 5). *Coryphantha scheeri* var. *robustispina* is not fire adapted, but may survive fires through refugia (e.g. older soils or spaces between native plants), chance, shrinking into the ground, reproducing through basal resprouting, or possibly recolonization from a surviving seedbank, barring adequate rainfall to allow for survival. Further research into the relationship of fire, drought, nonnative species, soil types, and *C. scheeri* var. *robustispina* and their seedbanks would help to better understand the tolerance of this taxon to wildland and prescription fires. Research into desert-scrubland and desert-grassland restoration (e.g. removal of nonnative grasses and the establishment of native plants) is also essential, as this is a large-scale problem currently without large-scale solutions.

Effects of Livestock Grazing

Native grasslands of southern Arizona have declined in size and health since the 1800s for a variety of natural and human-related reasons (Hastings 1959, p. 62; Bahre 1995, pp. 230-231). In the1800s, the Altar and Santa Cruz Valleys were said to have been open grassland supporting large herds of pronghorn, Mexican wolves (*Canis lupus baileyi*), and possibly prairie dogs (BANWR 2012, entire; Bahre 1995, p. 231). By the early 1860s, there was a boom in ranching in southern Arizona, which ended with the droughts of 1891-1893 and 1898-1904 when widespread livestock die-off occurred (Sayre 2007, p. 42; Austin 2010, p. 8). Stocking rates in southern Arizona prior to 1920 are estimated to have been roughly ten times greater than stocking rates today (Sayre 2007, p. 42), and during this time, antelope and large predators were displaced (Parmenter and Van Devender 1995, pp. 198, 203, 214; Van Auken 2000, p. 205; Sheridan 2001, p. 146).

Heavy grazing during the droughts of 1891-1893 and 1898-1904, as well as the droughts of the 1920s and 1950s, caused or contributed to soil erosion and compaction, arroyo formation, reduced water infiltration rates and increased runoff, invasion or expansion of woody perennials,

increases in open disturbed patches available for nonnative plant invasion, and shifts in understory species composition to less diverse and less palatable plant species, among other impacts (Klemmedson 1956, p. 137; Ellison 1960, p. 24; Arndt 1966, p. 170; Gifford and Hawkins 1978, p. 305; Waser and Price 1981, p. 407; Robinson and Bolen 1989, p. 186; Holechek et al. 1998, pp. 191–195, 216; Loftin et al. 2000, pp. 57–58; and Sayre 2005, p. xiv). Historically, much of the range of *C. scheeri* var. *robustispina* was heavily grazed, leading to degradation of the habitat that is still evident today in some areas.

In addition, some range management practices that contribute to the modification and loss of *C. scheeri* var. *robustispina* habitat and individuals, such as chaining, ripping, herbicide use, prescription fire, and the planting of nonnative grasses as forage, are still in use in Mexico and on some private lands in southern Arizona. Currently, within the range of *C. scheeri* var. *robustispina*, the primary tool for habitat manipulation is prescribed burning. Subsequent to the listing of *C. scheeri* var. *robustispina*, Endangered Species Act tools such as section 7 and Section 10 have been used to identify and reduce the negative effects to *C. scheeri* var. *robustispina*. The current approach to section 7 in Altar Valley uses proposed prescribed burns to gather data on the effects of fire on *C. scheeri* var. *robustispina*. Current grazing practices and levels are much different than they were historically and current habitat conditions are more the result of ongoing drought and historical livestock grazing than they are of current livestock grazing practices. Studies of other threatened, globular cacti of the Sonoran Desert have shown that low intensity grazing which occurs with high frequency over a long period of time can also negatively impact cacti through increased soil erosion, solar radiation, and a reduction in soil humidity (Ureta and Martorell 2009, p.1992). There are a few direct observations of trampling of individual *C. scheeri* var. *robustispina* (Ecosphere Environmental Services Inc. 1992, p. 24; Service 2002c, p. 10; Schmalzel 2002, p. 3). Livestock are not known to eat *C. scheeri* var. *robustispina*.

Although many species are vulnerable to disturbance, some cactus species tolerate or even benefit from low to moderate disturbance through increased recruitment in newly created environments (Martorell et al. 2012, p. 336). Mills (1991, p. 3) noted a higher quantity of *C. scheeri* var. *robustispina* individuals along cattle trails, though suggested it could be due to higher visibility there. Reichenbacher and Associates (1985, p. 21) noted *C. scheeri* var. *robustispina* occurred more regularly in areas where grasses were at least partially grazed by cattle and the cacti were temporarily released from competition. Ureta and Martorell (2009, p. 1998) observed other cactus species, e.g. *Mammillaria* spp., that benefited from moderate livestock use which thinned competing grasses. Livestock grazing that decreases the cover of nonnative grasses may also reduce the impact of fires on *C. scheeri* var. *robustispina*. Similarly, there have been a few instances where *C. scheeri* var. *robustispina* have been reported following certain mechanical disturbances such as road construction or chaining, which reduced competition with other plants for nutrients, water, and light (Service 2002c, p. 10; Service 2004c, p. 38). Urtrea and Martorell (2009, p. 1998) discuss that a disturbance threshold exists however, whereby even cacti that typically benefit from moderate levels of disturbance are eventually negatively impacted. Where that threshold is for *C. scheeri* var. *robustispina* is not known.

In summary, some livestock grazing practices that occurred in the past have resulted in enduring landscape-level impacts, because recovery in dryland ecosystems is slow or stagnant.

Historically overgrazed lands have altered microclimate and hydrology, increased soil compaction and erosion, reduced structural complexity and abundance of the vegetation community, and species composition; all of which may impact the current suitability of habitat for *C. scheeri* var. *robustispina* in certain areas of its range. In general, poorly managed livestock grazing may negatively impact *C. scheeri* var. *robustispina* seedlings and adult plants through soil erosion, soil compaction, hydrologic and micro-climatic changes, and invasion or expansion of invasive nonnative grasses. Low to moderate intensity grazing however, may also aid *C. scheeri* var. *robustispina* through the creation of open areas temporarily free of competition and with reduced fuels (Service 2000a, p. 9). Additional research into the relationships between livestock use and *C. scheeri* var. *robustispina* is needed to determine both the benefits of grazing and the threshold at which disturbance no longer benefits the taxon. In addition, research is needed into restoration of native species and fire regimes on desert grasslands and desertscrub.

Recreation and Border Activity

Off-road vehicle use within *C. scheeri* var. *robustispina* habitat can result in the destruction of cacti, and individual *C. scheeri* var. *robustispina* have been observed to be run over (Service 2004c, p. 38). On the Coronado National Forest, *C. scheeri* var. *robustispina* occur both within and outside of an exclosure; those within are protected from direct impacts from off-road vehicle use common to the area. Plants occurring outside of the exclosure are subject to direct mortality or habitat destruction due to off-road vehicle use. During 2015 *C. scheeri* var. *robustispina* monitoring, erosion from Forest Service Road 61 was noted within the exclosure at a known *C. scheeri* var. *robustispina* location; the plant was missing, perhaps buried under sediment or washed away (Service 2015b, p. 7).

In 2010, Schmalzel and McGibbon (2010, p. 11) noted trails, trash, human tracks, and off-road vehicle tracks within the Palo Alto Pima Pineapple Cactus Conservation Bank property. These activities did not directly impact known *C. scheeri* var. *robustispina* plants, but contributed to the overall deterioration of the habitat. Similarly, Pima County (2015, p. 1) noted a moderate amount of immigrant traffic including trails, trash, and cut fences. They conclude that this traffic is unlikely to have resulted in measurable impacts to the *C. scheeri* var. *robustispina* population.

In summary, off-road vehicle use and illegal border activity contribute to the overall degradation of *C. scheeri* var. *robustispina* habitat. In addition, individual *C. scheeri* var. *robustispina* have been run over by off-road vehicles. Although these activities could impact individual *C. scheeri* var. *robustispina*, off-road vehicles and illegal border activity are not likely significant sources of mortality for the taxon as a whole.

Factor B: Overutilization for commercial, recreational, scientific, or educational purposes

A 1981 report on the status of the species states that *C. scheeri* var. *robustispina* is sought by private and commercial collectors (Phillips et al. 1981, p. 12), and there is documentation that theft of this species has occurred (e.g. Kendall pers. comm. February 16, 1990, entire; Spiller pers. comm. January 31, 1996, entire; Richardson pers. comm. Feb 9, 2016). Illegal collection is among the threats discussed in the 1997 listing document and the basis for why the Service determined it was not prudent to designate critical habitat (58 FR 49875, p. 49878). The listing

rule examines three specific examples of plant theft and other, less verifiable, incidents are reported. Some of these incidents indicate hobbyists and commercial collectors are specifically interested in *C. scheeri* var. *robustispina*, while at other times it appears the collectors are just taking all cacti in a general area. An inquiry with the Arizona Department of Agriculture in 2015 revealed no current knowledge of a threat to this species from collection (Schade pers. comm. April 20, 2015). In early 2016 however, seven of nine individuals that had been transplanted for mitigation due to a development project, were found missing during a follow-up watering visit.

In summary, illegal collection of *C. scheeri* var. *robustispina* is difficult to detect and only one incident has been reported in recent years. Although illegal collection could impact *C. scheeri* var. *robustispina*, it is not as significant a threat for the taxon as previously thought. The determination to not designate critical habitat for the species has helped reduce this threat by not making maps publically available, and continued outreach and education related to the issue of illegal collection remain important tools in the conservation of this taxon.

Factor C: Disease or predation

In general, cacti are susceptible to attacks from numerous types of insects, and *C. scheeri* var. *robustispina* is no exception (Figures 14 and 15). The interior flesh of cacti provides both a nesting area and food source for beetles, weevils, and other insects. Once an infestation has occurred, cacti can die from the feeding and tunneling activities of insects or from the introduction of fungus or disease. Plants already stressed from prolonged drought are more susceptible to insect attack and disease, as drought may cause physiological stress responses in plants, such as limiting their photosynthesis and cell growth (Mattson and Haack 1987, p. 110). Predation by mammals and insects occurs on both adult *C. scheeri* var. *robustispina* and seedlings (Phillips et al. 1981, p. 10; Mills 1991, p. 5; Roller 1996a, p. 38; Schmalzal & McGibbon 2010, pp. 3, 10-11; Baker 2011, pp. 6; Service 2015b, p. 2).

Primary insect predators of *C. scheeri* var. *robustispina* are the native *Gerstaeckeria* sp. (cactus weevil) (Schmalzel2002, p. 3), the native *Moneilema* sp. (cactus beetle), and the native *Cactobrosis* sp. (pyralid moth) (SWCA 1999, p. 19). Cactus weevils are stem-boring insects; the adults feed externally while the larvae feed internally (Burger and Louda 1995, p. 1560). Cactus beetle adults feed on pads or terminal buds of cacti; their larvae burrow into stems or roots causing the severing of root and stem, and ultimately the collapse and death of plants (Johnson 1989, p. 10; Kelly and Olsen 2011, p. 7). Pyralid moth larvae feed in the base of flower buds and tunnel into cacti plants leaving open wounds subject to bacterial infection. Zimmerman hypothesyzed that *Gerstaeckeria* sp. and *Moneilema* sp. have increased in numbers in recent years due to climate warming, which faciliates longer breeding cycles and more reproduction in these insect predators (Rutman 2007, p. 6). Mills (1991, p. 6) hypothesized that cactus weevils could be causing high mortality and be responsible for the low density of *C. scheeri* var. *robustispina* across the range.

Figure 14. Insect damage (red oval) on *C. scheeri* var. *robustispina*, 2015. Photo by the Service.

Ants have been documented on *C. scheeri* var. *robustispina* (Mills 1991, p. 4; Baker 2011, p. 17) and will consume seed, however they are not specialists of *C. scheeri* var. *robustispina*. O'Dowd and Hay (1980, p. 539) suggest that ants may also aid in reducing the seedbank of competing plant species. It was noted during 2015 monitoring of *C. scheeri* var. *robustispina* in a grassland community, that areas barren of plants (including the exotic *E. lehmanniana*) supported a greater number of both ant colonies and *C. scheeri* var. *robustispina* individuals (Service 2015b, p. 7). In addition, ants may also scatter *C. scheeri* var. *robustispina* seed away from the mother plant, thereby reducing predation by small mammals that congregate in areas of dense seed (O'Dowd and Hay 1980, p. 536; Vander Wall et al. 2005, p. 802). The harmful or helpful role of these insects remains unknown and warrants research. Predation by grasshoppers has also been observed, though less frequently mentioned in the literature (Figure 15).

Figure 15. Grasshoppers and ants observed on and consuming *C. scheeri* var. *robustispina*, 2003. Photo by the Service.

Predation of *Coryphantha scheeri* var. *robustispina* by mammals is well-documented. Harris' antelope squirrel), antelope jackrabbits and desert cottontails are known to eat stem material of *C. scheeri* var. *robustispina*, especially when other food sources are scarce, such as in times of drought (Phillips et al. 1981, p. 10; Mills 1991, p. 5; Schmalzal & McGibbon 2010, pp. 3, 10-11; Baker 2011, p. 6; Service 2015a, p.1; Service 2015b, p. 2). Baker (2013, p. 4) concluded that 167 of 260 plants studied in 6 locations of the Altar Valley died between 2003 and 2012, likely from drought, rodent and insect predation, over shading from shrubs and trees that cause etiolation, and erosion. In March 2015, researchers noted Kangaroo rat burrows and trails dominated the landscape of Pima County's Madera Highlands Conservation Bank property (Service 2015a, p. 1). Here, predation on several of the remaining living *C. scheeri* var. *robustispina* plants, as well as other cacti in the area, was moderate to severe, even causing death (Service 2015a, p. 1).

Researchers have documented *C. scheeri* var. *robustispina* mortality caused by javelina (*Pecari tajacu*) within the BANWR (King 1993, entire; Roller and Halverson 1997, p. 12), and Schmalzel (2002, p. 27) noted that javelina ranked high among mortality factors of *C. scheeri* var. *robustispina*. These and other animals can also impact cacti by digging under stems, or, at least for larger animals, knocking over or trampling stems. The impacts from javelina may be particularly important given that populations of javelina have entered Arizona only within the past few hundred years (Arizona Game and Fish Department [AGFD] 2015, entire) providing little time for *C. scheeri* var. *robustispina* to evolve defenses.

In summary, there are many insect and mammalian predators to *C. scheeri* var. *robustispina* adults and seedlings. Predation increases during times of drought and following damage to a cacti's protective spines, such as post-fire. Many individual *C. scheeri* var. *robustispina* die or become disposed to death annually from predation which has been recorded on numerous occasions over the past decade.

Factor D: Inadequacy of existing regulatory mechanisms:

Approximately 14 percent of all known *C. scheeri* var. *robustispina* occur on the BANWR, one percent on Coronado National Forest land, and one percent on Bureau of Land Management lands. The Act provides some protection for listed plants on land under Federal jurisdiction, or on other lands where a listed plant is protected under State law. Specifically, under section 9(a)(2) of the Act, it is unlawful for any person subject to the jurisdiction of the United States to remove and reduce to possession any such plant species from areas under Federal jurisdiction; maliciously damage or destroy any such species on any such area; or remove, cut, dig up, or damage or destroy any such species on any other area in knowing violation of any law or regulation of any State or in the course of any violation of a State criminal trespass law.

Section 7(a) of the Act requires Federal agencies to evaluate their actions with respect to any species that is listed as an endangered or threatened species and with respect to its critical habitat, if any is designated, and section 7(a)(2) of the Act requires Federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of any endangered or threatened species or destroy or adversely modify its critical habitat. If a Federal action may affect a listed species or its critical habitat, the responsible Federal agency must enter into consultation with the Service. Through the section 7 process, conservation measures and best management practices can be implemented to reduce the threats and stressors to *C. scheeri* var. *robustispina* from urban development, and nonnative plant invasion and associated alteration of fire regimes, recreation, border activity, and the presence of livestock.

Approximately 50 percent of *C. scheeri* var. *robustispina* occur on State Trust lands and approximately 29 percent of *C. scheeri* var. *robustispina* occur on private land. Federally-listed plants occurring on State and private lands have limited protection under the Act, unless also protected by State laws or a Federal nexus is in place, such as with federally-funded or federally-permited projects. The Arizona Native Plant Law (Arizona Revised Statutes, Chapter 7, 2007, entire) prohibits collection without obtaining a permit on all public lands and directs that plants may not be moved off private property without contacting the Arizona Department of Agriculture. Due to the difficulty in implementing this law, it may not be effective in reducing impacts from illegal collection, nor does it protect habitat.

Approximately five percent of *C. scheeri* var. *robustispina* occur on Tribal land of the Tohono O'odham Nation. The Nation provides protection to the plant through conducting surveys prior to the implementation of any ground disturbing projects. In addition, Article 3 Section 7301 of the Tohono O'odham code states that no person shall destroy, dig up, mutilate, collect, or transport any native plant or plant part on Nation trust lands without first obtaining the required permit (TON, undated).

In summary, because most *C. scheeri* var. *robustispina* occur on private and State Trust lands, they and their habitats are not subject to Federal protection unless there is a Federal nexus to a proposed action. Habitat loss due to urbanization remains a substantial threat to *C. scheeri* var. *robustispina* on these lands. Although best management practices may be implemented with regard to development, nonnative plant invasion and associated alteration of fire regimes, recreation, border issues, and the presence of livestock, management is not continuous across the range of the species and *C. scheeri* var. *robustispina* remain vulnerable to these threats and stressors. There are no regulations in place that address stressors to *C. scheeri* var. *robustispina* and its habitat from predation, drought and climate change, or small population size.

Factor E: Other natural or manmade factors affecting its continued existence

Drought and Climate Change

Cacti are vulnerable to disturbance because they grow slowly, their germination and establishment occurs with low frequency, and they have little capability to recover from disturbance (Portilla 2011, p. 509). Disturbance can reduce recruitment, survival, fecundity, and population growth; disturbance coupled with drought, however, can exacerbate negative impacts on cacti.

Southeastern Arizona and much of the American Southwest have experienced serious drought in recent decades (Bowers 2005, p. 421; Overpeck et al. 2013, p. 3; CLIMAS 2015, entire) and precipitation is projected to be less in the future with climate change (Seager et al. 2007, p. 1181; Karl et al. 2009, pp. 24, 33). In the winter of 2017-2018, most weather stations in Arizona and New Mexico were recording less than 25 percent of normal snowpack and snow water equivalent (CLIMAS 2018a) and by June, 2018, below normal to record-dry conditions were reported throughout most of Arizona (CLIMAS 2018b). The current trend in the Southwest of less frequent, but more intense, precipitation events leading to overall drier conditions is also predicted to continue (Karl et al. 2009, p. 24).

Most climate change scenarios predict that the American Southwest will also get warmer during the 21st century (Overpeck et al. 2013, p. 5; Karl et al. 2009, p. 129). Globally, 2016 was the warmest year on record and it was the second warmest year in Arizona (CLIMAS 2017). The three hottest years on record globally are 2016, 2015, and 2017, respectively (NOAA 2018).

Plants already stressed from prolonged drought are more susceptible to insect attack and disease (Mattson and Haack 1987, p. 110), and such attack is prevalent among adult *C. scheeri* var. *robustispina* across their range (see discussion above in *Factor C. Disease or Predation*). These insects may be increasing due to warmer winters in recent decades (Rutman 2007, p. 6). Predation of cacti by small mammals may also increase during drought conditions and can cause declines in *C. scheeri* var. *robustispina* populations. Drought is also directly related to *C. scheeri* var. *robustispina* population health with regard to reproduction and establishment. As with many cacti species, seed germination and seedling survival are dependent on precipitation (Jordan and Nobel 1981, p. 905; Lina and Eloisa 2018, p. 1-2). Even if seedbanks are established and persist, which we do not know, adequate precipitation during the seedling's first year of growth is essential for survival (Roller 1996a, p. 38; Gurvich et al. 2016, p. 22). In studies of seed germination, Roller (1996a, p. 77) found that on average 88 percent of all seed

produced during the summer monsoon season germinated; however, only a small portion of the seedlings survived. Surveys show few seedlings and young juvenile plants among the *C. scheeri* var. *robustispina* population (e.g. Ecosphere Environmental Services Inc. 1995, pp. 17-21; Schmalzel 2000d, p. 5; Baker 2011, pp. 5-7).

Heat stress in adult cacti is minimal compared to other plant species, as they are able to survive heat stress due to both morphology and metabolism (Smith et al. 1984, pp. 647, 650; Wahid et al. 2007, p. 199). Extreme temperatures can, however, negatively impact seedling survival in many Sonoran Desert plants, and drought coupled with high temperatures lessens temperature tolerance in seedlings (Nobel 1984, pp. 310, 316).

In summary, since the late 1990s, the southwestern United States has been experiencing drought conditions and increasing high temperatures. Climatic predictions suggest continued less frequent, but perhaps more intense, summer precipitation, reduced winter precipitation, and increasing temperatures in this region (Seager et al. 2007, p. 1181; Archer and Predick 2008, pp. 23–24; Karl et al. 2009, p. 24). Drought and increased temperatures increase *C. scheeri* var. *robustispina* stress, reduce defenses to predation and disease, and reduce reproduction, among other impacts. These impacts will continue to affect *C. scheeri* var. *robustispina* and its habitat throughout its range into the foreseeable future.

Small Population Size and Isolation

High species diversity within the vegetative community is important to the survival of *C. scheeri* var. *robustispina,* as this cactus is not abundant enough to sustain its main pollinators. A key pollinator for *C. scheeri* var. *robustispina* is *Diadasia rinconis,* a cactus specialist bee which requires species of *Cylindropuntia, Opuntia,* and *Ferocactus* to survive (McDonald and McPherson 2006, p. 33; Blair and Williamson 2008, p. 428). McDonald (2005, p. 29) found that under favorable circumstances certain *C. scheeri* var. *robustispina* pollinators could transport pollen up to 1.2 km (3,937 feet), but most pollinators transport pollen less than 900 m (2,952.8 ft) (McDonald 2005, p. 29). He also concluded that *C. scheeri* var. *robustispina* individuals start to become isolated from potential pollination after 600 m (1,968.5 ft) and are likely to be genetically isolated after 900 meters (2,952.8 feet; McDonald 2005, p. 30). Fehlberg and Nidey noted that cacti species, even rare species, may have higher levels of heterozygosity and outcrossing, in general, with *C. scheeri* var. *robustispina* being no exception (Fehlberg and Nidey 2015, p. 7). Habitat fragmentation reduces the likelihood of successful pollination as *C. scheeri* var. *robustispina* become more and more isolated from one another and plant community diversity is reduced. Over time, this process could lead to loss in heterozygosity and the variability needed for adaptation to changing conditions, seed production and viability, and eventually extinction. In addition, the small number of individuals located in southern Arizona and northern Sonora makes *C. scheeri* var. *robustispina* vulnerable to catastrophic events, such as regional drought.

In summary, *C. scheeri* var. *robustispina* is a sparsely distributed plant that requires habitat connectivity and proximity to other plants for effective pollination. Large scale threats and stressors such as habitat degradation and regional drought increase the potential for isolation and genetic loss. Current information indicates that roughly 98 percent of all known *C. scheeri* var. *robustispina* occur within 900 m (2,952.8 ft) of one another. Should development or other

threats or stressors remove or cause the deterioration of corridors and connectivity, this could result in genetic isolation and inbreeding.

9. Past Conservation Efforts

The following are conservation efforts that have occurred since *C. scheeri* var. *robustispina* was listed in 1993:

1) The government of Pima County began developing the Sonoran Desert Conservation Plan in 1998 and has been implementing the plan since 2001 (Pima County 2000, entire). The plan was developed to conserve habitats and protect endangered species, while at the same time allowing development to continue on private lands. A main component of the Sonoran Desert Conservation Plan is the Multi-species Conservation Plan, which was finalized in 2016. This document includes specific conservation measures to help ensure the long-term conservation of 44 endangered or at risk plant and animal taxa, including *C. scheeri* var. *robustispina* (Pima County 2016, entire). Through these planning efforts, Pima County owns the land or holds a grazing lease to the following properties, all of which contain *C. scheeri* var. *robustispina*: Marley Ranch, Rancho Seco, Sopori Ranch, and Canoa Ranch, as well as, portions of Buckelew Farm, the King 98 Ranch, and the Diamond Bell Ranch. Each area is used for minimal recreation, as open space, and for cattle grazing according to a strict set of standards and guidelines (Pima County 2010, p. A-182; Pima County 2016, pp. 22, 72).

2) In 2002, the Palo Alto Conservation Bank was created on 411.2 ha (1,016 ac) of land in the Altar Valley of southeastern Arizona. This privately-owned conservation bank protects, in perpetuity, this area of habitat set aside for the preservation of *C. scheeri* var. *robustispina*. Landowners, municipalities, and developers are able to purchase habitat conservation credits to offset the loss of *C. scheeri* var. *robustispina* and their habitat by development and other land uses.

3) In 2006, Pima County established a *C. scheeri* var. *robustispina* mitigation bank on 214 ha (529 ac) divided into 2 subunits (Pima County 2006a, p. 1). Pima County Natural Resources Parks and Recreation is responsible for managing the parcels and monitoring the cacti. Pima County is able to purchase habitat conservation credits to offset the loss of *C. scheeri* var. *robustispina* and their habitat by development and other land uses.

4) The City of Tucson's Greater Southlands Habitat Conservation Plan could, if finalized, could be important for the preservation of large tracks of *C. scheeri* var. *robustispina* habitat. The Greater Southlands Habitat Conservation Plan Planning Area includes approximately 52,600 ha (130,000 ac) of developed and undeveloped land within and outside of the current city limits and encompasses much of the northeastern portion of the geographic range for *C. scheeri* var. *robustispina*. This document proposes to set aside "important riparian areas" and "biological core management areas" that could include valuable *C. scheeri* var. *robustispina* habitat in terms of numbers of individuals, diversity of occupied habitats, and providing a corridor for pollinators and gene flow.

5) The Buenos Aires National Wildlife Refuge in the Altar Valley of southeastern Arizona supports *C. scheeri* var. *robustispina* individuals. Here, the cacti are mostly found in the grasslands, where the main threats to their survival are nonnative grasses and wildfire and/or

prescribed fire. Refuge personnel contribute to conservation works by implementing intensive ground surveys and protecting (through clearing vegetation surrounding all known *C. scheeri* var. *robustispina*) from any prescribed burn activity (58 FR 49875, pp. 49875-49876). Similarly, protection measures, such as flagging and avoidance, take place where non-fire related resources management activities (i.e. soil aeration, disking, water catchment developments, revegetation, and mechanical removal of *P. velutina*) occur. Surveys for protection are guided through the use of a GIS model developed by the refuge to identify predicted *C. scheeri* var. *robustispina* habitat. The model has 89 percent accuracy within the refuge and further refinement may be implemented in the future. In the future, the Refuge may establish a Maximum Protection Area east of Arizona Highway 286 and north of Pozo Nuevo Road, in which 5,878 acres of *C. scheeri* var. *robustispina* habitat would be protected from ground disturbance.

6) The Arizona-Sonora Desert Museum stores the seed of *C. scheeri* var. *robustispina* for conservation and education purposes, and maintains approximately 36 individuals growing on their grounds and in greenhouses (Montgomery 2012, p. 1). The Pima County Natural Resources, Parks and Recreation Native Plant Nursery obtained six individual plants in 2014 which are used for educational purposes (Byrd pers. comm. July 10, 2014). This nursery also attained seed from plants growing on their lands and have successfully grown these seed into seedlings which have been donated to Boyce Thompson Arboretum, Arizona and the Denver Botanical Gardens, Colorado. Additional seedlings will be donated to the Desert Botanical Gardens in Phoenix, Arizona.

7) Research into transplanting *C. scheeri* var. *robustispina* as a conservation measure is ongoing and results thus far have been mixed. For example, in 1996, 47 individual *C. scheeri* var. *robustispina* were transplanted to 3 sites in the Santa Cruz Valley (McIntosh and Baldwin 2001, p. 3). These plants were last monitored in 2001, when at two of the sites relatively few individuals had died, yet all individuals (24) had died at the third site. These plants had been bare rooted and hardened off under shade. Schmalzel (2000a, p. 14) found that bare-rooted individuals had appreciable loss of weight and this should be considered in salvage efforts. Prior to another construction project between 2004 and 2005, during development and construction activities at a development near Tucson (Sycamore Canyon), 81 individual *C. scheeri* var. *robustispina* were transplanted (Westland 2014, p. 2). These individuals were watered in June of 2006 and were monitored periodically thereafter (Westland 2014, p. 3). In 2008, 43 transplanted individuals were still alive; in 2012, 28 of these were still alive (Westland 2014, p. 4); in 2016, 15 of these were still alive (Westland 2017, p. 3).

   In 1999, 46 *C. scheeri* var. *robustispina* were bare-rooted and transplanted due to a construction project and their status checked a few months later; 4 individuals had perished (SWCA 2000, p. 5). Similarly, in very preliminary research just six months following transplanting, Schmalzel (2000c. p. 12) found that six of six transplanted adults had survived and one was producing fruit. Neither of these transplant projects was followed over time, and the ultimate survival or mortality, as well as, reproductive potential post-transplant remain unknown. In 2005, 21 *C. scheeri* var. *robustispina* were transplanted beneath several mesquite trees on private property near Tucson (Westland 2006, p. 1). In 2015, personnel from Pima County located 19 of these individuals and noted that not only had they survived for 10 years, many had pups, flowers, and or fruits (Powell and Rice 2015, pp. 1-2).

Unfortunately, the circumstances of the initial transplant were not recorded, so we are unable to replicate their method.

Recent studies within the Pascua Yaqui tribal *C. scheeri* var. *robustispina* conservation land (a 13.8 ha [34 ac] parcel set aside to mitigate *C. scheeri* var. *robustispina* loss on tribal land) will provide much needed information on the possibility of transplanting as a tool for conservation. Most recently, research into transplanting *C. scheeri* var. *robustispina* on the Sierreta Pipeline (part of mitigation measures for the creation of the pipeline through *C. scheeri* var. *robustispina* habitat) found avoidance to be a better conservation measure than transplanting (Berthelette 2017, p. 33). This research also determined that, similar to Schmalzel's findings in 2000, bare rooted plants had higher mortality than those transplanted with adjacent soil (Berthelette 2017, p. 33).

A possible alternative to transplanting is the sowing of seeds directly in the field (*in situ*) and covering them with hardware cloth to prevent predation. This method has shown some success (Schmalzel 2000a, pp. 13-14; Service 2015b, pp. 3-4), but more research is needed. The substrate seeds are sown onto also needs further examination. For example, preliminary work by Schmalzel (2000c, p. 12) indicated that germination occurred in 4 of 8 cages where seeds were sown on soil with a thin crust of cyanobacteria. In this same work, no seeds germinated from 16 cages where seeds were sown on either coppice mounts or sandy shifting soil. It is unknown if the presence or absence of mycorrhizae or endophytic bacteria impact seedling survival. Bashan et al. (2000, p 165), in a study of other cacti species of the Sonoran Desert, concluded the presence of mycorrhizae was not the primary factor for the establishment of cactus seedlings and that edaphic factors probably play a more important role. However, others report that mycorrhizal symbiosis has been observed in desert plants and may improve drought tolerance and nutrient uptake (e.g. Cui and Nobel 1992, p. 648; Apple 2009, p. 122). Fonseca-Garcia et al. (2016, p. 10) note that cyanobacteria in desert soil crust may provide a significant input of nitrogen and moisture for cacti.

Part II. Recovery

1. Recovery Strategy

The principle recovery strategy is to preserve and restore *C. scheeri* var. *robustispina* habitat to protect individuals and their associated seedbanks within two recovery units representing the entire population and range of the taxon. The two recovery units center on the Altar and Santa Cruz valleys of southeastern Arizona. The major threats within the Altar Valley Recovery Unit, which is comprised of many private cattle ranches and State and Federal lands, include the spread of invasive, nonnative grasses and the resultant altered fire regimes and increased competition with native species. Urbanization is the major threat within the Santa Cruz Valley Recovery Unit, which includes Tucson, Nogales, and the areas between.

Throughout the entire range, *C. scheeri* var. *robustispina* is stressed by drought exacerbated by climate change, as well as predation by mammals and insects. The conservation and restoration of habitat within these two recovery units will promote a stable, self-sustaining population to persist with some level of connectivity between individuals throughout the range, and provide opportunities for population expansion.

We define a self-sustaining population as one that is stable or shows positive population growth for 10 years over a 15-year period, with evidence of natural reproduction and establishment. The recovery strategy entails minimizing or ameliorating the most significant long-term threats to the continued existence of the taxon, which are: 1) habitat loss due to mining and urbanization and 2) competition with nonnative grasses such as *C. ciliaris* and *E. lehmanniana*, and alteration of fire regimes. Additional efforts will focus on improving our understanding of *C. scheeri* var. *robustispina* ecology, distribution, and threats, as well as, reducing the impacts of stressors such as recreation and border activity and potential impacts from livestock grazing.

2. Recovery Goal

The ultimate goal of this Recovery Plan is to outline specific actions that, when implemented, will sufficiently reduce the threats and stressors to *C. scheeri* var. *robustispina*, ensure its long-term viability in the wild, and improve its status to the point that protection under the Act is no longer necessary.

3. Recovery Objectives

Major Objectives:

1) Threat and Habitat-based objective: Conserve, restore, and properly manage the quantity and quality of habitat (e.g. protected for conservation purposes, less than 20 percent cover of invasive nonnative plant species, contains contiguous habitat and corridors for pollinators; also see Habitat section above – e.g. <10% slope, 728-1,280 m elevation, Quaternary period soils, desert-scrub and desert-grassland vegetation type) needed for the continued survival of *C. scheeri* var. *robustispina* and its pollinators. This includes the reduction or mitigation of habitat loss and degradation; spread of invasive, nonnative plant species and the resultant altered fire regimes and increased competition; and other stressors.

2) Population-based objective: Conserve, protect, and restore existing and newly discovered *C. scheeri* var. *robustispina* individuals their seedbanks (approximately 10 meters), and habitat for pollinators (approximately 900 meter radius) in each recovery unit to ensure survival of the taxon. Maintaining and increasing successful seed set into the seedbank is important because seed availability must coincide with wet years for germination and initial seedling survival. The population must be self-sustaining, of sufficient number to endure climatic variation, stochastic events, and catastrophic losses, and must represent the full range of the species' geographic and genetic variability.

Detailed Objectives:

1) Threat-based objectives.

   Listing Factor A (habitat loss and degradation).

   1.1 Prevent the net loss or significant degradation of habitat within the population of *C. scheeri* var. *robustispina* and its pollinators. Loss or degradation of some occupied habitats

may be mitigated by a proportional increase or improvement of other occupied habitats; this may be accomplished through improved management, the in-perpetuity protection of existing occupied habitat, successful habitat restoration, or the discovery of new occupied habitats.

1.2 Reduce impacts from nonnative plant invasion. Currently, the principle nonnative species threats to *C. scheeri* var. *robustispina* are *E. lehmanniana* and *C. ciliaris*. Work toward developing or improving methods of habitat restoration in lands infested with these and other nonnative species.

Listing Factor B (over-utilization).

1.3 Prevent depletion of extant *C. scheeri* var. *robustispina* population and associated soil-seedbank. Seed collection, propagation, augmentation, and reintroduction efforts must comply with Service policy on controlled propagation of endangered species (Service 2000b, entire), including the prior establishment of a controlled propagation and reintroduction plan.

Listing Factor C (disease and predation).

1.4 A *C. scheeri* var. *robustispina* monitoring protocol will be developed and implemented to monitor for ongoing predation.

1.5 If excessive predation impact is occurring, individual *C. scheeri* var. *robustispina* plants may be protected with wire cages, hardware cloth, or other means of protection, as appropriate.

Listing Factor D (inadequacy of existing regulatory mechanisms).

1.6 Conserve *C. scheeri* var. *robustispina* in the United States through implementation of section 7 of the Act. When delisted, the continued status of the taxon should be tracked according to a post-delisting monitoring plan.

1.7 Collaborate and communicate with Tribal and State scientists, conservation planners, and private landowners to promote the species' conservation on State and private lands; seek information on the species status on Tribal and private lands.

1.8 Collaborate and communicate with Mexican government agencies, scientists, and conservation organizations to promote the species' conservation in Mexico; seek information on the species status and protection in Mexico.

Listing Factor E (other natural or man-made factors).
See population-based objectives below.

2) Habitat-based objectives.

Listing Factor A (habitat loss and degradation).
2.1 Determine the climate, soils, hydrology, and associated vegetation of *C. scheeri* var. *robustispina* habitat to guide surveys and conservation.

2.2 Increase the amount of protected *C. scheeri* var. *robustispina* habitat through acquisition of land for conservation purposes, successful habitat restoration on protected lands, or improved management and protection of existing habitat.

2.3 Alleviate habitat fragmentation and isolation and increase pollinator corridor protection. Habitats must be large enough to support healthy pollinator populations and allow for gene flow among neighboring individuals. Ideally, *C. scheeri* var. *robustispina* habitats are intact or restored to optimal or good quality (see habitat quality descriptions in Criterion 1 below), and these lands are managed for conservation of native flora and fauna and contain associated cacti species required by pollinators. Areas of smaller, protected, habitat patches may be considered suitable through linkage by intact or restored ecological corridors sufficient to allow passage of the insect pollinators of *C. scheeri* var. *robustispina* between habitat blocks.

2.4 Determine the best habitat management practices, and implement these practices where this is possible. Document the effects on *C. scheeri* var. *robustispina* habitat by wildfire and prescription fire, nonnative plant invasions, livestock grazing of varying intensities and timing, and off-road vehicle use. Further our understanding of nurse plants and associated pollinator plants in relation to *C. scheeri* var. *robustispina*. Implement best management practices where suitable habitat occurs on lands under Federal jurisdiction, and provide technical assistance and incentives to implement these practices on suitable habitat not under Federal jurisdiction.

3) Population-based objectives.

Listing Factor E (other natural or man-made factors).

3.1 Encourage scientific study to improve our understanding of *C. scheeri* var. *robustispina* biology, ecology, abundance, status, threats and stressors, viability, propagation, restoration of individuals and of habitat, distribution, and genetics in the United States and Mexico. Continue the development of effective methods of survey and coordinate surveys by qualified individuals in potential habitats throughout southern Arizona and northern Sonora, Mexico to demonstrate the species' presence and abundance or absence. Report on the associated species, habitats, ecology, and threats and stressors to *C. scheeri* var. *robustispina*. Surveys may be conducted on public lands and where private landowners and ejidos (communal land in Mexico used for agriculture) have granted permission for this purpose.

3.2 To determine long-term population trends, conduct long-term monitoring of *C. scheeri* var. *robustispina* individuals (e.g. size, health, phenology, etc.), habitat characteristics (e.g. associated species cover, soil moisture, solar radiation, etc.), and threats and stressors (e.g. nonnative plants, fire, predation, trampling, soil compaction, soil erosion, etc.). Ensure monitoring of transplanted individuals, plants grown *in situ*, and plants that have experienced disturbances such as fire and nonnative invasion. Monitor the impacts of habitat restoration on individual *C. scheeri* var. *robustispina* plants. Monitoring may be conducted on public lands and where private landowners and ejidos have granted permission for this purpose.

Monitoring must be carried out in a manner that minimizes potential negative impacts on the species and its habitat. Written agreements to continue monitoring after downlisting and delisting must be in place.

3.3 Prevent a net loss or decline of documented *C. scheeri* var. *robustispina* plants through improved management, protection, and augmentation of the existing population, successful reintroduction of plants, or the discovery of new plants through improved detection methods such as detection dogs, drones, distance sampling, and other techniques. Augmentation and reintroduction must comply with Service policy on controlled propagation of endangered species (Service 2000b, entire), including the prior establishment of a controlled propagation and reintroduction plan.

3.4 Prevent the depletion of genetic diversity within the *C. scheeri* var. *robustispina* population resulting from inbreeding depression (when closely related individuals mate and offspring have high chance of maintaining disadvantageous traits), outbreeding depression (when non-closely related individuals mate and fitness is low), genetic swamping (when genes from one group dominate over another group), or other factors. This objective requires a thorough understanding of the species' reproductive biology, pollination and pollinators, breeding system, and genetic variation within the population. This factor also requires the preservation of connectivity between individuals within the population.

3.5 Increase the number of protected plants to confer the resiliency, redundancy, and geographic and genetic representation necessary for the continued survival of *C. scheeri* var. *robustispina*. This objective may be reached largely through the conservation of land containing suitable habitat for the taxon. This objective may be reached in part by augmenting the natural population and by reintroducing plants onto protected land, within the species' range and known habitat types, in accordance with the Service policy on controlled propagation of endangered species (Service 2000b, entire) and a controlled propagation and reintroduction plan.

3.6 Assess the best *C. scheeri* var. *robustispina* management practices and implement these practices where this is possible. Document threats and stressors, design experiments to test their effects, and monitor their effects on *C. scheeri* var. *robustispina* plants. These experiments could include wildfire, nonnative plant invasion, presence of livestock, and predation by mammals and insects. Implement best management practices where plants occur on lands under Federal jurisdiction, and promote these practices on occupied habitat not under Federal jurisdiction.

3.7 Establish plants at botanical gardens for research, recovery, and educational purposes, and maintain seeds for conservation and recovery at seed storage facilities. Seeds should be genetically representative samples from determined focal areas (e.g. representing a range of elevation, slope, soil types, etc.), with appropriate targets for quantities and collection areas represented. Collect seed over time and conditions to capture expressed genetic variability, and gradually accumulate sufficient seed to support well-planned augmentation and reintroduction work.

3.8 Develop public outreach, collaborative partnerships, agency management plans, and agreements with private landowners in the United States and Mexico that encourage *C. scheeri* var. *robustispina* conservation.

4. Recovery Criteria

An endangered species is defined in the Act as a species that is in danger of extinction throughout all or a significant portion of its range. A threatened species is one that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range. When we evaluate whether or not a species warrants downlisting or delisting, we consider whether the species meets either of these definitions. A recovered species is one that no longer meets the Act's definitions of threatened or endangered due to amelioration of threats and no longer needs the protections of the Act. Determining whether a species should be downlisted or delisted requires consideration of the same five categories of threats that were considered when the species was listed and which are specified in section 4(a)(1) of the Act.

Recovery criteria are conditions that, when met, are likely to indicate that a species may warrant downlisting or delisting. Thus, recovery criteria are mileposts that measure progress toward recovery. Because the appropriateness of delisting is assessed by evaluating the five threat factors identified in the Act, the recovery criteria below address the applicable factors identified at the time the taxon was listed. These recovery criteria are our best assessment at this time of what needs to be completed so that the taxon may be removed from the list of threatened and endangered species. Because we cannot envision the exact course that recovery may take and because our understanding of the vulnerability of a species to threats is very likely to change as more is learned about the taxon and its threats, it is possible that a future status review may indicate that delisting is warranted although not all recovery criteria are met. Conversely, it is possible that the recovery criteria could be met and a future status review may indicate that delisting is not warranted.

To downlist *Coryphantha scheeri* var. *robustispina* from endangered to threatened status, all of the following conditions must be met to address the threats and stressors to the species:

1. Threat and Habitat-based objective: Conserve, restore, and properly manage the quantity and quality of habitat (e.g. protected for conservation purposes, less than 20 percent cover of invasive nonnative plant species, contains contiguous habitat and corridors for pollinators; also see Habitat section above – e.g. <10% slope, 728-1,280 m elevation, Quaternary period soils, desert-scrub and desert-grassland vegetation type) needed for the continued survival of *C. scheeri* var. *robustispina* and its pollinators. This includes the reduction or mitigation of habitat loss and degradation; spread of invasive, nonnative plant species and the resultant altered fire regimes and increased competition; and other stressors.

   Criterion: Threats and Habitat Criterion: At least 8,094 hectares (ha) (20,000 acres [ac]) of *C. scheeri* var. *robustispina* habitat per recovery unit are documented to be of optimal quality and remain that way through successful resource management, land conservation, and restoration techniques such as *in situ* germination. At least 24,281 ha (60,000 ac) of *C. scheeri* var. *robustispina* habitat per recovery unit are documented to be of good quality and remain that way in perpetuity.

Habitat is considered optimal quality when it: is protected for conservation purposes; is managed in a manner that promotes the long-term survival of *C. scheeri* var. *robustispina*; has less than 20 percent cover of *C. ciliaris, E. lehmanniana,* or other invasive nonnative plant species that alter ecosystem function; contains contiguous habitat and corridors for pollinators; and the *C. scheeri* var. *robustispina* population is observed to be stable or increasing.

Habitat is considered good quality when the cover of *C. ciliaris, E. lehmanniana*, or other nonnative plants that alter ecosystem function remains between 20 and 35 percent; the land is managed in such a way that promotes the continued existence or expansion of long-term survival of *C. scheeri* var. *robustispina*. Collectively, this represents approximately 42 percent of the known range of *C. scheeri* var. *robustispina.* Additional acres of lesser quality *C. scheeri* var. *robustispina* also exist throughout the range of the species; some of which occurs on lands where ongoing efforts may continue to improve habitat quality.

We believe that achieving the above targets of optimal and good quality habitat could significantly improve the conservation trajectory and status of this taxon to the point of downlisting under the Act.

Justification: Accomplishment of this criterion depends on successful resource management, land conservation, and restoration techniques to improve habitat quality for *C. scheeri* var. *robustispina*. *Coryphantha scheeri* var. *robustispina* plants that occur in optimal or good condition habitats, as defined above, should have the greatest resistance to nonnative plant invasion and associated high severity fire, as well as, to climatic extremes and other threats or stressors. We expect that these habitats will have healthy pollinator populations that enable gene flow between *C. scheeri* var. *robustispina* individuals, thus maintaining their long-term genetic diversity. Although only 42 percent of the known range would be in either optimal or good quality habitat, it is unlikely that more than this could be achieved due to the aggressiveness and persistence of nonnative grasses in the landscape.

2. Population-based objective: Conserve, protect, and restore existing and newly discovered *C. scheeri* var. *robustispina* individuals their seedbanks (approximately 10 meters), and habitat for pollinators (approximately 900 meter radius) in each recovery unit to ensure survival of the taxon. Maintaining and increasing successful seed set into the seedbank is important because seed availability must coincide with wet years for germination and initial seedling survival. The population must be self-sustaining, of sufficient number to endure climatic variation, stochastic events, and catastrophic losses, and must represent the full range of the species' geographic and genetic variability.

Criterion: Conserve, protect, and restore mature *C. scheeri* var. *robustispina* individuals, their seedbanks (approximately 10 meters), and habitat for pollinators (approximately 900 meter radius) in each recovery unit through resource management, land conservation, and restoration techniques such as *in situ* germination. Quantitative monitoring, using a standardized monitoring protocol, of established plots across a variety of land ownerships and land management scenarios, with landowner support, is conducted within each of the two

recovery units every 3 to 5 years. Plots demonstrate that the population is stable or increasing a minimum of 10 years over a 15-year period.

Justification: A mature individual is one that is capable of flowering and producing viable seed. Only mature individuals are considered in meeting this criterion, since large numbers of *C. scheeri* var. *robustispina* seeds may germinate following sporadic rainfall but not live long enough to reproduce. The number of monitoring plots and transects and their locations will be determined within a monitoring plan to be written within five years of the finalization of this document. The 15-year timeframe reflects the minimum period required to judge whether a population is stable, declining, or increasing. The species has a long generation time (>12 years to maturity) and warrants at least this timeframe to determine trends. In addition, due to the wide variation in the region's annual rainfall and the frequencies of severe droughts and freezes, populations will naturally fluctuate. The numbers of individuals during a single year or short span of years may provide a skewed representation of a population's longer-term trend.

To delist *C. scheeri* var. *robustispina*, the first two criteria for downlisting must be met or surpassed, and monitoring must demonstrate that the population is increasing for a minimum of 20 years over a 30-year period. The additional time necessary to achieve delisting ensures continued population viability. Additionally, it will allow land managers to continue to reduce threats to *C. scheeri* var. *robustispina* from nonnative species invasion achieved during downlisting and track the long-term effectiveness of management. The additional time will also allow land managers to develop methods to reduce anticipated cost and effort needed to maintain habitat and population viability absent the protections of the Act.

5. Recovery Action Outline and Narrative

The recovery action outline and narrative below lists actions, including site-specific management actions, required to meet the recovery objectives of this recovery plan. Please refer to Table 1 for a clear association among threats, stressors, and recovery actions.

1) Conserve existing and newly discovered *C. scheeri* var. *robustispina* and associated habitat, including unoccupied areas that provide habitat and connectivity for pollinators.

a) Promote urban planning for compact urban development, increase open space preservation and management (e.g. restrictions on trash dumping, off road vehicle use, placement of pedestrian trails, etc.), and connective habitat corridors.

Collaborations such as Pima County's Sonoran Desert Conservation Plan and Multi-Species Conservation Plan are essential for planning for development within *C. scheeri* var. *robustispina* in the United States. The human population of Pima County is expected to increase by one third in the next 35 years; development planning, including a better understanding of the role and value of open space preserved and managed within developments, especially in the areas of Tucson and the Santa Cruz Valley, are essential to the conservation of this taxon.

b) Engage in land acquisition to reduce habitat fragmentation and increase connectivity.

Tools for the protection of *C. scheeri* var. *robustispina* on privately-owned lands may include the purchase and management of such lands by government agencies or other conservation partners. Management of acquired properties would prohibit habitat conversion to urban uses. Managers would also develop and implement management plans promoting the conservation of *C. scheeri* var. *robustispina*. Potential sources of funding for the purchase of such properties include section 6 acquisition funds for habitat conservation plans, bond monies through county governments, or Wildlife Refuge acquisition funds.

c) Develop conservation easements for the protection of *C. scheeri* var. *robustispina* on private lands.

The protection of *C. scheeri* var. *robustispina* on privately-owned lands may also occur through the voluntary donation or sale of a conservation easement by a willing landowner to a qualified non-profit organization or branch of government. In a conservation easement, the land remains in private ownership with landowners in full control of their property. The deed of easement will, however, identify compatible and incompatible land uses and other management considerations for the taxon and its habitat. At a minimum, the deed of easement must prohibit habitat conversion to urban uses within *C. scheeri* var. *robustispina* habitat. Such lands must be covered by a management plan with best management practices that benefit *C. scheeri* var. *robustispina*.

d) Develop and monitor conservation mitigation banking to promote the protection of *C. scheeri* var. *robustispina* habitat.

Conservation mitigation banks aid in the protection of *C. scheeri* var. *robustispina* habitat that is being lost to urban development and other threats and stressors. There are two types of banks. One offers a market framework where the purchase of conservation bank credits for project-related impacts can be offset through a one-time credit purchase. There are currently two *C. scheeri* var. *robustispina* banks in place. The second type offers mitigation through preserving in place a portion of the land to be developed. This preservation in place may help achieve habitat connectivity and integrity goals.

2) Restore quality *C. scheeri* var. *robustispina* habitat in the U.S. and Mexico.

a) Develop and implement land management plans that support and promote the taxon, including through the reduction of nonnative plant species and unnatural fire regimes, soil erosion, soil compaction, and headcutting.

Management plans will include provisions, as appropriate, for habitat maintenance and restoration including decrease in cover of nonnative plants, remediation of unnatural fire regimes and the development of natural refugia, increased soil retention and water infiltration, decreased soil compaction and erosion, minimization of mechanical damage to plants, and identification of locations suitable for transplanting or growing cacti from seed.

In particular, nonnative plants put undue stress on *C. scheeri* var. *robustispina* and its habitat by competing for light, water, and nutrients, as well as by altering the fire regime and reducing available refugia. Efforts should be made to prevent further introduction or spread of nonnatives in systems that support *C. scheeri* var. *robustispina*. Whenever possible, established nonnative plants should be removed from systems that support *C. scheeri* var. *robustispina* and landscapes restored to promote native species and ecosystem function.

Management actions must be monitored (pre- and post-, when possible) to assess their effectiveness or discover unintended consequences. Management plans shall be modified if they are unsuccessful at providing protection and promoting recovery of *C. scheeri* var. *robustispina* and its habitat. This will facilitate the implementation of an adaptive management approach to recovery.

b) Work toward a better understanding of transplanting and seeding requirements for *C. scheeri* var. *robustispina* which could be implemented in appropriate habitat.

Past efforts to transplant individual *C. scheeri* var. *robustispina* to other locations have had limited success. As such, the Service does not currently consider transplanted *C. scheeri* var. *robustispina* as functional in their environment. Development of tested protocols that obtain high transplant success rates are needed. In addition, development of tested protocols for growing cacti from seed *in situ* in appropriate habitat that is managed for the conservation of the taxon, are needed.

3) Develop range-wide standardized long-term monitoring of individuals in established plots, as well as their habitats, threats, and stressors.

a) Monitor individuals in established plots across the range of the taxon using a tested standard protocol to enable an understanding of the long-term trend of the species, its habitat, threats, and stressors.

Develop and test a range-wide standardized long-term monitoring approach that will be adopted by all land managers, landowners, and conservation partners which will enable an understanding of current status and knowledge of when recovery criteria have been met. This will include: 1) timing of survey, 2) protocol for surveying and measuring individuals and their habitats, and 3) assessing the health of plants, threats, and stressors. Monitoring should also include pollinators, predators, climate, and other factors that may be influencing the taxon. Monitoring must be carried out in a manner that minimizes potential negative impacts on the species and its habitat. Written agreements to continue monitoring after downlisting must be in place.

b) Check the effectiveness of management actions by monitoring individuals subjected to natural and prescribed fire, mechanical site disturbance, various grazing regimes, various restoration techniques, and other management considerations.

Monitoring of plants that have experienced disturbance should take place at least every 3 years over a period of 15 years and, whenever possible, include pre-disturbance monitoring.

c) Monitor *in situ* grown and transplanted individuals for effectiveness of sowing, planting, and transplanting protocols.

Plants grown *in situ* or transplanted to a new location should be monitored at least every year for the first 5 years, and then every 3 years thereafter over a period of 15.

4) Encourage scientific study to improve our understanding of *C. scheeri* var. *robustispina* biology, ecology, abundance, status, threats, stressors, viability, propagation, restoration of individuals and of habitats, distribution, and genetics in the United States and Mexico.

a) Identify information gaps, compatible land uses, threats, stressors, and appropriate management actions that lead to the conservation of the taxon.

It is important to identify gaps in our current understanding of the taxon and how it relates to certain land management practices so that adaptive management (e.g. decision-making, follow-up monitoring, assessment, learning and feedback, institutional learning; Williams and Brown 2012, p. vii) can be practiced. Such information will inform better management of the taxon for its continued protection and recovery. For example, we currently lack adequate information related to the threshold at which disturbances such as cattle grazing are beneficial or detrimental to the taxon, the impact of natural and prescribed fire in relation to nonnative grasses and fire-free microsites, the impacts of drought, illegal collection, off road vehicles, mining, and other threats and stressors.

b) Conduct surveys in appropriate habitat, using a tested standard protocol, to better understand the geographic range and habitat requirements of the taxon. Investigate the feasibility of alternative survey methodologies, such as the use of detection dogs, drones, and distance sampling.

There is potential habitat in both the United States and Mexico that has not been surveyed for the presence of *C. scheeri* var. *robustispina.* Additional surveys are needed and repeated surveys or monitoring conducted to confirm continued presence at known locations.

c) Conduct research related to the biology, ecology, abundance, status, threats, stressors, viability, propagation, restoration of individuals and of habitat, and genetics of the taxon.

Although we currently know more about *C. scheeri* var. *robustispina* than at the time of listing, there remains a great deal about the biology, ecology, abundance, status, threats, stressors, viability, propagation, restoration of individuals and of habitat, and genetics of this taxon that we still do not understand. Examples of research that is needed to help recover this species include:

i) how long this taxon is able to withstand drought (seedbank longevity, predation impacts, desiccation, etc.)
ii) what is the relationship of the taxon to natural and prescribed fire in nonnative invaded landscapes,
iii) what is the threshold at which disturbance negatively impacts the taxon,
iv) what is the tolerance of the taxon to grazing, trampling, soil compaction, and soil erosion,
v) what are the most cost-effective and appropriate methods of habitat restoration in nonnative invaded landscapes? E.g. can the use of mycorrhizae or soil bacteria aid in restoration of *Eragrostis*-dominated grasslands,
vi) what is the relationship of the taxon to ants, jackrabbits, and other predators or dispersal agents, and
vii) what is the minimum patch size and degree of connectivity needed for this taxon to persist?

5) Maintain plants in captivity at botanic gardens and seeds at seed storage facilities; encourage research into propagation, *in situ* seed planting, and transplanting methods.

a) Promote the propagation and planting of individuals *ex situ* at botanic gardens for conservation and public education purposes.

Botanic gardens are protected and carefully managed areas that provide a last resort option for protecting individual plants threatened with habitat destruction. Botanic gardens also serve the important purpose of educating the public regarding threatened and endangered plants, and are sources of research, especially regarding genetics, propagation, and transplanting techniques.

b) Maintain seed from plants across the geographic range of the taxon for conservation purposes.

Ensure that seed is collected following the Center for Plant Conservation guidelines, is collected across both wet and dry years, and from a variety of geographic areas to ensure maximum genetic variability. Seed should be stored at both the Agricultural Research Service National Center for Genetic Resources Preservation in Fort Collins, Colorado and stored according to protocols at a local facility such as the Arizona-Sonora Desert Museum in Tucson, Arizona. In accordance with protocol, seed would be tested regularly for viability and replaced as necessary. Seeds would be used for research, seed storage, augmentation, and reintroduction.

c) Develop effective approaches to *in situ* conservation.

Because transplanting success has historically been variable, transplant methodology and *in situ* planting of seed in the field using hardware cloth or other techniques warrant further examination. There could be benefit from direct planting into native soils with appropriate mycorrhizae, although additional watering may be required to mimic wet year germination. Common garden experiments using different aged cacti may also

assist in the understanding of causes of mortality and survival of individual *C. scheeri* var. *robustispina*.

6) Develop public outreach, collaborative partnerships, and agreements with private landowners in the United States and Mexico that encourage *C. scheeri var. robustispina* conservation.

a) Increase public outreach regarding threats, stressors, and conservation measures relating to *C. scheeri* var. *robustispina* in both the United States and Mexico.

Work with both United States and Mexican government agencies, academic institutions, non-government organizations, and private citizens to promote public outreach and ultimately recovery of *C. scheeri* var. *robustispina* throughout its range. These agencies and groups likely include The Arizona Land and Water Trust, Arizona-Sonora Desert Museum, Arizona State University, Bureau of Land Management, Desert Botanical Garden, Fish and Wildlife Service, Forest Service, Pascua Yaqui Tribe, Secretaría de Medio Ambiente y Recursos Naturales, The Nature Conservancy, Tohono O'odham Nation, University of Arizona, United States Geological Survey, Universidad Nacional Autónoma de Mexico, and Universidad de Sonora.

b) Develop collaborative partnerships and agreements with private landowners that result in management plans or that otherwise encourage *C. scheeri* var. *robustispina* conservation in the United States and Mexico.

Develop partnerships with both United States and Mexican government agencies, academic institutions, non-government organizations, and private citizens to promote study, conservation, and recovery of the taxon throughout its range. The creation and adherence to management plans that address threats and stressors are necessary to protect the taxon and its habitat. Plans should include prescriptions to protect *C. scheeri* var. *robustispina* from habitat degradation, nonnative plant species, and that address restoration of habitat and the timing and intensity of prescribed burns.

c) Develop a recovery implementation team comprised of species experts, agency and non-government agency partners, landowners, and stakeholders to meet regularly, review progress, discuss problems, and revise this plan as needed.

This plan may need to be revised to address changing conditions, incorporate new findings, and update recovery actions. To ensure plan use and usefulness, the involvement of an implementation team is suggested.

Part III. Implementation

The following implementation schedule is comprised of three overarching elements that then tier down to individual recovery actions for implementation. The implementation schedule outlines actions and estimated costs for this draft recovery plan. It is a guide for meeting the objectives discussed in Chapter II. This schedule also prioritizes actions, provides an estimated timetable for performance of actions, and proposes the responsible parties for actions. For the sake of brevity in the Implementation Schedule, annual costs are shown for the first 5 years, along with an estimated total cost over a 20-year period, the minimum amount of time anticipated for recovery. Actions are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions. The most detailed actions are assigned a priority number for implementation. The actions in the Implementation Schedule, when accomplished, should result in the recovery and conservation of the species.

Key to Terms and Acronyms Used in the Recovery Action Narrative and Implementation Schedule:

Priority numbers are defined per Service policy (Service 1983) as:

Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.

Priority 2: An action that must be taken to prevent a significant decline in the species population/habitat quality or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to provide for full recovery of the species.

Explanation of Time Estimates:

20 Years – An action that involves continuous implementation throughout the recovery timeframe (minimum duration of 20 years), but is not yet underway, such as acquisition of conservation easements.

1-19 Years – A discrete action that will be implemented and completed within the specified timeframe, such as a scientific study.

P = Periodic – An action that will be implemented on a fairly regular or rotating basis, such as monitoring.

Responsible Parties:

ADOT	Arizona Department of Transportation
ALWT	Arizona Land and Water Trust
ARS	Agricultural Research Service
ASDM	Arizona-Sonora Desert Museum
ASU	Arizona State University
BLM	Bureau of Land Management
DBG	The Desert Botanical Garden
FWS	United States Fish and Wildlife Service
GOV	State or local governments and municipalities
NGO	Non-government organization
PC	Pima County
PYT	Pascua Yaqui Tribe
PVT	Private citizens
SNAT	Secretaría de Medio Ambiente y Recursos Naturales
TNC	The Nature Conservancy
TON	Tohono O'odham Nation
UA	University of Arizona
USFS	United States Forest Service
USGS	United States Geological Survey
UNAM	Universidad Nacional Autónoma de México
USON	Universidad de Sonora

Responsible parties are those agencies who may voluntarily participate in implementation of particular actions listed within this Recovery Plan. Responsible parties may willingly participate in project planning, or may provide funding, technical assistance, staff time, or any other means of implementation; however, responsible parties are not obligated to implement any of these actions. Other parties are invited to participate in the recovery of *C. scheeri* var. *robustispina*, as well.

Implementation Schedule

Costs are shown in 1,000s of dollars; we estimated cost over a 20-year period, which is the minimum amount of time anticipated to recover the species. Total cost over a 20-year period is $62,925,460. If recovery is not achieved within the first 20 years, we assume an additional cost of $1,173,230 over the subsequent 10 years to recovery (from 2038 to 2048) for a total cost to recovery of $64,098,690.

The importance of preserving functional *C. scheeri* var. *robustispina* habitat, including corridors for pollinators, in the United States cannot be overstated in the recovery of this and co-occurring listed species. The Pima County Association of Governments (2013, entire) projects current population of Pima County, where most *C. scheeri* var. *robustispina* occur, is 1,008,442 and it will rise to 1,518,154 by 2050. This projection emphasizes the need for urban development planning to concentrate development near urban areas and provide for conservation lands and corridors. It also emphasizes the need to restore existing *C. scheeri* var. *robustispina* habitat.

Restoring and preserving desert-scrub and desert-grassland will benefit *C. scheeri* var. *robustispina* and many other co-occurring listed and unlisted plant and animal species, ecosystem services provided by healthy landscapes, and economic benefits such as from increased tourism. Actions taken to improve desert-scrub and desert-grassland habitats for Sonoran desert tortoise (*Gopherus morafkai*), cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*), lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*), and masked bobwhite (*Colinus virginianus ridgewayi*) would benefit *C. scheeri* var. *robustispina*; therefore, costs listed below may not reflect the actual cost of recovery as such costs may be distributed across a variety of efforts targeting desert-scrub and desert-grassland restoration, reducing the recovery cost per species.

Implementation Schedule for *Coryphantha scheeri* var. *robustispina*; Threats*: a) Habitat loss due to commercial development; b) Historical range management practices, nonnative plant invasion, and altered fire regimes; c) Habitat degradation due to poorly managed livestock grazing d) Recreation and border activity; e) Illegal collection; f) Disease or predation; g) Inadequacy of existing regulatory mechanisms; h) Drought and climate change; i) Small population size and isolation. If recovery is not achieved within the first 20 years, we assume no additional cost over the subsequent 10 years to recovery (2038-2048), with the exception of: 1) reduction of nonnative plant species, soil compaction and erosion, and headcutting (2a, 6b), 2) monitor individuals in established plots across the range of the taxon (3a), and 3) check the effectiveness of management actions by monitoring individuals subjected to natural and prescribed fire, mechanical site disturbance, varied grazing regimes, and other management considerations (3b).

Priority Number	Threats*	Action Number	Action Description	Time Estimate (Years)	Responsibility	Total Cost (1,000s)	Cost ($1,000s) for Years 1-5	Cost ($1,000s) for Years 6-10	Cost ($1,000s) for Years 11-15	Cost ($1,000s) for Years 16-20	Comments
1	a; h; i	1a-b	Engage in land acquisition to reduce *C. scheeri* var. *robustispina* habitat fragmentation and increase connectivity.	20	FWS PC TNC	40,000	10,000	10,000	10,000	10,000	We based this cost on the historical cost of Pima County conservation acquisitions and currently available properties for sale; $2,000 /ac with a goal of acquiring 20,000 ac over the first 20 years.
1	a; h; i	1c	Develop conservation easements for the protection of *C. scheeri* var. *robustispina* on private lands.	20	ALWT FWS TNC PVT	20,000	5,000	5,000	5,000	5,000	We based this cost on an average cost of $1,000 /ac to acquire conservation easements, with a goal of 20,000 ac of private land put into easements over the first 20 years.
1	a; h; i	1d	Develop and monitor conservation mitigation banking to promote the protection of *C. scheeri* var. *robustispina* habitat.	20	ALWT FWS GOV PVT TNC	55	15	14	13	13	We based this cost on the cost of private conservation bank development and monitoring for *C. scheeri* var. *robustispina* in the Altar Valley.

Priority Number	Threats*	Action Number	Action Description	Time Estimate (Years)	Responsibility	Total Cost (1,000s)	Cost ($1,000s) for Years 1-5	Cost ($1,000s) for Years 6-10	Cost ($1,000s) for Years 11-15	Cost ($1,000s) for Years 16-20	Comments
1	a; b; c; d; e; g; i	2a, 6b	Develop and implement land management plans that support and promote the taxon, including through the reduction of nonnative plant species, soil compaction and erosion, and headcutting.	20	ALWT BLM FWS PVT TNC USFS	2304.2	579	575	575	575	Continuous through recovery. We based this cost on 1) management plan development (5 agency people at $35/hour, 8 hours/day for 3 days) 2) an average of the AGFD cost to restore an area of Bonito Grasslands in southern AZ ($600,000 for 20,000 ac or $30/ac; AGFD 2011, entire) and the USFS cost estimates for herbicide treatment of nonnative herbs and grasses ($40,000,000 for 20,000 ac or $200/ac).
1	a; b; c; d; i	2b, 3c	Work toward a better understanding of transplanting and seeding requirements for *C. scheeri* var. *robustispina*, which could be implemented in appropriate habitat.	10	ASDM ASU DBG FWS PVT UA USFS	90	60	30	0	0	We based this cost on the average cost of scientific studies of Arizona's rare plants that have been funded through our section 6 plant program. Anticipating three studies in the first 10-year period, at an average cost of $30,000/study.
2	a	3a	Monitor individuals in established plots across the range of the taxon to enable an understanding of the long-term trend of the species, its habitat, threats, and stressors.	P	BLM FWS TNC TON USFS USGS	27.56	10.04	5.84	5.84	5.84	Every 5 years; through recovery. We based this cost on the cost of: 1) monitoring plan development (5 agency people at $35/hour, 8 hours/day for 3 days) and 2) the cost of personnel and travel to monitor plots ($35/hour, 10 hours/day, 2 people, $30 gas per trip, 8 days/5 year period).

Priority Number	Threats*	Action Number	Action Description	Time Estimate (Years)	Responsibility	Total Cost (1,000s)	Cost ($1,000s) for Years 1-5	Cost ($1,000s) for Years 6-10	Cost ($1,000s) for Years 11-15	Cost ($1,000s) for Years 16-20	Comments
2	a; b; c; d; f	3b	Check the effectiveness of management actions by monitoring individuals subjected to natural and prescribed fire, mechanical site disturbance, varied grazing regimes, and other management considerations.	P	BLM FWS GOV TON USFS USGS	27.3	9.975	5.775	5.775	5.775	Every 3 years; through recovery. We based this cost on 1) monitoring plan development (5 agency people at $35/hour, 8 hours/day for 3 days) and 2) the cost of personnel and travel to monitor plants impacted by management actions ($35/hour, 10 hours/day, 2 people, $30 gas/trip, 5 days/3-year period).
2	a; b; c; d; i	3c	Monitor *in situ* grown and transplanted individuals for effectiveness of sewing, planting, and transplanting protocols.	P	BLM FWS GOV PYT TON USFS	42.2	23.2	6.333	6.333	6.333	We based this cost on 1) monitoring plan development in the first five years (5 agency people at $35/hour, 8 hours/day for 3 days) and 2) the cost of personnel and travel to monitor plants yearly for the first five years, then every third year after for the next 15 years ($35/hour, 10 hours/day, 2 people, 5 days/ year, + $30 per diem / trip)
2	a; b; c; d; f; i	4a	Identify information gaps, compatible land uses, threats, stressors, and appropriate management actions that lead to the conservation of the taxon.	5	FWS	5.6	1.4	1.4	1.4	1.4	This estimates the cost to review research and monitoring results and compile the information every 5 years and is included within the development of a Service 5-Year Review ($35/hour, 40 hours, 1 person).

Priority Number	Threats*	Action Number	Action Description	Time Estimate (Years)	Responsibility	Total Cost (1,000s)	Cost ($1,000s) for Years 1-5	Cost ($1,000s) for Years 6-10	Cost ($1,000s) for Years 11-15	Cost ($1,000s) for Years 16-20	Comments
2	a; h; i	4b	Conduct surveys in appropriate habitat to better understand the geographic range and habitat requirements of the taxon.	P	BLM FWS GOV TON USFS USGS	29.2	7.3	7.3	7.3	7.3	Every 5 years. This estimates the cost of periodic Roller method surveys of habitat ($35/hour, 10 hours/day, 4 people, $30 gas/day, 5 days/ 5-year period).
2	a; b; c; d; f; h; i	4c	Conduct research related to the biology, ecology, abundance, status, threats, stressors, viability, propagation, restoration of individuals and of habitat, and genetics of the taxon.	P	ALWT ASDM ASU BLM DBG FWS GOV PVT SNAT TNC UA USFS USGS USON UNAM	180	60	60	30	30	Every 5 years. We based this cost on the average cost of scientific studies of Arizona's rare plants that have been funded through our section 6 program. Anticipating two studies in the first two 5 year periods and one study per 5 year period of recovery thereafter, at an average cost of $30,000/study.
2	a; b; c; d; e; f; h; i	5a	Promote the propagation and planting of individuals *ex situ* at botanic gardens for conservation and public education purposes.	20	ASDM DBG	38	9.5	9.5	9.5	9.5	We based this cost on botanical garden care and propagation studies on 40 plants at an estimated rate of $1,900/year.
1	a; b; c; d; e; f; h; i	5b	Maintain seed from plants across the geographic range of the taxon for conservation purposes.	20	ARS ASDM DBG	2	0.5	0.5	0.5	0.5	We based this cost on estimates from an accredited seed storage facility to maintain seed in storage ($100/year).

Priority Number	Threats*	Action Number	Action Description	Time Estimate (Years)	Responsibility	Total Cost (1,000s)	Cost ($1,000s) for Years 1-5	Cost ($1,000s) for Years 6-10	Cost ($1,000s) for Years 11-15	Cost ($1,000s) for Years 16-20	Comments
2	a; b; c; d; e; f; h; i	5c	Develop effective approaches to *in situ* conservation.	10	ALWT ASDM ASU BLM DBG FWS GOV PYT PVT SNAT TNC UA USFS USON UNAM	90	60	30	0	0	We based this cost on the average cost of scientific studies of Arizona's rare plants that have been funded through our section 6 program. Anticipating two studies in the first 5-year period and one study thereafter, at an average cost of $30,000/ study.
3	a; b; c; d; e; g; i	6a	Increase public outreach regarding threats, stressors, and conservation measures relating to *C. scheeri* var. *robustispina* in both the United States and Mexico.	20	ALWT BLM FWS GOV NGO PVT SNAT TON TNC USFS	12	3	3	3	3	We estimated this cost based on the cost of creating outreach materials and providing presentations and field trips to interested parties ($35/hour, 8 hour days, 10/year, 1 person, printing, gas, and other costs).
3	a; b; c; d; e; g; i	6c	Develop a recovery implementation team comprised of species experts, agency and non-government agency partners, landowners, and stakeholders to meet regularly, review progress, discuss problems, and revise this plan as needed.	5	ALWT ASDM DBG FWS GOV NGO PVT TON TNC USFS	22.4	5.6	5.6	5.6	5.6	We based this cost on time for interagency personnel to attend meetings to discuss recovery ($35/hour; 8 hour/5-year period, 20 people).

Literature Cited

Alford, E., J. Brock, and G. Gottfried. 2005. Effects of fire on Sonoran Desert plant communities. USDA Forest Service Proceedings RMRS-P-36.

Allen, E., R. Steers, and S. Dickens. 2011. Impacts of fire and invasive species on desert soil ecology. Rangeland Ecology & Management, 64(5):450-462.

Altemus, M. 2016. Antelope jackrabbit (*Lepus alleni*) spatial ecology, habitat characteristics, and overlap with thee Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*) MS Thesis University of Arizona 86 pp.

Anable, M., M. McClaran, and G. Ruyle. 1992. Spread of introduced Lehmann lovegrass *Eragrostis lehmanniana* Nees. in southern Arizona, USA. Biological Conservation 61: 181-188.

Anable, M. 1990. Alien plant invasion in relation to site characteristics and disturbance: *Eragrostis lehmanniana* on the Santa Rita Experimental Range, Arizona, 1937-1989. M.S. Thesis, University of Arizona. 64 pp.

Anderson, E. 2001. The Cactus Family. Timber Press, Portland, Oregon.

Apple, M. 2009. Aspects of mycorrhizae in desert plants. Chapter 6 *In*: Ramawat (editor) Desert Plants Biology and Biotechnology. Springer.

Aragon, A. and E. Lasso. 2018. How do young cacti (seeds and seedlings) from tropical xeric environments cope with extended drought periods? Journal of Arid Environments 154:1-7

Archer, S. and K. Predick. 2008. Climate change and the ecosystems of the southwestern United States. Rangelands 20:23-28.

Arizona Department of Agriculture (ADA). 2010. Threatened, endangered, and proposed (TEP) plant profile for *Coryphantha robustispina* var. *robustispina*, Pima pineapple cactus. http://www.fs.fed.us/wildflowers/Rare_Plants/profiles/TEP/coryphantha_scheeri_robustispina/index.shtml

Arizona Game and Fish Department (AGFD). 2015. Javelina. http://azgfdportal.az.gov/hunting/species/biggame/javelina accessed April 1, 2015.

Arizona Game and Fish Department (AGFD). 2011. Bonita Grasslands Restoration Project. http://www.azgfd.gov/w_c/documents/10-504BonitaRanchPhase1BonitaGrasslands Restoration_000.pdf. Accessed June 11, 2015.

Arizona Rare Plant Guide Committee. 2001. *Coryphantha scheeri* var. *robustispina.* Unpaginated.

Arizona Revised Statutes, Chapter 7. 2007. Arizona Native Plants. Available online from: https://agriculture.az.gov/protected-arizona-native-plants. Accessed October 2, 2015.

Arndt, W. 1966. The distribution of traffic in tillage operations. Journal of Agricultural Engineering Research 11:170-187.

Austin, D. 2010. Baboquivari Mountain Plants: Identification, Ecology, and Ethnobotany. The University of Arizona Press.

Bahre, C. 1995. Human impacts on the grasslands of southeastern Arizona. Pp. 230-264 *In*: M. McClaran and T. Van Devender. 1995. The Desert Grassland. University of Arizona Press. 346 pp.

Baker, M. 2013. A demographic study of *Coryphantha robustispina* ssp. *robustispina* - Progress report for the 2012 field season and final report for the study. November 7, 2013. 66 pp.

Baker, M. 2012. A demographic study of *Coryphantha robustispina* ssp. *robustispina:* Progress report for the 2011 field season. Status report prepared for Bureau of Reclamation. Glendale, Arizona. 56 pp.

Baker, M. 2011. A demographic study of *Coryphantha robustispina* ssp. *robustispina*: Progress report for the 2011 field season. Status report prepared for Bureau of Reclamation. Glendale, Arizona.

Baker, M. 2005. Final report for: Geographic distribution and DNA analysis of *Coryphantha robustispina* ssp. *robustispina*. Draft report submitted to U.S. Fish and Wildlife Service for review under contract with the Arizona Board of Regents, University of Arizona, Tucson.

Baker, M. 2003. A morphometric analysis of the pineapple cactus, *Coryphantha robustispina*. First progress report. Prepared for U.S. Fish and Wildlife Service under the Arizona Board of Regents, University of Arizona, Tucson, Arizona.

Baker, M. 2000. Surveys for Pima pineapple cactus (*Coryphantha robustispina* [Schott ex Engelm.] Britton & Rose) ssp. *robustispina* within sections 14, 15, 21, 22, 23, 27, and 32 of T16S R10E, and sections 5, 6, 7, 8, 17, 18, 20, and 21 of T17S R10E (Three Points area); sections 22 and 23 of T16S R15E (near the Pima County Fairgrounds) and sections 10, 14, 15, 23, and 24 of TS16S R16E (Cienega Creek Preserve, Pima County, Arizona. A report submitted to the U.S. Bureau of Reclamation. 8pp + appendix.

Baker, M. and C. Butterworth. 2013. Geographic distribution and taxonomic circumscription of populations within Coryphantha section Robustispina (Cactaceae). American Journal of Botany 100(5):984-997.

Bashan, Y., E. Davis, A. Carrillo-Garcia, ad R. Linderman. 2000. Assessment of VA mycorrhizal inoculum potential in relation to the establishment of cactus seedlings under mesquite nurse trees in the Sonoran Desert. Journal of Soil Ecology 14(2):165-175.

Benson, L. 1982. The Cacti of the United States and Canada. Stanford University Press. Stanford, California. 1,044 pp.

Benson, L. 1969. The Cacti of Arizona. University of Arizona Press. 218 pp.

Berthelette, G. 2017. Variables that influence the endangered Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*) mortality after transplanting. M.S. Thesis. 40 pp.

Biedenbender, S. and B. Roundy. 1996. Establishment of native semidesert grasses into existing stands of *Eragrostis lehmanniana* in southeastern Arizona. Restoration Ecology 4(2):155-162.

Blair, A. and P. Williamson. 2008. Effectiveness and importance of pollinators to the star cactus (*Astrophytum asterias*). The Southwestern Naturalist 53(4):423-430.

Britton, N. and J. Rose. 1923. The Cactaceae. 4 vols. Carnegie Inst. Wash. Publ. 248.

Bock, C., J. Bock, K. Jepson, and J. Ortega. 1986. Ecological effects of planting African lovegrasses in Arizona. National Geographic Research 2(4):456-463.

Bowers, J. 2005. Effects of drought on shrub survival and longevity in the northern Sonoran Desert. Journal of the Torrey Botanical Society 32(3):421-431.

Brenner, J. 2011. Pasture conversion, private ranchers, and the invasive exotic buffelgrass (*Pennisetum ciliare*) in Mexico's Sonoran Desert. Annals of the Association of American Geographers. 101(1):84–106.

Brooks, M. and J. Chambers. 2011. Resistance to invasion and resilience to fire in desert shrublands of North America. Rangeland Ecology and Management 64(5):431-438.

Brooks, M. and D. Pyke. 2002. Invasive plants and fire in the deserts of North America. Pp. 1–14 *In*: K. Galley and T. Wilson (editors). Proceedings of the Invasive Species Workshop: the Role of Fire in the Control and Spread of Invasive Species. Fire Conference 2000: the First National Congress on Fire Ecology, Prevention, and Management. Miscellaneous Publication No. 11, Tall Timbers Research Station, Tallahassee, FL.

Buenos Aires National Wildlife Refuge (BANWR). 2012. History. http://www.fws.gov/refuge/Buenos_Aires/about/history.html. Accessed May 2015.

Burger, J. and S. Louda. 1995. Interaction of diffuse competition and insect herbivory in limiting brittle prickly pear cactus, *Opuntia fragilis* (Cactaceae). American Journal of Botany 82(12):1558-1566.

Butterworth, C. 2010. Genetic study of Pima pineapple cactus (*Coryphantha robustispina* ssp. *robustispina*) and phylogenetic study of the genus *Coryphantha*. Final Report prepared for the U. S. Department of the Interior Bureau of Reclamation, Phoenix, Arizona. 30 pp.

Cable, D. 1965. Damage to mesquite, Lehmann lovegrass, and black grama by a hot June fire. Journal of Range Management 18(6):326-329.

CLIMAS 2018a SW Climate Outlook. January southwest climate outlook. https://www.climas.arizona.edu/swco/jan-2018/southwest-climate-outlook-january-2018Accessed June 29, 2018

CLIMAS 2018b. SW Climate Outlook. June southwest climate outlook. https://www.climas.arizona.edu/swco/jun-2018/southwest-climate-outlook-june-2018. Accessed June 29, 2018

CLIMAS 2017. SW Climate Outlook. January southwest climate outlook. https://www.climas.arizona.edu/swco/jan-2017/southwest-climate-outlook-january-2017 Accessed June 29, 2018

CLIMAS 2015. SW Climate Outlook. http://www.climas.arizona.edu/swco/may-2015/ southwest-climate-outlook-may-2015. Accessed June 5, 2015.

Cline, K. 2015. Pima Pineapple Cactus; 1 Year Post-Burn Survey Report, Las Delicias Ranch. July 27, 2015. 56 pp.

Coronado National Forest. 2010. Pima pineapple cactus longevity from 1995 to 2010. Alisos Allotment, Sierra Vista Ranger District. Excel spreadsheet.

Crimmins, A. and A. Comrie. 2004. Interactions between antecedent climate and wildfire variability across south-eastern Arizona. International journal of Wildland Fire 13:455-466.

Cui, M. and P. Nobel. 1992. Nutrient status, water uptake, and gas exchange for three desert succulents infected with mycorrhizal fungi. New Phytologist 122:643-649.

D'Antonio, C. and P. Vituseck. 1992. Biological Invasions by Exotic Grasses, the Grass/Fire Cycle, and Global Change. Annual Review of Ecology and Systematics, 23: 63-87.

Dimmit, M. and R. Brusca. 2004. Biological status of *Coryphantha scheeri* var. *robustispina* (Pima pineapple cactus). Final report to the U.S. Fish and Wildlife Service, Tucson, Arizona. Permit No. TE22190-0. NFWF Contract No. 2000-0015. 26 pp.

Ecosphere Environmental Services Inc. 1997a. Final report 1997 refugia surveys in the Coyote Mountain and Santa Rita Experimental Range areas survey for *Coryphantha scheeri* var. *robustispina*. Conducted for the U.S. Bureau of Reclamation. June 1997.

Ecosphere Environmental Services Inc. 1997b. 1997 Resurvey of potential Tucson aqueduct system reliability investigation (TASRI) reservoir locations Survey for *Coryphantha scheeri* var. *robustispina*. Conducted for the U.S. Bureau of Reclamation. February 1997.

Ecosphere Environmental Services Inc. 1995. 1995 Refuge Study; A survey for *Coryphantha scheeri* var. *robustispina*. Conducted for U.S. Bureau of Reclamation Arizona Projects Office Phoenix, Arizona. Contract number 1-CS-32-01950. November 26, 1995.

Ecosphere Environmental Services Inc. 1992. A survey for threatened and endangered plant species at three proposed reservoir sites and associated pipelines. U.S. Bureau of Reclamation, Phoenix, Arizona. June 30, 1992. 76 pp.

Ellison, L. 1960. Influence of grazing on plant succession of rangelands. Botanical Review 26:1-78.

Emerson. K. 2010. Interagency cooperation on U.S.-Mexico border wilderness issues. A report on interagency cooperation. September 3, 2010. 29 pp.

Engelmann, G. 1856. Synopsis of the Cactaceae of the territory of the United States and adjacent regions. Proceedings of the American Academy of Arts and Sciences 3:259-314.

Environmental Planning Group. 2005. Pima pineapple cactus survey of the 98 Ranch. A report prepared for Pima County Natural Resources. August 2005. 15pp.

Esque, T., R. Webb, C. Wallace, C. VanRiper III, C. McCreedy, and L. Smythe. 2013. Desert fires fueled by native annual forbs: Effects of fire on communities of plants and birds in the lower Sonoran Desert of Arizona. The Southwestern Naturalist 58(2):223-233.

Fehlberg, S. and T. Nidey. 2015. Population genetic study of the Cochise pincushion cactus (*Coryphantha robbinsorum*) in Arizona. 17 pp.

Fernandez, R. and J. Reynolds. 2000. Potential growth and drought tolerance of eight desert grasses: lack of a trade-off? Oecologia 123:90-98.

Fonseca-Garcia, C., D. Coleman-Derr, E. Garrido, A. Visel, S. Tringe, and L. Partida-Martinez. 2016. The cacti microbiome: Interplay between habitat-filtering and host-specificity. Frontiers in Microbiology volume 7:article 150.

Fryer, Janet L.; Luensmann, Peggy S., compilers. 2012. Fire regimes of the conterminous United States, [Online]. *In*: Fire Effects Information System (FEIS). Missoula, MT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: www.fs.fed.us/database/feis/fire_regime_table/fire_regime_table.html. 22 pp.

Geiger, E. and G. McPherson. 2005. Response of semi-desert grasslands invaded by non-native grasses to altered disturbance regimes. Journal of Biogeography 32:895-902.

Gifford, G. and R. Hawkins. 1978. Hydrologic impact of grazing on infiltration: a critical review. Water Resource Research 14:304-313.

Godinez-Alvarez, H. 2003. Demographic Trends in the Cactaceae. Botanical Review 69(2):173-203.

Gori, D. and C. Enquist. 2003. An Assessment of the Spatial Extent and Condition of Grasslands in Central and Southern Arizona, Southwestern New Mexico and Northern Mexico. Prepared by The Nature Conservancy, Arizona Chapter. 28 pp.

Gurvich, D., R. Perez-Sanchez, K. Bauk, E. Jurado, M. Ferrero, G. Funes, and J. Flores. 2016. Combined effect of water potential and temperature on seed germination and seedling development of cacti from a mesic Argentine ecosystem. Flora 227:18-24.

Harris Environmental Group, Inc. 2002. Altar Valley Pima pineapple cactus survey Fall 2001 Survey Draft Report Order Number 01PG321063. A report submitted to the Bureau of Reclamation. January 2002. 58 pp.

Hastings, J. 1959. Science Vegetation Change and Arroyo Cutting in Southeastern Arizona. Journal of the Arizona Academy of Science 1(2):60-67.

Holechek, J.L, R.D. Pieper, and C.H. Herbel. 1998. Range management principles and practices. Prentice-Hall, Inc. Upper Saddle River, N.J. 542 pp.

Huang, C., E. Geiger, W. Van Leeuwen, and S. Marsh. 2009. Discrimination of invaded and native species sites in a semi-desert grassland using MODIS multi-temporal data. International Journal of Remote Sensing. 30(4):897-917.

Humphrey, R. R. and A. C. Everson. 1951. Effects of fire on a mixed grass-shrub range in southern Arizona. Journal of Range Management. 4:264-266.

Johnson, R. 1989. Reproductive ecology and natural history of acuña cactus, Echinomastus erectocentrus var. acunensis. Final Report submitted to Southwest Parks and Monuments Association and the National Park Service. 29 pp.

Jordan, P. and P. Nobel. 1981. Seedling establishment of *Ferocactus acanthodes* in relation to drought. Ecology 62(4):901-906.

Karl, T.R., J.M. Melillo, and T.C. Peterson. 2009. Global Climate Change Impacts in the United States. Cambridge University Press New York, NY. Available online from: http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/download-the-report. Accessed on February 28, 2012.

Kearney, T. and R. Peebles. 1951. Arizona Flora. University of California Press. 1,085 pp.

Kelly, J. and M.W. Olsen. 2011. Problems and pests of agave, aloe, cactus, and yucca. University of Arizona College of Agriculture and Life Sciences Publications – Extension – gardening and home horticulture. Available online from: http://arizona.openrepository.com/arizona/bitstream/10150/144789/1/az1399-2011.pdf. Accessed on February 16, 2012.

Kidder, A. 2015. Ecohydrological conditions associated with the distribution and phenology of the pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*). Master of Science Thesis, University of Arizona, School of Natural Resources and the Environment. 116 pp.

Kidder, A. 2014. Understanding Ecohydrological Conditions for Success of Pima Pineapple Cactus (*Coryphantha scheeri* var. *robustispina*) Distribution and Phenology. Poster.

King, D. 1993. Field form for *Coryphantha scheeri* var. *robustispina*. Location number 25. November 14, 1993.

Klemmedson, J.O. 1956. Interrelations of vegetation, soils and range conditions induced by grazing. Journal of Range Management 9:134-138.

Lina, A. and L. Eloisa. 2018. How do young cacti (seeds and seedlings) from tropical xeric environments cope with extended drought periods? Journal of Arid Environments 154:1-7.

Lindsay, D., P. Bailey, R. Lance, M. Clifford, R. Delph, N. Cobb. 2011. Effects of a nonnative, invasive lovegrass on *Agave palmeri* distribution, abundance, and insect pollinator communities. Biodiversity Conservation 20:3251-3266.

Loftin, S.R., C.E. Bock, J.H. Bock, and S.L. Brantley. 2000. Desert grasslands *In*: Jemison, R., Raish, C. eds. Livestock Management in the American Southwest: Ecology, Society, and Economics, Elsevier, New York., pp. 53-96.

Lyons, K., B. Maldonado-Leal, and G. Owen. 2013. Community and Ecosystem Effects of Buffelgrass (*Pennisetum ciliare*) and Nitrogen Deposition in the Sonoran Desert. Invasive Plant Science and Management, 6(1):65-78.

Maender, J. 1993. King's Ranch, State Lease 05-717. Notes to accompany photographic prints regarding *Coryphantha scheeri* var. *robustispina* located within prescribed burn of 1991. March 31, 1993 and April 7, 1993.

Mathias, A., G. Niu and X. Zeng. 2013. Modeling the climate and hydrological controls of the expansion of an invasive grass over southern Arizona. Poster. Project funded by the NSF (Grant no. EF-1065790) Data from the Santa Rita Digital Database and from the USDA ARS Walnut Gulch Experimental Watershed data archive.

Martin-R., J. Cox, and F. Ibarra-F. 1995. Climate effects on buffelgrass productivity in the Sonoran Desert. Society for Range Management. 48(10):60-63.

Martorell, C., P. Garcillan, and F. Casillas. 2012. Ruderality in extreme-desert cacti? Population effects of chronic anthropogenic disturbance on *Echinocereus Lindsay*. Population Ecology 2012. 54:335-346.

Mattson, W. and R. Haack. 1987. The role of drought in outbreaks of plant-eating insects. BioScience 37(2):110-118.

McDonald, C. 2005. Conservation of the rare Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*): recruitment after fires and pollination in the Altar Valley of southern Arizona. Master of Science Thesis, School of Natural Resource, University of Arizona. 82 pp.

McDonald, C. and G. McPherson. 2011a. Absence of a grass/fire cycle in a semiarid grassland: Response to prescribed fire and grazing. Rangeland Ecology and Management 64(4):384-393.

McDonald, C. and G. McPherson. 2011b. Fire behavior characteristics of buffelgrass-fueled fires and native plant community composition in invaded patches. Journal of Arid Environments 75(11): 1147–1154.

McDonald, C. and G. McPherson. 2006. Conservation of the rare Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*): recruitment after fires and pollination in the Altar Valley of Southern Arizona. Report prepared for the Bureau of Reclamation, Phoenix, Arizona. 85pp.

McDonald, C. and G. McPherson. 2005. Pollination of Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*): Does pollen flow limit abundance of this endangered species? USDA Forest Service Proceedings RMRS-36.

McIntosh, D. and T. Baldwin. 2001. Sahuarita Unified School District 2000-2001 Pima pineapple cactus annual report (*Coryphantha scheeri* var. *robustispina*) Monitoring and experimental activities. 22pp.

McLaughlin, S. and J. Bowers. 1982. Effects of wildfire on a Sonoran Desert plant community. Ecology 63(1):246-248.

McPherson, G. 2002. Relationship of ecological variables in the field with the presence of Pima pineapple cactus. Report to USFWS under agreement 1448-20181-01-J818. 4 pp.

McPherson, G. 1995. The role of fire in the desert grasslands. Pp. 136-137 *In*: McClaran and VanDevender (editors) The Desert Grassland.

McPherson, G. and J. Weltzin. 2000. Disturbance and climate change in United States / Mexico borderland plant communities: A state-of-the-knowledge review. USDA FS RMRS GTR 50. April 2000. 30pp.

Mills, G. 1991. Miscellaneous notes on *Coryphantha scheeri* var. *robustispina*.

Unpublished report. U. S. Fish and Wildlife Service, Arizona Ecological Services Field Office, Phoenix, Arizona. 23 pp.

Molano-Flores, B. and J. Coons. 2018. A demographic study of *Coryphantha scheeri* var. *robustispina*. A report submitted to the Arizona Department of Agriculture and the U.S. Fish and Wildlife Service. 61 pp.

Montgomery, G. 2012. USRWS Endangered Species Permit TE 022190-0 Annual report. November 20, 2012.

NOAA. 2018. 2017 was 3rd warmest year on record for the globe; NOAA, NASA scientists confirm Earth's long-term warming trend continues. http://www.noaa.gov/news/noaa-2017-was-3rd-warmest-year-on-record-for-globe. January 18, 2018.

Nobel, P.S. 1984. Extreme temperatures and thermal tolerances for seedlings of desert succulents. Oecologia (Berlin) 62:310-317.

O'Dea, M. 2007. Influence of mycotrophy on native and introduced grass regeneration in a semiarid grassland following burning. Restoration Ecology 15(1):149-155.

O'Dowd, D. and M. Hay. 1980. Mutualism between harvester ants and a desert ephemeral: seed escape from rodents. Ecology 61(3):531-540.

Olsson, A., J. Betancourt, M. McClaran, and S. Marsh. 2012. Sonoran desert ecosystem transformation by a C4 grass without the grass/fire cycle. Diversity and Distributions 18: 10-21.

Ordway, E. 1987. The life history of *Diadasia rinconis* Cockerell (Hymenoptera: Anthophoridae). Journal of the Kansas Entomological Society 60(1):15-24.

Orr, T., S. Newsome, and B. Wolf. 2015. Cacti supply limited nutrients to a desert rodent community. Oecologia 178:1045-1062.

Overpeck, J., G. Garfin, A. Jardine, D. Busch, D. Cayan, M. Dettinger, E. Fleishman, A. Gershunov, G. MacDonald, K. Redmond, W. Travis, and B. Udall. Pp. 1-20 *In*: Garfin, G. A. Jardine, R. Merideth, M. Black, S. LeRoy. 2013. Assessment of climate change in the southwest United States: A report prepared for the national climate assessment. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Parfitt, B. and A. Gibson. 2004. Cactus Family; *Coryphantha robustispina*. In: Flora of North America Vol 4. p. 226.
http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=242415320. Accessed March 30, 2015.

Parmenter, R. and T. Van Devender. 1995. Diversity, spatial variability, and functional roles of vertebrates in the desert Grassland. Pp. 196-229 *In*: M. McClaran and T. Van Devender. 1995. The Desert Grassland. University of Arizona Press. 346 pp.

Phillips, A., B. Phillips, and N. Brian. 1981. Status report for *Coryphantha scheeri* var. *robustispina*. Report submitted to Office of Endangered Species, Fish and Wildlife Service, U. S. Department of the Interior, Albuquerque, New Mexico. 15 pp.

Pima County Association of Governments. 2013. 2013-2050 Incorporated Places Population Projections in Pima County. http://www.pagnet.org/documents/population/2013-2050IncorporatedPlacesPopulation PimaCounty.pdf. Accessed June 10, 2015.

Pima County. 2016. Multi-species Conservation Plan: Final. http://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Office%20of%20Sustainability%20and%20Conservation/Conservation%20Sciece/Multi-species%20Conservation%20Plan/MSCP_Final_MainDoc_w_Cover.pdf, Accessed June 29, 2018.

Pima County. 2015. Pima County Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*) conservation bank status update, January 2015. 4 pp.

Pima County. 2010. Multi-species Conservation Plan: Administrative Draft. Submitted to the U.S. Fish and Wildlife Service, Tucson, Arizona. http://www.pima.gov/cmo/sdcp/MSCP/MSCPdocs/MSCP_Public_Draft.pdf, Accessed May 2015

Pima County. 2006a. Pima County's Pima pineapple cactus mitigation bank. http://www.pima.gov/cmo/admin/Reports/ConservationReport/PDF/Chapters/Reserves/PC%20Pima%20Pineapple%20Cactus%20Mitigation%20Bank.pdf. Accessed June 5, 2015.

Pima County. 2006b. Modified management prescriptions Pima County Pima Pineapple Conservation Bank (*Coryphantha scheeri* var. *robustispina*). 3 pp.

Pima County. 2000. Draft preliminary Sonoran Desert Conservation Plan. Report to the Pima County Board of Supervisors for the Sonoran Desert Conservation Plan. Tucson, Arizona.

Portilla-Alonso, R. and C. Martorell. 2011. Demographic consequences of chronic anthropogenic disturbance on three populations of the endangered globose cactus *Coryphantha werdermannii*. Journal of Arid Environments. 75: 509-515.

Powell, B. 2015. Pima pineapple cactus surveys on select parcels of the Marley Ranch, Pima County, Arizona. Final Report. May 7, 2015. 15 pp.

Powell, B. and M. Rice. 2015. Pima pineapple cactus survey of the Diablo Village Estates and Sonoran Ranch Estates. August 9, 2015. 5 pp.

Reichenbacher, F. W. 1985. Rare plant survey: Selected areas of the Schuk Toak and San Xavier Districts of the Papago Indian Reservation, Sells, Arizona. 72 pp.

Riegel, A. 1941. Some coactions of rabbits and rodents with cactus. Transactions of the Kansas Academy of Science 1903-(44): 96-103.

Robinett, D. 1996. John King – Anvil Ranch. Summary of information regarding a 1995 controlled burn and 1996 observations. Note in File. 1 p.

Robinett, D. 1992. Lehmann lovegrass and drought in southern Arizona. Rangelands 14(2):100-103.

Robinson, W. and E. Bolen. 1989. Wildlife Ecology and Management. MacMillan publishing, New York. 605 pp.

Roller, P. 1996a. Distribution, growth, and reproduction of Pima pineapple cactus (*Coryphantha scheeri* Kuntz var. *robustispina* Schott). M.S. Thesis University of Arizona, Tucson, Arizona.

Roller, P. 1996b. Pima pineapple cactus transplant methods. Technical report dated 24 April 1996. 2 pp. plus illustration.

Roller, P. S. and W. L. Halvorson. 1997. Fire and Pima pineapple cactus (*Coryphantha scheeri* Kuntze var. *robustispina* Schott) in southern Arizona. *In*: Proceedings of Fire Effects on Rare and Endangered Species and Habitats Conference, Coeur d'Alene, Idaho. 267-274.

Roundy, B., R. Taylorson, and L. Sumrall. Germination responses of Lehmann lovegrass to light. Journal of Range Management 45:81-84.

Routson, R. 2003. Demographic Study of *Coryphantha scheeri* var. *robustispina*. Final Report to The U.S. Fish and Wildlife Service, Tucson, Arizona. Permit No. TE22190-0. NFWF Contract No. 2000-0015.

Rutman, S. 2007. Acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) draft summary of available information.

Saguaro National Park. 2018. Buffelgrass. https://www.nps.gov/sagu/learn/nature/buffelgrass.htm #CP_JUMP_2667226 accessed 6-29-2018

Sayre, N. 2007. A history of working landscapes: The Altar Valley, Arizona, USA; How ranchers have shaped the West – and continue to do so. Society for Range Management. Pp 41-45.

Sayre, N. 2005. Ranching, endangered species, and urbanization in the southwest; Species of capital. University of Arizona Press. 279 pp.

Schmalzel, R. 2014. Fire Effects on a population of the endangered cactus (*Coryphantha robustispina*) on the San Pedro East and West Mill pastures, King's Anvil Ranch, State Trust

land, Altar Valley, Pima County, Arizona. 13 pp. A report to the Arizona Department of Agriculture and the U. S. Fish and Wildlife Service, Section 6 grant segment 18.

Schmalzel, R. 2002. Quarterly report # 9. *Coryphantha scheer*i var. *robustispina* study to National Fish and Wildlife Foundation, Tucson, Arizona. 41 pp.

Schmalzel, R. 2000a. Quarterly report # 2 (of 16). *Coryphantha scheer*i var. *robustispina* study to National Fish and Wildlife Foundation, Tucson, Arizona. May 3, 2000. 24 pp. plus appendices.

Schmalzel, R. 2000b. Growth and age-structure of a clonal cactus, *Coryphantha scheeri* var. *robustispina*, and notes on its performance with respect to soil age and to banner-tailed kangaroo rat mounds. West San Pedro Pasture, King Anvil Ranch. Arizona Department of Agriculture Final Report, June 2000. 11 pp. plus appendices.

Schmalzel, R. 2000c. Recommendations on how to transplant Coryphantha scheeri. 2 p. memo in files.

Schmalzel, R. 2000d. Quarterly report # 4 (of 16). *Coryphantha scheer*i var. *robustispina* study to National Fish and Wildlife Foundation, Tucson, Arizona. September 29, 2000. 18 pp.

Schmalzel, R. and M. McGibbon. 2010. Pima Pineapple Cactus (*Coryphantha robustispina*), Third Monitoring Report for the Phase I Conservation Land (T 17S, R 9E, NW portion of section 26) of the Palo Alto Ranch Conservation Bank, Altar Valley, Pima County, Arizona. Report prepared for the Altar Valley Conservation Alliance, Anvil Ranch, Tucson, Arizona and the U. S. Fish and Wildlife Service, Phoenix, Arizona. 35 pp.

Schmalzel, R. and Westland Resources. 2006. Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*) monitoring report for the Phase 1 Conservation Land (T 17S, R 9E, NW portion of Section 26) of the Palo Alto Ranch Conservation Bank Altar Valley, Pima County, Arizona. A report prepared for the Altar Valley Conservation Alliance and the U.S. Fish and Wildlife Service. March 9, 2006. 22 pp.

Schmalzel, R,. R. Nixon, A. Best, and J. Tress Jr. 2004. Morphometric variation in *Coryphantha robustispina* (Cactaceae). Systematic Botany 29(3):553-468.

Schmidt, M. and G. Rogers. 1988. Trends in fire occurrence in the Arizona Upland Subdivision of the Sonoran Desert, 1955-1983. Southwestern Association of Naturalists. 33(4):437-444.

Schussman, H., E. Geiger, T. Mau-Crimmins, and J. Ward. 2006. Spread and current potential distribution of an alien grass, *Eragrostis lehmanniana* Nees, in the southwestern USA: comparing historical data and ecological niche models. Diversity and Distribution. 12:582-592.

Seager, R., M. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H. Huang, N. Harnik, A. Leetmaa, N. Lau, C. Li, J. Velez, and N. Naik. 2007. Model projections of an imminent transition to a more

arid climate in southwestern North America. Science 316:1181-1184. Available online from: http://www.sciencemag.org/content/316/5828/1181.full.pdf. Accessed on August 21, 2012.

Sheridan, T. 2001. Cows, condos, and the contested commons: The political ecology of ranching on the Arizona-Sonora borderlands. Human Organization 60(2):141-152.

Smith, S., B. Didden-Zopfy, and P. Nobel. 1984. High-temperature responses of North American cacti. Ecology, 65(2):643-651.

Sommers, P. and P. Chesson. 2016. Caching rodents disproportionately disperse seed beneath invasive grass. Ecosphere 7(12):1-12.

Steidl, R., A. Litt, and W. Matter. 2013. Effects of plant invasions on wildlife in desert grasslands. Wildlife Society Bulletin 37(3):527-536.

SWCA Environmental Consultants (SWCA). 2000. Pima pineapple cactus mitigation program at Las Campañas, Pima County, Arizona: Completion of short-term monitoring. January 11, 2000. 5pp. plus appendices.

SWCA Environmental Consultants (SWCA). 1999. Mitigation and monitoring plan for the Toga Casino II Project at Pima Mine Road, Tohono O'odham Nation, Pima County, Arizona. Report submitted to the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service, Phoenix, Arizona. 26 pp.

Taylor, N. 1998. *Coryphantha robustispina* (Engelm.) Britton & Rose, the correct name for the taxon variously known as *Coryphantha scheeri* Lemaire and *Coryphantha muehlenpfordtii* Britton and Rose (*nom. illeg.*). Cactus Consensus (Dec, no.6).

Tellman, B. 1997. Exotic pest plant introduction in the American southwest. Desert Plants. 13(1):3-9.

The Nature Conservancy. 2004. Grasslands assessment GIS data. December 2004. http://azconservation.org/downloads/category/grassland_assessment. Accessed June 5, 2015.

Thomas, P. 2006. Mortality over 16 years of cacti in a burnt desert grassland. Plant Ecology 183:9-17.

Thomas, P. 1991. Response of succulents to fire: A review. International Journal of Wildland Fire 1(1): 11-22.

Thomas, P. and P. Goodson. 1992. Conservation of succulents in desert grasslands managed by fire. Biological Conservation 60:91-100.

Thomas, P. and P. Goodson. 1991. Long-term effects of fire on cacti: Report on field research conducted at the Appleton-Whittell Research Ranch Sanctuary and the Buenos Aires National Wildlife Refuge. August 1991. 3 pp.

Thomas, K., C. Jarchow, and J. Crawford. 2017. Survival of the Endangered Pima Pineapple Cactus: Does Clearing Before Prescribed Fire Alter Survival Postfire? Southwestern Association of Naturalists. 62(3):200-206.

Tierra Right of Way Services, Ltd. 2010. Biological evaluation of Pascua Yaqui fee land consisting of ten Pima County parcels totaling approximately 363 acres in Pima County, Arizona. Report prepared for Terracon Consultants, Inc. July 15, 2010. 50 pp.

Tierra Right of Way Services, Ltd. 2007a. Results of a Pima pineapple cactus survey conducted on Parcel 19, located in a portion of the southwest and southeast ¼ of Section 2, and the southwest ¼ of Section 22, Township 17 South, Range 13 East, Pima County, Arizona. A report prepared for the Park Corporation. November 5, 2007.

Tierra Right of Way Services, Ltd. 2007b. Results of a Pima pineapple cactus survey in section 2, Township 15 South, Range 15 East; City of Tucson, Pima County, Arizona. A report prepared for the Tucson Electric Power Company and the U.S. Fish and Wildlife Service. January 29, 2007.

Tierra Right of Way Services, Ltd. 2004. A summary of the results of a Pima pineapple cactus survey in sections 24 and 25, Township 17 South, Range 15 East; and in Section 30, Township 17 South, Range 16 East, Corona de Tucson, Pima County, Arizona. A report prepared for TRICO Electric Cooperative. June 4, 2004. 4 pp.

Tohono O'odham Nation. Undated. Tohono O'odham code, Title 15 Environment, Chapter 7 Tohono O'odham native plants. 11 pp. http://tolc-nsn.org/docs/DraftNativePlantsLaw.pdf accessed April 1, 2015.

Tolley, S. 1992. A summary of the Pima pineapple cactus studies on the Buenos Aires National Wildlife Refuge. U.S. Fish and Wildlife Service, Buenos Aires National Wildlife Refuge, Sasabe, Arizona. Unpublished Report. 8 pp.

United States Department of Agriculture (ADA). 2010. Threatened, endangered and proposed plant profile: *Coryphantha robustispina* var. *robustispina.* http://www.fs.fed.us/wildflowers/ Rare_Plants/profiles/TEP/coryphantha_scheeri_robustispina/index.shtml. Accessed February 24, 2015)

United States Fish and Wildlife Service (Service). 2017. Biological Opinion on the TOKA III housing project located on the San Xavier District of the Tohono O'odham Nation. 17 pp.

United States Fish and Wildlife Service (Service). 2016a. 82 FR 28875 Endangered and threatened wildlife and plants; Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*) Draft Recovery Plan Notice of availability; request for comment. June 26, 2016. 3 pp.

United States Fish and Wildlife Service (Service). 2016b. Biological Opinion on the extension of development rock stockpiles and related activities at the existing Sierrita open pit copper mine. 24 pp.

United States Fish and Wildlife Service (Service). 2015a. Memo to Files: March 9, 2015 - *Coryphantha scheeri* var. *robustispina* (Pima pineapple cactus)(PPC) partial survey of the Pima County PPC Conservation Bank, Madera Highlands. 1 p.

United States Fish and Wildlife Service (Service). 2015b. Memo to Files: April 13, 2015 – *Coryphantha scheeri* var. *robustispina* (Pima pineapple cactus (PPC)) partial re-measure of US Forest Service east and west exclosure individual plants (Alisos Allotment, Mesquital Pasture, next to the Granger Corrals). 7 pp.

United States Fish and Wildlife Service (Service). 2015c. 80 FR 20241 Endangered and threatened wildlife and plants; 5-year status reviews of black-lace cactus, bone cave harvestman, Pima pineapple cactus, Texas snowbells, and Walker's manioc in the southwest Region Notice of initiation of reviews; request for information. April 15, 2015. 3 pp.

United States Fish and Wildlife Service (Service). 2014a. Biological Opinion on the effects of the proposed construction of the Sierrita Pipeline Project in the Altar Valley of Pima County, Arizona. 62 pp.

United States Fish and Wildlife Service (Service). 2014b. Biological Opinion on the effects of the proposed stormwater controls project for the Mission Complex near Sahuarita, Arizona. 19 pp.

United States Fish and Wildlife Service (Service). 2013. Biological and Conference Opinion on the effects of the proposed approval of the Mine Plan of Operations for the Rosemont Copper Company Project in Pima County, Arizona. 506 pp.

United States Fish and Wildlife Service (Service). 2011. Biological Opinion on the effects of the proposed reconfiguration of the traffic interchange ramp connections between Interstate-19 and Sahuarita Road. 12 pp.

United States Fish and Wildlife Service (Service). 2010. Biological Opinion on the effects of the proposed construction of the New Tucson Substation in Pima County, Arizona. 17 pp.

United States Fish and Wildlife Service (Service). 2009a. Biological Opinion on the effects of the proposed construction of a CAP water delivery system for the Community Water Company of Green Valley, Arizona. 13 pp.

United States Fish and Wildlife Service (Service). 2009b. Biological Opinion on the effects of the proposed extension on the Buenos Aires National Wildlife Refuge Fire Management Plan for the 2009 season. 26 pp.

United States Fish and Wildlife Service (Service). 2008. Biological Opinion on the effects of the proposed improvements to State Route 86 between Sandario Road and Kinney Road. 11 pp.

United States Fish and Wildlife Service (Service). 2007a. 5-year Review for Pima Pineapple Cactus (*Coryphantha scheeri* var. *robustispina*). Arizona Ecological Services Field Office, Tucson, Arizona. 17 pp.

United States Fish and Wildlife Service (Service). 2007b. Las Delicias Pima pineapple cactus burn experiment results. Buenos Aires National Wildlife Refuge, Sasabe, Arizona. February 2, 2007. 3 pp.

United States Fish and Wildlife Service (Service). 2007c. Biological Opinion on the effects of the proposed construction of a petroleum products pipeline from El Paso, Texas, to Phoenix, Arizona. 15 pp.

United States Fish and Wildlife Service (Service). 2007d. Biological Opinion on the effects of the proposed issuance a Department of the Army Section 404 permit for construction of the Fagan Ranch subdivision. 8 pp.

United States Fish and Wildlife Service (Service). 2007e. Biological Opinion on the effects of the proposed project to remove the noxious weed, buffelgrass (*Pennisetum ciliare*) from Air Force Plant 44. 3 pp.

United States Fish and Wildlife Service (Service). 2006a. Biological Opinion on the effects of the proposed issuance a Department of the Army Section 404 permit for construction of the Ocotillo Preserve subdivision. 14 pp.

United States Fish and Wildlife Service (Service). 2006b. Biological Opinion on the effects of construction of Hayhook Road. 3 pp.

United States Fish and Wildlife Service (Service). 2006c. Biological Opinion on the effects of the proposed issuance a Department of the Army Section 404 permit for construction of the Diablo Village subdivision. 8 pp.

United States Fish and Wildlife Service (Service). 2006d. Biological Opinion on the effects of the proposed issuance a Department of the Army Section 404 permit for construction of the Bajada Ranch subdivision. 6 pp.

United States Fish and Wildlife Service (Service). 2005a. Biological Opinion on the effects of the proposed issuance a Department of the Army Section 404 permit for construction of Santa Rita Foothills Estates. 15 pp.

United States Fish and Wildlife Service (Service). 2005b. Biological Opinion on the effects of the proposed change of access located within the right-of-way for Interstate 19. 12 pp.

United States Fish and Wildlife Service (Service). 2005c. Biological Opinion on the effects of the proposed construction of a residential subdivision, Solar del Viejo. 13 pp.

United States Fish and Wildlife Service (Service). 2005d. Biological Opinion on the effects of the proposed issuance a Department of the Army Section 404 permit for construction of Andrada Ranch. 13 pp.

United States Fish and Wildlife Service (Service). 2004a. Biological Opinion on the effects of the proposed issuance a Department of the Army Section 404 permit for construction of Canoa Hills Estates. 13 pp.

United States Fish and Wildlife Service (Service). 2004b. Biological Opinion on the effects of the lease of 80 acres of public lands to Pima County for a recreational park. 3 pp.

United States Fish and Wildlife Service (Service). 2004c. Biological Opinion for the proposed issuance of a Presidential Permit to construct a new, double-circuit, 345,000-volt transmission line from Sahuarita, Arizona to a sub-station in Nogales, Arizona, continuing south across the United States-Mexico border for approximately 60 miles into Sonora, Mexico. 51 pp.

United States Fish and Wildlife Service (Service). 2004d. Biological Opinion on the effects of the proposed issuance a Department of the Army Section 404 permit for construction of the Mirasol development. 13 pp.

United States Fish and Wildlife Service (Service). 2004e. Biological Opinion on the effects of the proposed issuance a Department of the Army Section 404 permit for construction of Oasis Santa Rita. 13 pp.

United States Fish and Wildlife Service (Service). 2004f. Biological Opinion on the effects of the proposed issuance a Department of the Army Section 404 permit for construction of a residential subdivion at Corona de Tucson, Pima. 13 pp.

United States Fish and Wildlife Service (Service). 2003. Biological Opinion on the effects of the proposed issuance of a Department of the Army Section 404 permit for construction of Santa Rita Mountain Ranch Community on Pima pineapple cactus. 16 pp.

United States Fish and Wildlife Service (Service). 2002a. Biological Opinion on the effects of the proposed construction of a new United States Penitentiary located in Tucson, Arizona. 18 pp.

United States Fish and Wildlife Service (Service). 2002b. Biological Opinion on the effects of the proposed improvements to the Duval Mine Road Traffic Interchange. 17 pp.

United States Fish and Wildlife Service (Service). 2002c. Biological Opinion for the proposed issuance of a National Pollution Discharge Elimination System (NPDES) permit to Asarco, Inc. for the Mission Complex located near Sahuarita, Pima County, Arizona. 16 pp.

United States Fish and Wildlife Service (Service). 2001a. Biological Opinion for the proposed construction of the Green Valley Performing Arts Center on 7.7-ha (19-ac) site in Green Valley, Arizona. December 20, 2001. 16 pp.

United States Fish and Wildlife Service (Service). 2001b. Biological Opinion on the effects of the proposed construction of the Madera Highlands housing project. 18 pp.

United States Fish and Wildlife Service (Service). 2001c. Biological Opinion on the effects of the proposed construction of a new Safeway shopping center in Sahuarita, Arizona. 16 pp.

United States Fish and Wildlife Service (Service). 2001d. Biological Opinion on the effects of the proposed construction of a sand and gravel operation proposed by the County on a 20-acre parcel. 17 pp.

United States Fish and Wildlife Service (Service). 2000a Biological Opinion for the Tohono O'odham Gaming Authority located in Pima County, Arizona. January 5, 2000. 15 pp.

United States Fish and Wildlife Service (Service). 2000b. 65 FR 56916. Policy regarding controlled propagation of species listed under the Endangered Species Act. September 20, 2000.

United States Fish and Wildlife Service (Service). 1999a. Biological Opinion on the effects of the proposed San Xavier CAP Link Pipeline. 12 pp.

United States Fish and Wildlife Service (Service). 1999b. Biological Opinion on the effects of the proposed issuance of a Department of the Army Section 404 permit for the Tohono O'odham Gaming Authority. 15 pp.

United States Fish and Wildlife Service (Service). 1999c. Biological Opinion on the effects of the proposed Arizona State Prison expansion project. 17 pp.

United States Fish and Wildlife Service (Service). 1998a. Biological Opinion on the effects of the proposed tailings facility at the ASARCO Inc. Mission complex. 11p.

United States Fish and Wildlife Service (Service). 1998b. Biological Opinion on the effects of the proposed Tucson aqueduct system reliability investigation reservoir. 12 pp.

United States Fish and Wildlife Service (Service). 1998c. Biological Opinion for the proposed issuance of a permit to authorize discharge of fill material into 2.7 hectares (6.6 acres) of unnamed washes for the residential development of property named Las Campanas Housing Development. May 26, 1998.

United States Fish and Wildlife Service (Service). 1997. Biological Opinion on the effects of the proposed channelization and diversion of an unnamed wash around a 32-acre parcel proposed for a new high school. 19pp.

United States Fish and Wildlife Service (Service). 1995a. Biological Opinion on the effects of the proposed Sahaurita Unified School District wetland construction. 8 pp.

United States Fish and Wildlife Service (Service). 1995b. Biological Opinion on the effects of the proposed Sierra Tordilla / Alisos allotments term grazing permit. 10 pp.

United States Fish and Wildlife Service (Service). 1995c. Biological Opinion on the effects of the proposed Sopori Access Road Project. 5 pp.

United States Fish and Wildlife Service (Service). 1995d. Biological Opinion on the effects of a proposed 200-acre Pasca Yaqui Pueblo housing expansion project. 9pp.

United States Fish and Wildlife Service (Service). 1995e. Biological Opinion on the effects of the proposed Two Hills housing project. 8 pp.

United States Fish and Wildlife Service (Service). 1994. Biological Opinion on the effects of a proposed prescribed burn in the San Pedro pasture on the Anvil Ranch. 16 pp.

United States Fish and Wildlife Service (Service). 1993. 58 FR 49875. Endangered and threatened wildlife and plants: Determination of endangered status for the plant Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*). September 23, 1993.

United States Fish and Wildlife Service (Service). 1992. 57 FR 14374. Endangered and threatened wildlife and plants: Proposal to list the plant Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*) as endangered. April 20 1992.

United States Fish and Wildlife Service (Service). 1983. 48 FR 43098. Endangered and threatened species listing and recovery priority guidelines. September 21, 1983.

United States Fish and Wildlife Service (Service). 1980. 45 FR 82480. Review of plant taxa for listing as endangered or threatened species. December 15, 1980.

United States Fish and Wildlife Service (Service). 1975. 40 FR 27824. Review of status of vascular plants. July 1, 1975.

United States Forest Service Burned Area Emergency Response (BAER). 2017. Fire burn severity for southern Arizona fires - Geographical Information System data.

Ureta, C. and C. Martorell. 2009. Identifying the impacts of chronic anthropogenic disturbance on two threatened cacti to provide guidelines for population-dynamics restoration. Biological Conservation 142;1992-2001.

Van Auken, O. 2000. Shrub invasions of North American semidesert grasslands. Annual Review of Ecological Systems 31:197-215.

Vander Wall, S.B., K.M. Kuhn, and M.J. Beck. 2005. Seed removal, seed predation, and secondary dispersal. Ecology 86(3): 801-806.

Van Devender, T., R. Felger, and A. Búrquez. 1997. Exotic plants in the Sonoran Desert region Arizona and Sonora. California Exotic Pest Plant Council Symposium Proceedings. October 2-4, 1997 Sheraton Concord Hotel, Concord, California. 6 pp.

Wahid, A., S. Gelani, M. Ashraf, and M.R. Foolad. 2007. Heat tolerance in plants: An overview. Environmental and Experimental Botany 61(3):199-223.

Waser, N. and M. Price. 1981. Effects of grazing on diversity of annual plants in the Sonoran Desert. Oecologia 50:407-411.

Westland Resources, Inc. (Westland). 2017. Sycamore Canyon Conservation lands 2016 annual monitoring report ACOE File No. 2000-00730-SDM. Report prepared for Sycamore Canyon Conservation Foundation. January 31, 2017. 101 pp.

Westland Resources, Inc. (Westland). 2015. 2015 Palo Alto Pima pineapple cactus conservation bank monitoring. A report prepared for the Altar Valley Conservation Alliance. August 26, 2015. 26 pp.

Westland Resources, Inc. (Westland). 2014. Sycamore Canyon conservation lands 2013 annual monitoring report ACOE File No. 2000-00730-SDM. A report prepared for the Sycamore Canyon Conservation Foundation. January 27, 2014. 11 pp. plus appendices.

Westland Resources, Inc. (Westland). 2007. Pima pineapple cactus sample survey for the approximately 11-acre NDGPS site. Prepared for the Louis Berger Group, Inc. October 22, 2007. 7 pp.

Westland Resources, Inc. (Westland). 2006. Spatial analysis of Pima pineapple cactus on Diablo Village Estates. March 20, 2006. 21 pp.

Westland Resources, Inc. (Westland). 2005. Biological assessment; Vahalla and Valencia (Diablo Village Estates) ACOE file no. 2005-01601-MB. Prepared for Pima County Flood Control District. November 2005. 110 pp.

Westland Resources, Inc. (Westland). 2004. A preliminary population estimate of Pima pineapple cactus (*Coryphantha robustispina*) in south-central Arizona (Pima and Santa Cruz Counties). January 26, 2004. 21 pp.

Williams, B. and E. Brown. 2012. Adaptive Management: the U.S. Department of the Interior Applications Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC. https://www.doi.gov/sites/doi.gov/files/migrated/ppa/upload/DOI-Adapative-Management-Applications-Guide.pdf

Williams, D. and Z. Baruch. 2000. African grass invasion in the Americas: ecosystem consequences and the role of ecophysiology. Biological invasions 1:123-140.

Personal Communication

Buchmann, S. 2012. E-mail correspondence from Stephen Buchmann to Julie Crawford, U.S. Fish and Wildlife Service. Re: *Diadasia rinconis*. March 12, 2012.

Byrd, J. 2017. Email from Jessie Byrd, Pima County native plant nursery manager, to Julie Crawford, U.S. Fish and Wildlife Service Plant Ecologist. July 10, 2017.

Byrd, J. 2014. Email from Jessie Byrd, Pima County native plant nursery manager, to Julie Crawford, U.S. Fish and Wildlife Service Plant Ecologist. July 3, 2014.

Chenevert-Steffler, A. 2015. Email from Ann Chenevert-Steffler, Buenos Aires National Wildlife Refuge wildlife biologist, to Julie Crawford, U.S. Fish and Wildlife Service Plant Ecologist. January 29, 2015.

Cohan, D. 2015. Email from Dan Cohan, former Buenos Aires National Wildlife Refuge wildlife biologist, to Julie Crawford, U.S. Fish and Wildlife Service Plant Ecologist. June 19, 2015.

Kendall, B. 1990. Letter from Bill Kendall, Arizona Department of Agriculture agricultural inspector, to Larry Richards, Arizona Commission of Agriculture and Horticulture native plant law specialist and Terry Johnson, Arizona Game and Fish Department non-game branch supervisor. February 26, 1990.

Maender, J. 1992. Letter to Dan Robinett. March 4, 1992.

Maender, J. 1991. Letter to Walter Alexander. April 19, 1991

Molano-Flores, B. 2018. Email from Brenda Molano-Flores, University of Illinois, to Julie Crawford, U.S. Fish and Wildlife Service Plant Ecologist, February 2, 2018.

Richardson, S. Email from Scott Richardson, U.S. Fish and Wildlife Service, to Julie Crawford, U.S. Fish and Wildlife Service Plant Ecologist. February 9, 2016.

Robinett 1992. Letter to Jim Maender with accompanying photographs. June 23, 1992.

Schade, S. 2015. Email from Scott Schade, Arizona Department of Agriculture special investigator, to Julie Crawford, U.S. Fish and Wildlife Service Plant Ecologist. April 20, 2015.

Schmalzel, R. 2001. Letter from Robert Schmalzel, researcher, to Sabra Schwartz, Arizona Game and Fish Department. September 16, 2001.

Schmalzel, R. 2000. Letter from Robert Schmalzel, researcher, to Mima Falk, U.S. Fish and Wildlife Service Plant Ecologist. May 22, 2000. 2 pp.

Spiller, S. 1996. Letter from Sam Spiller, U.S. Fish and Wildlife Service field supervisor, to senior resident agent, Fish and Wildlife Service, Mesa, Arizona. AZ ESFO/SE 2-21-96-I-134. January 31, 1996.

SWCA Environmental Consultants (SWCA). 1992. Letter to Arizona Electric Power Cooperative, Inc. September 7, 1992. 1 p.

Tonn, S. Email from Sabra Tonn, HDMS Program Supervisor, Arizona Game and Fish Department, to Julie Crawford, U.S. Fish and Wildlife Service Plant Ecologist. July 13, 2018.

Tonn, S. Email from Sabra Tonn, HDMS Program Supervisor, Arizona Game and Fish Department, to Julie Crawford, U.S. Fish and Wildlife Service Plant Ecologist. March 16, 2016.

APPENDIX 1

Documented *Coryphantha scheeri* var. *robustispina* individuals (alive and dead) located during surveys in appropriate southern Arizona habitat and the number of acres surveyed to locate them. There may be minor overlap of individuals across surveys. This represents the majority of known *C. scheeri* var. *robustispina* surveys in southern Arizona since 1985. The current status of these individuals is unknown.

Project Title	Individual Plants	Acres	Month	Day	Year	Reference
Altar Valley, Vaya Strip, 10k WSW of Three Points	24	4,480	November	19	1985	Reichenbacher 1985
NW portion of the San Xavier District, SE of Tucson	220	15,760	November	19	1985	Reichenbacher 1985
SSC Sierrita Ring site	8	27	May	11	1987	Mills 1991
Black Wash, Black Wash #2, Coyote Mountains, SRER, TASRI, Pascua Yaqui, Valencia, Snyder Hill	249	2,363	March	2	1991	Ecosphere Environmental Services Inc. 1992
Arizona Electric Power Cooperative Valencia 115 kV Powerline	49	14	September	7	1991	SWCA pers. comm. September 7,1992
University of Arizona southern Avra Valley project (In 02-21-94-F-100)	2	65	June	1	1993	Service 1994
Private development n. of Green Valley (In 02-21-94-F-100)	22	80	June	1	1993	Service 1994
La Canada Norte II housing development north of Green Valley (In 02-21-94-F-100)	9	43	December	1	1993	Service 1994
Anvil Ranch San Pedro Pasture RX Burn 02-21-94-F-100	185	1,690	May	11	1994	Service 1994
Sahaurita Unified School District 02-21-95-F-089	1	0.25	September	11	1995	Service 1995a
Sierra Tordilla/Alisos Grazing allotments 02-21-95-F-293	39	20	October	5	1995	Service 1995b
Sopori Access Road 02-21-95-I-386	36	6	October	19	1995	Service 1995c
New Pascua 02-21-95-F-117	45	200	October	31	1995	Service 1995d
Two Hills housing project 02-21-95-F-046	5	12	November	22	1995	Service 1995e
TASRI Reservoir, 15 km SE of Tucson	293	2,280	February	1	1997	Ecosphere Environmental Services Inc. 1997a
Tucson Proving Grounds / new high school 02-21-97-I-133	15	58	April	4	1997	Service 1997
Coyote Mountain and Santa Rita Experimental Range Areas surveys	517	2,120	June	1	1997	Ecosphere Environmental Services Inc. 1997b
ASARCO Mission Complex - Dames and Moore 2-21-97-F-	405	1,975	June	24	1997	Service 1998a

Project Title	Individual Plants	Acres	Month	Day	Year	Reference
328						
Tucson Aquaduct System Reliability Investigation Reservoir (02-21-91-F-406)	214	1,334	February	11	1998	Service 1998b
Las Campanas Housing Development (2-21-96-F-134)	47	437	May	26	1998	Service 1998c
CapLink Pipeline 2-21-99-I-190	6	68	May	13	1999	Service 1999a
Realign and Channelize Unnamed Washes on an 80 Ac Parcel for the Tohono O'odham Gaming Authority (2-21-99-F-170)	41	66	January	5	2000	Service 1999b
Altar Valley Survey by M. Baker	93	980	July	10	2000	Baker 2000
Arizona State Prison Expansion South of Tucson (NPDES) (02-21-99-F-227)	68	1,295	August	4	2000	Service 1999c
Palo Alto Ranch PPC Conservation Bank	15	100	January	1	2001	Schmalzel and Westland 2006
Guy Street, Stagecoach Road, Anvil Tank, South of Black Hills, Square Tank, Cerro Prieto Wash, East of Blanco Tank, Mouth of Mendoza	247	480	February	12	2001	Schmalzel, pers. comm. Sept. 16, 2001
Green Valley Performing Arts Center 02-21-01-F-417	5	16	December	20	2001	Service 2001a
Madera Highlands Proposed by Harvard Investment, Inc., East of Green Valley, Arizona 02-21-99-F-273	49	162	February	14	2001	Service 2001b
Safeway Shopping Center - Sahuarita , Arizona 02-21-01-F-271	1	13	August	9	2001	Service 2001c
Pima County Proposed Sand and Gravel Operation on North Side of Helmet Peak Road 02-21-00-F-248	10	15	January	26	2001	Service 2001d
Altar Valley survey for Bureau of Reclamation	564	2,100	September	1	2001	Harris Environmental Group, Inc. 2002
Tucson Federal Prison 02-21-01-F-101	18	423	March	18	2002	Service 2002a
Duval Mine Road Traffic Interchange 02-21-02-F-071	10	18	May	30	2002	Service 2002b
Mission Mine 02-21-03-F-0014	306	165	December	4	2002	Service 2002c
Santa Rita Mountain Ranch 02-21-03-F-0406	268	1,597	November	5	2003	Service 2003
Canoa Hills Estates 02-21-03-F-374	23	21	January	15	2004	Service 2004a
Lease of public land to Pima County for a recreational park 02-21-02-I-0240	25	80	March	23	2004	Service 2004b
345,000-volt transmission line from Sahuartia, Arizona to a sub-station in Nogales, Arizona 01-21-00-F-0427	52	29	April	26	2004	Service 2004c
Corona de Tucson	1	67	June	4	2004	Tierra Right of Way Services 2004
Construction of road and Utility Crossing in an unnamed Wash at the Mirasol Development 02-21-03-F-0483	61	17	June	22	2004	Service 2004d
Santa Rita Residential Development 02-21-04-F-0122	7	128	November	2	2004	Service 2004e

Project Title	Individual Plants	Acres	Month	Day	Year	Reference
New Tucson, in unnamed washes at Corona de Tucson 02-21-04-F-0200	272	50	December	15	2004	Service 2004f
Santa Rita Foothills Estates, in unnamed washes located in Corona de Tucson 02-21-04-F-0403	32	157	June	17	2005	Service 2005a
98 ranch	6	146	July	14	2005	Environmental Planning Group 2005
Change of Access Located within ADOT Right-of-Way for Interstate 19 02-21-05-F-0265	1	4	August	5	2005	Service 2005b
Solar del Viejo 02-21-05-F-0346	120	138	August	31	2005	Service 2005c
Andrada Ranch 02-21-05-F-0347	35	79	November	23	2005	Service 2005d
Pima County Pima Pineapple Cactus Conservation Bank	67	568	unknown		2006	Pima County 2006b
Ocotillo Preserve Residential Subdivision 02-21-02-F-0210 and 02-21-04-F-0160	21	92	February	3	2006	Service 2006a
Pima County DOT and Flood Control District Hayhook Road construction 22410-2006-I-0536	3	17	July	21	2006	Service 2006b
Diablo Village Residential Subdivision 22410-2006-F-0138	63	189	August	24	2006	Service 2006c
Bajada Ranch 22410-2006-F-0471	5	21	December	5	2006	Service 2006d
City of Tucson section 2, township 15 south range 15 east	0	9	January	29	2007	Tierra Right of Way Services 2007b
Las Delicias BANWR and AZ State Lands RX burn	97	1,151	February	2	2007	Service 2007b
SFPP,L.P. El Paso to Phoenix Expansion 22410-2006-F-0470	28	73	February	5	2007	Service 2007c
Fagan Ranch Residential Development 22410-2006-F-0537	65	376	March	22	2007	Service 2007d
Air Force Plant 44 buffelgrass spraying 22410-2007-I-0353	180	1,598	July	13	2007	Service 2007e
Nationwide Differential Global Positioning System property	2	11	October	22	2007	Westland 2007
Parcel 19 Pima County	31	59	November	5	2007	Tierra Right of Way Services 2007a
Improvements to State Route 86 between Sandario Road and Kinney Road 22410-2008-F-0281	7	142	July	2	2008	Service 2008
BANWR FMP and reinitiation 22410-2005-F-0243-R001	485	58,733	March	23	2009	Service 2009b
Community Water Company of Green Valley Central Arizona Project Water Delivery System 22410-2009-F-0090	5	14	May	20	2009	Service 2009a
Pascua Yaqui Fee Land - Terracon	40	364	July	15	2010	Tierra Right of Way Services 2010
New Tucson Substation 22410-2010-F-0458	25	25	November	2	2010	Service 2010
Traffic Interchange Ramp Connections between I-19 and Sahuarita Road 22410-2011-F-0343	25	34	September	6	2011	Service 2011
Rosemont Copper Mine, Pima County 22410-2009-F-0389	67	33	October	30	2013	Service 2013
Sierrita Pipeline Project 02EAAZ00-2013-F-0035	142	487	April	14	2014	Service 2014a
Stormwater Controls Project for Asarco's Mission Complex 02EAAZ00-2014-F-0456	6	60	August	26	2014	Service 2014b

Project Title	Individual Plants	Acres	Month	Day	Year	Reference
Pima County Marley Ranch partial survey	26	123	December	1	2014	Powell 2015
Sierrita open pit copper mine	8	215	unknown		2016	Service 2016b
Tohono O'odham Ki:Ki Association	12	14	unknown		2017	Service 2017
Total	**6,131**	**105,786**				

Appendix 2 – Comments on the Draft Recovery Plan and our responses

Public Review
A draft of this Recovery Plan was published and distributed for review to all interested parties. The Service published a notice in the Federal Register on June 26, 2017 (82 FR 28875) to announce that the document was available for public review and comment. The comment period lasted for 60 days and closed on August 25, 2017. An electronic version of the draft Recovery Plan was also posted on the Service's Southwest Region website (*https://www.fws.gov/southwest/es/arizona/Documents/SpeciesDocs/PimaPineappleCactus/Draft%20PPC%20Recovery%20Plan_for%20public%20comment.pdf) and the Species Profile website (https://ecos.fws.gov/ecp0/profile/speciesProfile?sId=4919*).

Peer Review
We asked four individuals to serve as peer reviewers of the document and all four reviewers provided comments. The qualifications of the peer reviewers are in the administrative record for this recovery plan.

Public Comments Received
We received six sets of comments on the draft Recovery Plan from interested parties. These included comments from one Federal agency, two local government agencies, one non-profit organization, and two sets of comments from individual citizens. We did not receive any public comments from State or Tribal entities.

Responses to Comments
A summary of all comments received and our responses is included in the table below. The Service reviewed all comments received for substantive issues and new information, and we have amended the draft Recovery Plan as appropriate. The Service acknowledges the public comments and the great care with which individuals and organizations responded to the draft recovery plan. The Service recognized that public participation is essential to the task of protection PPC. The final Recovery Plan is the product of many years of work on the part of the U.S. Fish and Wildlife Service and numerous Federal, state, and local organizations, as well as individuals from Arizona and Mexico.

Some comments provided were supportive of the Recovery Plan overall and offered constructive advice that has substantially improved the plan. Some commenters suggested editorial changes to the text of the document and we have incorporated suggestions as appropriate. Some commenters suggested additions and clarifications, and we tried to clarify the document and have accommodated these suggestions as appropriate. The remaining comments were taken into consideration in the final version of the recovery plan, and specific responses are provided below. Several of the comments were similar in nature and were combined and summarized for brevity. Comments are grouped under 10 categories based on the related section of the Recovery Plan: 1) Entire Recovery Plan; 2) Distribution and Abundance; 3) Habitat, 4) Life History and Ecology; 5) Reasons for Listing and Current Threats and Stressors; 6) Past Conservation Efforts; 7) Recovery Objectives; 8) Recovery Criteria; 9) Recovery Action Outline and Narrative; and 10) All Other Sections.

Submitted by	Comment	Our Response
1) Entire Recovery Plan		
Pima Natural Resource Conservation District	The commenter is concerned that the Service is not using the information gathered on the taxon in a meaningful way.	We have used the best available commercial and scientific data to develop the downlisting and delisting criteria in the Draft and Final Recovery Plans. Our objective is to conserve, protect, and enhance *C. scheeri* var. *robustispina* and its habitat.
King Anvil Ranch	The commenter feels that after 25 years of data collection, the draft recovery plan ought to have been more informative.	We have used the best available commercial and scientific data to develop the downlisting and delisting criteria in the Draft and Final Recovery Plans. In the Final Recovery Plan, we have added additional information on threats such as fire, nonnative invasion, and drought. Our objective is to conserve, protect, and enhance *C. scheeri* var. *robustispina* and its habitat.
Pima Natural Resource Conservation District	The commenter feels that that recovery plan does not lay out a clear plan for recovery of the taxon.	Based on regulations and policy, we have developed quantifiable and measurable recovery criteria. We have added language to clarify the criteria.
Altar Valley Conservation Alliance; Pima County Office of Sustainability and Conservation	The commenters state that several of the maps contained in the Draft Recovery Plan are coarse and outdated.	Maps are coarse due to the size of the area. The best commercial and scientific geographic data available was used in the creation of these maps. For example, although we tried to acquire more recent nonnative plant geographic data (e.g. Figure 9), it is not available.
King Anvil Ranch; Cindy Coping	The commenters state that most of the cited references in the draft recovery plan are unavailable to the public and were not made available in response to timely requests.	A complete list of all references cited within the Draft Recovery Plan was made available upon request from the Arizona Ecological Services Field Office. This information was written in the Federal Register Notice under the heading Supplemental Information. References for all surveys listed in Appendix A have been added to the Final Recovery Plan.
King Anvil Ranch	The commenter feels there should be talk about delisting the taxon.	Per section 4(c)(2) of the Act, the Service will conduct a 5-year status review of the taxon, at which time a recommendation on its listing status will be made.

Submitted by	Comment	Our Response
Arizona-Sonora Desert Museum	The commenter suggests accepting the current taxonomy of *Cenchrus cilaris*.	We have used the most current taxonomy of *Cenchrus ciliaris* in the Final Recovery Plan.
2) Distribution and Abundance		
Pima County Office of Sustainability and Conservation	The commenter requests density values be provided.	Density values are provide on page iv and in Appendix 1.
Pima County Office of Sustainability and Conservation	The commenter wishes confirmation that 80,000 acres in good or optimal quality habitat represents 42 percent of the known range of the species.	The values presented are correct.
Pima County Office of Sustainability and Conservation	The commenter questions the statement that genetic isolation occurs over a distance of more than 900 meters.	We have addressed this comment in the Final Recovery Plan. We are simply reporting the results of McDonald 2005.
Pima County Office of Sustainability and Conservation	The commenter requests that the results of the Baker 2005 study on distribution and relative densities be provided.	We reviewed Baker 2005 and did not find anything additional to add to the document.
Pima County Office of Sustainability and Conservation	The commenter states that monitoring the same individuals over time to talk about population dynamics is bad science.	We disagree with this comment, as monitoring individuals provides indications regarding population dynamics.
Pima County Office of Sustainability and Conservation	The commenter notes that the development of survey techniques is already underway.	We have modified the language to reflect the continuation of development of survey techniques.
3) Habitat		
Pima County Office of Sustainability and Conservation	The commenter suggests the removal of information pertaining to negative survey results.	We disagree with the removal of information on the similarity of habitat surveyed in negative surveys. This information illustrates suitability of habitat with no plants found.
4) Life History and Ecology		
Forest Service	The commenter asks if it is native or nonnative grass that *C. scheeri* var. *robustispina* growth, seed output, and longevity are inversely correlated with in the Schmalzel 2000a study.	The Schmalzel 2000a study does not differentiate native and nonnative, however, we have added more discussion of native vs. nonnative grassland ecology in relation to *C. scheeri* var. *robustispina* growth, seed output, and longevity in the Final Recovery Plan.

Submitted by	Comment	Our Response
Forest Service	The commenter asks if extra-floral nectaries are producing and if they attract ants/small rodents for seed dispersal as well as pollinators?	It is unknown if extra-floral nectaries are useful for seed dispersal.
Forest Service	The commenter suggests that either previous estimates of reproduction are way off, or these plants were once much more abundant across the landscape than they are now.	We do not have the data to make conclusions with regard to estimates of reproduction or abundance across the landscape historically.
Forest Service	The commenter asks if seed production studies were conducted in the wild or in a greenhouse. If studies were conducted in a greenhouse setting, then that would show that early viability is not a problem, and that's about it.	We have added clarifying language in the Final Recovery Plan.
Forest Service	The commenter asks if the habitat requirements for *Diadasia rinconis* are separate/distinct from those of the cacti, if it is a common cactus specialist bee, if there is information on its vulnerability and any different threats to the pollinator vs. the plant?	The habitat conditions required for *Diadasia rinconis* are similar to those conditions needed by *C. scheeri* var. *robustispina*. This information can be found on page 11.
5) Reasons for Listing and Current Threats and Stressors		
Altar Valley Conservation Alliance	The commenter states that the information provided on pre- and post-prescribed burn surveys on BANWR and Las Delicias Ranch does not include specifics about recruitment, mortality, or a discussion of the potential effects of drought conditions.	In the Final Recovery Plan, additional information was included in the discussion of fires in the Altar Valley.
Altar Valley Conservation Alliance	The commenter feels that more thorough results from current monitoring efforts would provide valuable information.	We have used the best scientific and commercially available data on which to base our conclusions, which includes results from current monitoring efforts.

Submitted by	Comment	Our Response
King Anvil Ranch; Pima Natural Resource Conservation District	The commenters feel that the existing pre- and post-burn survey data from ranches in the Altar Valley and BANWR should be enough to provide the Service with an understanding of the effects of fire.	We have used the best scientific and commercially available data on which to base our conclusions. In the Final Recovery Plan, we added more information on the effects of historical prescription and wildfires on *C. scheeri* var. *robustispina* in the Altar Valley.
King Anvil Ranch; Pima Natural Resource Conservation District	The commenters suggest that the survey data that has been collected from managed grazing areas can be compared to the survey data collected from the cattle-free BANWR to understand the effects of grazing.	We have used the best scientific and commercially available data on which to base our conclusions, which includes additional language on the effects of low to moderate grazing vs. historical heavy grazing.
Altar Valley Conservation Alliance	The commenter suggests a description of the causes of mortality for plants lost under section 7 consultation to help explain some of the largest threats.	Most plants lost under section 7 consultation were removed due to construction activities. This was stated on page 14 of the Draft and Final Recovery Plans.
Altar Valley Conservation Alliance	The commenter believes that increased fire intensity from *Eragrostis lehmanniana* is a contradiction to what would have occurred historically in the valley, and identifying this as a threat may create challenges to future applications of prescribed burning as a resource management tool and ecosystem restoration goals.	We have used the best commercially and scientifically available data which indicates nonnative grasses, in particular, can alter wildfire behavior and remove safe niches for *C. scheeri* var. *robustispina* during fires.
Altar Valley Conservation Alliance	The commenter states that currently grazed rangeland in southern Arizona provides the majority of current habitat for the taxon, and suggests that grazing may contribute to survival by reducing dense grass stands.	We have used the best scientific and commercially available data on which to base our conclusions. In both the Draft and Final Recovery Plans, we acknowledge that low to moderate intensity grazing may benefit *C. scheeri var. robustispina*, although we do not know at what level of disturbance the taxon becomes negatively impacted. We have identified a need for scientific study on disturbance tolerance and thresholds for the taxon.

Submitted by	Comment	Our Response
Cindy Coping	The commenter states that the Service should weigh the harmful influences on the taxon (human activities, climate, etc.) against the beneficial influences of those same factors.	We have used the best available commercial and scientific data to assess the threats and stressors to the plant in the Draft and Final Recovery Plans. Under Recovery Action 4, we have identified a need for scientific study on disturbance tolerance and thresholds for the taxon.
Altar Valley Conservation Alliance	The commenter states that *C. ciliaris* was never released in Arizona.	To address this comment, we have expanded the section regarding the introduction of nonnative grasses into Arizona and added citations.
Altar Valley Conservation Alliance; Cindy Coping	The commenters state that chaining, ripping, and planting of nonnative grasses as current management actions are not known to occur in *C. scheeri* var. *robustispina* habitat	We have addressed this comment in the Final Recovery Plan.
Cindy Coping	The commenter states that the descriptions of range conditions and management practices in Arizona and Mexico belong in separate sections of the recovery plan.	We have addressed this comment in the Final Recovery Plan.
Altar Valley Conservation Alliance	The commenter states that drought has continued beyond the range of October 2011 to September 2012, and the Recovery Plan should be updated to include the most recent CLIMAS Water Year in Review	We have addressed this comment in the Final Recovery Plan.
Cindy Coping	The commenter states that there is no proof that livestock step on *C. scheeri* var. *robustispina*, and at a level that is threatening the entire species.	We have revised the language in the Final Recovery Plan to clarify that livestock trampling likely occurs, though there are no known direct observations. We do not state in either the Draft of Final Recovery Plants that trampling threatens the entire species.
Cindy Coping	The commenter claims that *C. ciliaris* is being dispersed into Arizona rangeland by illegal immigrants and drug mules from Sonora.	Nonnative plants are dispersed by many methods, but dispersal of nonnative plants is outside the scope of this recovery plan.
Pima County Office of Sustainability and Conservation	The commenter questions whether prairie dogs ever occupied the Altar or Santa Cruz valleys.	We have addressed this comment in the Final Recovery Plan.

Submitted by	Comment	Our Response
Pima County Office of Sustainability and Conservation	The commenter suggests that historically, the Altar Valley may not have been habitat for *C. scheeri* var. *robustispina*, and the habitat that is there now could be an artifact and benefit from overgrazing and loss of dense grass cover.	We have used the best available commercial and scientific information including providing additional discussion on the differences between historical native-dominated grasslands vs. nonnative dominated grasslands.
Cindy Coping	The commenter suggests the observation of higher quantities of *C. scheeri* var. *robustispina* along cattle trails could be the result of seed dispersal by jackrabbits that have freedom to move in patchy habitat, rather than higher visibility along trails.	We have used the best available commercial and scientific data on which to base our conclusions. We have no information indicating a higher density distribution of *C. scheeri* var. *robustispina* along cattle trails as a result of jackrabbit dispersal.
Pima Natural Resource Conservation District	The commenter feels there is a pressing need for well-vetted, detailed accounts of the outcomes for *C. scheeri* var. *robustispina* populations on Federal lands, specifically a comparison of Coronado National Forest and BANWR.	Coronado National Forest *C. scheeri* var. *robustispina* are discussed on pages 7 and 26; BANWR *C. scheeri* var. *robustispina* are discussed on pages 6, 10, 16, 21-24, and 29.
Pima County Office of Sustainability and Conservation	The commenter suggests that the grassland and scrub systems should be separated when discussing fire, as the current density of *Eragrostis lehmanniana* may not match the historical density of native plants.	We have used the best available commercial and scientific information including providing additional discussion on the differences between historical native-dominated grasslands vs. nonnative dominated grasslands in both grassland and scrubland habitat types.
Pima County Office of Sustainability and Conservation	The commenter states that the frequency of historical low severity grassland fires should be every 5-10 years instead of 10-20.	We have addressed this comment in the Final Recovery Plan by adding additional citations supporting the 10-20 year timeframe.
Pima County Office of Sustainability and Conservation	The commenter questions if the species range data for *Eragrostis lehmanniana* suggests the occurrence of fire is more frequent.	We have used the best available commercial and scientific information including providing additional discussion on the differences between historical native-dominated grasslands vs. nonnative dominated grasslands with relation to fire.
Pima County Office of Sustainability and Conservation	The commenter questions the statement that nonnative grasses produce more fine fuels than native vegetation, allowing for more uniform and higher intensity burns.	We have used the best available commercial and scientific information including providing additional discussion on the differences between historical native-dominated grasslands vs. nonnative dominated grasslands.

Submitted by	Comment	Our Response
Pima County Office of Sustainability and Conservation	The commenter requests that more specifics be added regarding the statement that research into desert-scrubland and desert-grassland restoration is essential.	We have addressed this comment in the Final Recovery Plan.
Pima County Office of Sustainability and Conservation	The commenter asks if there is range management literature that provides guidance on grazing intensity and benefits to *C. scheeri* var. *robustispina*, and what does the Service make of higher densities of the taxon occurring in areas with high grazing pressure.	We are unaware of any literature relating to grazing intensity and benefits to *C. scheeri* var. *robustispina*.
Pima County Office of Sustainability and Conservation	The commenter suggests that more recent, updated drought information would be best.	We have addressed this comment in the Final Recovery Plan.
Forest Service	The commenter asks if the current rangeland condition has any greater trend toward contraction of geographic dispersion across the landscape with grazing or not, as Benson discussed is the case for many small cacti.	We do not have the data to make conclusions with regard to current rangeland condition and trends toward contraction and dispersion.
6) Past Conservation Efforts		
Altar Valley Conservation Alliance; Pima County Office of Sustainability and Conservation	The commenters state that the descriptions of various past conservation efforts can be updated.	We have addressed this comment in the Final Recovery Plan.
Pima County Office of Sustainability and Conservation	The commenter disagrees with the statement that landowners, municipalities, and developers are able to purchase habitat conservation credits in Pima County.	We have addressed this comment in the Final Recovery Plan.
Forest Service	The commenter asks about mycorrhizae and endophytic bacteria carried in seed as factors in seedling survival.	In the Final Recovery Plan, we added additional discussion on the role of mycorrhizae and endophytic bacteria carried in seed as factors in seedling survival.
7) Recovery Objectives		

Submitted by	Comment	Our Response
Pima County Office of Sustainability and Conservation	The commenter suggests specifying *C. ciliaris* or other species that alter ecosystem function, rather than a blanket statement about nonnative species. They also note that habitat restoration techniques on lands infested with *C. ciliaris* are known.	We have addressed this comment in the Final Recovery Plan.
Pima County Office of Sustainability and Conservation	The commenter states that the recovery objectives are confounded and confusing.	We have addressed this comment in the Final Recovery Plan.
Pima County Office of Sustainability and Conservation	The commenter requests more detail on the recovery objective to determine best management practices for *C. scheeri* var. *robustispina.*	We have addressed this comment in the Final Recovery Plan.
Forest Service	The commenter notes that while seed survive in the soil for a few years, the critical factor is synchronicity with wet years for germination and initial seedling survival which may be many years apart. So maintaining and increasing successful seed set and recent seed rain is also perhaps critically important.	We have addressed this comment in the Final Recovery Plan.
Forest Service	The commenter suggests the following additional language for Recovery Objective 3.7: Maintain genetically representative samples of seed from determined focal areas, with appropriate targets for quantities and collection areas represented. Seed should be collected over time and conditions to capture expressed genetic variability, and gradually accumulate sufficient seed to support well-planned augmentation and reintroduction work.	We have addressed this comment in the Final Recovery Plan.
8) Recovery Criteria		
Pima Natural Resource Conservation District; King Anvil Ranch	The commenter feels it may not be necessary for the Service to acquire and perpetually manage additional lands to protect the taxon, as protected habitat already exists on BANWR, National Forest lands, the Palo Alto Bank, the Pima County Bank, and additional lands already set aside to mitigate impacts of urban	The commenter misunderstands the Recovery Plan in that we do not propose additional lands must be acquired, but may be, in addition to the protected habitat already in existence.

Submitted by	Comment	Our Response
	development.	
Pima County Office of Sustainability and Conservation	The commenter states that habitat quality has not been defined.	We have addressed this comment in the Final Recovery Plan.
Pima Natural Resource Conservation District	The commenter states that land acquisitions will not significantly expand the total number of acres of land occupied by the taxon that remains undeveloped.	The commenter misunderstands the Recovery Plan in that we do not propose additional lands must be acquired, but may be, in addition to the protected habitat already in existence.
Cindy Coping	The commenter suggests that the Service should preserve and expand existing management regimes in places where the taxon is already thriving.	The Recovery Plan promotes preserving and expanding management regimes in places where the taxon is already thriving. For example, refer to Criteria 2, the habitat-based objective: conserve, restore, and manage the quantity and quality of habitat needed for the continued survival of *C. scheeri* var. *robustispina* and its pollinators.
Pima County Office of Sustainability and Conservation	The commenter requests that spatial scale be addressed in recovery criterion 1.	We have addressed this comment in the Final Recovery Plan by directing the reader to Criteria 2.
Forest Service	The commenter asks if additional language about configuration to support species integrity and corridors is needed, or does the extent of the criteria ensure that this will occur?	We have addressed this comment in the Final Recovery Plan.
Forest Service	The commenter asks if the 15 year time period in the justification for criterion 3 can be revised if rainfall events supporting sufficient recruitment occur but are in a longer cycle.	The commenter suggests a longer period of time be used to ensure species response. We do not feel this is necessary for downlisting criteria and we already suggest a longer period (25 out of 30) years for delisting criteria.
Forest Service	The commenter requested that monitoring of historic and current land management scenarios (as available information can demonstrate) be added to Criterion 3.	We have addressed this comment in the Final Recovery Plan.
9) Recovery Action Outline and Narrative		

Submitted by	Comment	Our Response
Altar Valley Conservation Alliance	The commenter states that there are already standardized forms and protocols for long-term monitoring used by NRCS and BANWR.	We have addressed this comment in the Final Recovery Plan.
Altar Valley Conservation Alliance	The commenter suggests that a better description and outline of land acquisition methods as a way to recover the taxon would strengthen the Recovery Plan.	The commenter misunderstands the recovery plan in that we do not propose additional lands must be acquired, but may be, in addition to the protected habitat already in existence. Voluntary land conservation is promoted (for example, see the Past Conservation Efforts section).
Pima County Office of Sustainability and Conservation	The commenter requests the addition of Department of Interior definitions of adaptive resource management.	We have addressed this comment in the Final Recovery Plan.
Universidad Autónoma de Tamaulipas, México	The commenter recommends additional existing research that could contribute to Cactaceae conservation.	We agree that additional research could contribute to Cactaceae conservation and have recommended additional research on this species in the Final Recovery Plan. We have to focus on this species for this particular Recovery Plan, but hope this helps with overall conservation of Cactaceae.
Universidad Autónoma de Tamaulipas, México	The commenter advises propagating and reintroducing plants of various ages to new conservation areas to investigate differences survival and mortality.	We have addressed this comment in the Final Recovery Plan.
Universidad Autónoma de Tamaulipas, México	The commenter suggests conducting studies on species that are closely related to *C. scheeri* var. *robustispina*.	We have addressed this comment in the Final Recovery Plan.
Universidad Autónoma de Tamaulipas, México	The commenter suggests conducting a study on the main nurse plants associated with different populations of *C. scheeri* var. *robustispina.*	We have addressed this comment in the Final Recovery Plan.
Universidad Autónoma de Tamaulipas, México	The commenter suggests obtaining lambda values to project population viability.	The Recovery Plan encourages scientific study which could address this suggestion in the future.
Forest Service	The commenter asks how managing the impacts of increasing recreational use and pressure to preserve habitat quality and integrity feature into increased open space preservation?	We have addressed this comment in the Final Recovery Plan.

Submitted by	Comment	Our Response
Forest Service	The commenter states that planning of conservation mitigation banks should occur ahead of development to achieve connectivity and integrity goals.	We have addressed this comment in the Final Recovery Plan.
Forest Service	The commenter believes that monitoring of plants grown *in situ* or transplanted should occur every year for the first 3-5 years, and is vital to understand early factors causing loss.	We have addressed this comment in the Final Recovery Plan.
Forest Service	The commenter states that plants maintained in captivity should not be kept as an *ex situ* genetic collection.	We have addressed this comment in the Final Recovery Plan.
Forest Service	The commenter states that too much effort shouldn't be put into *in situ* conservation, as most plants can be started in cultivation and skip seed mortality.	We disagree with the commenter, as there is some indication that *in situ* growing of seeds can result in seed germination and seedling establishment. Further, results of transplanting has been variable.
10) All Other Sections		
Pima County Office of Sustainability and Conservation	The commenter asks what it means to be a responsible party for implementation.	The description of responsible parties is included in section III – Implementation of both the Draft and Final Recovery Plans.
Pima County Office of Sustainability and Conservation	The commenter notes the County has done a spatial analysis that can inform implementation	We appreciate the offer to use the spatial analysis done by the County and will coordinate how to use this analysis as we move forward with implementation.
Pima County Office of Sustainability and Conservation	The commenter requests that in Appendix 1, surveys whereby density can be derived be split out.	All surveys shown in Appendix 1 indicate the number of acres surveyed and the number of individual *C. scheeri* var. *robustispina* found. Therefor density can be derived for all of the surveys shown in this table.