

D R A F T

STAR CACTUS

(Astrophytum asterias)

RECOVERY PLAN



Astrophytum asterias (Zuccarini-Lemaire). Photo courtesy of Charlie McDonald, USDA Forest Service

Region 2
U.S. Fish and Wildlife Service
Albuquerque, New Mexico

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(*Astrophytum asterias*)

RECOVERY PLAN

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DISCLAIMER

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect listed species. Plans are published by the U.S. Fish and Wildlife Service, sometimes prepared with the assistance of recovery teams, contractors, state agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved as well as the need to address other priorities. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service **only** after they have been signed by the Regional Director or Director as **approved**. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 2002. Star cactus (*Astrophytum asterias*) Recovery Plan. U.S. DOI Fish and Wildlife Service, Albuquerque, New Mexico. 30pp.

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EXECUTIVE SUMMARY

Current Status: Star cactus is listed as endangered. There are currently two known populations: one population composed of two subpopulations on private land in Starr County, Texas, and one in Tamaulipas, Mexico. The species has also been reported in Nuevo Leon, Mexico. Other populations may exist in the United States and Mexico, but remain undocumented due to the difficulty in surveying for the species on private land. Due to this lack of information, it is difficult to accurately gauge the current status of the species. It is therefore recommended that conservation measures for the species proceed as if there is a high probability that the known United States population is the only existing population relevant for recovery under the Endangered Species Act (Act).

Habitat Requirements and Limiting Factors: The star cactus grows in the grasslands and thorn shrub of the Rio Grande. The species is found on gravelly clays or loams overlaying the Tertiary Catahoula and Frio formations in the United States and on soils of limestone origin overlaying Cenozoic to Mesozoic marine sediments in Tamaulipas. Habitat destruction and modification, collection, competition with exotic grasses, and decreased population numbers are major threats to the star cactus.

Recovery Objective: The recovery objective for the star cactus is to reclassify the species as threatened through the reintroduction of populations in natural habitat and in refugia collections and seed bank reserves. Protection of known or newly documented existing populations, surveys, research, and development of a formal conservation agreement between the United States and Mexico are integral to achieving the reclassification goal. Delisting criteria must be developed to guide further recovery work. Recovery actions in the Star Cactus Recovery Plan (Plan) will both ensure the species' survival and provide the information necessary to develop delisting criteria.

Recovery Criteria: Establish and/or maintain three fully protected, self-sustaining (i.e., a minimum of 2000 individuals) populations of star cactus in Texas on Federal lands (e.g., National Wildlife Refuge lands), voluntary state lands (e.g., state parks), voluntary private lands, or a combination. Full protection is considered management of the populations on Federal or state lands as part of an approved management plan, or a formal stewardship agreement with private landowners. Management should include monitoring the species' numbers and distribution, habitat, and threats. In addition, a formal conservation agreement for star cactus, such as a Memorandum of Understanding (MOU), should be developed and implemented between the United States and Mexico.

Major Actions Needed:

1. Protect and manage existing star cactus populations and habitat in the United States and Mexico.
2. Gather information for management and monitoring programs for star cactus.
3. Search for new populations of star cactus in the United States and Mexico.
4. Establish and maintain a botanical garden population of star cactus.
5. Establish new populations as necessary to meet reclassification criteria.
6. Develop and implement a formal conservation agreement (e.g., MOU) for star cactus between the United States and Mexico.
7. Develop a public education and awareness program for the species.
8. Evaluate progress toward recovery, management direction, and status of information needed for development of delisting criteria within five years (2008).

These actions are not necessarily listed in order of priority; prioritized stepped-down actions are given in the Implementation Schedule. The Major Actions Needed translate directly to the Step-down of Recovery Actions and Narrative Outline of Recovery Actions.

Estimated Cost of Recovery (in 1,000s):

The Estimated Cost of Recovery is given for five years, as progress and management direction will be evaluated at that time. Costs that may continue throughout the estimated time to downlisting (10 years), assuming no major changes are made to the Plan during the five-year evaluation, are given in footnotes to the table. The costs below are also given in the Implementation Schedule. Costs associated with delisting are not given in this Plan, as it is not possible to develop a full recovery strategy at this time.

Year	Major Action 1	Major Action 2	Major Action 3	Major Action 4	Major Action 5	Major Action 6	Major Action 7	Major Action 8	Total Estimated Cost
2003	14.0	40.0	6.0	4.0	5.0	–	2.0	0.0	71.0
2004	7.0	34.25	6.0	4.0	5.0	–	2.0	0.0	58.25
2005	7.0	34.25	6.0	4.0	5.0	–	2.0	0.0	58.25
2006	7.0	24.0	6.0	0.0	5.0	–	0.0	0.0	42.0
2007	7.0	24.0	6.0	0.0	5.0	–	0.0	0.0	42.0
Total	42.0¹	156.5²	30.0	12.0	25.0	–³	6.0	0.0⁴	271.5

¹ Costs of approximately \$7,000/year may continue throughout the estimated ten years to reclassification for activities such as development of stewardship agreements for private landowners and law enforcement. ² Costs of approximately \$8,000/year may continue throughout the estimated ten years to reclassification for development of management/monitoring programs. ³ Costs will be developed when interested parties have been identified; costs could include meeting/travel logistics. ⁴ Major Action 7 may incur costs throughout the estimated ten years to reclassification if significant management adjustments need to be made to the Plan in the future. Costs could include convening a Recovery Team to develop delisting criteria based on new information.

Date of Recovery: Time to achieve reclassification to threatened status is estimated at ten years. This is based on the time it will take to survey existing habitat for unidentified populations, accomplish priority research needs, establish a botanical garden population and new wild populations, and implement management plans and stewardship agreements to protect known populations. Estimated time to delisting is contingent upon results obtained during the downlisting recovery period. The identification and protection of previously unknown populations, and information obtained through research, will set the stage for defining recovery and determining the degree of effort needed to reach recovered status. The Plan will be reevaluated in five years (2008) to assess progress on reintroduction, research, and survey efforts; management should be adapted as needed, including revision of the Plan.

PART I - INTRODUCTION

Overview

Star cactus (*Astrophytum asterias* (Zuccarini-Lemaire)) was listed as an endangered species under authority of the Endangered Species Act (ESA) of 1973, as amended, on October 18, 1993 (U.S. Fish and Wildlife Service 1993). Critical habitat was not designated. Star cactus was listed as endangered by the State of Texas on January 30, 1997 (Texas Parks and Wildlife Executive Order No. 97-002). The star cactus has a recovery priority of 2; this recovery designation indicates that the species faces a high degree of threat yet has high recovery potential.

The star cactus is presently known from one population sub-divided into two smaller populations in Starr County, Texas (Figure 1), and a population in Tamaulipas, Mexico. Several other Tamaulipan populations may exist, but verification is needed from Mexico. The star cactus has also been reported in the State of Nuevo Leon in Mexico (Correll & Johnston 1979). Additional populations may exist in Texas and Mexico; however, surveys and documentation are difficult due to lack of access to private land.

The species can be found in semi-arid grassland and open thorn shrub habitats. Star cactus normally occurs on gravelly, calcareous loam and clay soils. The species is threatened by habitat destruction and modification through conversion of native habitat to row crop; rangeland and urban development; collection of wild plants for the cactus trade; possible competition with exotic grasses introduced for cattle forage; and genetic vulnerability due to low population numbers.

Taxonomy

The star cactus was originally collected in Tamaulipas, Mexico, by Baron von Karwinsky in 1843, and named *Echinocactus asterias* by Joseph Zuccarini in 1845. It is possible that both Karwinsky and Zuccarini collected star cactus from Tamaulipas in 1843 (Benson 1982). Charles A. Lemaire described *Astrophytum prismaticum* in 1868 and included *Echinocactus asterias* in the new genus *Astrophytum*. Star cactus then became *Astrophytum asterias* (Zuccarini) Lemaire. Various taxonomic treatments have placed star cactus in either the genus *Astrophytum* or *Echinocactus*. Placement of star cactus in the genus *Astrophytum* was chosen by the U.S. Fish and Wildlife Service (Service) because of the prevalent use of this name in the horticultural literature.

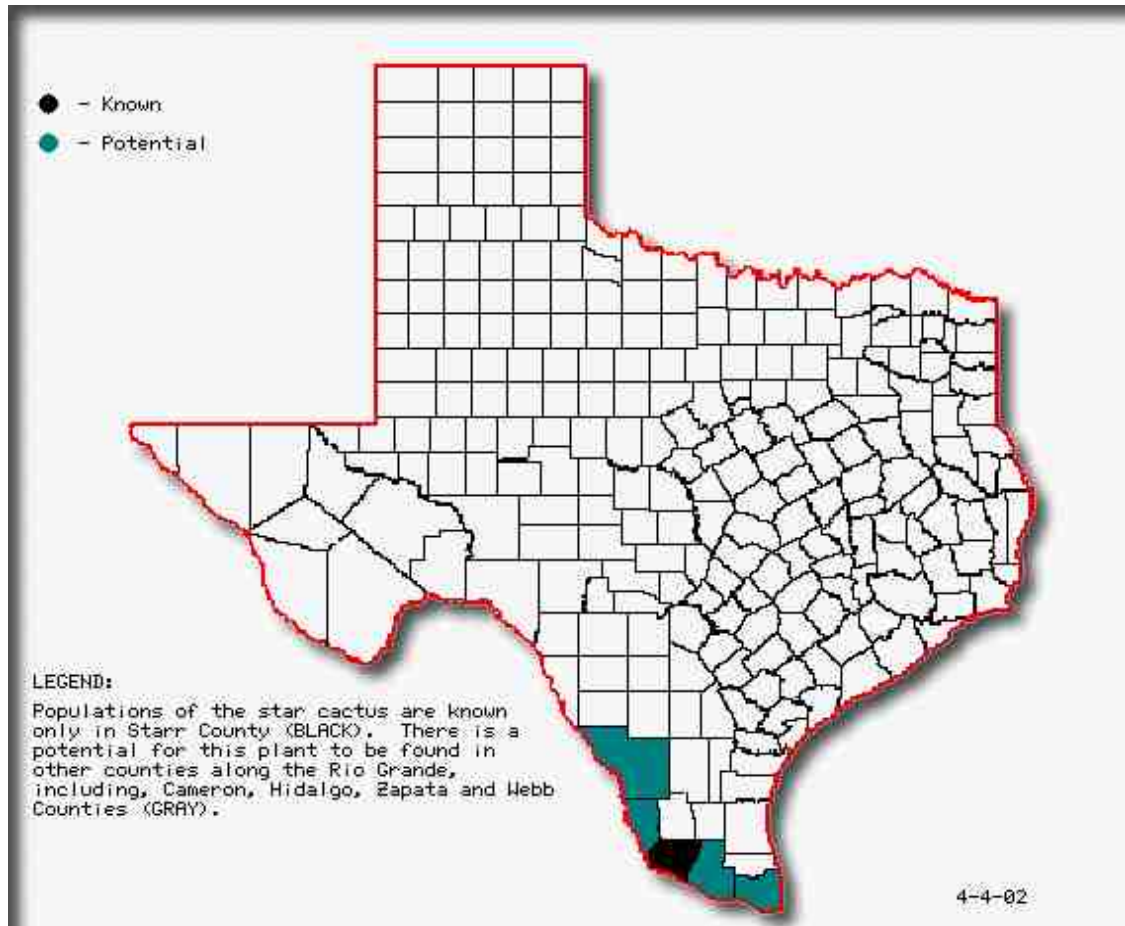


Figure 1. Counties of occurrence of currently known and potential star cactus populations in Texas, United States.

Morphology

The star cactus is a small, spineless, disk or dome-shaped member of the Family Cactaceae (Cactus Family). It is 2–15 centimeters (1–6 inches) across, and up to 7 centimeters (3 inches) tall. Star cactus is dull green-to-brown in color, often speckled with a covering of tiny white scales. The body is divided into eight, vaguely triangular sections. Each triangular section has a central line of circular indentations (areoles) filled with whitish, woolly hairs. During periods of adequate moisture, star cactus is usually a dull green color; however, during droughts, the cactus becomes brownish and loses fullness so that it becomes flush with the ground and almost perfectly camouflaged. Flowers are yellow with orange centers, and up to 5 centimeters (2 inches) in diameter. The fruits of star cactus are green to grayish-red, somewhat obscured by white woolly hairs, about 1.25 centimeters (0.5 in) long, oval, and fleshy when mature. The seeds are glossy, dark brown with an enlargement of a chamber of the seed coat forming a flaring collar that encircles the hilum (Damude and Poole 1990, Benson 1982).

Habitat

Star cactus occurs at low elevations in sparse, open thorn shrub and grasslands in a warm-temperate, subtropical steppe climate in the United States and in dry, hot thorn shrub in Mexico. The species is found within the Tamaulipan biotic province (Blair 1950) which includes South Texas and Mexico. This semi-arid biotic province is characterized by scattered mesquite and grasses (mesquital-zacatal) on sandy soils and thorn brush species (mesquital-chaparral) on heavier soils. The introduction of cattle and the suppression of fire have reduced the grassland component of this province while increasing the woody species component. While star cactus individuals are occasionally found in the open, they generally occur within the partial shade of other plants or rocks.

Star cactus can be found growing on gravelly clays and loams overlaying the Tertiary Catahoula and Frio formations in the United States, and on soils of limestone origin overlaying Cenozoic to Mesozoic marine sediments in Tamaulipas (Sanchez-Mejorada *et al.* 1986, Damude and Poole 1990). The site of the known United States population is mapped as part of the Catarina soil series; however, Damude and Poole (1990) note that observers at the site characterized the soils as being gravelly loams more closely resembling the Jimenez-Quemado association (Thompson *et al.* 1972). A recently rediscovered historical site, now likely extirpated by colonia development, located in the hills northeast of Roma in Starr County, is mapped as Jimenez-Quemado soils (Thompson *et al.* 1972). These shallow, gravelly soils are underlain by caliche and support a barreta (*Helietta parvifolia*) community.

The existing United States population consists of two subpopulations with approximately 2,000 individuals located within a twenty-acre area. One of the subpopulations occurs within an open, gravelly, flat area dominated by a sparse cover of mesquite (*Prosopis glandulosa*) and grasses (*Pennisetum ciliare*, *Bouteloua trifida*, *Aristida* sp.). The other subpopulation is found nearby on rocky hillsides with a heavier cover of mesquite and blackbrush (*Acacia rigidula*). In both areas the original native vegetation has been significantly altered by range management practices of clearing and overgrazing. The original vegetation of the site was more likely an open desert or subtropical grassland. Several other species of cacti, both common and somewhat rare, are found at this site. Other species found at the site in association with star cactus include: goldenweed (*Isocoma drummondii*), Lindheimer prickly-pear (*Opuntia lindheimeri*), tasajillo (*Opuntia leptocaulis*), amargosa (*Castela texana*), allthorn (*Koberlinia spinosa*), twisted-rib cactus (*Echinocactus setispinus* var. *hamatus*), horsecrippler (*Echinocactus texensis*), lotebush (*Ziziphus obtusifolia*), saladillo (*Varilla texana*), coma (*Bumelia celastrina*), popote (*Ephedra antisyphilitica*), nipple cactus (*Mammillaria heyderi*), Runyon's coryphantha (*Coryphantha macromeris* var. *runyonii*), glory of Texas (*Thelocactus bicolor*), shoregrass (*Monanthochloe littoralis*), Fitch's hedgehog cactus (*Echinocereus reichenbachii* var. *fitchii*), sacasil (*Wilcoxia poselgeri*) and coyotillo (*Karwinskia humboldtiana*) (Correll and Johnston 1979, Damude and Poole 1990).

In Tamaulipas, star cactus occurs in Tamaulipan thorn shrub, which is also classified as Bosque Espinoso (Rzedowski 1978), in sparsely vegetated, flat rocky soils of limestone origin at elevations below 200 meters (Sanchez-Mejorada *et al.* 1986). Associated plants at this site include: lechuguilla (*Agave lechuguilla*), *Acacia* sp., *Prosopis glandulosa*, *Mammillaria heyderi*, *Yucca elephantipes*, cuajote amarillo (*Bursera fagaroides*), palo verde (*Cercidium macrum*), *Ariocarpus trigonus*, *Thelocactus bicolor* var. *schwarzii*, *Echinocactus texensis*, *Ancistrocactus megarhizus*, *Agave striata*, *Argemone platyceras*, *Hechtia* sp., creosotebush or gobernadora (*Larrea tridentata*), *Mammillaria meiacantha*, abrojo (*Opuntia imbricata*), *Mammillaria sphaerica*, *Echinocactus setispinus*, and ballmoss (*Tillandsia*

recurvata) (Sanchez-Mejorada et al. 1986, Mason and Mason 1987, Glass pers.comm., Hoock pers.comm.). The Tamaulipan population has few individuals remaining due to collection from the site (Sanchez-Mejorada et al. 1986).

Population Biology

Star cactus has been observed flowering in the wild from March through May, with fruiting occurring from April through June. Cultivated specimens reportedly flower throughout the summer (Damude and Poole 1990). Sanchez-Mejorada et al. (1986) report flowering as occurring during the summer months. Clover (1932) reports star cactus as flowering in April, with the flower only opening slightly the first bloom day and closing that evening. The following morning the flower opens fully and remains open until approximately 5:00 P.M. The flower remains fresh, yet almost closed, and withers by the end of the following day. It is not clear, however, whether this observation of flowering was noted from the wild or from a cultivated specimen. Star cactus is likely insect pollinated, but specific pollinators have not been observed. Further information on phenology and reproductive biology is needed.

While star cactus has been reported to reproduce strictly by sexual out-crossing and seed production (Sanchez-Mejorada et al. 1986), individuals have been observed with the original, larger plant dead and shrunken, yet with juveniles present and growing up from the top of the desiccated remains of the mature plant. It is possible that these small cacti were the result of seed germination and establishment on the surface of the dead individual. Investigation into this possible vegetative reproductive ability using cultivated material is warranted. Evidence of ongoing reproduction has been observed at both populations. Damude and Poole (1990) note that approximately 25 percent of the estimated 2,000 individuals were juveniles. Sanchez-Mejorada et al. (1986) report observation of several seedlings within the 100 noted individuals at the Tamaulipas site. Actual age structure determination in the wild is difficult; therefore, it is not certain whether the populations are reproductively stable or fluctuating.

Seed dispersal mechanisms in the wild are virtually unknown. Mature fruits appear to disintegrate while still attached to the plant and leave a small cluster of seed on top of the plant. Wind and rain may carry the seeds away to establishment sites. Small rodents may also store the seeds at cache sites. Additionally, ants may play a role in seed dispersal. Ants have been observed by Service personnel in several fruits during field visits. They may not directly disperse the seed, but eating the funiculus may aid in seed dispersal.

Star cactus is easy to cultivate from seed if given an appropriate sandy, slightly alkaline soil medium, containing a low amount of organic matter that allows the plants to better resist fungal attacks of the root system (Steven Brack, Mesa Garden, in litt. 1992). San Antonio Botanical Garden, a Center for Plant Conservation member garden, has also reported successful germination of seed in a sandy medium (Dianne Simpson, in litt. 1994).

Distribution and Abundance*Present*

Star cactus is presently known from one population (2 subpopulations) comprised of 2,000 individuals in Starr County, Texas, and from one population with approximately 100 individuals in Tamaulipas, Mexico. Steven Brack (in litt. 1992) reports knowledge, but not site verifications, of two populations in Tamaulipas. Correll and Johnston (1979) indicate the possibility of additional populations in Tamaulipas and Nuevo Leon. One of the populations reported by Brack appears to be the same population documented in the Sanchez-Mejorada et al. report of 1986. In Mexico, the species appears to be limited in distribution to areas unsuitable for cultivation, as most of the available habitat for the species in Mexico has been converted to corn fields or orange groves (Sanchez-Mejorada et al. 1986). Cameron and Hidalgo counties in Texas have also undergone a massive conversion of available native habitat to agriculture.

Historic

The historical range of star cactus included Cameron, Hidalgo, and Starr Counties in South Texas and the States of Nuevo Leon and Tamaulipas in Mexico. The Nuevo Leon site near Linares was probably extirpated by collectors; the same collection threat is reducing the Tamaulipan population (Sanchez-Mejorada et al. 1986).

Octavio Solis collected star cactus in 1919 from Barretillas, Nuevo Leon, and Ciudad Guerrero, Tamaulipas (Britton and Rose 1922). Elzada Clover (1932) documented the collection of star cactus by Romeo Posselt near Ciudad Victoria, Tamaulipas, from heavy soils of limestone origin. Posselt noted that the species was generally found growing in clusters of five to twenty plants in grassy areas and under small, sparse shrubs. Interestingly, Posselt also noted that star cactus was never found growing near other succulents, which is not the case at the Texas site. Damude and Poole (1990) note a historical location for this species at Presa de las Adjuntas, Tamaulipas.

The first documentation of the species occurrence in the United States is taken from receipts of a shipment from Flossie Garrison in January 1932, of cacti that were collected in the Rio Grande Valley of Texas (Clover 1932). This specimen was collected by M.A. Clover from a ranch north of Rio Grande City in Starr County, Texas. Plants were found growing on a south slope in sandy loam soils. Damude and Poole (1990) note the ambiguity of this site location; however, Benson (1969) indicates that this location may have also been the collection site for a specimen from A.D. Wood and F. L. Curtis.

Benson (1969) documents a collection of star cactus northeast of Roma, Starr County, Texas, by A.D. Wood on September 10, 1967. These baretta-dominated gravelly hills are rapidly undergoing urban and colonia development despite the lack of infrastructure such as utilities.

In 1960, W. H. Earle found star cactus at a location west of Brownsville, Cameron County, Texas (Benson 1969). This site has not been relocated and is likely extirpated due to conversion of native habitat to agricultural fields. Weniger (1984) lists Hidalgo County, Texas, as part of the range of star cactus, but does not give an exact location nor indicate a collected specimen.

Impacts and Threats

The Service (1993) described 4 major threats to the star cactus which, when combined, justified listing the species as endangered: (1) Destruction or modification of range through agricultural practices, highway construction, pesticide or herbicide use, invasive exotic grasses, suppression of fire cycles, excessive grazing, and in Mexico, alteration of natural vegetation to cultivation for cash crops; (2) Collection, due to the fact that star cactus is highly prized by cactus enthusiasts for its rarity and unusual appearance; (3) Disease or predation, which although not evidenced at the time of listing, may be having deleterious effects, as herbivory by rodents has been reported recently in Texas; (4) Genetic variability and viability through the loss of habitat and/or modification.

Habitat Loss

Habitat destruction and modification are the primary threats to star cactus. Methods of habitat conversion include range management for agriculture and livestock grazing. Range management practices in South Texas include root-plowing and other mechanical and chemical brush clearing techniques, followed by the introduction of exotic, aggressive invasive grasses such as buffelgrass for cattle forage. These activities may directly or indirectly affect star cactus individuals and populations, but the mechanisms and degree to which such management is detrimental to the species is not well understood. Little is known regarding the effects of livestock grazing or trampling on the species or its associated community. However, by comparing portions of the known star cactus site in the United States that is currently grazed to areas that have not been grazed, it is evident that the original native habitat has been significantly altered due to severe grazing and pasture improvements such as brush clearing and root plowing. The Mexico site is reportedly grazed by both cattle and goats (Sanchez-Mejorada *et al.* 1986). Additionally, the suppression of the natural fire cycles may have significantly altered or destroyed available habitat for the species throughout its range (Damude and Poole 1990).

Habitat loss may also occur through urban or rural development. The known star cactus site in the United States has been bisected by the construction of a paved road. The potential for future road improvements and current right-of-way management practices using pesticides or herbicides may pose a threat to this population or others that have not yet been identified.

Most of the available habitat for star cactus in Mexico is now under cultivation. Historic star cactus populations in Hidalgo and Cameron Counties have likely been extirpated through conversion of native habitat to agricultural fields. While much of the land suitable for agriculture has already been cleared, the remaining remnant of native habitat is increasingly threatened by urban development due to the rapid population increase along the Rio Grande border. The species is presently restricted to rockier sites less suitable for agriculture; however, even these sites are threatened by overgrazing, primarily by cattle and goats (Sanchez-Mejorada *et al.* 1986).

Collection

Another major threat to star cactus is collection of plants from the wild. This cactus is highly prized by cacti enthusiasts and has been in cultivation since the 1930s; however, plants collected from the wild are valued for their extreme rarity (U.S. Fish and Wildlife Service 1993). Clover (1932) noted that wild plants of star cactus (possibly smuggled from Mexico) were in commerce at that time. Two dozen individuals purchased for the University of Michigan Botanical Garden collection at a flower market in Ann Arbor, Michigan, were obtained through a wholesaler in Detroit who had procured them

from a dealer in Austin, Texas (Clover 1932). A 1991 survey of the cactus trade in Texas included 400 field-dug specimens at a Texas nursery (Poole and Westlund 1991). It was presumed that these specimens were collected from Mexico; however, it is probable that the plants could have been collected from a site in the United States that has never been documented. Star cactus may also be inadvertently removed and destroyed during the harvesting of peyote (*Lophophora williamsii*), a plant used in some Native American cultures for religious ceremonies. Star cactus and peyote occur on the same soil type, and when the two plants grow beside each other, the star cactus is sometimes mistakenly collected and discarded.

The star cactus population in Nuevo Leon is believed extirpated by collection. Sanchez-Mejorada, et al. (1986) also note that the Tamaulipan population had historically contained many large individuals up to 15 centimeters (6 inches) in diameter in 1978, but the site had no individuals larger than 7 centimeters (3 inches) when surveyed in 1985. There are indications that collection is ongoing at the Tamaulipan site and that local children are aware of foreigners' interest in star cactus and willingness to pay money for plants (Glass pers. comm.).

Star cactus is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (50 CFR 23.23), which protects the species from international trade. Although Mexico has laws prohibiting export of native cacti, both Mexican import/export laws and CITES protections are difficult to enforce along a heavily trafficked border area such as Texas and Mexico (U.S. Fish and Wildlife Service 1993). Therefore, collection of wild plants will remain a primary threat to star cactus until education regarding conservation of plants replaces the present high value placed on plants collected from the wild.

Disease or Predation

Drought has been ongoing in this area for an extended period (NOAA 2002), possibly resulting in lowered seed production and seedling recruitment. During a survey in 2001 by The Nature Conservancy (TNC), Texas Parks and Wildlife Department (TPWD), and Service personnel, there was indication of predation on the plants by either small rodents or rabbits. Some plants were only scarred by herbivores, but in some cases whole plants were consumed down to the root structure. This species of cactus is not known to regrow after significant levels of decimation.

Reduction of Genetic Variability

At the time of listing, the one site known to have the star cactus present contained fewer than 2,100 plants. Genetic variability and viability decrease with reduced numbers of plants across the range (Ledig 1986). This, along with the pressures of other natural and anthropogenically-induced threats, increases the possibility of extinction of the species in the wild.

Conservation Measures and Research

There are several regulatory tools that aid in the conservation of the star cactus, including:

Taking and Trade Prohibitions

In addition to the above-mentioned CITES protections regarding international trade, the ESA prohibits the malicious damage, destruction, or removal and reduction to possession of listed plants on areas under Federal jurisdiction. For areas not under Federal jurisdiction (e.g. private or state-owned lands), the ESA prohibits removing, cutting, digging up, damaging or destroying listed plants in knowing violation of any State law, including the violation of a State criminal trespass law. The ESA prohibits a person subject to the jurisdiction of the United States from selling, offering for sale, importing, exporting, or transporting in interstate or foreign commerce any listed plant species in the course of a commercial activity. The Lacey Act prohibits the same activities if the species is listed under any state law that provides for the conservation of species threatened with extinction, or is listed on an appendix to CITES. Under certain circumstances, the ESA also provides for the issuance of permits to carry out otherwise prohibited activities involving listed species. Star cactus is listed as a state endangered species under the Texas Parks and Wildlife Department Code for Wildlife and Plant Conservation, Chapter 88.004.

ESA Section 7 Requirements

Section 7 of the ESA requires that all Federal agencies consult with the Service to ensure that actions authorized, funded or carried out by such agencies do not jeopardize the continued existence of any listed threatened or endangered species. It is the responsibility of the Federal action agency to determine if the proposed action may affect a listed species. Informal consultations with the Service are often undertaken by Federal action agencies to assist them with their determination of a project's potential impacts. If a "may affect" determination is made, the Federal action agency shall initiate the section 7 consultation process. During informal consultation, the Service may be able to assist the action agency in alternatives that eliminate the potential "may affect" action.

Other conservation measures and research efforts for the star cactus include:

The Wildlife Diversity Program of TPWD has conducted many surveys for this species in Texas and several in Mexico. At present, star cactus is included as a search species in Mexico and ongoing surveys are performed by state (TPWD) and Federal (United States & Mexico) biologists. One population of star cactus in Mexico is protected under a conservation agreement, and botanists at the Universidad Autonoma de Tamaulipas have performed research on size, distribution, related plant species, and pollination of the star cactus in Linares and San Carlos, Tamaulipas, Mexico (Martinez-Avalos *et. al. In litt*). Efforts to locate additional populations of the cactus are ongoing by private researchers under university programs, contracts with ESA Section 6 funding, and with other non-governmental agencies such as the Nature Conservancy of Texas.

The Star Cactus Recovery Plan (Plan) should function as an important conservation tool, as it provides a roadmap for the species survival and recovery by recommending protection of existing populations, reintroduction of populations to increase stability, and prioritizes research needs.

PART II - RECOVERY

OBJECTIVE AND RECOVERY CRITERIA

The primary objective of this recovery plan is to ensure survival and promote recovery of the star cactus in its natural habitat. The actions recommended in this plan, if followed, will also provide information necessary to develop a full recovery strategy and delisting criteria within five to ten years.

The Criteria for reclassification to threatened are:

(1) Establish or maintain three geographically distinct, fully protected, self-sustaining populations of star cactus in the United States, each with a minimum of 2000 individuals and an age class structure reflecting that plants are reproducing and becoming naturally established within the population. These populations can be composed of smaller subpopulations so that the units function as one large meta-population if habitat availability is limited and fragmented. The number of plants, numbers of reproductive individuals, and age class structure must be verified through monitoring. Reintroductions can occur on Federal land, voluntary state land, or private land that has been voluntarily entered into a stewardship agreement for the star cactus by its owners.

(2) Develop and implement a formal conservation agreement for star cactus, such as a Memorandum of Understanding (MOU), between the United States and Mexico.

The recommendation for minimum viable population size for star cactus of 2000 individuals is based on the concept that a minimum viable population (MVP) should maintain enough individuals that there is a 95 percent probability that the population will remain viable over a period of one-hundred years (Mace and Lande 1991). MVP size for the star cactus should take into account the life characteristics of the plant, the extent of appropriate habitat, and threats to the species. Characteristics of the plant that should be examined include the life habit, breeding system, growth form, fecundity, ramet production (if any), survivorship, seed duration, environmental variation, and successional status (Pavlik 1996). According to these characterization standards, MVP for the star cactus requires a population size of approximately 2,000 individuals. This is based on the perennial lifestyle, possible outcrossing ability, growth form, low fecundity, survivorship, reproduction patterns, seed duration and age when the plant matures, as well as the seasonal patterns in relation to rainfall.

Full protection is considered management of the populations on Federal or state lands as part of an approved management plan (e.g., National Wildlife Refuge Comprehensive Conservation Plan), or a formal stewardship agreement for private landowners that includes management and monitoring of the population, habitat, and threats. Management should include measures to lessen or alleviate relevant threats (e.g., habitat loss or collection pressure) to star cactus and to measure the species' numbers, habitat quality, and threats.

The wording "Establish or maintain" in Criteria (1) should be interpreted to mean that efforts to reintroduce (i.e., "establish") star cactus should begin immediately as the method to reach reclassification. If, however, survey efforts discover populations on Federal, state, or private land that fit the definition of a minimum viable population and can be protected with adequate management and monitoring programs (i.e., "maintain"), such populations can and should be substituted for reintroduced populations to count towards reclassification.

As stated previously, a lack of information on actual star cactus abundance and distribution makes it difficult to gauge the true status of the species. However, in order to ensure the survival of the species in the event that other populations do *not* exist, reintroduction of the species in the wild is necessary, as a catastrophic event (e.g., fire) could extinguish the known population. Reintroductions can take place on Federal, state, or private lands. There are currently at least two distinct tracts of Service National Wildlife Refuge (NWR) land that have the type of soil and habitat necessary for star cactus reintroduction (Chris Best, pers. comm.). There may be a variety of other lands available for reintroduction, such as state park lands, or private lands whose owners are willing to enter into stewardship agreements to manage and protect the species. However, until these partnerships can be developed, the Service NWR lands may offer the most immediate avenue for reintroduction and should therefore be pursued. To protect the species from smaller-scale catastrophic events (a localized fire as opposed to widespread drought), it is recommended that populations be geographically distinct from one another.

It is clear that until more information is gained about the basic life history and ecology of the species, a full strategy for recovery (i.e., delisting criteria) can not be developed. In response to this, reintroduction sites should also be used for compatible research activities. The reintroduction sites will maximize the immediate survival and protection of the species while allowing for the information gathering that is critical to move the species toward full recovery. The research actions listed in the step-down and narrative outlines will supply information that will be used to determine how many populations are needed for full recovery, how the populations should be distributed, management options for alleviating threats, and other relevant objectives. In addition, surveys for existing, unidentified star cactus populations on Federal, state, and private lands are essential. *Information gained in survey efforts will have a significant bearing on the full recovery strategy for this species.* For example, if information suggests that a certain number of populations are needed for recovery of star cactus, these populations will either need to be reintroduced to natural habitat or will already exist and will need protection and management. The time to achieve downlisting and delisting will be greatly reduced by extensive survey efforts over the next decade that indicate the true status of the species; the number of populations found will likely determine the intensity of reintroduction efforts required for delisting. The recovery program therefore will greatly benefit from continued and increased cooperation between all partners, including private landowners.

Scientific workshops should be held to discuss and resolve information needs for the star cactus. Genetic data analysis, reintroduction protocol, and research priorities are all topics integral to the development of recommendations for survival and long-term viability of the species. Workshops should include Federal, state, academic, conservation, and other experts as necessary, including binational collaboration with Mexico.

The range of the star cactus spans the border between the United States and Mexico. Although the ESA provides protection for the species within the United States, the status of star cactus in each country is important for the overall conservation of the species. Therefore, a formal conservation agreement, such as a Memorandum of Understanding, should be developed between the United States and Mexico. This agreement will provide (further) protective measures for the species and may be integral to its' recovery, as significant opportunities for recovery projects may exist outside of the United States.

The time estimated to accomplish these Criteria is ten years. However, the Plan should be reevaluated in five years to assess progress on reintroduction, research, and survey projects. The overall

management strategy for the species, including the Plan, should be revised, based on new information, if needed. Delisting criteria should be developed at this time or when the objectives of the Plan have been met.

Step-down Outline of Recovery Actions

These actions are recommended to reclassify the species as threatened. Some actions are also part of a larger recovery strategy needed to determine delisting criteria (e.g., Step-down Action 2). Although some actions are immediately needed to ensure the species survival (e.g., Step-down Action 1), it is recommended that a coordinated approach to recovery be taken such that reintroduction, surveys, and research are occurring simultaneously.

1. Protect star cactus populations in the United States and Mexico.
 - 1.1 Provide landowners with information on the identity, rarity, and significance of star cactus, and on threats to the species.
 - 1.2 Develop and implement star cactus stewardship agreements with voluntary landowners whose long- and short-term land-use goals are compatible with star cactus conservation needs.
 - 1.3 Enforce applicable laws and regulations.
2. Conduct studies to gather biological information about star cactus that is needed for management and recovery in the wild.
 - 2.1 Determine specific habitat requirements.
 - 2.1.1 Study soils and underlying geology.
 - 2.1.2 Determine community structure.
 - 2.1.3 Study ecology and dynamic processes of associated community.
 - 2.1.3.1 Study direct and indirect effects of land use practices on star cactus and its associated habitat.
 - 2.1.3.2 Study interactions with other species (beneficial and negative).
 - 2.1.3.3 Study the responses to periodic or cyclic processes such as flooding, fire and freezing temperatures.
 - 2.2 Study population biology.
 - 2.2.1 Conduct a demographic analysis of the populations.
 - 2.2.2 Characterize phenology.
 - 2.2.3 Study pollination biology.
 - 2.2.4 Study seed production and dispersal in the wild.

2.2.5 Study seedling recruitment.

2.3 Develop management/monitoring programs for existing and reintroduced populations.

3. Search for new populations.
4. Establish a botanical garden population and seed bank.
5. Establish new populations as necessary to meet downlisting criteria.
6. Develop and implement a formal conservation agreement for star cactus between the United States and Mexico.
7. Develop a public information and awareness program.
8. Evaluate progress toward recovery, management direction, and status of information needed to develop delisting criteria, within five years (2008).

Narrative Outline of Recovery Actions

1. Protect star cactus populations in the United States and Mexico. The existing known population(s) and newly discovered populations of star cactus should be protected from anthropogenic threats such as collection and habitat destruction or degradation.
 - 1.1 Provide landowners with information on the identity, rarity, and significance of star cactus, and on threats to the species. Landowner involvement is an important aspect of this Plan, as the only known United States' population exists on private land, and other populations may be identified through public outreach and survey efforts. The landowners at the known United States site have been aware of the presence of the star cactus on their property for a number of years. An outreach program will be established to educate landowners in the species' historic habitat on Federal and State endangered species programs, and on how such programs may be compatible with private landowner land use practices. The Service will work with the government of Mexico to provide information on the significance of star cactus so that partnerships with landowners are developed in both countries. If you would like more information on the Service's projects or programs, or if you have information you wish to share concerning star cactus, please contact:

U.S. Fish and Wildlife Service, Corpus Christi Ecological Services, c/o TAMUCC, 6300 Ocean Dr., Box 338, Corpus Christi, Texas 78412. Tel. (361) 994-9005.
 - 1.2 Develop and implement star cactus stewardship agreements with voluntary landowners whose long and short term land-use goals are compatible with star cactus conservation needs. Landowner participation should be encouraged in establishing long-term protection to as many population sites as possible. Simply locating additional populations will not recover the species. Protection for known and newly discovered populations is necessary to ensure the survival and recovery of the species. A variety of stewardship agreements are available that can be customized to protect the land use practices of the landowner, as well as the star cactus. Voluntary, non-binding agreements with conservation organizations such as the Nature Conservancy and/or a similar agency in Mexico should be established with private landowners. These non-binding agreements help recognize landowners who voluntarily protect sensitive species or ecosystems. Long-term, binding agreements could include conservation easements or the sale or donation of land to a conservation organization. Programs that could include active habitat restoration or research could be funded through Partners for Wildlife (U.S. Fish and Wildlife Service) or private lands programs with Texas Parks and Wildlife Department. For information on any of these programs, contact:

U.S. Fish and Wildlife Service, Corpus Christi Ecological Services, c/o TAMUCC, 6300 Ocean Dr., Box 338, Corpus Christi, Texas 78412. Tel. (361) 994-9005.

Texas Parks and Wildlife, Wildlife Diversity Program, 3000 IH 35 South, Suite 100, Austin, Texas 78704. Tel. (512) 912-7011.

Lisa Williams, The Nature Conservancy of Texas, South Texas Office, P.O. Box 6281, McAllen, Texas 78502-6281. Tel. (956) 580-4241.

- 1.3 Enforce applicable laws and regulations. Federal and State agencies should exercise their full authority to assist landowners and land managers to protect populations. The legal responsibilities of landowners for conserving endangered plants occurring on their land are limited. However, if the landowners receive Federal funds or authorization for a project on their land, the Federal action agency providing the funds or authorization must ensure that those activities do not jeopardize the continued existence of the species in the wild. Federal agencies must conduct formal section 7 consultations under the ESA if an action authorized, funded, or carried out by a Federal agency may adversely affect a threatened or endangered species. Informal consultations with the Service are often undertaken by Federal agencies to assist in determining a project's potential impact. It is a violation of the ESA for any person to maliciously damage or destroy an endangered plant in the course of a violation of a state criminal trespass law. Investigators must obtain permission from landowners prior to conducting studies on private land.

Federal or state trade permits will likely be sought for this species as it has been commercially traded since the 1930s. The majority of trade in star cactus involves plants artificially propagated from seed; however, field collected plants from the wild were still being offered for sale as recently as 1990. Requests for copies of the regulations on listed plants and inquiries regarding prohibitions and permits for international trade may be addressed to:

Office of Management Authority, U.S. Fish and Wildlife Service, 4401 N. Fairfax Drive, Room 432, Arlington, Virginia 22203. Tel (703)358-2104, fax (703)358-2281.

Similar requests concerning interstate trade are to be addressed to the appropriate Regional Office of the U.S. Fish and Wildlife Service. For the States of Arizona, New Mexico, Oklahoma, and Texas, contact:

Division of Endangered Species/Permits, U.S. Fish and Wildlife Service, P.O. Box 1306, Albuquerque, New Mexico 87103. Tel. (505)766-3972, fax (505)766-8063.

Star cactus was included in Appendix II of CITES (50 CFR 23.23) on July 1, 1975, and transferred to Appendix I effective October 22, 1987 (52 FR 35743). Appendix I species are those in which both an import and export permit is usually required before international shipment occurs. The import or export can not be allowed if the purpose is primarily commercial. Plants that are certified as artificially propagated require only an export document under international shipment and commercial shipments may be allowed.

2. Conduct studies to gather biological information about star cactus that is needed for management and recovery in the wild. Information on the ecology, life history, population biology, and pollination of star cactus in its native habitat is scarce. This lack of information limits efforts to develop management for the species. Most of the information available on star cactus relates to

its ease of cultivation and growth in greenhouses. No studies have been carried on the species in the wild. Studies conducted to gather basic biological information on the species should focus on factors that will enable a better understanding of its habitat and provide insight into effective management for the species. Information obtained from the studies should be incorporated into management plans, as appropriate, to assist recovery of the species. Ultimately the information should be used to determine a comprehensive strategy to fully recover and delist the species. Workshops should be convened, as necessary, to further develop, prioritize, and coordinate research needs, and synthesize research results.

- 2.1 Determine specific habitat requirements. While little is known about the habitat requirements of star cactus, it is evident that available habitat is not being used by the species. More detailed habitat information would aid in predicting potential habitat for surveys and in locating additional populations. This specific information would also enable the Service to identify appropriate areas on Federal lands (within the historic range of the species) for future reintroduction efforts.
 - 2.1.1 Study soils and underlying geology. Only the most general information regarding soils and underlying geology is known for the populations of star cactus. A preliminary soils analysis for a subpopulation of the United States site, undertaken by the San Antonio Botanical Garden, provides information somewhat contradictory to observations of associated plants. This analysis indicated a lower salinity (325 ppm) than is typical in those areas where halophytic plants are usually found. This preliminary analysis also provided expected information, such as moderate alkalinity (8.1) and high calcium content (18,732 ppm). Other elements measured in the analysis were noted as follows (in ppm): nitrogen (5), phosphorous (71), magnesium (493), zinc (0.20), iron (2.91), manganese (3.06), copper (0.34), sodium (137), sulphur (560), and boron (1.43). A complete soils analysis from the subpopulation site, both near individual plants and in the surrounding habitat, needs to be undertaken. This basic information may provide a partial explanation as to why star cactus has not established in other areas of apparently suitable, available habitat.
 - 2.1.2 Determine community structure. Only general information regarding the community structure at the United States and Mexico sites is known. Specific, detailed, quantitative measurements have not been carried out for either population. The characterization of the community structure should include associated species, calculations of dominance, density, frequency, fidelity, species diversity, age class structure, and spatial patterning of associated thorn shrub and star cactus.
 - 2.1.3 Study ecology and dynamic processes of associated community. Little is known about the basic community ecology and dynamic processes that may be critical to the preservation of star cactus. Studies are needed to determine this species' response to seasonal and cyclical processes, differing management practices and disturbances (such as grazing), periodic climatic factors such as flooding and freezing, and interactions with other species with which it occurs. Successful management and recovery of the species depends on an understanding of the species' appropriate habitat, its significance as a component within the

community, and the potential importance of interactions with associated species.

2.1.3.1 Study direct and indirect effects of land use practices on star cactus and its associated habitat. Although the habitat of the known populations of star cactus in Texas is presently grazed, little is known regarding the effects of grazing or trampling on the species or its associated community. In addition to these potential direct effects, the extent to which grazing alters existing vegetation, nutrient cycling, or the edaphic (stability and water infiltration ability) basis of the system is not known. It is evident that the original native habitat at portions of the United States site has been significantly altered due to past grazing and pasture improvements such as brush clearing, root-plowing, and introduction of non-native grasses such as buffelgrass.

2.1.3.2 Study interactions with other species (beneficial and negative). Interaction studies between star cactus and associated species need to be conducted. Although plants are sometimes found in the open, most individuals are located within the protection and semi-shade of open, scattered thorn shrub. Frequently, multiple cacti species are grouped beneath these shrubs at the United States site. Star cactus is also found within the shade of larger rocks or growing out in the open, surrounded and almost camouflaged, by rocks of varying sizes. The extent to which other plants may act as "nurse plants", providing shelter from predation, shading (with the resultant tempered microclimate), more favorable microclimate for seedling germination and establishment, higher nutrient levels or other favorable edaphic factors, warrants investigation (Barbour *et al.* 1979, Nabhan 1987). The degree of fidelity (dependence) of star cactus with other species is not known.

Star cactus is vulnerable to increased competition from invasive, non-native forage grasses such as buffelgrass. This grass is commonly introduced for cattle forage following range improvement practices such as root-plowing and brush removal. However, buffelgrass has invaded areas where it was not originally planted. Buffelgrass can displace native vegetation and possibly create changes in the surrounding habitat through allelopathic mechanisms that prevent re-establishment of other species.

Although cattle are not known to graze star cactus, grazing and trampling may cause direct and indirect impacts to the species by trampling on individuals, alteration of vegetation composition and structure, changes in soil and water resource distribution as a result of long-term grazing in an arid environment, introduction of non-native species, disruption of nutrient cycling through damage to the thin microbiotic crust over the soil, and edaphic macrohabitat changes, such as soil compaction, decreased water infiltration ability, and the reduction of soil litter (Sanchez-Mejorada *et al.* 1986, Schlesinger *et al.* 1990, Fleischner 1994). The impacts of grazing on star cactus need

careful assessment given the significant ecosystem changes that can result from grazing. However, since all known star cactus populations have been used as range sites, comparison of sites with a non-grazed population may not be possible. Small enclosure studies may provide some insight; however, the actual impact of grazing will likely be underestimated because the original, and far more intense, impact has already occurred (Fleischner 1994). Research in this area should be coordinated with Step-down Action 2.1.3.1 so that duplication does not occur.

No specific predators or pests have been identified for star cactus; however, damaged individuals have occasionally been noted. Damude and Poole (1990) report that fungal infections and scale insects have proven to be problems for plants under cultivation in greenhouses.

2.1.3.3 Study the responses to periodic or cyclic processes such as flooding, fire and freezing temperatures. Nothing is known about the response of star cactus to events such as flooding, fire, or freezing temperatures. A portion of one subpopulation at the United States site is within a low flat area that occasionally ponds water. Only a few plants have become established here. The role of star cactus in its native habitat prior to significant alteration of the vegetation resulting from fire suppression, grazing, and possible shrub encroachment is unknown. The effect of periodic freezes on star cactus is unknown. While such temperatures are estimated to occur seven years out of ten, the actual response of the species in the wild to these freezes is unknown (Thompson et al. 1972). Plants growing in a cold greenhouse have not shown signs of stress from temperatures as low as 10°F (S. Brack in litt. 1992).

2.2 Study population biology. Little is known about the status of star cactus in terms of stability or demographic trends, genetic viability and variation between populations, phenology (relationship of climate and seasonality to plant life cycle stages), and the reproductive biology of the species in the wild. This information is critical to establishing effective management for the maintenance and establishment of populations.

2.2.1 Conduct a demographic analysis of the populations. Little is known of the demographics of the star cactus population. The U. S. population is actually a metapopulation comprised of two subpopulations with varying habitats. One subpopulation occurs on gravelly slopes within a thorn shrub community. The other subpopulation occurs in a rocky flat area with scattered shrubs and grasses. This site has approximately 2,000 individuals with 25 percent being juvenile plants (Damude and Poole 1990). The Tamaulipas site has been reduced to small individuals through collection (Sanchez-Mejorada et al. 1986). Brack (in litt. 1992) had specimens under cultivation that are 20 years old; however, age determination for wild individuals has not been undertaken. Studies on the natural population variation, age class

distribution, survivorship, resource allocation patterns, and the spatial relationships of star cactus to its associated species are necessary to evaluate critical life stages and vulnerability to threats (Harper 1977, Pavlik 1987).

2.2.2 Characterize phenology. The relationship of climate and seasonality of the star cactus' life cycle in the wild needs investigation. Cultivated specimens apparently flower throughout the summer months (June - September), while the species in the wild at the United States site flowers March through May and during summer at the Mexico site (Brack in litt. 1992, Damude and Poole 1990, Sanchez-Mejorada et al. 1986). Brack (in litt. 1992) reports that cultivated specimens begin flowering after four years. Both populations need phenological observations during growing and dormant seasons to assess the species' response to varied climatic conditions. Observations at each visit should note present and recent climatic conditions at the time so that climatic data can be correlated with life cycle stages. This information would be necessary to determine management strategies to address vulnerable life stages and favorable times for establishment of individuals.

2.2.3 Study pollination biology. Sanchez-Mejorada et al. (1986) report star cactus as being strictly sexually reproductive through outcrossing, therefore, understanding the pollination biology of this species is critical to the establishment and maintenance of populations. The showy, large flower remains open only during the day and would likely attract bee pollinators; however, pollinators have not been observed for star cactus. Other insects such as bee-like flies, butterflies, moths or beetles may be pollinators (Damude and Poole 1990). Identification of specific pollinators is critical information necessary for management of the species and an evaluation of pesticide threats to pollinators.

Pollination studies for star cactus should include insect visitation, pollinator effectiveness, pollen predation and viability, the potential maximum population density necessary for pollinator attraction and adequate pollen flow, and an assessment of the potential for pollination factors limiting the species' reproduction. This could be information critical to the management of the species.

2.2.4 Study seed production and dispersal in the wild. Seed production and dispersal mechanisms in the wild are poorly understood. Mature fruits disintegrate while still attached to the plant and leave the small cluster of shiny, brown seed on top of the plant. It is likely that wind and rain carry the seed to establishment sites. Small rodents may also gather and store the seed. Ants may play a role in seed dispersal, either directly or indirectly, through seed or fruit predation. Ants have been observed in mature fruits although there is indication that ants are eating the funiculus rather than the seed. Steven Brack (in litt. 1992) notes from

cultivated specimens that each fruit produces approximately 40 seeds which can remain viable for almost 10 years when stored under cool, dry conditions. This type of information from plants in the wild could prove invaluable in determining recruitment potential and long-term survivability for the species.

2.2.5 Study seedling recruitment. While seedlings have been observed in the wild, little is known about conditions necessary for seedling growth. Studies are needed to determine optimum conditions for seedling establishment and growth, effects of climatic factors on seedling growth, effects of disease and predation on seed production, and habitat factors that may be limiting seed production and seedling establishment.

2.3 Develop management/monitoring programs for existing and reintroduced populations. Management plans should be part of any stewardship agreement, Federal, State, or other protection provided for the star cactus. Management should address relevant threats to the species such as habitat loss or degradation. For example, pasture improvements, such as the introduction of non-native forage grasses, mechanical or chemical brush removal, or an increased animal stocking rate, could impact the species and/or its habitat. As information becomes available about the life history, ecology, and population biology of this species and its threats, it should be incorporated into management plans.

Monitoring should be incorporated into management planning. When possible, monitoring techniques should be standardized so that results between populations at different locations will be comparable. For instance, monitoring procedures for assessing reintroduction success should be coordinated with those implemented for naturally existing populations so that comparisons are verifiable and valid. The results from monitoring programs should enable an evaluation of management practices (i.e., adaptive management), as recovery progresses. Factors to be assessed during monitoring include the general condition of the habitat, plant numbers and distribution, reproductive success, threats, and responses to management practices. Monitoring should be conducted at least three times annually during and following flowering and fruiting. Any decline noted in the species' condition during monitoring should be brought to the attention of the Service, managers, recovery team, landowners, and other stakeholders involved in the species' recovery so that an effective response is possible.

At the five-year evaluation of the Plan (i.e., Step-down Action 7), consider convening a Recovery Team to work with stakeholders to formulate management and monitoring options for the future.

3. Search for new populations. Following a more detailed determination of community associations and habitat profiles, surveys for the star cactus should be conducted to locate unidentified populations in the United States and Mexico. There are many areas of native habitat that have not been surveyed for this species due to lack of access on private lands.

Additionally, this species is difficult to detect without an intensive search due to its almost perfect camouflage within its habitat. Federal and state agency field personnel should be trained in survey methodology for star cactus and should be educated about its rarity and collection threats.

4. Establish a botanical garden population and seed bank. With cooperation from landowners, plants from the known population should be maintained at different institutions. A seed bank should be established for the species and maintained at the National Seed Storage Laboratory in Fort Collins, Colorado. Two or more refugia collections and seed bank reserves should be established and maintained to provide assurance against extinction if a loss of the natural population should occur. Cultivated plants could also provide individuals for research efforts and as a plant source for possible reintroductions. Genetic considerations, such as maladaptive genes and hybridization should be assessed and protocols established to guide botanical garden and seed bank management.

5. Establish new populations in natural habitats as necessary to meet downlisting criteria. Due to the perceived rarity of star cactus and the small remaining amount of native habitat within its range, a reintroduction of the species is necessary to aid recovery. The Service defines reintroduction as placing species in the general range where they occurred historically. As some of the collection data for this species is somewhat ambiguous, any reintroduction will need to be undertaken in areas of appropriate habitat within the historic range of the species. Reintroduction efforts could be implemented on Federal lands such as those within the Lower Rio Grande Valley National Wildlife Refuge Complex or on state or private lands volunteered for use. Any reintroduction efforts will follow Service policy on controlled propagation of endangered and threatened species. As individuals are easy to grow from seed and propagation techniques are well understood, a separate cultivation study is not needed (Martin *et al.* 1971, Backeberg 1977, Pilbeam 1987, Minnich and Hutflesz 1991). As any reintroduction project develops, the most recent reintroduction guidelines available should be incorporated into the project plans (Falk, Millar, Olwell, EDS. 1996).

Reintroduction programs should be incorporated into applicable agency land management plans. Reintroduction success should be assessed through the development and implementation of a long-term monitoring program.

6. Develop and implement a formal conservation agreement for star cactus, such as a Memorandum of Understanding (MOU), between the United States and Mexico. The star cactus spans the border between the United States and Mexico. The status of the species in both countries is speculative, yet important for overall conservation measures. A formal conservation agreement between the United States and Mexico could have significant benefits for the recovery program, as adequate protection and conservation in both countries will be assured. Details of the agreement should be developed between the Service and relevant partners in the United States and Mexico.

7. Develop a public information and awareness program. Public education is one of the most important elements of the recovery process for a species facing collection threats. Public

awareness and cooperation are essential for the success of the star cactus recovery program. An informative program about star cactus, its recovery plan, the collection threat to the species, and the ESA in general, should be developed for presentation to private landowners, agency personnel, and other interested groups. The program should include the identification of recovery tasks that the individuals or groups being addressed can accomplish to participate in recovery of the species. Additionally, information on star cactus should be included within any Lower Rio Grande Ecosystem program so that a coordinated approach to recovery can be implemented.

8. Evaluate progress toward recovery, management direction, and status of information needed to develop delisting criteria, within five years (2008). Due to the critical need for information gathering and synthesis for the overall recovery strategy of star cactus, the Plan will be evaluated in five years. At this time, new information will be incorporated as appropriate, including research and survey results, and reintroduction progress. Changes in management direction will be made, if needed, and development of delisting criteria and a post-delisting monitoring plan will be considered. As required by the Section 4 (g) of the ESA, post-delisting monitoring must be conducted for a minimum of five years.

Minimization of Threats to the Star Cactus Through Implementation of Recovery Actions

The final rule listing the star cactus as endangered under the ESA evaluated threats to the species in terms of the five ESA listing factors. Implementation of the recovery actions recommended in the Plan would minimize these threats as follows:

Listing Factor 1: The present or threatened destruction, modification, or curtailment of its habitat or range. Several common range management practices threaten the present habitat of star cactus. Root-plowing or other mechanical or chemical brush clearing activities, introduction of aggressive exotic grass species such as buffelgrass, suppression of the natural fire cycle, and excessive livestock numbers may all contribute to the decline of the species. Roadway construction and further development of municipalities as roadways improve could reduce the amount of star cactus populations by eliminating habitat. Insecticides reduce pollinators, and herbicides may reduce the numbers of the cacti that are adjacent to roadways and within rangeland. Habitat where the star cactus is present in Mexico has been turned to farming for corn and citrus. Implementation of recovery actions 1.1, 1.2, 2.1.3.1, 5, 6, and 7 will help to protect the star cactus' habitat by; (a) providing landowners and land managers education on the significance, rarity and threats facing the cactus, (b) encouraging establishment of Stewardship Agreements, (c) determining short-term and long-term land use goals, (d) developing management and monitoring plans with willing landowners and land managers, (e) studying effects of land use patterns on star cactus and associated habitat, (f) searching for additional populations on private, state and federal lands, as well in Mexico, (g) establishing new populations on private, state, and federal lands, (h) promoting conservation of the species in Mexico, (i) developing public awareness through outreach efforts to protect both the star cactus populations and its associated habitat.

Listing Factor 2: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes. Star cactus is highly prized by cactus collectors for its unusual appearance. It has been in cultivation since the 1930s, although it is suspected that wild plants are still being collected. Implementation of recovery actions 1.1, 1.2, and 6, and 7 will be used to educate the public on the importance of protecting the wild populations from collecting pressures, the importance of buying and/or selling only star cactus

that has been propagated from seed, and initiating a plan to develop a point of contact within the Service so that new populations can be documented and protected from collection.

Listing Factor 3. Disease or Predation. Little is known about diseases or predation on the star cactus, although there is some indication from recent surveys that rodents or lagomorph species may prey on star cactus. Exclosure units may help in deterring the herbivores which may be using the cacti for moisture or food. Drought within the last few years may have reduced the ability of the plant to successfully set seed and may decrease new seedling growth. Studies under the implementation of recovery actions 2.1.3.2 and 2.1.3.3 will help to determine if drought conditions, freezing, flooding, and/or fire would reduce growth and reproduction.

Listing Factor 4. The Inadequacy of Existing Regulatory Mechanisms. Protection of the star cactus under the ESA provides mechanisms to recover the species. Other regulatory mechanisms identified herein to recover the star cactus are described in recovery action 1.3. Recovery action 1.3 will continue the ongoing efforts of Section 7 Consultation, whereby federal agencies are required to consult with the Service on projects that they fund, authorize, or permit on any projects that may disturb native habitat and possibly reduce the numbers of listed species. Recovery implementation actions 1.2, 2, 4, and 5 would enable additional recovery benefits by increasing the interests of non-governmental organizations, other Federal and state agencies, and academics in searching for populations, performing research activities, establishing seed banking projects, and creating reintroduced populations. Action 7 will address binational conservation efforts and will strengthen existing

Listing Factor 5. Other Natural or Manmade Factors Affecting its Continued Existence. In the final listing of the star cactus, only one population composed of 2,100 plants was known to occur. No additional populations have been located since the final listing. It is crucial to locate additional populations to increase the genetic variability and viability of the species. It is also necessary to reintroduce populations to increase the number of individuals of this species remaining in the wild.

Implementation Schedule

The following Implementation Schedule outlines actions and costs for the star cactus recovery program. It is a guide for meeting the objectives elaborated throughout Part II of this plan. This schedule indicates action numbers, priorities, descriptions, and duration, responsible agencies, and estimated costs. These actions, when accomplished, should bring about the recovery of star cactus and protect its habitat. The costs estimated are intended to assist in planning. The time estimated to reclassification as threatened is 10 years. However, due to the potential for downlisting to occur somewhat sooner due to the discovery of existing populations, costs have been estimated for five years, with remaining estimates in the "Comments" field. Costs of full recovery can not yet be estimated, as actions needed to delist the species have not been fully determined. This recovery plan does not obligate any involved agency to expend the estimated funds. Although cooperation and collaboration with private landowners is called for in the recovery plan, private landowners are also not obligated to expend any funds.

Action Priority

Priority of actions for recovering the star cactus are based on the following ranking system: Actions with a value of 1 are necessary to prevent extinction or irreversible decline in the species in the foreseeable future; actions with a value of 2 are necessary to prevent a significant decline in species population/habitat quality, or some other significant negative impact, short of extinction; and actions with a value of 3 include all other actions necessary to meet recovery objectives.

Abbreviations Used

CPC - Center for Plant Conservation
FWS - U.S. DOI Fish and Wildlife Service
ES-Ecological Services
LE-Law Enforcement
NWRs- National Wildlife Refuge System
TNC - The Nature Conservancy
TPWD- Texas Parks and Wildlife Department
UAT - Universidad Autónoma de Tamaulipas
UNAM- Universidad Nacional Autónoma de Mexico

STAR CACTUS RECOVERY PLAN IMPLEMENTATION SCHEDULE

Priority #	Action #	Action Description	Action Duration	Responsible Party			Year 1	Year 2	Year 3	Year 4	Year 5	Comments
				FWS		Other						
				Region	Program							
1	1.1	Provide landowners with information on the identity, rarity, and significance of star cactus, and on threats to the species.	1-10+	2	ES	NWRS	2.0	-	-	-	-	Materials will be developed during Year 1; communication with landowners will be ongoing as needed.
1	1.2	Develop and implement star cactus stewardship agreements with voluntary landowners whose long and short term land-use goals are compatible with star cactus recovery needs.	1-10+	2	ES	TNC	9.0	4.0	4.0	4.0	4.0	Cost will depend on # of popns. found on private land and willingness of landowners to promote star cactus recovery. Costs may continue through Year 10 at an approximate cost of \$4,000/year.
1	1.3	Enforce applicable laws and regulations.	Ongoing	2	ES LE	TPWD	1.0 1.0 1.0	1.0 1.0 1.0	1.0 1.0 1.0	1.0 1.0 1.0	1.0 1.0 1.0	Ongoing as needed throughout recovery program.
2	2.1.1	Study soils and underlying geology.	2	2	ES	UAT / UNA M or other	1.0 -0-	0.25 -0-	0.25 -0-	--	--	
2	2.1.2	Determine community structure.	3	2	ES	UAT / UNA M or other	5.0 -0-	5.0 -0-	5.0 -0-	--	--	

Priority #	Action #	Action Description	Action Duration	Responsible Party			Year 1	Year 2	Year 3	Year 4	Year 5	Comments
				FWS		Other						
				Region	Program							
1	2.1.3.1	Study effects of land use practices on star cactus and its associated habitat.	5	2	ES	-	5.0	5.0	5.0	2.0	2.0	
2	2.1.3.2	Study interactions with other species.	5	2	ES	-	2.0	2.0	2.0	--	--	
2	2.2.2	Characterize phenology	5	2	ES		3.0	3.0	3.0	3.0	3.0	
3	2.2.3	Study pollination biology.	5	2	ES		5.0	5.0	5.0	5.0	5.0	
3	2.2.4	Study seed production and dispersal in the wild.	5	2	ES		3.0	3.0	3.0	3.0	3.0	
2	2.2.5	Study seedling recruitment.	5	2	ES		3.0	3.0	3.0	3.0	3.0	
2	2.3	Develop management/monitoring programs for existing and reintroduced populations.	1-10	2	ES NWRS	TPWD TNC other	13.0	8.0	8.0	8.0	8.0	Development of management/monitoring programs should continue as needed.
1	3	Search for new populations.	Ongoing	2	ES	TPWD UAT / UNA	4.0 2.0 -0-	4.0 2.0 -0-	4.0 2.0 -0-	4.0 2.0 -0-	4.0 2.0 -0-	Surveys should continue as needed.
1	4	Establish a botanical garden population	Ongoing	2	ES	CPC	2.0 2.0	2.0 2.0	2.0 2.0	-	-	
1	5	Establish new populations as necessary.	1-10	2	ES NWRS	TNC TPWD	5.0	5.0	5.0	5.0	5.0	Costs may continue through Year 10, as needed.

Priority #	Action #	Action Description	Action Duration	Responsible Party			Year 1	Year 2	Year 3	Year 4	Year 5	Comments
				FWS		Other						
				Region	Program							
2	6	Develop and implement a formal conservation agreement for star cactus between the United States and Mexico.	1-10	2	ES	Other Interested Parties.	--	-	-	-	-	Cost estimates will be developed when interested parties have been identified; would include meeting/travel costs.
2	7	Develop a public information and awareness program.	3	2	ES NWRS	TPWD	1.5 - 0.5	1.5 - 0.5	1.5 - 0.5	-	-	
3	8	Evaluate progress toward recovery, management direction, and status of information needed to develop delisting criteria within five years.	1-10	2	ES NWRS	TPWD TNC UAT/ UNA Mother	-	-	-	-	-	Cost of this action can not be estimated until progress in Actions 1-6 is achieved. If significant adaptation to management is not needed, costs will be negligible. If a recovery team is convened (or other significant action taken), costs could include meeting, travel, or related costs.

PART III - LITERATURE CITED

- Backeberg, C. 1977. Cactus Lexicon. Blandford Press, Poole, Dorset, United Kingdom.
- Barbour, M.G., J.H. Burk and W.D. Pitts. 1979. Terrestrial Plant Ecology. Benjamin Cummings Publishing Co., Inc. Menlo Park, California.
- Benson, L. 1969. Cactaceae. In C.L. Lundell and collaborators, Flora of Texas, Vol. 2. Texas Research Foundation, Renner.
- Benson, L. 1982. The Cacti of the United States and Canada. Stanford University Press, Stanford, California.
- Blair, W.F. 1950. The biotic provinces of Texas. Texas Journal of Science, 2(1):93-117.
- Britton, N.L. and J.N. Rose. 1922. The Cactaceae. Vol. 3: 183-184.
- Clover, E.U. 1932. *Astrophytum* in the United States. Desert Plant Life 5: 20-21.
- Correll, D.S. and M.C. Johnston. 1979. Manual of the Vascular Plants of Texas. University of Texas at Dallas, Richardson, Texas. 1881 pp.
- Damude, N. and J. Poole. 1990. Status report on *Echinocactus asterias* (= *Astrophytum asterias*). U.S. Fish and Wildlife Service, Albuquerque, New Mexico.
- ESA. 1973. Endangered Species Act of 1973, as Amended. U.S. Fish and Wildlife Service. U. S. Department of the Interior.
- Falk, D.A. and K.E. Holsinger, eds. 1991. Genetics and Conservation of Rare Plants. Oxford University Press, New York.
- Falk, D. A., C. I. Millar, and M. Olwell, eds. 1996. Restoring Diversity: Strategies for Reintroduction of Endangered Plants. Island Press, Washington, D.C. 505 pp.
- Fleischner, T. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology Vol. 8 No. 3:629-644.
- Harper, J.L. 1977. Population Biology of Plants. Academic Press, New York. 892 p.
- Ledig, Thomas, F. 1986. Genetic Structure and the Conservation of California's Endemic and Near-Endemic Conifers. In: Conservation and Management of Rare and Endangered Plants. Proceedings from a Conference of the California Native Plant Society.
- Lemaire, C.A. 1868. Les Cactées. Librairie Agricole de la Maison Rustique, Paris.

- Mace, G. M., and R. Lande. 1991. In: Defining and measuring success. Restoring Diversity; Strategies for reintroduction of endangered plants. Island Press.
- Martin, M.J., P.R. Chapman, and H.A. Auger. 1971. Cacti and their cultivation. Winchester Press, New York.
- Martínez-Avalos, J. G., E. Jurado and F. Garza Ocañas.(In Evaluation). Geographical distribution and conservation of Cactaceae in the northeastern Mexico region. Diversity and Conservation.
- Mason, C.T. Jr. and P.B. Mason. 1987. A Handbook of Mexican Roadside Flora. University of Arizona Press, Tucson. 380 pp.
- Minnich, W.S. and F. Hutflesz. 1991. Cacti and succulents for the amateur. Cactus and Succulent Journal (U.S.) 63:122-123.
- Nabhan, G.P. 1987. Nurse plant ecology of threatened desert plants. In: Conservation and management of rare and endangered plants. Ed. T.S. Elias. California Native Plant Society, Sacramento.
- National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina. 2002.
- Pavlik, B. 1987. Autecological monitoring of endangered plants. In: Conservation and management of rare and endangered plants. Ed. T.S. Elias. California Native Plant Society, Sacramento.
- Pavlik, B. M. 1996. Defining and measuring success. In: Restoring Diversity; Strategies for reintroduction of endangered plants. Island Press.
- Pilbean, J. 1987. Cacti for the connoisseur: A guide for growers and collectors. Timber Press, Oregon.
- Poole, J. and B.L. Westlund. 1991. Cactus trade and collection impact survey. Texas Natural Heritage Program, Austin.
- Rzedowski, J. 1978. Vegetacion de Mexico. Editorial Limusa, Mexico City.
- Sanchez-Mejorada, H., E.F. Anderson, N.P. Taylor and R. Taylor. 1986. Succulent plant conservation studies and training in Mexico. World Wildlife Fund, Washington, D.C.
- Schlesinger, W.H., J.F. Reynolds, G.L. Cunningham, L.F. Huenneke, W.M. Jarrell, R.A. Virginia and W.G. Whitford. 1990. Biological Feedbacks in Global Desertification. Science Vol. 247:1043-1047.
- Thompson, C.M., R. Sanders and D. Williams. 1972. Soil survey of Starr County, Texas. U.S. Department of Agriculture.
- U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants; Final rule to list *Astrophytum asterias* (star cactus) as endangered. Federal Register Vol. 58, No. 199:53804.
- Weniger, D. 1984. Cacti of Texas and neighboring states. University of Texas Press, Austin.

Zuccarini, J.G. 1845. Act. acad. monagr. Echinocactus asterias. Abb. Bayer. Akad. Wiss. Munchen 4(2):13.

Personal Communication

Best, Chris. U.S. Fish and Wildlife Service. Personal Communication. 2002.

Glass, Charles. Personal Communication. 1993.

Hoock, Heinz. Personal Communication. 1994.