Star Cactus
(Astrophytum asterias)

5-Year Review:
Summary and Evaluation

Photo by: Lisa Williams, The Nature Conservancy

U.S. Fish and Wildlife Service
Corpus Christi Ecological Services Field Office
Corpus Christi, Texas

5-YEAR REVIEW
Star Cactus *(Astrophytum asterias)*

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional or Headquarters Office Southwest Region, Region 2, Albuquerque, NM
Susan Jacobsen, Chief Threatened and Endangered Species, 505-248-6641
Wendy Brown, Regional Recovery Coordinator, 505-248-6664
Jennifer Smith-Castro, Recovery Biologist, 505-248-6663

Lead Field Office Corpus Christi Ecological Services Field Office
Frank Weaver, Fish and Wildlife Biologist, 361-994-9005 x224
Robyn Cobb, Fish and Wildlife Biologist, 361-994-9005 x241

Cooperating Field Office(s) Austin Ecological Services Field Office,
Chris Best, Texas State Botanist, 512-490-0057 x225

1.2 Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (Service) is required by section 4(c)(2) of the Endangered Species Act (Act) to conduct a status review of each listed species at least once every 5 years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing as endangered or threatened is based on the species' status considering the five threat factors described in section 4(a)(1) of the Act. These same five factors are considered in any subsequent reclassification or delisting decisions. In the 5-year review, we consider the best available scientific and commercial data on the species, and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process including public review and comment.

1.3 Methodology used to complete the review:

This review was conducted through a comprehensive review of all documents regarding *Astrophytum asterias* that were available to the USFWS Corpus Christi Ecological Services Field Office (CCESFO). The Federal Register notice (75 FR 15454) announcing this review published on 29 March 2010, and solicited new information about *Astrophytum asterias* from both Federal and State agencies, non-governmental organizations (NGOs), academia, and the general public. Scientific information from Service files, the recovery plan, section 7 consultations, Texas' Natural Diversity Database (formerly known as the Biological Conservation Database), unpublished reports, monitoring reports, conversations with and comments from biologists familiar with the species, peer-reviewed journal articles, and information available on the

Internet, was used in the preparation of this document. We used this information to provide a historical context of the species' status, a synopsis of its status and threats, and as a basis for our final status recommendation. This 5-year review was not contracted to an outside party. The first use of technical terms is underlined, and terms are defined in the glossary in Appendix C.

1.4 Background:

1.4.1 FR Notice citation announcing initiation of this review:

75 FR 15454 15456; 29 March 2010.

1.4.2 Listing history

Proposed Listing
FR notice: 57 FR 46528 46531
Date listed: 9 October 1992
Entity listed: *Astrophytum asterias*
Classification: Endangered without critical habitat

Final Listing
FR notice: 58 FR 53804 53807
Date listed: 18 October 1993
Entity listed: *Astrophytum asterias*
Classification: Endangered without critical habitat

1.4.3 Associated rulemakings None

1.4.4 Review History: The Service proposed listing *Astrophytum asterias* as endangered on October 9, 1992 (57 FR 46528). The final rule designating *A. asterias* as an endangered species published in the Federal Register October 18, 1993 (58 FR 53804). The state of Texas listed the *A. asterias* as endangered on January 30, 1997. This is the first 5-year review conducted for this species. Other review documents that summarize the species and its habitat include:

- Status report by Damude and Poole, 1990
- Final Recovery Plan, USFWS 2003
- Section 6 Final Report by Janssen et al., 2010
- Star Cactus Restoration Implementation and Monitoring, Starr County, Texas by Janssen, 2011.
- Conservation and Restoration of Star Cactus (*Astrophytum asterias*) and Other at-Risk Species in Starr County, Texas by Patrick Conner, 2011.

1.4.5 Species' Recovery Priority Number at start of 5-year review: 2

Species are assigned priority numbers ranging from 1 – 18 based upon degree of threats, recovery potential, and taxonomic distinctiveness. *Astrophytum asterias* received a priority of 2 indicating that the degree of threat is high, the recovery potential is high, and the listed entity is a species (48 FR 43098).

1.4.6 Recovery Plan or Outline

Name of plan: Star Cactus *(Astrophytum asterias)* Recovery Plan
Date issued: November, 6, 2003
Dates of previous revisions, if applicable: None

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy:

2.1.1 Is the species under review a vertebrate? No

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan? Yes

2.2.1.1 Does the recovery plan contain objective, measurable criteria? Yes

2.2.2 Adequacy of recovery criteria.

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat?

No, the recovery criteria are dated and the recovery plan does not address delisting. The recovery plan was published in 2003 and therefore does not reflect any information gathered since then, new information has become available that includes: population monitoring and demography, herbivory, habitat analysis, phenology, and reproductive biology. A pilot reintroduction project was initiated in March 2007 and surveys for additional populations of *A. asterias* were conducted between 2007 and 2010. A report detailing the results of these efforts was published in 2010 (Janssen et al. 2010). A South Texas Plant Recovery Team, formed in June 2010, is working towards recovery of nine federally-listed plants in southern Texas, including *A. asterias*.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information.

Delisting criteria have not yet been developed. However, the recovery plan does contain two recovery criteria that were developed for downlisting. These criteria are described below:

Recovery Criteria 1.
Maintain or establish ten geographically distinct, fully protected, self-sustaining populations of star cactus in the United States or Mexico, each with a minimum of 2,000

individuals and an age class structure reflecting that plants are reproducing and becoming naturally established within the population.

Discussion. Maintenance and establishment of 10 fully protected, self-sustaining populations involves short and long term protection (e.g. acquisition of fee title or perpetual conservation easements), introductions, reintroductions, creation of refugia, and research and monitoring of the populations. When listed in 1993, only two extant populations of *A. asterias* were known, one population in the United States, in Starr County, Texas; and one population in Tamaulipas, Mexico (58 FR 53804). As of 2011, several new populations were reported as a result of surveys conducted in 2004-2010 in Starr County, Texas, and Mexico. In Starr County, Texas, these surveys brought the known total of extant *A. asterias* populations to 24, containing a total of 5,125 individual plants (Tables 1 and 2). These populations occur on 24 privately-owned properties that total 145 square kilometers (km^2) (56 square mile [mi^2]) in area (Janssen et al. 2010). Of the 24 properties, eight private land owners have signed Cooperative Conservation Agreements (CCAs) with The Nature Conservancy since 2004 (Janssen et al. 2010). These CCAs are not legally binding, and do not meet the designation of "fully protected". Long-term or perpetual conservation easements have not been signed by any of the relevant private land owners, but one tract, Las Estrellas Preserve, was acquired by The Nature Conservancy (TNC) in Texas with the intent to protect and conserve *A. asterias* in perpetuity, so it is considered a fully protected population (Conner 2011).

Reintroduction and establishment of refugia were some of the tools used in the protection and establishment of the 10 target populations. Reintroduction efforts, including establishing refugium populations, have taken place. Seeds were collected from TNC's Las Estrellas Preserve in 2004 by Anna Strong (Texas State University-San Marcos) and were germinated at the University of Texas-Austin. Seedlings (n=333) were germinated, and one seedling mortality was recorded (Janssen et al. 2010). Seeds collected from Starr County, Texas, populations were deposited in the Desert Botanical Garden (DBG) in Phoenix, Arizona, for use in future projects. As of May 2011, 9,000-10,000 seeds are in storage and maintained at the DBG seed room (Eide 2010). Three progeny of the Las Estrellas population are in the living collection at the University of Texas' Ladybird Johnson Wildflower Center in Austin, Texas (Oxely 2011).

Reintroduction procedures for *A. asterias* were determined by a 2007 pilot project that compared success rates of propagule type (seed/seedling) and seasonality (spring/fall) of planting (Janssen et al. 2010). Sandy Birnbaum, Texas State University graduate student, and Texas Parks and Wildlife Department employees, located and prepared a reintroduction site in Las Estrellas Preserve. One hundred and twenty seeds and 120 seedlings were planted in both the spring and the fall of 2007. Of the seeds and seedlings planted in the spring and fall, only five and four seeds and 78 and 87 seedlings, respectively, survived the 14- month observation period (See Pilot Reintroduction, Section 2.3.1.1.) (Janssen et al. 2010).

Table 1. Summary of *A. asterias* distribution, property descriptions, population size and Lower Rio Grande Valley (LRGV) cooperative conservation agreements (CCA) in Starr County, TX (Janssen et al. 2010).

Property #	First Obs.	Last Obs.	Property Description	Population size and Observations	Lower Rio Grande Valley Coperative Conservation Agreement (LRGV)(CCA)
1		2009	741 acre ranch	277 individuals in five areas	no
2	early 2000s	2009	419 acre property	roughly 328	yes
3	2004	2009	15,200 acre high fenced ranch. Ranch manager believes poachers have depleted this population.	196 individuals in six different areas	yes
4	2004	2009	80 acre ranch, originally thought to be part of property 10.	968 individuals. A 2009 fire did not seem to harm star cactus	yes
5	2004	2010	750 acre ranch	143 individuals in five different locations	yes
6	2004	2009	30 acre ranch	70 individuals in three different areas	yes
7	2002	2007	ca 20 acres	487 individuals	yes
8	2005	2009	400 acre site first discovered by TPWD	587 individuals found. The owners are currently building a house on the ranch	yes
9	2004	2010	20 acres, this property was originally thought to be part of property 10 because no fencing divided them	142 individuals; habitat impacted by trampling from stray cattle.	yes
10	2004	2009	200 acre ranch	175 individuals have been found in seven areas. Also, 25 years ago the woman who leases the property dug up two *A. asterias* and started a conservation garden by her house; she now has 203 individual plants	no
11	2007	2010	416 acre ranch, not near the majority of the other ranches with *A. asterias*.	655 individuals	no
12	2007		107 acre ranch	41 individuals	no
13	2007	2010	630 acre ranch	235 individuals in 7 different areas	no
14a/14b	2007	2009	850 acres total -- ownership shared by brothers with *A. asterias* on both ownerships	90 individuals	no

15	2008	2010	250 acres just west of property 5. Mostly salt flats	32 individuals	no
16	2008	2010	200 acre ranch (P # 15 and # 16 belong to brothers)	100 individuals located near the southern fence line	no
17	2008	2009	111 acre tract	one individual found in 2008, when surveyed again in 2009 there were none	no
18	2009	2009	100 acre tract south of property 17.	8 individuals were found. The conditions during the field season were subpar; it was very hot and dry that year	no
19	2009	2009	213 acre tract	61 individuals were found in 3 areas	no
20	2009	2009	545 acre ranch, has prime *A. asterias* habitat.	16 individuals found along power line easement	no
21	Jun-09	Oct-09	518 acre ranch	294 individuals were found on twelve areas	no
22	2009	2009	100 acre ranch	2 individual plants were found	no
23	2008	2008	36 acre triangular lot	149 individual plants were found	no
24	2010	2010	63 acre tract	68 individuals were found that were very large	no

Table 2. Number of *A. asterias* individuals on properties in (a) Starr County, Texas, and (b) Mexico (Janssen et al. 2010, Martinez-Avalos 2002).

a) Starr County, Texas

Property #	Number of individuals
1	277
2	328
3	196
4	968
5	143
6	70
7	487
8	587
9	142
10	175
11	655
12	41
13	235
14a/14b	90
15	32
16	100
17	1
18	8
19	61
20	16
21	294
22	2
23	149
24	68
Total	**5,125**

b) Mexico

Population	Number of individuals
General Teran, Nuevo Leon	701
Mendez, Tamaulipas	192
Gonzales, Tamaulipas	172
San Carlos. Tamaulipas 1	89
San Carlos. Tamaulipas 2	39
Villagran, Tamaulipas 1	38
Villagran, Tamaulipas 2	21
China, Nuevo Leon	13
Xicotencall, Tamaulipas	10
Total	**1,275**

Research on monitored populations of *A. asterias* in Starr County, conducted from 2004 to present, has produced biological and ecological information that has improved management of the species. These efforts produced demographic, genetic, herbivory, habitat, and reproductive biology data.

A conservation and restoration project for *A. asterias* was initiated in 2007 by Patrick Conner, TNC's South Texas project manager. As a result of the conservation and restoration project, 14 land owners allowed botanical surveys on 7,886 hectares (ha) (19,488 acres), and eight of the land owners signed CCAs covering a total of 1,147 ha (2,835 acres). In 2009, two seismic exploration projects resulted in damage to and loss of *A. asterias* at 12 locations on six of the 14 private ranches in Starr County. Subsequently, in 2010, three of the six ranches allowed planting of seedlings to restore damaged populations (using Anna Strong's germination experiment as the seedling source) and agreed to a 10-year monitoring program. Seeds were collected from Las Estrellas Preserve in 2010 and deposited at the DBG. The restoration project also addressed poaching issues by developing an abatement strategy calling for education and outreach to landowners and legal peyote sellers (Conner 2011).

There are 33 populations of *A. asterias* that occur in the United States and Mexico, but none have reached the 2,000 minimum threshold described in the recovery criteria.

Recovery Criteria 2. Develop and implement a formal conservation agreement between the U.S. and Mexico.

Discussion. In 1996, the wildlife conservation agencies of the United States, Mexico, and Canada signed a Memorandum of Understanding establishing the Canada/Mexico/US Trilateral Committee for Wildlife and Ecosystem Conservation and Management (Trilateral Committee). This agreement formally brought together the three nations of North America, consolidating a continental effort for wildlife and ecosystem conservation and management.

The Trilateral Committee facilitates and enhances cooperation and coordination among the wildlife agencies of the three nations in projects and programs for the conservation and management of wildlife, plants, biological diversity, and ecosystems of mutual interest. The Trilateral Committee also facilitates the development of partnerships with other associated and interested entities. Delegations from each country meet annually for discussions on a wide range of topics such as joint, on-the-ground projects, climate change adaptation and mitigation and issues of law enforcement. Faced with the increasing number of species and ecosystems at risk and escalating threats conservation managers needed a way to prioritize conservation challenges in order to allocate limited resources. To better manage for species and ecosystems of conservation concern, a prioritized list was developed to optimize allocation of resources. The prioritized list of species of international concern included 60 species which are shared with the US. At this time *A. asterias* is not included on the list, however communication between the Service and the Mexican government has underscored the importance of conservation of *A. asterias.*

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

Astrophytum asterias is a small, spineless dome-shaped member of the Cactaceae family. It is 2-15 centimeter (cm) (0.8-5.9 inches (in)) wide and 7 cm (2.8 in) tall. It is green to brown in color, and covered with small white scales. The cactus stem, when viewed from above, is divided into eight vaguely triangular lobes. The flowers, up to 15 cm (5.9 in) wide, are yellow with orange centers (Poole et al. 2007). Flowers usually bloom from March - May, opening in the morning and closing in the evening. The fruits are fleshy, green to a gray-rust color, and covered in white wool-like hairs. *Astrophytum asterias* occurs in South Texas and northeast Mexico in openings between thorn scrub and grasslands on gravelly clay and loam soils (Poole et al. 2007). *Astrophytum asterias* generally grows in semi-protected areas under brush. *Astrophytum asterias* is an obligate outcrosser (USFWS 2003).

2.3.1.1 New information on the species' biology life history, habitat and ecosystems:

This 5-year review summarizes all information that has become available since the publication of the recovery plan in 2003. New information on the biology and ecology of *A. asterias* has become available as a result of population monitoring, surveys, habitat analysis, a pilot reintroduction effort, and research projects. This has enhanced our knowledge of demographics, herbivory, habitat parameters, phenology, and reproductive traits.

Population Monitoring and Demography

Research was carried out at four Starr County populations on demographic parameters including mortality rates, reproductive size classes, and growth rates. Belt transects were used to determine size classes. One hundred and twenty-six individuals were tagged and numbered in 2004. Plots were monitored monthly from 2004-2007, biannually from '07-'08, and annually '08-'09 (Janssen et al. 2010).

Of the four populations monitored, the highest mortality rates were among the reproductive class, followed by the juvenile size class. Establishment of juvenile seedlings was minimal but reproductive size classes remained stable. Illustrating the observations of Harper (1977), the trend of smaller plants representing a smaller proportion of the overall population suggests that the reproductive size class produces enough offspring to counter mortality, resulting in a stable population structure (Janssen et al. 2010).

Two growth rates were determined using different calculation methods. Based on the assumption that the mean annual growth rate is constant among all size classes, the growth rate was determined to be 2.71 millimeters (mm)/year (0.10

in/year). Using this growth rate, it would take 15 years to reach the 4-cm (1.57 in) benchmark for reproductive maturity.

The second method took into account the premise that growth rates differ by size class (growth rates range from -0.85 – 3.65 mm/year (-0.03 – 0.14 in/year). This resulted in the mean diameter growth rate of 2.1 mm/year (0.08 in/year). Using this growth rate it would take 25 years to reach the 4-cm (1.57 in) benchmark for reproductive maturity (Janssen et al. 2010).

Herbivory

In the Star Cactus Recovery Plan (USFWS 2003), herbivory was listed as a threat to *A. asterias* but the extent and magnitude was not understood. Martinez-Avalos (2007) reported that herbivory poses a substantial threat to populations of *A. asterias* in the states of Nuevo León and Tamaulipas, Mexico. Damage to *A. asterias* was documented to be caused by the plant pathogen *Phytophtora infestans,* the Mexican ground squirrel *(Spermophilus mexicanus),* and cerambycid beetles (unknown species) at two sites with different vegetation types in Mexico (Martinez-Avalos 2007). Mexican ground squirrels caused the majority of star cactus mortality (Martinez-Avalos 2007).

Motion sensor cameras and quadrat surveys were employed to determine herbivore-induced mortality in Texas populations of *A. asterias* by capturing images of mammals near *A. asterias* populations. Between March 2006 and July 2007, a total of 277 images documented 27 species, with avian species comprising 43 percent of the total images. The most common herbivores included Desert cottontails (*Sylvilagus audubonii)* with 26.7 percent of the images followed by Mexican ground squirrels with 14.1 percent.

Janssen et al. (2010) established five quadrats totaling 50,000 m² in length (12.3 acres) in July 2007 around populations of *A. asterias* in Starr County, Texas, and surveyed for signs of herbivory. They documented disproportionate herbivory levels among the five quadrats (Janssen et al. 2010). Three major causes of *A. asterias* mortality, producing a total of 644 deaths, included mammalian herbivory, rot or fungal infection, and insect-induced mortality (Janssen et al. 2010). The cerambycid beetle *Moneilema armatum* accounted for 8.7 percent of the total deaths. Mammalian herbivory was associated with 463 deaths of *A. asterias* totaling 71.9 percent of mortality. Evidence suggests that in addition to the Desert cottontail and Mexican ground squirrel, other mammals including the Southern plains woodrat *(Neotoma micropus)* and hispid cotton rats (*Sigmodon hispidus),* damage and kill *A. asterias*.

Habitat Analysis

Astrophytum asterias occurs on flats in shrublands and grasslands in Tamaulipan thornscrub and prefers to grow in the shade of plants or rocks (Damude and Poole 1990). Janssen et al. (2010) analyzed vegetation along 15 transects of Texas *A.*

asterias to characterize habitat and determine differences between subpopulations. She based the selection of subpopulations for analysis on soil types, plant density, and area. She recorded plant species, cover, relative plant dominance, and *A. asterias* density using the line-intercept method. Each vegetation transect had three 25m (82 ft) line intercepts (totaling 75 m or 246 ft). The first transect was randomly placed and the remaining two were placed 10 m (32.8 ft) and 20 m (65.6 ft) away. To include plant species not intercepted by the line intercepts, a 2 m (6.5 ft) belt transect was centered on each transect. Appendix A, Table A5, lists ten species with the greatest dominance and relative dominance. In Appendix A, Table A1 lists dominance and relative dominance of all plant species documented. Birnbaum (2009) and Janssen et al. (2010) documented 69 plant species on the 15 transects, including the 2 m (6.5 ft) belt transects (Appendix A, Table A2.)

Ten species not intercepted in the line transects, but recorded in the 2 m (6.5 ft) belt transect were the windmillgrass (*Chloris* sp.), the ivy treebine (*Cissus incisa),* brasil (*Condalia hookeri),* Runyon's cory-cactus (*Coryphantha macromeris* var. *runyonii),* dodder (*Cuscuta* sp.), Lindheimer's globeberry (*Ibervillea lindheimeri*), cenizo (*Leucophyllum frutescens* var. *frutescens*), pale mammillaria (*Mammillaria sphaerica),* Runyon's huaco (*Manfreda longiflora),* and shrubby blue sage (*Salvia ballotiflora*) (Birnbaum 2009, Janssen et al. 2010).

Two-hundred and four *A. asterias* individual plants were present in the 2 m belt transect areas. *Astrophytum asterias* showed a significant nurse plant association with 81 percent having a plant or combination of plants directly overhead (Birnbaum 2009). Appendix A, Table A3 includes all plant species or objects directly overhead or adjacent to *A. asterias*.

Soil Analysis

Soil samples in the area covered by the vegetation transects were collected using soil collection guidelines of the Texas Cooperative Extension Service (TCE). The TCE laboratory determined pH, conductivity, nitrate levels phosphorus, potassium, calcium, magnesium, sulfur, sodium, iron, zinc, manganese, and copper, salinity, soil adsorption ratio, and sodium saturation percentage. The results of these analyses can be found in Appendix B1. Two soil tests were performed: a routine soil test and a detailed salinity test. The two different pH results can be attributed to the differences in the amount of water used in each test. When soil and water meet, the pH levels interact and combine to influence both. When the water is drained away, the soil assumes a slightly different acidic content. The average pH of the soil samples determined by the routine soil test (more water) was 8.3 with nitrate, phosphorus, and potassium levels averaging 10, 16, and 300 parts per million (ppm), respectively (Birnbaum 2009, Janssen et al. 2010). The average pH of the sampled sites determined by the detailed salinity test (less water) was 7.5 (Janssen et al. 2010). Nine of the 15 sampled sites were classified as saline-sodic soils according to the soil absorption ratio (Janssen et al.

2010). Soil analysis indicates that the highest density of *A. asterias* was found on saline-sodic, followed by saline soils (Janssen et al. 2010).

Phenology and Reproductive Biology

Phenology and reproductive data was recorded between 2004 and 2007 at two sites in Starr County, Texas. Anthesis began each year in the middle of March. Multiple flowering peaks were observed in March and April. Fruiting peaked from April through July. Flowering was not synchronous within the whole population, but bloom cycles coincided with small geographical areas (Janssen et al. 2010). Most flowers were open for 1 to 2 days (Janssen et al. 2010).

Fruit set average at the first property ranged from 35.2 - 61.5 percent, and 43.5 - 90.0 percent at the second property from 2004 - 2006 (Janssen et al. 2010).

Breeding System

Using controlled pollen transfers, Janssen et al. (2010), determined that *A. asterias* is an obligate xenogamous species (fruits and seeds form only when pollen is transferred to a flower from a different plant). Seed set was significantly higher in hand-pollinated flowers versus naturally-pollinated controls, suggesting that pollination vectors may be limiting.

Pollinator limitation and effectiveness

To assess the extent of pollinator limitation, 20 individual plants, each with two flowers were compared. One flower on the individual plant was not manipulated while the other was hand-pollinated with pollen from another individual in the population. The hand-pollinated flower produced significantly more fruit and seed than the control (Janssen et al. 2010). Therefore, pollinator limitation appears to place a constraint on the species' reproductive capacity. In the spring of 2006 – 2007, pollinator effectiveness was measured to determine which insect visitor was most successful at pollinating *A. asterias*. The cactus specialist bee *Diadasia rinconis* was found to be the most effective of all the observed pollinators (Janssen et al. 2010). Other insects visited the flowers more frequently but because of low effectiveness, they are not considered the most important (Janssen et al. 2010).

Pilot reintroduction

Reintroduction is a component of many recovery plans for federally-listed plants (Center for Plant Conservation 2012). Prior to initiating large-scale reintroductions, feasibility may be tested and techniques perfected through smaller-scale "pilot" reintroductions. (See Pilot Reintroduction, Section 2.2.3.) In this pilot reintroduction, 65 percent of the 120 seedling planted in the spring, and 72.5 percent of the 120 seedlings planted in the fall survived the observation

period (Janssen et al. 2010). As of 2010, only one of the 240 seeds planted is still alive. The survival rate for the seedlings planted in spring and fall was 31.25 percent after three years (The Nature Conservancy 2011). Therefore, it is recommended that any future reintroduction or restoration projects should utilize seedlings.

2.3.1.2 Trends in population, demography, and spatial distribution:

When Janssen's research began, only two properties were known to have *A. asterias* (Janssen et al. 2010). Surveys of the properties surrounding the known populations, and investigations of rumored locations from 2006 to 2010, resulted in locating new populations of *A. asterias* (Table 1) (Janssen et al. 2010). As of 2011, 24 privately owned properties in Starr County, Texas (Table 1), covering 145 km² (56 miles²), have been identified as supporting 5,125 individual *A. asterias* (Table 2a) (Janssen et al. 2010). Nine populations in Mexico contain a total of 1,275 plants: seven populations in Tamaulipas and two in Nuevo León, with population numbers ranging in size from 10-701 individuals (Table 2b) (Martinez-Avalos 2004). Historical range for *A. asterias* in southern Texas and northern Mexico is displayed in Figure 1 (Terry 2005). The locations of the Starr County, Texas populations are displayed in Figure 2.

Figure 1. Map of the historical range of *Astrophytum asterias* (yellow area) and Peyote (broken line) throughout Texas and Mexico (Terry 2005).

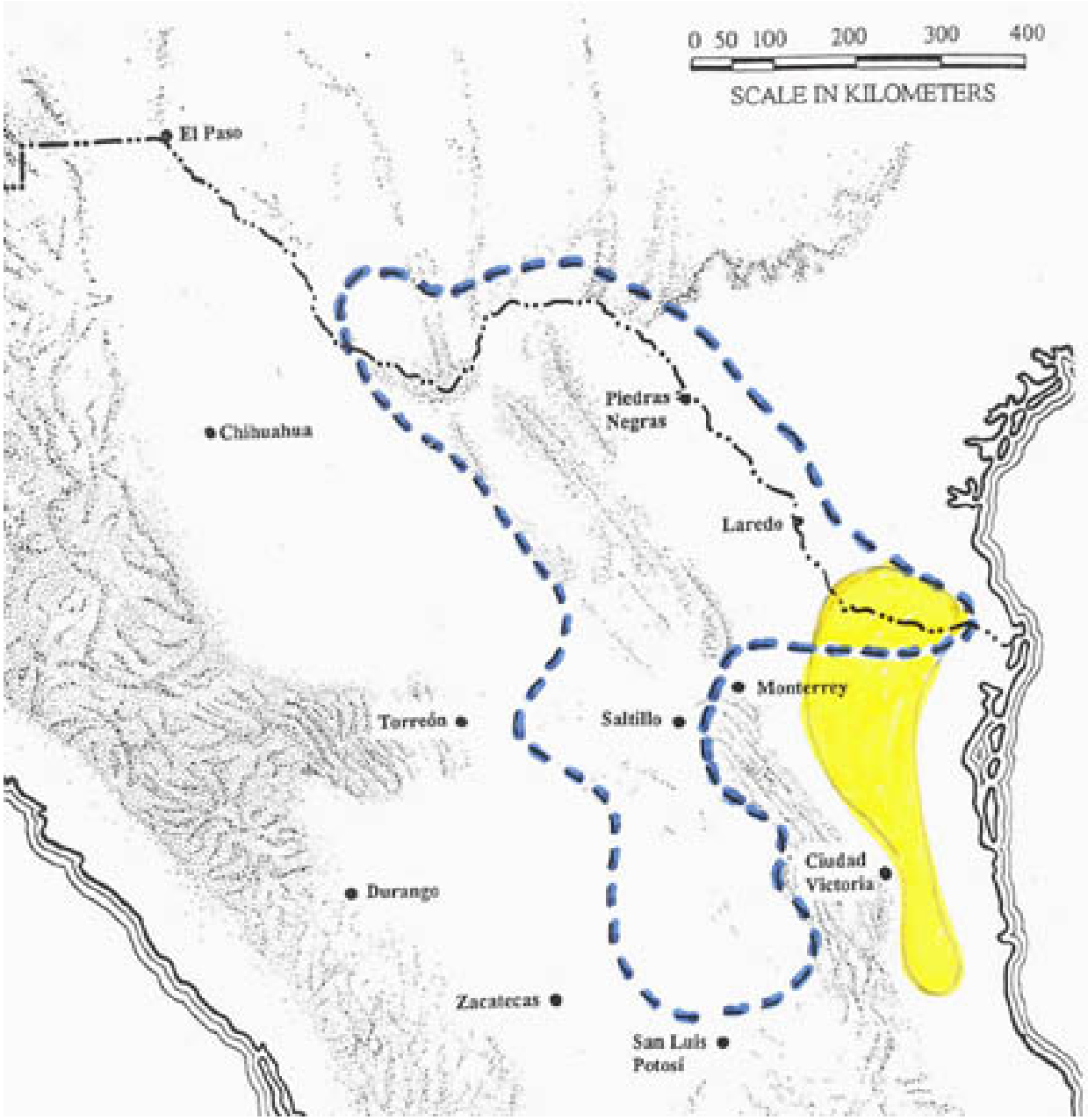
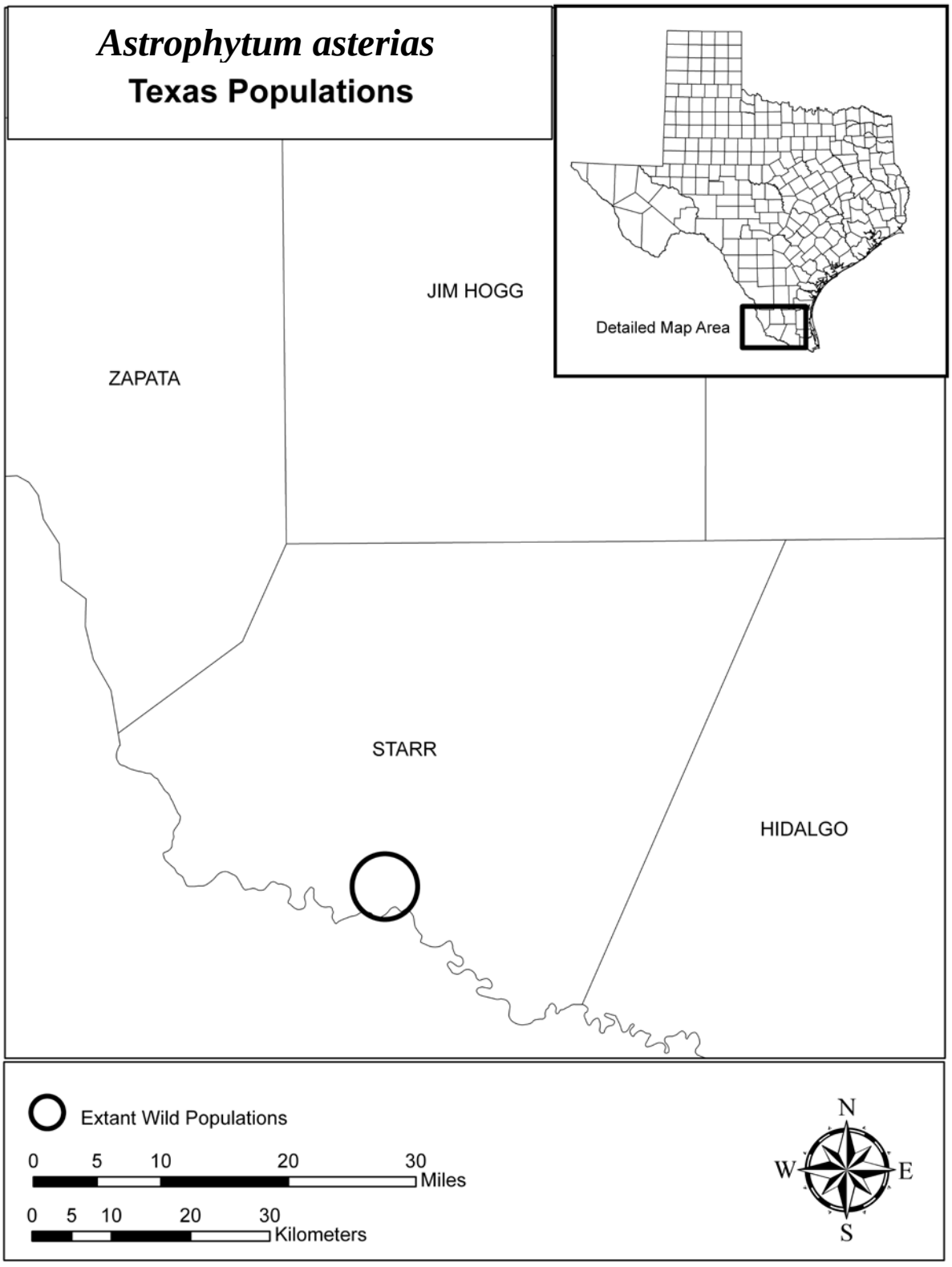


Figure 2. Currently known distribution of *Astrophytum asterias* in Starr County, Texas.



2.3.1.3 Genetics, and taxonomic classification:

Astrophytum asterias was originally collected by Baron von Karwinsky in 1843 and described as *Echinocactus asterias* by Joseph Zuccarini in 1845 (Damude and Poole 1990, USFWS 2003). Charles Lemaire described the new genus *Astrophytum* in 1868, into which he placed *A. asterias*. According to Damude and Poole (1990), the type specimen no longer exists or has been destroyed. The name *A. asterias* is widely accepted. Common names for *A. asterias* include: Biznaga-algononcillo de estrella, sanddollar, sea urchin star cactus, and false peyote (Integrated Taxonomic Information System 2011).

Terry et al. (2012) conducted a genetic survey of *A. asterias*, developing six polymorphic microsatellite loci and locating a total of 60 alleles in 142 sampled and genotyped *A. asterias* individuals in the Starr County populations. These 60 detectable alleles were used to estimate genetic parameters of the populations. Results indicate that four of the five subpopulations are "genetically robust" with relatively high heterozygosity and genetic diversity compatible with efficient outcrossing, and high rates of gene flow. A small relatively isolated subpopulation showed a high degree of homozygosity and low genetic diversity, suggesting inbreeding and/or genetic isolation at this site (Terry et al. 2012).

2.3.1.4 Conservation measures:

In order for conservation to be a priority, the public must understand the importance of maintaining natural diversity and how each species is an important factor in the environment. The Nature Conservancy developed and implemented a three part approach to public education. First, plant surveys were reviewed with landowners. Emphasis was placed on presence of *A. asterias*, and the uniqueness of their property. The landowners' participation in the search for *A. asterias* was encouraged in order to help develop a sense of pride in having stewardship of a rare species. This emotional connection to the land inspired conservation of their property. The second part was to educate the legal peyote sellers and address the issue of misidentification between peyote and star cactus. Two sizes of laminated plant identification cards were distributed to sellers for field use and market use. Sellers said they would distribute the field identification cards to the 'peyoteros' and also would ask them to provide information to TNC on new *Astrophytum asterias* populations (Conner 2011). The third part was to educate the legal peyote consumers. Two Native American tribal leaders were contacted in 2010 to discuss peyote and star cactus with tribal members, peyote sellers, and peyoteros (Conner 2011).

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

2.3.2.1 Present or threatened destruction, modification or curtailment of its

habitat or range:

The leading threat to *A. asterias* throughout its range currently, and at the time of listing, is habitat loss. All *A. asterias* populations in Starr County, Texas, are located on private property; the majority of which do not have signed conservation agreements (Table 1). As previously discussed in section 2.2.3, conservation agreements are not legally binding and do not meet the intent of a "fully protected population" designation. An extensive land area in Starr County has been root-plowed and converted to buffelgrass (*Pennisetum ciliare*) pasture; this has presumably destroyed an unknown amount of star cactus habitat. Mechanical disturbance makes habitat unsuitable for *A. asterias*. However, due to the predominantly saline-sodic soils that characterize star cactus habitat, relatively little has been converted to row-crop agriculture. An additional but unknown amount of habitat has probably been lost to urban and residential development and highway construction.

Highly competitive introduced grasses (specifically buffelgrass) are clearly incompatible with *A. asterias* conservation. Buffelgrass reduces native vegetation coverage, density, species richness, and diversity (Sands et al. 2009). However, we do not know what proportion of potential habitat has been converted to improved pasture, nor the current rate at which this practice continues. Introduced grasses should be considered a real threat of unknown extent that is likely to continue into the future.

Seismic surveys, oil and gas well development, and other construction related to oil and gas exploration can cause surface damage and irrevocably damage or completely destroy the habitat (Conner 2011). In 2009, seismic surveys for fossil fuels killed 163 plants and damaged, fragmented, and decreased habitat size (Star Cactus Work Group Meeting 2010). More than 1600 km² (700 mi²) of South Texas, including 103 km² (40 mi²) in Starr County, Texas, has been subjected to 3-D surveys for oil and gas exploration (Calvin Resources, Inc. 2010; Conner 2011, Swift Energy Company 2011). Due to these surveys, several *A. asterias* individuals probably have been destroyed without our knowledge.

Habitat could be lost through development, such as surface mining; petroleum exploration; highway, power line, and pipeline construction; etc. All known populations occur on private land, where state and federal regulations provide only minor protection to endangered plants. Development and construction in areas occupied by or directly adjacent to *A. asterias* populations would threaten the species. Habitat loss is considered to be a significant current and ongoing threat to the continued existence of the species.

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Collectors for many years have removed cacti for private collections. *Astrophytum asterias* are collected by individuals for personal use or trade, sometimes being mistaken for peyote (*Lophophora williamsii*). The demand for rare cacti by collectors has escalated in the United States and in other countries, including Asia and Europe (Westlund 1991). The demand for export of cacti to these countries is primarily attributed to the attractive blooms of the species (Westlund 1991).

In 1991 the TPWD published a report on the cactus trade, monitoring impacts by investigating 72 individual collectors, family nurseries, and commercial nurseries (Westlund 1991). Although many of these collectors/growers had less than 50 individual cactus plants, representing only three to four species, one "digger" had more than 1,000 freshly dug cacti of 13 subspecies. Four hundred field-collected *A. asterias* were observed in nurseries, and eight mail order catalogs had *A. asterias* listed for sale. The report concluded that the already established monitoring of the trade of these flowering cacti needed to be increased. Another finding was that other cactus species have been exploited by smaller dealers, as well as commercial nurseries, without permits (Westlund 1991).

Information on the level of threat due to field collecting of this species since TPWD's 1991 report is lacking. All known populations occur on private land where access is controlled and limited. Due to the demand for rare cacti by collectors, the threat remains. The continued uncontrolled collection of *A. asterias* from wild populations threatens the continued existence of the species.

2.3.2.3 Disease or predation:

In the U.S. and Mexican populations, the leading cause of mortality was found to be herbivory by Mexican-ground squirrels. It does appear that during periods of drought, the level of herbivory is increased. Other causes of mortality were found to be insect herbivory and fungal infections (See Section 2.3.1.1 Herbivory). Combination of pathogens and herbivory was shown to greatly reduce the population by over 50 percent (Martinez-Avalos 2007).

Several animal and insect species appear to utilize and destroy *A. asterias.* The threat to *A. asterias* continues to remain high, especially during periods of drought.

2.3.2.4 Inadequacy of existing regulatory mechanisms:

Section 9(a)(2)(B) of the Endangered Species Act (Act) prohibits removal and possession of endangered plants from areas under Federal jurisdiction. However, we are unaware of any *A. asterias* populations on Federal land.

All native cacti, including *A. asterias*, are on Appendix II of CITES. This Convention only regulates imports and exports, and does not regulate internal

trade or habitat destruction. CITES was designed to ensure that international trade does not affect species' survival (USFWS 2000) and should afford protection to *A. asterias* from collection pressure for exportation purposes.

Chapter 88 of the Texas Parks and Wildlife Code lists plant species as State threatened or endangered once they are federally-listed with these designations. *Astrophytum asterias* was listed as endangered by the State of Texas on January 30, 1997. The State of Texas prohibits taking and/or possession for commercial sale of all or any part of an endangered, threatened, or protected plant from public land. The TPWD requires permits for the commercial use of listed plants collected from private land. Scientific permits are required for collection of endangered plants or plant parts from public lands (including state-owned or municipally-owned lands) for scientific or education purposes. In addition to state endangered species regulations, other state laws may apply. State law prohibits the destruction or removal of any plant species from state lands without a TPWD permit.

Federally-listed plants occurring on private lands have limited protection under the Act, unless also protected by state laws (e.g. trespassing laws). The State of Texas provides very little protection to listed plant species on private lands. Approximately 95 percent of Texas land area is privately-owned, and this large private landownership pattern is also true in Starr County. All known populations of *A. asterias* in Texas are found on privately-owned land. Given land ownership patterns in the area where *A. asterias* is found, it is reasonable to assume that most unexplored but suitable *A. asterias* habitat also occurs on private land. Therefore, most of the species' populations and habitat are not subject to Federal or state protection unless there is a Federal nexus, such as a federally funded or permitted project that would trigger a consultation with the Service under section 7 of the Act.

Astrophytum asterias is listed "*en peligro de extinción*" (in danger of extinction) under Mexican federal law (SEMARNAT 2010).

In the past two decades Mexico has implemented actions to protect its wildlife resources. Mexico joined the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1991 and the Convention on Biological Diversity in 1993, then established its own National Biodiversity Strategy. Mexico created the Office of the Attorney General for Environmental Protection (PROFEPA) in 1992 and the Ministry of Environment and Natural Resources (SEMARNAT) in 1994. Mexico enacted its Law for Endangered Species Protection in 1994.

In 1995, SEMARNAT established Mexico's national wildlife agency. The same year, it joined forces with the United States and Canada to create the Canada/Mexico/U.S. Trilateral Committee for Wildlife and Ecosystem

Conservation and Management. Then, in 2000, Mexico enacted its General Wildlife Law, the country's most comprehensive wildlife legislation.

The known locations of *A. asterias* in Mexico are on private ranches and *ejidos*. None of these sites are legally protected, however, the species does have some protection from illegal collection due to Mexico's endangered species laws.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

Our analyses under the Act include consideration of ongoing and projected changes in climate. The terms "climate" and "climate change" are defined by the Intergovernmental Panel on Climate Change (IPCC). The term "climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2007a). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2007a).

Scientific measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change has been faster since the 1950s. Examples include warming of the global climate system, and substantial increases in precipitation in some regions of the world and decreases in other regions. (For these and other examples, see IPCC 2007a; and Solomon et al. 2007). Results of scientific analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is "very likely" (defined by the IPCC as 90 percent or higher probability) due to the observed increase in greenhouse gas (GHG) concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (IPCC 2007a, figures SPM.3 and SPM.4; Solomon et al. 2007). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011), who concluded it is extremely likely that approximately 75 percent of global warming since 1950 has been caused by human activities.

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (e.g., Meehl et al. 2007, Ganguly et al. 2009, Prinn et al. 2011). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), until about 2030. Although projections of the magnitude and rate of warming differ after about 2030, the overall trajectory of all the projections is one of increased global warming through the end of this

century, even for the projections based on scenarios that assume that GHG emissions will stabilize or decline. Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the extent of GHG emissions (IPCC 2007a, Meehl et al. 2007, Ganguly et al. 2009, Prinn et al. 2011). (See IPCC 2007b, for a summary of other global projections of climate-related changes, such as frequency of heat waves and changes in precipitation. Also see IPCC 2011 for a summary of observations and projections of extreme climate events.)

Various changes in climate may have direct or indirect effects on species. These effects may be positive, neutral, or negative, and they may change over time, depending on the species and other relevant considerations, such as interactions of climate with other variables (e.g., habitat fragmentation) (IPCC 2007). Identifying likely effects often involves aspects of climate change vulnerability analysis. Vulnerability refers to the degree to which a species (or system) is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the type, magnitude, and rate of climate change and variation to which a species is exposed, its sensitivity, and its adaptive capacity (IPCC 2007a; see also Glick et al. 2011). There is no single method for conducting such analyses that applies to all situations (Glick et al. 2011). We use our expert judgment and appropriate analytical approaches to weigh relevant information, including uncertainty, in our consideration of various aspects of climate change.

Although many species already listed as endangered or threatened may be particularly vulnerable to negative effects related to changes in climate, we also recognize that, for some listed species, the likely effects may be positive or neutral. In any case, the identification of effective recovery strategies and actions for recovery plans, as well as assessment of their results in 5-year reviews, should include consideration of climate-related changes and interactions of climate and other variables. These analyses also may contribute to evaluating whether an endangered species can be reclassified as threatened, or whether a threatened species can be delisted.

We do not know whether the climate changes that have already occurred have affected *A. asterias* populations or distribution, and we cannot predict how the species might be affected by the type and degree of climate changes forecast by the range of models. Rising temperatures might enable the species to survive further north than at present, but might also reduce the southern limit of the range. Similarly, changes in the frequency and amount of precipitation could favor a shift in geographic range or habitat type. However, the limited seed dispersal range, and the existence of new barriers to migration could impede alteration of the range of *A. asterias* (Malanson and Cairns 1997). Some climate change models also predict increased precipitation along the Gulf Coast, largely due to increased tropical storm frequency and severity (Twilley et al. 2001). The

species' range in south Texas and northern Tamaulipas and Nuevo León could experience both decreased annual precipitation as well as increased storm severity. Changes in temperature and rainfall amounts and patterns could alter the species' competitive advantage in the unique micro-habitats it now inhabits. Regardless of how these changes may affect the autecology of *A. asterias*, the altered synecology may be far more significant. For example, higher winter temperatures could increase competition from invasive grasses (Patterson 1993). Conversely, higher temperatures and altered rainfall patterns might also stimulate the parasites and pathogens of invasive grasses, thereby reducing competition. At present, we cannot predict how the complex aggregation of climate change effects will affect the synecology of the species and its habitat. Therefore, we will continue to monitor the species and its habitat, and will adapt our recovery and management strategies when necessary to address the changing conditions.

2.4 SYNTHESIS

When *A. asterias* was listed as endangered in 1993, botanists could confirm only a single extant site in Texas. Since listing, surveyors have documented 5,125 individuals on 24 sites in Texas and 1,275 individuals on nine sites in Mexico, all of which are on private lands. The owners of eight of the 24 privately-owned properties in Texas have signed conservation agreements to voluntarily protect the habitat. One site in Texas has been purchased by a conservation organization to manage and protect the site in perpetuity. The Mexican sites are located on private ranches and *ejidos*; while none of these sites are legally protected, the species does have some protection from illegal collection due to Mexico's endangered species laws.

The known threats to *A. asterias* are habitat destruction by oil and gas industry activities, including exploration and development; habitat loss to agricultural and urban development including conversion of native habitat to introduced grasses; overutilization due to collection; and mammalian herbivory. Potential threats include genetic isolation if additional habitat fragmentation and population loss occur and a wide array of potential climate change impacts. Because *A. asterias* is only known from a few sites in Texas and Mexico, all known populations are still faced with a moderate-to-high degree of threat. Therefore, we recommend that *A. asterias* continue to be classified as endangered.

The pilot reintroduction project did demonstrate that reintroduced populations can be effectively established. Perhaps, if implemented on a larger scale, this could create self-sustaining refugium populations that replicate the genetic compositions of wild population(s) and reduce the risk of catastrophic loss at one or more natural population sites.

We do not recommend a change in classification at this time. Recovery action implementation will result in additional information vital for management and recovery, and the improvement of habitat and demographic conditions. These improvements may be such that the assessment for the next five year review would indicate that downlisting to threatened may be warranted.

3.0 RESULTS

3.1 Recommended Classification:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (*Indicate reasons for delisting per 50 CFR 424.11):*
____ *Extinction*
____ *Recovery*
____ *Original data for classification in error*
_ X _ No change is needed

3.2 New Recovery Priority Number

No change is needed; remain a priority 2.

Brief Rationale: When listed as endangered in 1993, only one U.S. population was known to exist and the status of populations in Tamaulipas and Nuevo Leon, Mexico, was unknown. As of July, 2011, 24 confirmed sites in the U.S. with a total of 5,125 individual plants, and nine confirmed sites in Mexico with a population totaling 1,275 plants have been documented. Most of the known sites face considerable threats from agricultural and oil and gas activities, and from illicit collection. Natural herbivory levels which can intensify during drought, may also cause localized threats. The degree of threat remains high.

The discovery of new populations in close enough proximity to one another to allow for opportunity for pollen exchange increases the likelihood that the remaining populations have sufficient genetic diversity for long-term survival. A successful pilot reintroduction indicates that a comprehensive reintroduction program could be a valuable tool for recovery. These positive developments lead us to believe that recovery potential is high for this species. *Astrophytum asterias* continues to be recognized as a distinct species.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Detailed recovery actions can be found in the recovery plan (USFWS 2003) and the action numbers below are taken directly from this plan. The most important recovery actions during the next five years include, but are not limited to, the following:

1. Action 2.3. Continue periodic monitoring of the known populations in Texas and Mexico to track demographic trends, and to detect and attempt to alleviate threats to these populations.
2. Action1.2. Conduct public outreach efforts to encourage conservation of the species and its habitat on private lands. Work with private landowners to establish a private landowner support group and pursue conservation agreements with landowners (Action 1.1).
3. Action 3. Conduct surveys of high-potential habitat within the known range of the species in South Texas and Mexico, focusing on sites that have not previously been surveyed.

4. Action 5. Develop an official reintroduction plan for *A. asterias.* Collect seeds from the known populations, propagate in a greenhouse to produce seedlings, and reintroduce at protected sites, in accordance with Service policy on controlled propagation of endangered species (65 FR 56916).
5. Although the recovery plan (USFWS 2003, p. 13) stated that at least two distinct tracts of National Wildlife Refuge (NWR) land in Texas have the type of soil and habitat necessary for *A. asterias* reintroduction, and Recovery Action 5 further stated that reintroduction could be implemented on Lower Rio Grande Valley NWR, subsequent habitat assessments, conducted by two separate teams of star cactus experts (in 2005 and in 2010), did not find any suitable star cactus habitat on any existing tracts of Lower Rio Grande valley NWR. However, this refuge could target some future land acquisitions to include suitable habitat for *A. asterias*.

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Appendix A

Table A1. Plant species with the greatest dominance and relative dominance within surveyed transects, March and May 2006 (Birnbaum 2009).

Species	Dominance (%)	Relative Dominance (%)
Varilla texana	11.6	27.8
Prosopis glandulosa	6.1	14.5
Acacia rigidula	5.2	12.5
Opuntia leptocaulis	4.4	10.5
Castela erecta subsp. *texana*	1.7	4.1
Ziziphus obtusifolia var. *obtusifolia*	1.6	3.9
Suaeda conferta	1.2	2.8
Parkinsonia texana var. *macra*	1.2	2.8
Monanthochloë littoralis	1.0	2.4
Xylothamia palmeri	0.9	2.0
Krameria ramosissima	0.7	1.8
Bouteloua trifida	0.6	1.5
Sporobolus airoides subsp. *airoides*	0.6	1.4
Hilaria belangeri var. *belangeri*	0.4	1.0
Prosopis reptans var. *cinerascens*	0.4	0.9
Gutierrezia texana	0.4	0.9
Sporobolus pyramidatus	0.4	0.9
Lycium berlandieri var. *berlandieri*	0.3	0.8
Opuntia engelmannii var. *lindheimeri*	0.3	0.7
Pennisetum ciliare var. *ciliare*	0.3	0.6
Pappophorum bicolor	0.2	0.5
Billieturnera helleri	0.2	0.5
Jatropha dioica	0.2	0.5
Tiquilia canescens var. *canescens*	0.2	0.4
Setaria sp.	0.2	0.4
Karwinskia humboldtiana	0.1	0.3
Isocoma coronopifolia	0.1	0.3
Echinocereus enneacanthus	0.1	0.3
Schaefferia cuneifolia	0.1	0.2
Thelocactus setispinus	0.1	0.2
Guajacum angustifolium	0.1	0.2
Celtis pallida	0.1	0.2

Dominance and relative dominance was ≤0.1% for the following species: *Acleisanthes longiflora*, *A. obtusa*, *Ancistrocactus sheerii*, *Argythamnia* sp., *Astrophytum asterias*, *Atriplex acanthocarpa*, *A. texana*, *Coryphantha robertii*, *Cynanchum* sp., *Desmanthus virgatus* var. *depressus*, *Echinocactus texensis*, *Echinocereus berlandieri*, *E. reichenbachii* var. *fitchii*, *Ferocactus hamatacanthus*, *Forestiera angustifolia*, *Koeberlinia spinosa* var. *spinosa*, *Leptochloa* sp., *Lophophora williamsii*, *Mammillaria heyderi*, *Matelea sagittifolia*, *Opuntia schottii*, *Opuntia* sp. (seedling), *Panicum* sp., *Polygala glandulosa*, *Ruellia* sp., *Thelocactus bicolor* var. *bicolor*, *Wilcoxia poselgeri*, and *Yucca treculeana*.

Table A2. Comprehensive list of plant species associated with *A. asterias* (Birnbaum 2009).

Acacia rigidula	*Leptochloa* sp.
Acleisanthes longiflora	*Leucophyllum frutescens* var. *frutescens*
Acleisanthes obtusa	*Lophophora williamsii*
Ancistrocactus sheerii	*Lycium berlandieri* var. *Berlandieri*
Argythamnia sp.	*Mammillaria heyderi*
Astrophytum asterias	*Mammillaria spaerica*
Atriplex acanthocarpa	*Manfreda longiflora*
Atriplex texana	*Matelea sagittifolia*
Billeturnera helleri	*Monanthochloe littoralis*
Bouteloua trifida	*Optunia engelmanni* var. *lindhiemeri*
Castela erecta subsp. *Texana*	*Optunia leptocaulis*
Celtis pallida	*Optunia schottii*
Chloris sp.	*Optunia* sp.
Cissus incisa	*Panicum* sp.
Condalia hookeri	*Pappophorum bicolor*
Coryphantha macromeris var. *runyonii*	*Parkinsonia texana* var. *macra*
Coryphantha robertii	*Pennisetum ciliare* var. *ciliare*
Cuscuta sp.	*Polygala glandulosa*
Cynanchum sp.	*Prosopis glandulosa*
Desmanthus virgatus var. *depressus*	*Prosopis reptans* var. *cinerascens*
Echinocactus texensis	*Ruellia* sp.
Echinocactus berlandieri	*Salvia ballotiflora*
Echinocactus enneacanthus	*Schaefferia cuneifolia*
Echinocereus reichenbachii var. *fitchii*	*Setaria* sp.
Ferocactus hamatacanthus	*Sporobolus airoides* subsp. *Airoides*
Forestiera angustifolia	*Sporobolus pyramidatus*
Guajacum angustifolium	*Suaeda conferta*
Guiterrezia texana	*Thelocactus bicolor* var. *bicolor*
Hilaria belangeri var. *belangeri*	*Thelocactus setispinus*
Ibervillae lindheimeri	*Tiquilia canescens* var. *canescens*
Isocoma coronopifolia	*Varilla Texana*
Jatropha dioca	*Wilcoxia poselgeri*
Karwinskia humboldtiana	*Xylothamia palmeri*
Koeberlinia spinosa var. *spinosa*	*Yucca Treculeana*
Krameria ramosissima	*Ziziphus Obtusifolia* var. *obtusifolia*

Table A3. All plants or objects directly overhead or adjacent to *A. asterias* within the 2m belt transects at 15 vegetation sampling sites (Birnbaum 2009).

Plant species/object(s)	Percent
Varilla texana	23.8
rock(s) (no nurse plant)	12.2
bare ground (no nurse plant)	6.8
Monanthochloë littoralis	5.1
Prosopis glandulosa , *M* . *littoralis*	3.4
Varilla texana , rocks	3.4
Opuntia leptocaulis	3.1
Thelocactus bicolor var. *bicolor* , rocks	2.7
Varilla texana , *Opuntia leptocaulis*	2.4
V . *texana* , *Prosopis glandulosa*	2.4
Monanthochloë littoralis , rocks	2.0
Varilla texana , *Opuntia leptocaulis* , *Prosopis glandulosa*	1.7
Acacia rigidula , *Bouteloua trifida*	1.4
Krameria ramosissima	1.4
Opuntia leptocaulis , *Monanthochloë littoralis*	1.4
O . *leptocaulis* , *Prosopis glandulosa*	1.4
O . *leptocaulis* , rock	1.4
Prosopis glandulosa	1.4
Ziziphus obtusifolia var. *obtusifolia*	1.4
Acacia rigidula	1.0
Prosopis glandulosa , rock(s)	1.0
Isocoma coronopifolia	<1.0
I . *coronopifolia* , rocks	<1.0
Jatropha dioica , rocks	<1.0
Setaria sp.	<1.0
Sporobolus pyramidatus	<1.0
Suaeda conferta	<1.0
Thelocactus bicolor var. *bicolor*	<1.0
Varilla texana, Hilaria belangeri var. *belangeri*	<1.0
V . *texana* , *Opuntia leptocaulis* , *Castela erecta* subsp. *texana*	<1.0
V . *texana* , *Prosopis glandulosa* , *Monanthochloë littoralis*	<1.0
Acacia rgidula , *Tiquilia canescens* var. *canescens*	<1.0
A . *rigidula* , *Hilaria belangeri* var. *belangeri*	<1.0
A . *rigidula* , *Opuntia engelmannii* var. *lindheimeri* , *Krameria ramosissima*	<1.0
Bouteloua trifida , rocks	<1.0
Castela erecta subsp. *texana*	<1.0
Thelocactus setispinus	<1.0
Jatropha dioica	<1.0
Monanthochloë littoralis , *Prosopis reptans* var. *cinerascens* , rocks	<1.0

Table A3. Continued. All plants or objects directly overhead or adjacent to *A. asterias* within the 2m belt transects at 15 vegetation sampling sites (Birnbaum 2009).

Plant species/object(s)	Percent
Opuntia leptocaulis , *Isocoma coronopifolia*	<1.0
O . *leptocaulis* , *Prosopis glandulosa* , *Pappophorum bicolor*	<1.0
P . *bicolor*	<1.0
P . *bicolor* , rock	<1.0
Parkinsonia texana var. *macra*	<1.0
P . *texana* var. *macra* , *Panicum* sp.	<1.0
Pennisetum ciliare var. *ciliare* , rocks	<1.0
Prosopis glandulosa , *Castela erecta* subsp. *texana*	<1.0
P . *glandulosa* , *Monanthochloë littoralis* , *Thelocactus setispinus*	<1.0
Setaria sp., *Jatropha dioica*	<1.0
Setaria sp., rocks	<1.0
Sporobolos airoides subsp. *airoides* , *Prosopis glandulosa*	<1.0
Sporobolus pyramidatus , *Prosopis reptans* var. *cinerascens*	<1.0
Thelocactus bicolor var. *bicolor* , *Jatropha dioica*	<1.0
T . *bicolor* var. *bicolor* , *Tiquilia canescens* var. *canescens* , rocks	<1.0
T . *canescens* var. *canescens* , rocks	<1.0
Varilla texana, Acacia rigidula , *Opuntia leptocaulis*	<1.0
V . *texana* , *Billieturnera helleri*	<1.0
V . *texana* , *B* . *helleri* , *Prosopis glandulosa*	<1.0
V . *texana* , *B* . *helleri* , *P* . *glandulosa* , *Thelocactus setispinus*	<1.0
V . *texana* , *Castela erecta* subsp. *texana*	<1.0
V . *texana* , *Monanthochloë littoralis*	<1.0
V . *texana, Parkinsonia texana* var. *macra* , rocks	<1.0
V . *texana* , *Prosopis glandulosa* , *Gutierrezia texana*	<1.0
V . *texana* , *P* . *glandulosa* , *Pappophorum bicolor*	<1.0
V . *texana* , *P* . *glandulosa* , *P* . *bicolor* , *Monanthochloë littoralis*	<1.0

Table A4. Dominance and relative dominance of plant species intercepted by the 15 vegetation transects conducted March and May 2006 (Birnbaum 2009).

Species	Dominance(%)	RelativeDominance (%)
Varilla texana	11.6	27.8
Prosopis glandulosa	6.1	14.5
Acacia rigidula	5.2	12.5
Opuntia leptocaulis	4.4	10.5
Castela erecta subsp. *texana*	1.7	4.1
Ziziphus obtusifolia var. *obtusifolia*	1.6	3.9
Suaeda conferta	1.2	2.8
Parkinsonia texana var. *macra*	1.2	2.8
Monanthochloë littoralis	1.0	2.4
Xylothamia palmeri	0.9	2.0
Krameria ramosissima	0.7	1.8
Bouteloua trifida	0.6	1.5
Sporobolus airoides subsp. *airoides*	0.6	1.4
Hilaria belangeri var. *belangeri*	0.4	1.0
Prosopis reptans var. *cinerascens*	0.4	0.9
Gutierrezia texana	0.4	0.9
Sporobolus pyramidatus	0.4	0.9
Lycium berlandieri var. *berlandieri*	0.3	0.8
Opuntia engelmannii var. *lindheimeri*	0.3	0.7
Pennisetum ciliare var. *ciliare*	0.3	0.6
Pappophorum bicolor	0.2	0.5
Billieturnera helleri	0.2	0.5
Jatropha dioica	0.2	0.5
Tiquilia canescens var. *canescens*	0.2	0.4
Setaria sp.	0.2	0.4
Karwinskia humboldtiana	0.1	0.3
Isocoma coronopifolia	0.1	0.3
Echinocereus enneacanthus	0.1	0.3
Schaefferia cuneifolia	0.1	0.2
Thelocactus setispinus	0.1	0.2
Guajacum angustifolium	0.1	0.2
Celtis pallida	0.1	0.2

Dominance and relative dominance was ≤0.1% for the following species: *Acleisanthes longiflora*, *A. obtusa*, *Ancistrocactus sheerii*, *Argythamnia* sp., *Astrophytum asterias*, *Atriplex acanthocarpa*, *A. texana*, *Coryphantha robertii*, *Cynanchum* sp., *Desmanthus virgatus* var. *depressus*, *Echinocactus texensis*, *Echinocereus berlandieri*, *E. reichenbachii* var. *fitchii*, *Ferocactus hamatacanthus*, *Forestiera angustifolia*, *Koeberlinia spinosa* var. *spinosa*, *Leptochloa* sp., *Lophophora williamsii*, *Mammillaria heyderi*, *Matelea sagittifolia*, *Opuntia schottii*, *Opuntia* sp. (seedling), *Panicum* sp., *Polygala glandulosa*, *Ruellia* sp., *Thelocactus bicolor* var. *bicolor*, *Wilcoxia poselgeri*, and *Yucca treculeana* (Birnbaum 2009).

Table A5. Ten species with the greatest dominance and relative dominance within surveyed transects, March and May 2006, Starr County, Texas (Birnbaum 2009).

Nurse Species/Item	Percentage
Varilla texana	23.8
rock(s)	12.2
bare ground	6.8
Monanthochloe littoralis	5.1
Prosopis glandulosa & *Monanthochloe littoralis*	3.4
Varilla texana & rocks	3.4
Opuntia leptocaulis	3.1
Thelocactus bicolor & rocks	2.7
Varilla texana and *Opuntia leptocaulis*	2.4
Varilla texana and *Prosopis glandulosa*	2.4

Appendix B

Table B1. Routine soil analysis results of soil samples collected within the 15 vegetation transects, pilot reintroduction site (RE), and one sample (Out) collected adjacent to site. Samples collected March and May 2006, and March 2007 (Birnbaum 2009).

Conductivity (cnd) = µmho/cm; No_3, P, K, Ca, Mg, S, Na, Fe, Zn, Mn, Cu = parts per million. **Site**	**pH**	**cnd**	**NO_3**	**P**	**K**	**Ca**	**Mg**	**S**	**Na**	**Fe**	**Zn**	**Mn**	**Cu**
1	8.4	361	8	10	342	22,680	213	67	330	2.26	0.20	1.04	0.18
2	8.0	4,641	28	21	386	27,732	269	1,484	4,048	3.50	0.27	3.54	0.60
3	7.8	231	8	20	273	16,791	197	44	240	3.84	0.26	2.54	0.42
4	7.9	459	10	14	226	35,901	278	62	292	3.79	0.25	1.73	0.25
5	8.8	3,082	15	16	316	16,690	382	155	4,530	5.07	0.24	2.26	0.63
6	8.5	2,023	9	20	204	15,179	308	79	2,254	2.13	0.22	2.16	0.39
7	8.3	2,982	8	12	358	13,876	230	166	3,109	6.30	0.23	1.92	0.33
8	8.4	2,212	7	18	286	18,468	191	121	3,195	5.42	0.21	1.99	0.52
9	9.0	2,897	11	9	294	25,695	178	127	3,524	5.31	0.21	1.82	0.37
10	7.9	3,292	9	14	347	17,363	176	4,225	1,424	4.48	0.20	2.25	0.36
11	8.1	3,729	9	18	363	9,852	232	100	3,463	4.30	0.24	2.87	0.47
12	8.7	1,121	9	16	176	15,041	201	35	1,750	2.71	0.14	1.99	0.39
13	8.2	1,582	9	18	329	10,158	313	51	2,073	3.95	0.26	2.24	0.61
14	8.1	2,880	8	21	330	25,954	288	6,143	1,023	4.68	0.32	1.79	0.72
15	8.2	2,348	8	14	273	15,107	346	139	1,824	5.35	0.24	1.96	0.68
Avg	**8.3**	**2,256.0**	**10.4**	**16**	**300**	**19,099**	**253**	**867**	**2,205**	**4.21**	**0.23**	**2.14**	**0.46**
Low	7.8	231	7	9	176	9,852	176	35	240	2.13	0.14	1.04	0.18
High	9.0	4,641	28	21	386	35,901	382	6,143	4,530	6.30	0.32	3.54	0.72
RE	8.3	586	3	19	231	12,010	152	69	835	2.57	0.21	2.16	0.19
Out	8.2	4,748	7	13	493	13,557	197	4,352	3,186	5.83	0.27	4.81	0.32

Glossary of Terms

Allele- is one of two or more forms of a gene or a genetic locus (Wikipedia 2012).

Anthesis- the period during which the flower is fully open and functional (Wikipedia 2012).

Anthropogenic- an effect or object resulting from human activity (Wikipedia 2012).

Autecology- The branch of ecology that deals with the biological relationship between an individual organism or an individual species and its environment (Wikipedia 2012).

Ejidos- is an area of communal land used for agriculture, on which community members individually possess and farm a specific parcel.

Genetic drift- a change in the gene pool of a small population that takes place strictly by chance (Encyclopedia Britannica, 2012).

Genetic isolation- organisms that have little genetic mixing or exchange with other organisms within the same species (Wikipedia 2012).

Genotype- the genetic makeup of a cell, an organism, or an individual (Wikipedia 2012).

Heterozygosity- a measure of genetic variation in a population. Refers to having different alleles for the same trait (Encyclopedia Britannica, 2012).

Homozygosity- pertaining to an individual (or a condition in a cell or an organism) containing two copies of the same allele for a particular trait located at the same position (locus) on paired chromosomes (Wikipedia 2012).

Phenology- refers to recurring plant life cycle stages, or phenophases, such as leafing and flowering (Wikipedia 2012).

Inbreeding- is reproduction from mating of two genetically related parents, which can increase the chances of offspring being affected by recessive or deleterious traits (Wikipedia 2012).

Locus- (Loci pl.) the position of a gene (or other significant sequence) on a chromosome (Wikipedia 2012).

Nurse Plant- An adult plant that provides shade or other protection allowing plants of its own or other species to germinate and survive (Cain et al. 2011).

Outcrossing- to cross (animals or plants) by breeding individuals of different strains but usually of the same breed (Wikipedia 2012).

Progeny- A genetic descendant or offspring (Wikipedia 2012).

Saline-sodic- soil that contains more than 15 percent exchangeable sodium, a saturation extract with a conductivity of more than 0.4 siemens per meter (25°C) and in the saturated soil usually has a pH of 8.5 or less (Wikipedia 2012).

Saline Soil- A soil containing a high concentration of soluble salts (Wikipedia 2012).

Synecology- the study of groups of organisms in relation to the environment—or community ecology. (Wikipedia 2012).

Type specimen- is one particular specimen (or in some cases a group of specimens) of an organism to which the scientific name of that organism is formally attached (Wikipedia 2012).

Xenogamous- transfer of pollen from one plant to another; cross-pollination (Wikipedia 2012).

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *Astrophytum asterias*

Current Classification:

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Frank Weaver, Corpus Christi Ecological Services Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, U.S. Fish and Wildlife Service, Christi Ecological Services Field Office

Approve Allan M. Strand Date 09-21-12

REGIONAL OFFICE APPROVAL:

Acting **Assistant Regional Director, Ecological Services, U.S. Fish and Wildlife Service, Region 2**

Approve [signature] Date 4/9/13