Recovery Plan for
***Echinocereus viridiflorus var. davisii* (Houghton) W.T. Marshall (Davis's Green Pitaya).**

Draft Amendment 1

Superseding only Part II, page 11 of the Recovery Plan.

U.S. Fish and Wildlife Service
Region 2
Albuquerque, New Mexico
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Approved: _____DRAFT_____ Date: _____
Regional Director, Region 2
U.S. Fish and Wildlife Service

I. Background Information.

a. Summary of prior actions.

Listing:	44 FR 64738.
Date:	November 7, 1979.
Listed status:	Endangered.
Recovery Plan:	Davis' Green Pitaya Cactus (*Echinocereus viridiflorus* var. *davisii*) Recovery Plan.
Prepared by:	Kenneth D. Heil, San Juan College, Farmington, New Mexico.
Approved:	September 20, 1984.
Five-year review(s):	February 10, 2012.

b. Reason for amendment.

Section 4(f)(1)(B)(ii) of the Endangered Species Act (ESA) requires that each recovery plan shall incorporate, to the maximum extent practicable, "objective, measurable criteria which, when met, would result in a determination…that the species be removed from the list." Legal challenges to recovery plans (see Fund for Animals v. Babbitt, 903 F. Supp. 96 (D.D.C. 1995)) and a Government Accountability Audit (GAO 2006) also have affirmed the need to frame recovery criteria in terms of threats assessed under the five delisting factors.

Recovery criteria are targets for determining when recovery objectives have been met, and should address the biodiversity principles of resilience, redundancy, and representation (Shaffer and Stein 2000, pp. 307—310; National Marine Fisheries Service and USFWS 2010, pp. 5.1-14–5.1-19). Recovery criteria specify when an endangered species may be reclassified (downlisted) as threatened, or when any listed species may be removed from the endangered species list (delisted). The term "endangered species" means any species (species, sub-species, or distinct population segment) that is in danger of extinction throughout all or a significant portion of its

range. The term "threatened species" means any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

The original recovery plan for Davis's green pitaya (Recovery Plan) states (U.S. Fish and Wildlife Service (USFWS) 1984, pp. i, 12):

> "The criteria for downlisting and/or delisting the Davis' green pitaya cactus have not as yet been determined. Implementing studies in this recovery plan will provide the necessary data from which quantification of downlisting and/or delisting criteria can be established."

The 5-year status review recommends revising the Recovery Plan to include both downlisting and delisting criteria that comply with updated recovery planning guidance (USFWS 2012, pp. 5, 25).

II. Methods used to revise the recovery criteria.

These revised criteria are based on the recommendations and new information summarized in the 5-year review.

We have not appointed a recovery team for Davis's green pitaya, but have requested information individually from botanists at Texas Parks and Wildlife Department (TPWD) and academic institutions. Additionally, the rationale used here for revising delisting criteria was developed through recommendations of the South Texas Plant Recovery Team for revising delisting criteria of several listed plants in South Texas. The appointed members of this team include representatives from TPWD, The Nature Conservancy, the University of Texas Rio Grande Valley, Sul Ross State University, the U.S. Department of Agriculture - Natural Resources Conservation Service, Texas A&M-Kingsville, the USFWS' Lower Rio Grande Valley National Wildlife Refuge, and private landowners.

III. Rationale for establishing the recovery criteria.

USFWS bases assessments of species viability, defined as the likelihood of persistence over the long term, on analyses of the species' resilience, redundancy, and representation. Resilience refers to the population size necessary to endure stochastic environmental variation (Shaffer and Stein 2000, pp. 308-310). Redundancy refers to the number and geographic distribution of populations or sites necessary to endure catastrophic events (Shaffer and Stein 2000, pp. 308-310). Representation refers to the extent of genetic and ecological diversity, both within and among populations, necessary to conserve long-term adaptive capability (Shaffer and Stein 2000, pp. 307-308). In this amendment, we base the criteria for downlisting to the threatened status on the minimum conditions necessary so that the species is no longer in danger of extinction, but is still likely to become endangered within the foreseeable future. These criteria are defined by minimum viable population sizes, the number and distribution of populations, and the abatement of threats through the conservation and protection of populations and habitats. These criteria must specify which individuals can contribute to determinations of MVP, and must also describe how populations are to be delimited.

The delisting criteria (for removal from the list of threatened and endangered species) consist of attaining the downlisting criteria levels and sustaining or improving this status long enough to demonstrate that Davis's green pitaya is no longer likely to become endangered in the foreseeable future. This will require a defined period of monitoring needed to detect demographic trends and responses to climate changes.

The five-year review (USFWS 2012) is our most recent compilation of information about the species. However, researchers and conservation agencies have had very little access to the private lands that comprise nearly all of the global range of Davis's green pitaya. Consequently, our knowledge of the species' life history and current status is rudimentary. We base these recovery criteria on the limited information that we do have (summarized below), as well as the best available information derived from similar cactus species.

The metric for resilience is MVP, the smallest population size that has a high probability of surviving a prescribed period of time. For example, Mace and Lande (1991, p. 151) propose that species or populations be classified as vulnerable when the probability of persisting 100 years is less than 90 percent. We are unable to calculate MVP for Davis's green pitaya because we do not possess the extensive demographic data needed to perform these calculations. Consequently, we have adapted a practical method for estimating plant MVPs (Pavlik 1996, p. 137) that is based on 9 life history traits: Longevity, survivorship, growth form, breeding system, fecundity, ramet production, the longevity of seed viability, environmental variation, and successional status.

Although cultivated individuals have lived up to 10 years, lifespan and survivorship data for wild Davis's green pitaya are not available; nevertheless, the species is clearly perennial. The growth form of this small columnar cactus is intermediate between herbaceous and woody. Taxa of the *Echinocereus viridiflorus* complex are self-incompatible (Leuck and Miller 1982, p. 1669); in other words, the breeding system is obligately outcrossing. The Recovery Plan (USFWS 1984, pp. 6-7, 9) summarized the reproductive biology of Davis's green pitaya. Flowering begins at three to four years in age. Flowering occurs in March and April; individual flowers remain open for two to three days. Flowers produce nectar at the base of stamens immediately after anthesis (opening), and are pollinated by Halictid bees (sweat bees), usually within 2 hours of anthesis (Leuck and Miller 1982, pp. 1670-1671). Individuals flower and set fruit abundantly, and produce from 85 to 340 seeds per year. Seeds disperse by gravity and rain water, and are often found near mature plants. Within populated areas, abundant seedlings and juveniles indicate successful recruitment. However, the absence of populations in apparently suitable habitats near established populations may indicate that birds or other animals are not effective seed dispersers. Taken together, these reproductive factors indicate a moderate level of fecundity. Individuals in the wild only rarely produce multiple stems (Zimmerman and Parfitt 2004), so ramet production is low. Mature seeds germinate readily and apparently do not undergo dormancy, and retain viability for 5 to 10 years (an intermediate value for wild plant species). Due to the wide annual variation in rainfall in Brewster County, environmental variation is high. The known habitats are in a climax successional status.

We entered these values for Davis's green pitaya, indicated in bold letters, in Pavlik's table (Table 1). Column A lists traits of species with MVPs of about 50 individuals, and Column C

includes traits of species with MVPs of about 2,500 individuals. We added an intermediate column (B) to Pavlik's table to account for species with intermediate or unknown traits, to which we assigned an intermediate MVP value of 1,000 individuals. Two factors require fewer individuals (perennial lifespan and climax successional status). Four factors are intermediate or unknown (unknown survivorship, intermediate growth form, moderate fecundity, and intermediate longevity of seed viability). Three factors require more individuals (outcrossing, rare ramet production, and high environmental variation). The weighted average of these factors is:

$$\frac{((2 \times 50) + (4 \times 1{,}000) + (3 \times 2{,}500))}{9} = 1{,}289$$

Therefore, we have adopted a provisional estimate for the MVP of Davis's green pitaya of about 1,300 individuals, and include this metric as one of the recovery criteria for both the threatened and endangered classification.

This estimate of MVP is based only on numbers of mature individuals (those that have flowered at least once or are judged capable of flowering) because most juveniles die before they are able to reproduce and therefore do not contribute to the effective population size or future genetic diversity. Furthermore, population surveys that do not distinguish mature plants from seedlings would appear to fluctuate wildly, depending on how recently seeds had germinated and on the proportion of surviving seedlings.

Table 1. Minimum viable population guidelines applied to Davis's green pitaya (adapted from Pavlik 1996, p. 137).

Life History Trait	A. MVP of 50 individuals for species with these traits.	B. Intermediate MVP of 1,000 individuals for species with intermediate or unknown traits.	C. MVP of 2,500 individuals for species with these traits.
Longevity	**Perennial**		Annual
Survivorship	High	**Unknown**	Low
Growth Form	Woody	**Intermediate**	Herbaceous
Breeding System	Selfing		**Outcrossing**
Fecundity	High	**Moderate**	Low
Ramet Production	Common		**Rare or None**
Longevity of Seed Viability	Long	**Intermediate**	Short
Environmental Variation	Low		**High**
Successional Status	**Climax**		Seral or Ruderal

The metric of redundancy is the number of populations. Davis's green pitaya is endemic to outcrops of the Caballos Novaculite, a unique geological formation in Brewster County, Texas (see USFWS 2012, Figure 2, attached below). The Caballos Novaculite outcrops (mapped together with the Maravillas Chert) total 12,094 hectares (ha) (29,887 acres (ac) (Stoeser et al.

2005; USFWS 2012, pp. 7-8, 11). Weniger (1979, p. 4) estimated that a few hundred individuals of this species occupied at most 40 ha (100 ac). The Recovery Plan (USFWS 1984, pp. 5-6) estimated that approximately 20,000 individuals occur on a single Novaculite ridge, scattered over an area of 50 meters (m) by 4 kilometers (km) or 20 ha (164 feet (ft) by 2.5 miles (mi) or 49.4 ac). At the stated density of 1 to 5 plants per m^2 (0.09 to 0.46 plants per ft^2) these figures would extrapolate to a total population of 200,000 to 1,000,000 individuals, a discrepancy noted in the five-year review (USFWS 2012, p. 9). Ballew (1989) surveyed three privately owned tracts where she documented three populations covering 65 ha (161 ac), 4.5 ha (11.1 ac), and 20 ha (50 ac). Based on surveys conducted on private ranches and on 156 individuals observed in a single 700-m^2 (7,535-ft^2) plot, McKinney (2000) extrapolated a total population of more than 500,000 individuals on 15,540 ha (60 square miles) of occupied habitat; however, we are unable to verify McKinney's population estimate based on the data provided (USFWS 2012, p. 15). McKinney noted that the number of individuals observed in the plot more than doubled from 1998, a dry year, to 1999, a wet year. She attributed the lower numbers seen in 1998 to the retraction of live, drought-stressed individuals below the surface layer of Novaculite gravel, and their re-emergence the following year. While these estimates of population size and distribution vary widely, all surveyors concurred that, within populated sites, Davis's green pitaya is unevenly distributed through its habitat in scattered colonies. In synthesis, we believe that the entire Caballos Novaculite formation is suitable habitat for the species, due to the consistency of this unique substrate and the similarity of climate over this limited geographic range. Nevertheless, we have no documentation to indicate how extensively Davis's green pitaya is distributed throughout these outcrops.

The patchy distribution pattern of Davis's green pitaya may be driven by natural factors, since larger populations may be more vulnerable to decimation by parasites or herbivores (USFWS 2017, pp. 27-28, 31, 39-40)—as well as cactus collectors. The distances between colonies is probably highly variable. The principal pollinators are small Halictid bees (sweat bees; Halictidae) that have correspondingly small forage ranges (Leuck and Miller 1982, p. 1670; Greenleaf et al. 2007). Colonies separated by as little as 250 m (820 ft) could be reproductively isolated, but this is speculative; we conclude that it would be difficult to delineate populations among the colonies scattered over contiguous bands of Caballos Novaculite habitat. Nevertheless, we need to define how populations are delineated to determine whether the size and number of populations meets the recovery criteria. It may be more practical to apply MVP sizes to metapopulations consisting of multiple colonies or subpopulations distributed over areas of contiguous habitat. Due to the discontiguous geographic distribution of Caballos Novaculite outcrops, at least 20 such areas could support metapopulations that are separated by 0.5 to 1.0 km (0.3 to 0.6 mi) or more, a separation distance often used to delineate Element Occurrences (NatureServe 2002, p. 26). Consequently, we have adopted this separation distance for the delineation of the populations.

We are not aware of a scientific method to determine the minimum number of populations or metapopulations needed to assure long-term survival of a species; in general, more populations distributed over a wider geographic range are better. A recovery criterion of 10 viable metapopulations is similar to other highly endemic listed cactus species, such as star cactus (*Astrophytum asterias*) (USFWS 2003). Since at least 20 areas of potential habitat exist in the

Caballos Novaculite (as described above), the criterion of 10 viable populations/metapopulation is also attainable.

The metric of representation is derived from the geographic distribution of populations as well as the genetic variation within and between populations. However, the amount of genetic variation between and within populations of Davis's green pitaya has not been investigated. Consequently, the distribution of populations across the species' range is the best metric of its representation. Since the species is endemic to the Caballos Novaculite outcrops, spanning only a portion of a single Texas county, very little environmental variation exists within this range. Thus, the species' representation would likely be conserved if the criterion of 10 viable populations/metapopulations is achieved.

The long-term viability of metapopulations requires that they are protected from development and other threats, and are managed in a manner that promotes the species' conservation. There are no state or federally-owned lands within the geographic range of Davis's green pitaya (other than highway rights-of-way). However, protection and management may be accomplished through conservation easements or long-term conservation agreements with private landowners.

Davis's green pitaya may be reclassified as threatened when the species is no longer endangered with extinction, but is likely to become endangered within the foreseeable future. To be delisted, the protected metapopulations must be monitored long enough to detect stable or increasing demographic trends and responses to threats, including the potential threats of climate changes. Plant population sizes in the wild vary in response to variations in rainfall and temperature, parasite and disease populations, and many other factors. Changes in population sizes that occur over one to several generation spans may represent only natural variations rather than longer-term demographic trends. We do not possess the demographic data necessary to calculate how many generation spans are necessary to detect demographic trends, and we are unlikely to obtain this data soon enough to benefit the species' recovery. To distinguish longer-term demographic trends from random variations in population sizes, we provisionally estimate thattrend detection will require periodic monitoring through at least 5 generation spans. One generation span is the time required for a newly formed seed to disperse, germinate, grow to a mature size, flower, and disperse new seeds. The Recovery Plan (USFWS 1984, p. 6) states that the species flowers at three to four years of age, although this may refer to individuals in cultivation. Based on this information, we believe that a typical generation span in the wild is at least 5 years. Therefore, the protected metapopulations must be monitored for at least 25 years.

IV. Amended Recovery Criteria.

a. Downlisting Recovery Criteria.

We establish downlisting criteria for Davis's green pitaya based on the minimum conditions that justify reclassification of the species. Davis's green pitaya will be considered for downlisting when:

1. Ten or more viable metapopulations are legally protected and managed for the purpose of conserving Davis's green pitaya and its habitats. Examples include, but are not limited

to, conservation easements on private lands, lands owned and managed for conservation by non-profit organizations, and legally-binding long-term management agreements with private landowners.

Justification: A recovery criterion of 10 viable metapopulations is similar to other highly endemic listed cactus species, such as star cactus (*Astrophytum asterias*) (USFWS 2003). Since at least 20 areas of potential habitat exist in the Caballos Novaculite (as described above), the criterion of 10 viable populations/metapopulations is also attainable.

2. The 10 or more protected metapopulations described in the previous criterion must have a minimum viable population size of 1,300 or more mature individuals.

   Justification: We adapted the method of Pavlik (1996) to provisionally estimate a minimum viable population size of 1,300 for Davis's green pitaya.

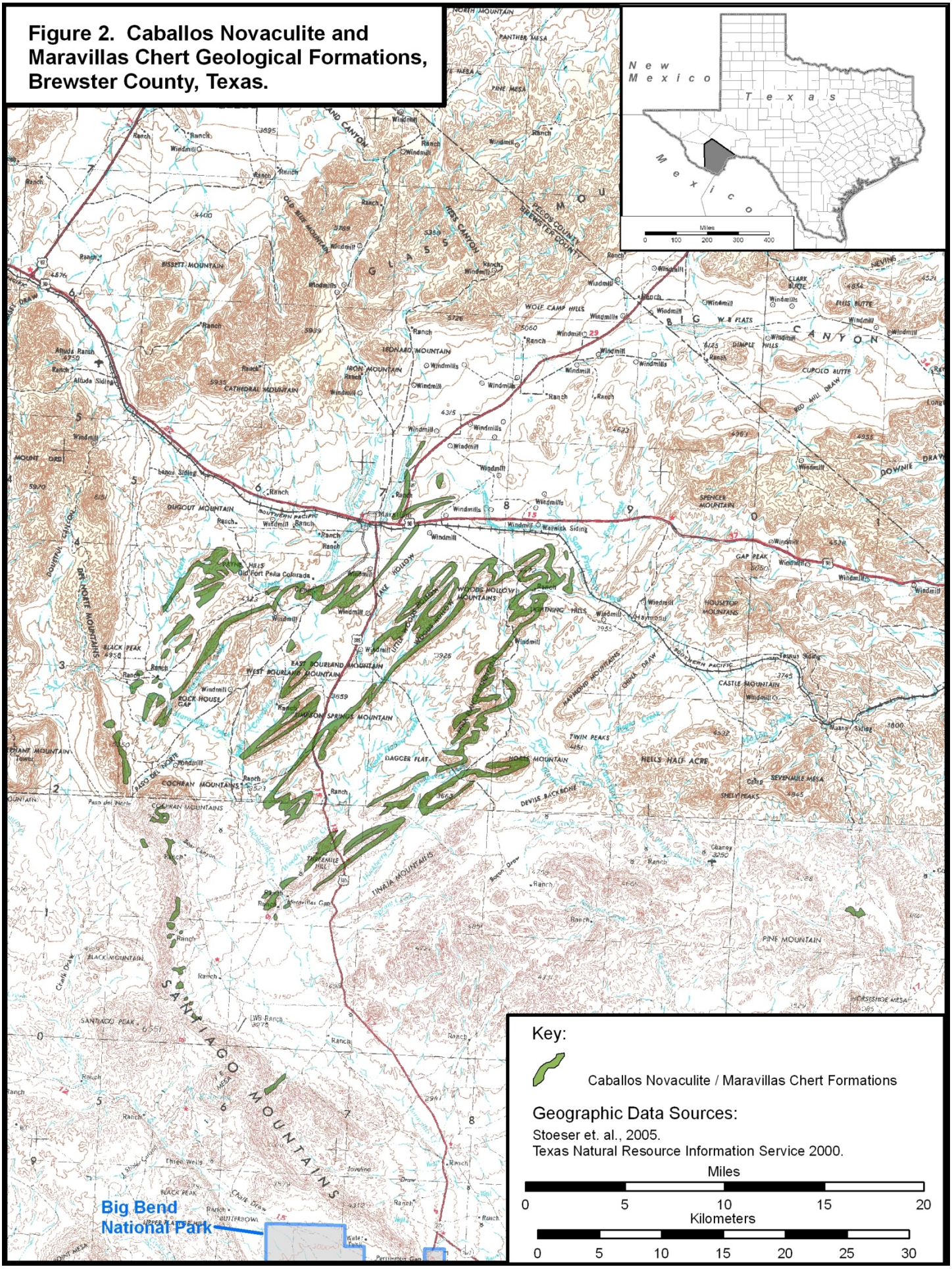
b. Delisting Recovery Criterion.

Davis's green pitaya will be considered for delisting when:

1. Periodic monitoring indicates that the minimum viable population levels of 1,300 mature individuals within each of 10 protected metapopulations (the criteria for downlisting to threatened) have remained stable or have increased over a period of 25 years. Monitoring (censuses) of each protected metapopulation must be conducted at least once every five years.

   Justification Davis's green pitaya may be reclassified as threatened when the species is no longer endangered with extinction, but is likely to become endangered within the foreseeable future. To be delisted, the protected metapopulations must be monitored long enough to detect stable or increasing demographic trends and responses to threats, including the potential threats of climate changes. Plant population sizes in the wild vary in response to variations in rainfall and temperature, parasite and disease populations, and many other factors. Changes in population sizes that occur over one to several generation spans may represent only natural variations rather than longer-term demographic trends. We do not possess the demographic data necessary to calculate how many generation spans are necessary to detect demographic trends, and we are unlikely to obtain this data soon enough to benefit the species' recovery. To distinguish longer-term demographic trends from random variations in population sizes, we provisionally estimate that trend detection will require periodic monitoring through at least 5 generation spans. One generation span is the time required for a newly formed seed to disperse, germinate, grow to a mature size, flower, and disperse new seeds. The Recovery Plan (USFWS 1984, p. 6) states that the species flowers at three to four years of age, although this may refer to individuals in cultivation. Based on this information, we believe that a typical generation span in the wild is at least five years. Therefore, the protected metapopulations must be monitored for at least 25 years.

Figure 2. Caballos Novaculite and Maravillas Chert Geological Formations, Brewster County, Texas.



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