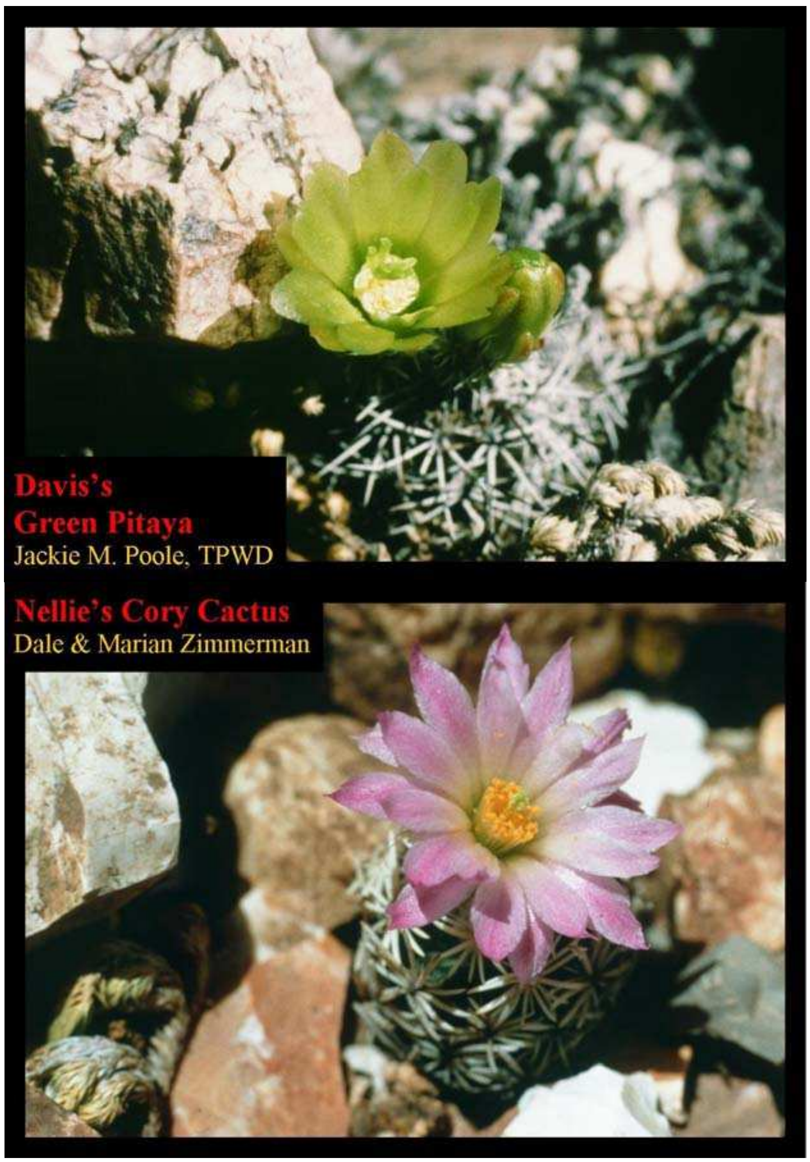
Davis's Green Pitaya
***Echinocereus viridiflorus* var. *davisii* Houghton**
And
Nellie's Cory Cactus
***Escobaria minima* (Baird) D.R. Hunt (Syn. *Coryphantha minima* Baird)**

5-Year Review:
Summary and Evaluation



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

5-YEAR REVIEW

Davis's Green Pitaya / *Echinocereus viridiflorus* var. *davisii* Houghton
Nellie's Cory Cactus / *Escobaria minima* (Baird) D.R. Hunt
(Syn. *Coryphantha minima* Baird)

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office: Southwest Regional Office (Region 2)
Susan Jacobsen, Chief, Threatened and Endangered Species, (505) 248-6641
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1.2 Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (USFWS) is required under section 4(c)(2) of the endangered Species Act (ESA) to conduct a status review of each listed species once every 5 years. The purpose of five-year reviews is to evaluate whether or not a species' status has changed since it was listed, or since completion of the most recent 5-year review. Our original listing as endangered or threatened is based on the five threat factors described in section 4(a)(1) of the ESA. In the 5-year review, we first review the best available scientific and commercial data on the species, focusing on any new information obtained since the species was listed or last reviewed. We then consider the same five threat factors to determine whether the species' status should remain the same or be changed from threatened to endangered, endangered to threatened, or be removed from the endangered species list. However, recommended status changes only become final through a separate rule-making process that includes public review and comment.

1.3 Methodology used to complete the review:

The public notice for this review was published in the *Federal Register* on February 11, 2009 (74 FR 6917). This review considers both new and previously existing information from Federal and State agencies, non-governmental organizations, academia, and the general public. Information used in the preparation of the review include the Texas Parks and Wildlife Department (TPWD) Natural Diversity Database (TXNDD), final reports of Section 6-funded projects, monitoring reports, scientific publications, unpublished documents, personal communications from botanists familiar with the species, and Internet web sites. The 5-year review was prepared without peer review by personnel of Austin Ecological Services Field Office.

1.4 Background:

U.S. Fish and Wildlife Service (USFWS) listed both Davis's green pitaya and Nellie's cory cactus as endangered without critical habitat on November 7, 1979 (44 FR 64738). The State of Texas listed both species as endangered on April 29, 1983.

Both of these cactus species are referred to by a variety of common names and taxonomic synonyms. See Section 2.3.1.3 for an explanation of the nomenclature used here. For brevity, this report uses the abbreviations "*E. v. davisii*" and "*E. minima*" for *Echinocereus viridiflorus* var. *davisii* and *Escobaria minima*, respectively, where the species are referred to repeatedly. The first use of technical terms and words with arcane meanings in the lexicons of science and government are underlined, and are defined in the glossary on pages 34-37. For convenience, the first uses of scientific units are spelled out, and are also summarized on page 34. Photographic credits are on page 34.

1.4.1 FR Notice citation announcing initiation of this review:

74 Federal Register 6917, February 11, 2009 (both species).

1.4.2 Listing history

Original Listing

FR notice: 44 Federal Register, 64738.
Date listed: November 7, 1979.
Entities listed: *Echinocereus viridiflorus* var. *davisii* (Davis' green pitaya) and *Coryphantha minima* (Nellie cory cactus).
Classification: Endangered without Critical Habitat.

1.4.3 Associated rulemakings: N/A

1.4.4. Review History

No previous 5-year review has been conducted for either of these species. Other review documents include:

Status Report on *Echinocereus viridiflorus* var. *davisii*: Weniger 1979a.

Status Report on *Coryphantha minima*: Weniger 1979b.

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

The Recovery Priority Number for *Echinocereus viridiflorus* var. *davisii* is 3, meaning that it is a subspecies (or variety) with a high degree of threat and a high recovery potential.

The Recovery Priority Number for *Escobaria minima* is 2, meaning that it is a full species with a high degree of threat and a high recovery potential.

1.4.6 Recovery Plan or Outline

Name of plan or outline: Davis' Green Pitaya Cactus (*Echinocereus viridiflorus* var. *davisii*) Recovery Plan.
Date issued: September 20, 1984.
Dates of previous revisions, if applicable: N/A

Name of plan or outline: Nellie Cory Cactus (*Coryphantha minima*) Recovery Plan.
Date issued: September 20, 1984.
Dates of previous revisions, if applicable: N/A

2.0 REVIEW ANALYSIS

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

The Distinct Population Segment policy applies only to vertebrate animals.

2.2 Recovery Criteria

2.2.1 Do these species have final, approved recovery plans?

Both species have final approved recovery plans.

2.2.1.1 Do the recovery plans contain objective, measurable criteria?

Neither recovery plan includes recovery criteria.

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? N/A

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:

The recovery plans for both species state: "The criteria for downlisting and/or delisting … 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 plans do include virtually identical step-down outlines of recovery actions. The actions that have been implemented are indicated with an asterisk (*) in the list. The step-down outline for *E. v. davisii* is as follows:

1. Remove threats to *Echinocereus viridiflorus* var. *davisii* by enforcement of existing regulations for protection.
   11.* Enforce existing trade regulations under the Endangered Species Act of 1973, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the Lacey Act.
   12. Determine the extent of collecting impacts on Davis' green pitaya cactus.
      121. Develop a monitoring system.
      122. Determine the extent and number of *E. viridiflorus* var. *davisii* in commercial trade.
   13.* Display "no trespassing" signs along U.S. Highway 385 property fence lines, after obtaining landowner approval.
2. Obtain management rights for existing populations of *E. viridiflorus* var. *davisii*.
   21. Develop cooperative agreements with private landowners for the protection and management of the Davis' green pitaya cactus populations and habitat.
   22. Develop and implement habitat management plans for all existing Davis' green pitaya cactus habitat.
   23. Protect occupied suitable habitat presently in private ownership.
3. Initiate and support studies on the population biology and ecology of Davis' green pitaya cactus.
   31. Survey for new populations on other outcrops of the Caballos Novaculite Formation.
   32. Determine all mechanisms involved in seed dispersal.
   33. Determine what microhabitat factors are involved in seedling establishment ecology.
   34. Determine the germination percentage rate of seeds and the taxon's overall reproductive potential and actual success in its natural habitat.
   35. Determine what insects and/or other invertebrates are involved in the pollination of *E. viridiflorus* var. *davisii*.
4. Develop a comprehensive, trade management plan for all cacti.
   41. Develop a trade study.
   42. Develop a monitoring study to determine the impact of collecting.
   43. Determine the feasibility of reducing the collecting pressure on the wild populations by promoting a commercial, artificial propagation program.
   44. Establish Fish and Wildlife Service policy on the cactus trade problem.
5. Develop public awareness, appreciation, and support for the preservation of Davis' green pitaya cactus.

Since the current recovery plans for these cactus species lack recovery criteria, the plans should be revised to conform to the standards of the interim endangered and threatened species recovery planning guidance (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007; U.S. Fish and Wildlife Service 2010a). The USFWS received a response to the Agency Draft of the recovery plans, recommending that *E. v. davisii* and *E. minima* recovery plans be combined (Fielding, in. litt. 1984). Considering that both species are narrowly endemic to the same unique mineral outcrop, and that they were listed together and share the same threats, this recommendation is appropriate.

Recovery Team

Neither of these cactus species has a recovery team.

Section 7 Consultations

Neither of these species has been considered in any formal consultations under section 7(a)(2) of the ESA for actions not initiated by USFWS. A single formal intra-service consultation (no. 2-12-85-F-89) in 1989 determined that a proposed project to protect habitat for *E. v. davisii* and *E. minima* in Brewster County was "not likely to jeopardize the continued existence of these species, but would promote their conservation." This proposed project, which was never implemented, sought to protect 25 to 50 acres (ac) of habitat on privately owned land through easement or other management agreement.

Section 6-funded Grants

"The Cooperative Endangered Species Conservation Fund (section 6 of the ESA) provides grants to States and Territories to participate in a wide array of voluntary conservation projects for candidate, proposed, and listed species. The program provides funding to States and Territories for species and habitat conservation actions on non-Federal lands" (U.S. Fish and Wildlife Service 2009). TPWD and USFWS have supported two section 6 grants in Texas that directly addressed *E. v. davisii* and *E. minima* conservation and recovery, summarized in Table 1 (below). The results of these projects are discussed in sections 2.3.1.2. Additionally, section 6 grant no. E-1 (Project WER71) contributed to the creation of Rare Plants of Texas (Poole *et. al*. 2007), an invaluable compilation of data on 232 rare, threatened and endangered plants of Texas, including *E. v. davisii* and *E. minima*.

Table 1. Section 6 grants involving Davis's green pitaya and Nellie's cory cactus.

Job/Project/ Grant no.	**Final Report Date**	**Principal investigator (citation)**	**Project title**
Job 35/ Grant E-1-6	31 Jan 1997	J.M. Poole and G.J. Janssen (Poole and Janssen 1997)	Managing and monitoring rare and endangered plants on highway Right-of-Ways in Texas.
Project WER48/ Grant E-1-12	30 Nov 1999	B.J. McKinney (McKinney 2000).	Rare plants, birds, mammals in the Trans-Pecos Ecoregion of western Texas.

Contracts and Cooperative Agreements

USFWS has not supported any cooperative agreements that involved *E. v. davisii* or *E. minima*.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

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

Very little new information on the biology and life history of these cactus species has been published since the completion of their recovery plans (U.S. Fish and Wildlife Service 1984a, 1984b). For convenience, we summarize here the relevant information from the recovery plans and other sources.

Description (adapted from Poole et al. 2007)

These diminutive cactus species are often concealed among rock fragments and club-moss clumps; during long droughts, they may shrink until hidden within cracks in the rock (see Figure 1). Therefore, these cacti cannot be effectively surveyed unless they are flowering during a year of adequate rainfall. *E. v. davisii* has rounded, usually solitary stems from 1.0 to 3.5 centimeters (cm) (0.4 to 1.4 inch [in]) tall, 6 to 10 ribs, from 8 to 15 radial spines per areole and infrequently a single central spine. The faintly lemon-scented flowers have a yellowish-green perianth from 1.5 to 2.7 cm (0.6 to 1.1 in) in diameter. The reddish-green to purplish-brown oval fruits are 5.5 to 11 mm (0.2 to 0.4 in) long by 4 to 8 mm (0.2 to 0.3 in) wide, bearing black, warty seeds up to 1.1 mm (0.04 in) long. *E. minima* has ovoid to cylindrical, tuberculate, solitary or branching stems from to 1.0 to 4.0 cm (0.4 to 1.6 in) tall and 0.6 to 2.5 cm (0.2 to 1.0 in) wide; when cultivated, the plants often form caespitose clusters with numerous stems. Dense, appressed, peg-like spines, from 15 to 27 per areole, obscure the stems. The flowers have pink to reddish-purple perianths from 1.5 to 2.7 cm (0.6 to 1.1 in) wide. The fruits are green to yellowish, from 1.5 to 7.0 mm (0.06 to 0.3 in) long, and the dark brown to black, pitted seeds are up to 1.0 mm (0.04 in) long.

Habitat

Houghton (1931) and Baird (1931) first described *E. v. davisii* and *E. minima*, respectively. Both species were discovered earlier that same year near Marathon, in Brewster County, Texas, at elevations ranging from 1,200 to 1,350 meters (m) (3,937 to 4,429 feet [ft]) where the average annual precipitation is 41 cm (16.1 in) (U.S. Fish and Wildlife Service 1984a, 1984b). *Echinocereus v. davisii* and *E. minima* are found in outcrops of an unusual mineral formation called the Caballos novaculite (see figures 1 and 2). Novaculites are a type of white chert or quartzite that was deposited in the Ouachita geosyncline during the Paleozoic geological era; in addition to the Caballos, the only other known novaculite outcrops are in the Ouachita Mountains of western Arkansas and eastern Oklahoma (McBride and Thomson 1970; Ketner, in litt. 1979). The Caballos novaculite – Maravillas chert outcrops, mapped as green polygons in figure 2 (Stoeser et al. 2005), cover a total of 12,094 hectares (ha) (29,887 acres [ac]). The outcrops are narrow, knife-edged ridges that trend generally southwest to northeast within a range of 52.8 kilometers (km) (32.8 miles [mi]) north to south, and 61.5 km (38.2 mi) east to west. The extremely hard and brittle novaculite resists erosion but fractures profusely. Since the time of their discovery, both *E. v. davisii* and *E. minima* have only been documented in a very small portion of the Caballos novaculite geological formation (however, see the discussion in 2.3.1.2).

Within the Caballos formation, *E. v. davisii* and *E. minima* grow in novaculite cracks and fragments, often in association with *Selaginella peruviana* (club-moss) (Weniger 1979a, 1979b; U.S. Fish and Wildlife Service 1984a, 1984b; Poole et al. 2007). The vegetation map of Frye et al. (1984) classifies the vegetation of the Caballos novaculite outcrops and of the surrounding valley floors as creosotebush - mesquite shrub (*Larrea tridentata – Prosopis glandulosa*) and tobosa - blackgrama grasslands (*Hilaria mutica – Bouteloua eriopoda*), respectively. Poole et al. (2007) describe the specific habitats of the endemic plants of the Caballos novaculite as sparse Chihuahuan Desert scrub or sparsely vegetated desert or semi-desert grasslands or shrublands. Table 1 lists the plant species associated with *E. v. davisii* and *E. minima*. At least five other rare, non-listed plant taxa are associated with these species in the Caballos novaculite geological formation: *Echinocereus chloranthus* var. *neocapillus*, *Echinocereus viridiflorus* var. *correllii* (Correll's green pitaya), *Escobaria hesteri*, *Thelocactus bicolor* var. *flavidispinus* (straw spine cactus), and *Paronychia wilkinsonii* (Wilkinson's nailwort) (Poole, et. al. 2007).

Weniger (1979a, 1979b) conducted field work on these cactus species in 1964 and 1979. He observed *E. v. davisii* flowering from May to August and fruits ripening in the summer and fall, while *E. minima* flowered in April and May and the fruits ripened by mid-summer. Individual *E. v. davisii* plants bloomed about 4 days per year, and were very difficult to find when not in bloom (see figures 1.2 and 1.3). While *E. minima* plants typically occur as dense, caespitose clusters, *E. v. davisii* individuals are scattered throughout the habitat. He found that both species are insect pollinated and reproduce entirely by sexually-produced seeds, and that wild-collected seeds of both species germinated readily.

The recovery plans (U.S. Fish and Wildlife Service 1984a, 1984b) describe the phenology and reproduction of these species as follows: plants of both species begin flowering at three to four years of age; *E. v. davisii* flowers from late March to early April and *E. minima* flowers in May, with fruits of both species maturing a month after flowering; virtually all flowering adults of cultivated plants of both species set fruit; *E. minima* plants produce up to four fruits per year containing 80 to 100 seeds each, and individual *E. v. davisii* plants produce from 85 to 340 seeds per year; and seeds of both species apparently fall near the parent plants as fruits decompose and are dispersed by the surface flow of rain water. Although not explicitly stated, all of these observations apparently were made on cultivated rather than wild plants. Brack (in. litt. 1983) also reported that the fruits of cultivated *E. minima* plants remained attached to the parent plants until they decomposed. He determined that the seeds produced by cultivated plants had a germination rate of 80 percent.

Leuck and Miller (1982) found that all taxa within the *Echinocereus viridiflorus* complex are xenogamous and self-incompatible. Solitary halictid bees pollinate the flowers within the first two hours after anthesis. These bees forage for pollen and nectar that is produced at the base of stamens only on the first day of anthesis.

2.3.1.2 Trends in populations, demography, and spatial distribution.

***Echinocereus viridiflorus* var. *davisii* – Davis's green pitaya**

Barton Warnock collected *E. v. davisii* on April 17, 1965, in the same restricted portion of Brewster County where, in 1931, the species was first discovered (University of Texas 2011). Weniger (1979a), who surveyed this area in 1964 and again in1979, reported that cactus collectors had wiped out a portion of the population from private land between 1964 and 1967. He estimated the total remaining population to be a few hundred individuals occupying about 40 ha (100 ac) dispersed over a 29 km- (18 mile-) span of a single outcrop.

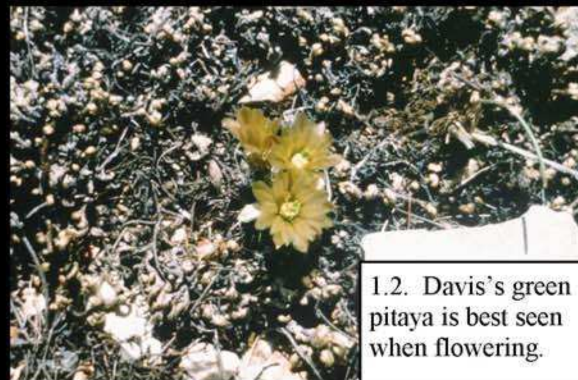
Brack (1983) observed 25 large, healthy *E. v. davisii* at the type locality, near Marathon, in February 1983. In October and November of that year, he searched several other novaculite outcrops between Persimmon Gap and the type locality, but did not observe this species.

The recovery plan (U.S. Fish and Wildlife Service 1984a) states that *E. v. davisii* plants are evenly scattered at a density of 1 to 5 plants per m^2 (0.09 to 0.46 plants per ft^2) over an area of 50 m by 4 km or 20 ha (164 ft by 2.5 mi or 49.4 ac); this implies that the total population would be from 200,000 to 1,000,000. Note that this information is found on page 5, and that pages 1 and 5 are missing from the electronic version of the plan which can be downloaded from the USFWS website (U.S. Fish and Wildlife Service 2011a). However, the recovery plan also estimates a total population of approximately 20,000 individuals. Although this figure is one tenth to one fiftieth of the amount that the previous information indicates, the plan does not explain the discrepancy.

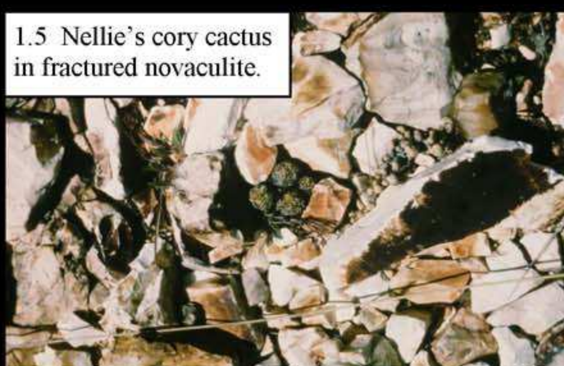
Ballew (1989) reported that *E. v. davisii* occurred on three separate tracts of land along U.S. Highway 385; based on information from the previous surveyors, we assume this is a single contiguous population spanning the three properties. The populations occupied approximately 65 ha (160 ac), 4.5 ha (10 ac), and 20 ha (50 ac) of a barren novaculite ridge. Two of the landowners voluntarily protected the populations, but did not allow access to the sites.

Figure 1. Photographic images of Davis's green pitaya and Nellie's cory cactus.

1.1. Nellie's cory cactus in cultivation.


1.2. Davis's green pitaya is best seen when flowering.


1.3. Davis's green pitaya nearly obscured by club-moss.


1.5 Nellie's cory cactus in fractured novaculite.


1.4. Typical Caballos novaculite outcrop.

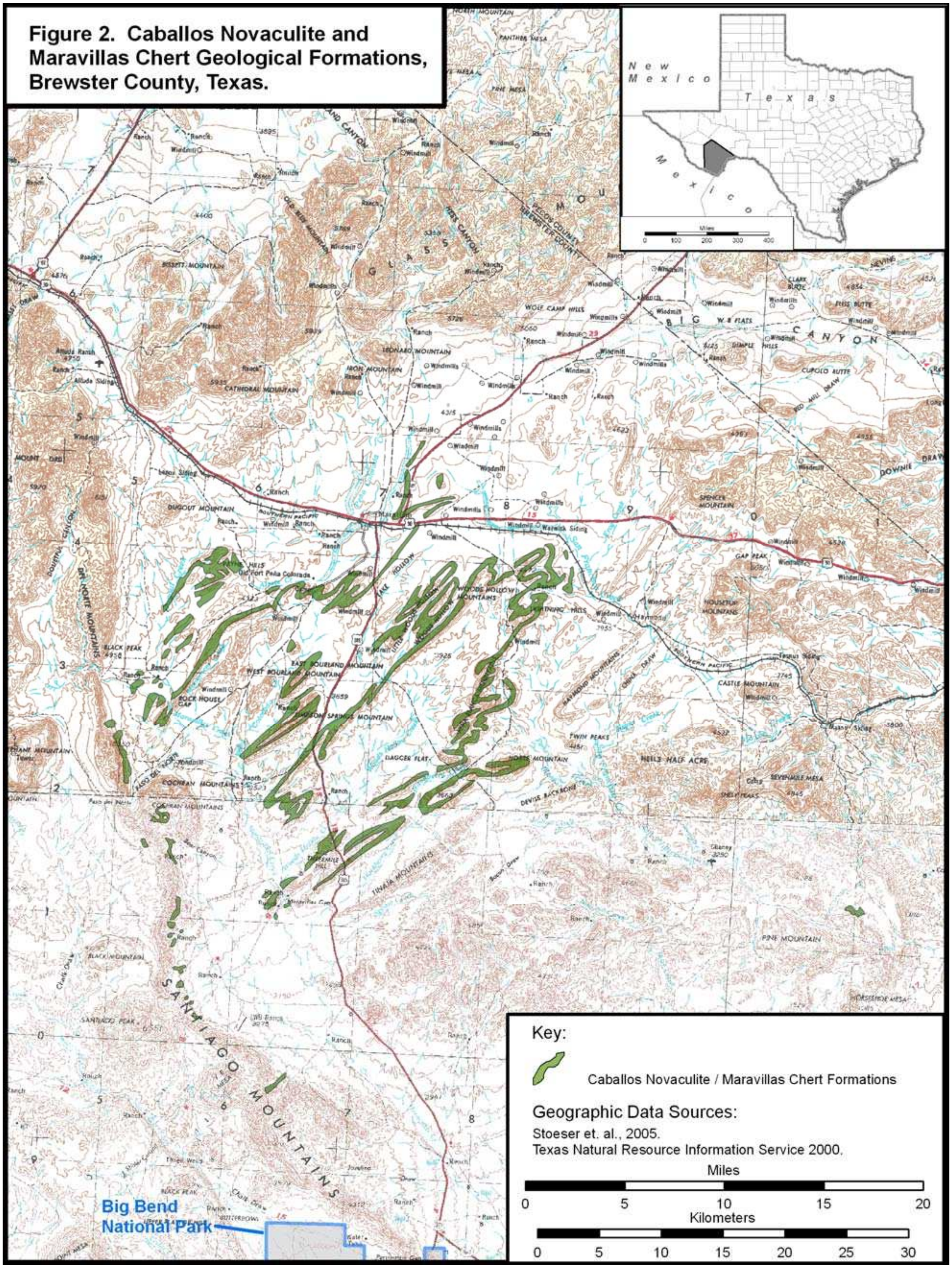


Figure 2. Caballos Novaculite and Maravillas Chert Geological Formations, Brewster County, Texas.

Table 2. Plant species associated with Davis's green pitaya and Nellie's cory cactus.

Family	**Genus**	**Species**	**Infraspecies**	***E. v. davisii***	***E. minima***	**USFWS 1984**	**Poole 2007**	**McKinney 2000**
Agavaceae	*Agave*	*lechuguilla*		X	X		X	
Agavaceae	*Yucca*	*elata*		X	X	X	X	X
Agavaceae	*Yucca*	*torreyi*		X	X	X	X	X
Asclepiadaceae	*Asclepias*	*nummularia*		X	X	X		
Asteraceae	*Artemisia*	*sp.*		X	X	X		
Asteraceae	*Erigeron*	*sp.*		X	X	X		
Asteraceae	*Tetraneuris*	*scaposa*		X	X	X		X
Asteraceae	*Thymophylla*	*pentachaeta*		X	X	X	X	X
Asteraceae	*Viguiera*	*stenoloba*		X	X		X	
Asteraceae	*Zinnia*	*acerosa*		X	X	X	X	X
Berberidaceae	*Mahonia*	*trifoliolata*		X	X	X		X
Cactaceae	*Coryphantha*	*echinus*		X	X			X
Cactaceae	*Echinocereus*	*chloranthus*	*neocapillus*[3]		X		X	
Cactaceae	*Echinocereus*	*stramineus*		X	X	X	X	X
Cactaceae	*Echinocereus*	*viridiflorus*	*correllii*[3]	X	X	X	X	
Cactaceae	*Echinocereus*	*viridiflorus*	*davisii*[3]	X	X	X	X	X
Cactaceae	*Escobaria*	*hesteri*[3]		X	X	X	X	X
Cactaceae	*Escobaria*	*minima*[3]		X	X	X	X	X
Cactaceae	*Escobaria*	*tuberculosa*		X	X	X		
Cactaceae	*Mammillaria*	*heyderi*		X	X	X	X	
Cactaceae	*Opuntia*	*macrocentra*[2]		X	X	X	X	X
Cactaceae	*Thelocactus*	*bicolor*	*flavidispinus*[3]	X	X	X	X	X
Capparaceae	*Koeberlinia*	*spinosa*		X	X	X		X
Caryophyllaceae	*Paronychia*	*wilkinsonii*[3]		X	X		X	
Cupressaceae	*Juniperus*	*pinchottii*		X	X	X		X
Ephedraceae	*Ephedra*	*aspera*		X	X	X		X
Fabaceae	*Acacia*	*constricta*		X	X	X	X	X
Fabaceae	*Acacia*	*rigidula*		X	X	X		X
Fabaceae	*Prosopis*	*glandulosa*		X	X	X		
Liliaceae	*Dasylirion*	*leiophyllum*		X	X	X	X	X
Liliaceae	*Nolina*	*texana*		X	X	X	X	X
Onagraceae	*Calylophus*	*sp.*		X	X	X		
Poaceae	*Bouteloua*	*breviseta*		X	X	X		X
Poaceae	*Bouteloua*	*ramosa*		X	X		X	
Poaceae	*Dasyochloa*	*pulchella*		X	X	X	X	X
Pteridaceae	*Cheilanthes*	*villosa*		X	X	X		X
Rhamnaceae	*Condalia*	*ericoides*		X	X	X		X
Scrophulariaceae	*Castilleja*	*integra*		X	X	X		
Scrophulariaceae	*Castilleja*	*sessiliflora*		X	X	X		
Scrophulariaceae	*Leucophyllum*	*frutescens*		X	X	X		
Scrophulariaceae	*Penstemon*	*fendleri*		X	X	X		
Selaginellaceae	*Selaginella*	*peruviana*		X	X		X	
Selaginellaceae	*Selaginella*	*sp.*		X	X	X		X
Verbenaceae	*Aloysia*	*wrightii*		X	X	X		
Verbenaceae	*Verbena*	*sp.*		X	X	X		
Zygophyllaceae	*Larrea*	*tridentata*		X	X	X	X	

1. Taxonomy updated to conform to USDA PLANTS database (Natural Resources Conservation Service 2010).
2. Listed in recovery plan as *O. violacea*; *O. macrocentra* var. *macrocentra* or *O. santa-rita* in USDA PLANTS.
3. Geoendemic taxa of the Caballos novaculite formation.

The Desert Botanical Garden has monitored the publicly-accessible portion of the population along the highway ROW since about 1991 (Ecker in litt. 1993, Ecker and Kozak 1993, Slauson 1994). The Texas Natural Diversity Database (2010a) indicates that 103 *E. v. davisii* plants were observed at this site in 1987, and 77 individuals were seen as recently as 1995. In annual surveys conducted from 1991 to 1995, Poole and Janssen (1997) observed 43, 59, 49, 70, and 79 individuals, respectively; these plants had an average of 1.0 to 2.0 flowers each. Rice (2004a) observed numerous divots at the site and only one or two non-reproductive individuals in 2004. Manning (pers. comm. 2010) observed only two individuals along the highway ROW in 2010. It is unlikely that these plants were impacted by highway maintenance, due to the steep, rocky terrain. Therefore, it appears that the publicly-accessible portion of the population has been almost completely extirpated, and this is almost certainly due to illicit collection.

Three *E. v. davisii* plants were observed in 1988 at another sight on private land nearby which has not since been surveyed (Texas Natural Diversity Database 2010a).

McKinney (2000), based on a survey of three properties, concluded that *E. v. davisii* occurs throughout the Caballos novaculite formation, with a total population of more than 500,000; see discussion below.

We found no records of *E. v. davisii* in searches of Mexican herbarium databases (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad 2010).

***Escobaria minima* – Nellie's cory cactus**

Weniger (1979b) estimated that the population of *E. minima* occupied a total area of no more than 40 ha (100 ac) in a discontinuous band 28 km (18 mi) long. The population occurred on two privately-owned ranches, one of which permitted cactus collectors to take the plants between 1964 and 1967. This portion of the population was extirpated or greatly reduced. Where protected from collection, dense stands of as many as 6 - 8 individuals per ft^2 (65 – 86 per m^2) remained in 1979. An anecdotal report of *E. minima* from Mt. Ord, about 28 km (17 mi) west of the type locality, has never been confirmed (Texas Natural Diversity Database 2010b).

Brack (1983) surveyed additional novaculite outcrops between Persimmon Gap and the type locality, but did not observe *E. minima*.

The Recovery Plan (U.S. Fish and Wildlife Service 1984b) estimated that the total *E. minima* population was approximately 40,000 to 80,000 individuals spanning an area of 11 km by 50 m (6.8 mi by 164 ft), totaling 55 ha (136 ac). The plants were unevenly distributed, with dense clumps containing up to several hundred individuals per m^2.

Ballew (1989) reported five populations of *E. minima* from five privately-owned tracts near Marathon. These populations covered 20 ha (50 ac), 4 ha (10 ac), 20 ha (50 ac), 162 ha (400 ac), and 40 ha (100 ac) on barren novaculite ridges. Two sites were voluntary protected by the landowners.

McKinney (2000), based on a survey of three properties, concluded that *E. minima* occurs throughout the Caballos novaculite formation, with a total population of more than 1,000,000; see discussion below.

The Texas Natural Diversity Database (2010b) reported that, as recently as 1987, more than 200 individuals occurred at the type locality along the U.S. Highway 385 ROW; by 1993 no *E. minima* plants were observed there. Poole and Janssen (1997) reported a single plant from this site in 1992 and 1993, and none during the following two years. It is assumed that the population was extirpated by illicit collection. Another population of about 200 individuals was observed in 1988 on private land southwest of Marathon, but no surveys have been reported from this site since that time (Texas Natural Diversity Database 2010b). An anecdotal report indicated that a population of unknown size also occurred on novaculite outcrops northeast of Marathon (Texas Natural Diversity Database 2010b).

We found no records of *E. minima* in searches of Mexican herbarium databases (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad 2010).

Summary of known populations of *E. v. davisii* and *E. minima*

In summary, both *E. v. davisii* and *E. minima* are endemic to outcrops of Caballos novaculite in the Marathon Basin, Brewster County. The reported populations occupied an area of 89 ha (220 ac) and 247 ha (610 ac), respectively (Ballew 1989), and several sites hosted both species. Both species have been nearly or completely extirpated from the minute slice of public highway ROW that bisects the populations. The remaining populations occur entirely on privately-owned lands. Reports from botanists who have requested and were denied access to survey the populations indicate that the owners of these sites are firmly dedicated both to the conservation of these species as well as to the defense of their property rights at this time. Consequently, we have no recent documentation of the status of these populations, nor any verifiable documentation of the presence or absence of the species from the vast majority of the Caballos novaculite outcrops that occur on more than 12,000 ha (nearly 30,000 ac) of privately-owned land.

Nevertheless, McKinney (2000) received permission from several landowners to access their properties to conduct a three-year population study. Table 3 (below) summarizes quantitative data from one 20 m by 35 m (65.6 ft by 114.8 ft) plot located on a randomly-selected novaculite ridge near the center of the Marathon Basin; the site had not previously been surveyed.

Table 3. Observations of *E. v. davisii* and *E. minima* from 700 m^2 (7,535 ft^2) plot.

Year	No. *E. v. davisii*	No. *E. minima*.	Observations
1998	63	516	Mature plants and seedlings of both species present.
1999	142	840	Adults of both species flowered in May.
2000	156	879	Reduced flowering due to severe drought.

McKinney stated that mature, live plants of both species withdraw into the rock fragments during prolonged drought and may not be visible. She attributed at least some of the increased numbers of both species observed in 1999 to re-emergence of live plants, following recent rainfall, that were not evident the previous year. In addition to this plot, McKinney also conducted surveys on at least two other ranches (McKinney, pers. com. 2010). She concluded that both species were abundant and wide-spread over a 155 km^2 (60 mi^2) area of novaculite ridges and slopes, but not in the intervening valleys. Her estimate of 155 km^2 appears comparable to the 121 km^2 we obtained from Stoeser et al. (2005) for the area occupied by novaculite outcrops; the difference is probably due to different methods used to map this area. McKinney estimated that total populations of *E. v. davisii* and *E. minima* were more than 500,000 and more than 1,000,000, respectively. She stated that the landowners were well aware of the endangered cactus populations on their properties, which they protected by prohibiting access to the land and collection of the plants. However, in order to respect landowner confidentiality, McKinney's report does not include maps, geographic locations, or property names, and we have not received independent verification of the conclusions. Furthermore, the report does not provide data from additional quantitative plots, nor an explanation of the sampling methods and statistical analyses used; therefore, it is impossible to confirm how the data from a single plot was extrapolated to estimate total population sizes covering the entire geologic formation. Nevertheless, the report does indicate that these cactus populations may be more abundant than previously known. The report's conclusion that these species are widespread in the Caballos novaculite formation is encouraging. The management of these species would benefit greatly if these conclusions could be confirmed by some means that is both acceptable to the landowners and scientifically verifiable.

2.3.1.3 Genetics and taxonomic classification:

Neither of the cactus species considered in this review has been spared from the relentless debate over the systematics of the cactus family. Tables 4 – 7 summarize the recognized scientific and common names for these taxa.

Table 4. Taxonomic classifications of Davis's green pitaya.

Scientific Name	Recognized by:
Echinocereus davisii A.D. Houghton	Houghton 1931; Poole et al. 2007; Zimmerman and Parfitt 2011a; Tropicos 2011a; University of Texas 2011.
Echinocereus subinermis var. *aculeatus* (Houghton) G. Unger	Unger 1941 (cited in Tropicos 2011a).
Echinocereus viridiflorus subsp. *davisii* (A.D. Houghton) N.P. Taylor	Taylor 1997; Anderson 2001.
Echinocereus viridiflorus Engelm. var. *davisii* (A.D. Houghton) W.T. Marsh	Marshall and Bock 1941; Benson 1982; Integrated Taxonomic Information System 2011a; Natural Resources Conservation Service 2011a; U.S. Fish and Wildlife Service 2011a.

Leuck and Miller (1982) investigated floral ultraviolet light (UV) reflectance and flavonoid chemistry to gain insights into the taxonomic relationships of the *Echinocereus viridiflorus* complex. This complex is distinguished from other *Echinocereus* species by the relatively small flowers born on areoles that are at least two years old. Members of the complex flower at different times, and therefore do not form interspecific hybrids even when growing in the same habitats (Leuck 1980, cited in Leuck and Miller 1982). Members of this complex are xenogamous and self-incompatible, and are pollinated by solitary halictid bees (Leuck 1980, cited in Leuck and Miller 1982). Ultraviolet photography revealed two floral types within the complex. The tepal margins of "target-type" flowers reflect long-wave UV while the rest of the flower absorbs UV; *E. davisii*, *E. viridiflorus* var. *correllii*, and *E. viridiflorus* var. *viridiflorus*, which all have greenish-yellow flowers in the visible spectrum, have target-type flowers in the UV spectrum. The flowers of *E. chloranthus* sensu lato (s.l.), *E. chloranthus* var. *neocapillus*, *E. russanthus*, and *E. viridiflorus* var. *cylindricus* all uniformly absorb long-wave UV light. This difference in UV reflectance may present a form of reproductive barrier between species of these differing floral types, since bees and many other insect pollinators have UV-sensitive vision (Kevan et al. 2001). Leuck and Miller also report that target-type flowers were distinguished by a lemon-like aroma, but they detected no qualitative differences in flavonoid chemistry between floral types; consequently, they concluded that *E. chloranthus*, *E. davisii*, and *E. russanthus* should be recognized as distinct intraspecific taxa (subspecies or varieties) of *E. viridiflorus*.

Based on this evidence, we (USFWS) continue to classify Davis's green pitaya as *E. viridiflorus* var. *davisii*. Nevertheless, we can expect further systematic revisions in the *E. viridiflorus* complex, particularly as genetic studies provide new tools to reveal the phylogeny of the cactus family.

The common names used for this cactus, summarized in Table 5, are no less varied than the taxonomic epithets. The standards published by the United States

Government Printing Office (2000) indicate that the possessive form of Davis is Davis's; we (USFWS) recommend the name "Davis's green pitaya".

Table 5. Common names used for *Echinocereus viridiflorus* var. *davisii*.

Common Name	**Citation**
Davis' dwarf hedgehog cactus	Poole et al. 2007
Davis' green pitaya	Poole et al. 2007; Center for Plant Conservation 2011a; U.S. Fish and Wildlife Service 2011a
Davis's green pitaya	Anderson 2001
Davis' hedge cactus	Poole et al. 2007
Davis' hedgehog cactus	Poole et al. 2007; Natural Resources Conservation Service 2011a
Davis's hedgehog cactus	Zimmerman and Parfitt 2011a
dwarf hedgehog cactus	Poole et al. 2007

Chromosome numbers of n = 11 have been reported for *E. viridiflorus* var. *cylindricus* (Pinkava et al. 1977), *E. viridiflorus* var. *viridiflorus* (Pinkava et al. 1977; Ross 1981), and *E. viridiflorus* var. *davisii* (Weedin and Powell 1978).

Table 6. Taxonomic classifications of Nellie's cory cactus.

Scientific Name	**Recognized by:**
Coryphantha minima Baird	Baird 1931; Benson 1982; Zimmerman and Parfitt 2011b; Tropicos 2011b; U.S. Fish and Wildlife Service 2011b.
Coryphantha nellieae Croizat	Croizat 1934.
Escobaria minima (Baird) D.R. Hunt	Hunt 1978; Anderson 2001; Poole, et al. 2007; Integrated Taxonomic Information System 2011b; Natural Resources Conservation Service 2011b.
Escobaria nelliae (Croizat) Backeb.	Backeberg 1961.
Mammillaria nelliae (Croizat) Croizat	Croizat 1942.

These taxonomic reviews have all recognized this entity as a distinct species; the persistent question has been the genus classification. The genus *Escobaria* was first described by Britton and Rose (1919-1923, cited in Anderson 2001), and is distinguished by pitted seed testa, fringed outer perianth parts, absence of nectar-secreting stem glands, flowers that are not yellow, and other characters (Anderson 2001). The closely-related genus *Coryphantha* has yellowish to greenish flowers, smooth seed testa, and un-fringed outer perianth parts (Taylor 1986, cited in Butterworth et al. 2002; Anderson 2001). Both *Escobaria* and *Coryphantha* have grooved tubercles and flowers arising at or near the stem tip, distinguishing them from the genus *Mammillaria*, which has smooth tubercles and flowers arising from older tubercles (not at the stem apex) (Anderson 2001). The separation of *Escobaria* from *Coryphantha* and their relationship to other members of the

“Mammilloid clade” is controversial (Butterworth et al. 2002). Zimmerman (1985) recognizes *Escobaria* (Britton and Rose) A. Berger as a subgenus of *Coryphantha*, within which he placed *Coryphantha minima* Baird. Nevertheless, he concurs that *Escobaria* is a useful taxonomic concept that future investigations might support raising to a genus. Zimmerman and Parfitt (2011b), in the Flora of North America treatment, also subsume *Escobaria* into *Coryphantha*. Conversely, the International Cactaceae Systematics Group (2006) continues to recognize *Escobaria* at the genus level. Butterworth and Wallace (2004) investigated the genetic relationships of 113 taxa of the Mammilloid clade (including *Mammillaria*, *Ortegocactus*, *Pelecyphora*, *Neolloydia*, *Escobaria*, and *Coryphantha*), based on variance in the rpl16 intron sequence and psbA-trnH intergenic spacer regions of the chloroplast. They determined that *Coryphantha* and *Escobaria* may form a separate clade from most *Mammillaria* species. In a subsequent investigation, Butterworth (2010) determined that “*Coryphantha* s.l. may not be monophyletic as currently circumscribed. For example, a narrow delimitation of *Coryphantha* likely renders *Escobaria* paraphyletic.”
In summary, the taxon *minima* under consideration is a valid species that clearly pertains to the genus or subgenus *Escobaria*. Both morphological and genetic data suggest the probable monophyly of an *Escobaria* clade. Therefore, we (USFWS) recognize this taxonomic entity as *Escobaria minima*.

Table 7. Common names used for *Escobaria minima.*

Common Name	**Citation**
Birdfoot cactus	Poole et al. 2007
Dwarf cory cactus	Poole et al. 2007
Least cory cactus	Poole et al. 2007
Nellie cory cactus	Poole et al. 2007; Center for Plant Conservation 2011b; Natural Resources Conservation Service 2011b; U.S. Fish and Wildlife Service 2011b
Nellie’s cory cactus	Poole et al. 2007
Nellie’s cory-cactus	Anderson 2001
Nellie’s pincushion cactus	Zimmerman and Parfitt 2011b

2.3.1.4 Conservation measures:

***Echinocereus viridiflorus* var. *davisii* – Davis’s green pitaya**

In 1991, Desert Botanical Garden (DBG) found that previously-collected seeds that had been dried and frozen had lost viability (Ecker and Kozak 1993). DBG, as authorized through Federal Fish and Wildlife Permits TE814841-0 and TE814841-1, has collected *E. v. davisii* seeds from an accessible portion of the wild population (see Table 8), which are stored in conservation seed banks at DBG and the National Seed Storage Lab in Ft. Collins, Colorado. By 2004 this seed bank included 41 accessions (Rice 2004a). DBG has germinated the seeds using Steven Brack’s screened box method as well as a sterilized medium

(Turface Quick-Dry) in a germination chamber. The seeds were relatively easy to germinate but had low survival rates (Desert Botanical Garden 2010). DBG possessed a single live individual that flowered in 2003 and 2004. Since the species is an obligate out-crosser, they fertilized this plant with pollen from another *E. v. davisii* provided by a cactus collector; however, the seeds produced by this cross had a germination rate of only 0.5 percent (Rice 2005a, 2005b).

Sul Ross State University has occasionally propagated *E. v. davisii* from seed for educational purposes (Manning, in litt. 2004).

E. v. davisii is collected and propagated by private cactus collectors; propagation instructions are publicized on many websites (B & T World Seeds 2011, Cactus Art Nursery 2011, Desert Tropicals 2011).

Table 8. *Echinocereus viridiflorus var. davisii* seeds collected by Desert Botanical Garden from an accessible portion of the wild population.

Year Visited	No. Individuals	Number of Fruits	No. of Seeds	Citation
1993	0	0	0	Ecker and Kozak1993
1994	30	49	479	Slauson 1994
2001	3	3	247	Desert Botanical Garden 2001
2002	n/r	3	324	Rice 2003
2003	0	0	0	Rice 2004b
2004	0	0	0	Rice 2005a

***Escobaria minima* – Nellie's cory cactus**

Brack (pers. comm. 1983) reported a germination rate or 80 percent or higher for captive-grown *E. minima* seeds. The seeds did not appear to have dormancy requirements, and the species was relatively easy to grow.

DBG has been authorized to collect *E. minima* seeds for seed banking and propagation through Federal Fish and Wildlife Permits TE814841-0 and TE814841-1, which expired on March 31, 2010. They visited the accessible portion of the wild population concurrently with seed collection for *E. v. davisii* (Table 8) but did not observe live plants. However, DBG obtained 37 individuals of *E. minima* that were produced through tissue culture of 2 seeds (Malda et al. 1999a, 1999b; Desert Botanical Garden 2010; see also discussion below). Two of these plants flowered in 1997 and were cross-pollinated, but did not produce fruits.

Malda et al. (1999a, 1999b) propagated *E. minima* using *in vitro* tissue culture of seeds provided by DBG. The observed growth rates were up to 7 times faster than in *ex vitro* culture of naturally-germinated seeds, due to the use of growth regulators, high humidity, and nutrient media. After micro-propagation and regeneration, the plantlets were successfully transferred to *ex vitro* culture. Giusti et al. (2002) also propagated *E. minima* using tissue culture. Of 25 Murashige and Skoog-based media (basal salt nutrient mixtures/solutions), TDZ (1-phenyl-3-(1-2-3-thiadiazol-5-yl) urea, a growth stimulator) induced a high proliferation rate but also much callus formation and watery shoot growth. BA (6-benzylaminopurine, a plant growth regulator) induced a high multiplication rate, good quality shoots and little or no callus. Micro-propagated plants were successfully restored in the field, and later flowered. These techniques demonstrate that tissue culture could permit large-scale propagation of *E. minima* and other rare cactus species for reintroduction and population augmentation, and might also reduce the incidence of illicit collection from wild populations by providing abundant specimens for the commercial market. Nevertheless, since tissue culture can be used to create infinite numbers of genetically-identical clones, the use of these techniques should be carefully planned and monitored to prevent genetic damage to wild populations.

Sul Ross State University has occasionally propagated *E. minima* from seed for educational purposes (Manning 2004).

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

The Recovery Plans for *E. v. davisii* and *E. minima* (U.S. Fish and Wildlife Service 1984a, 1984b) list the following existing and potential threats to the conservation and recovery of both species: Over-collection by commercial and private cactus collectors; trampling by livestock; competition from other plant species; and the narrow endemic restriction to a small portion of a single mineral formation.

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

Weniger (1979a, 1979b) did not observe evidence of trampling and determined that livestock grazing apparently does not significantly threaten either *E. v. davisii* or *E. minima*. The novaculite outcrops are steep and full of sharp rock fragments, and produce so little forage that livestock spend little time there. The low-density stocking rate typically practiced in this region appears to be very compatible with the long-term conservation of these cactus species.

Wildfires do occur in this region, and prescribed burning may also be practiced to control woody plant encroachment. Nevertheless, the sparse fuel loads on novaculite outcrops and the minute stature of these plants probably protects them from fire.

Herbicides that are commonly used to control woody plants in rangelands would probably harm both cactus species and their habitat. This potential threat could be alleviated by restricting herbicide applications to the level valleys between outcrops; since the valleys produce more forage than the nearly barren outcrops, this restriction would probably also make good economic sense.

Novaculite, which is nearly pure silicon dioxide, is mined in the state of Arkansas (Ketner, in litt. 1979; Weniger 1979a, 1979b). Silicon dioxide is the second most abundant mineral in the Earth's continental crust (Wikipedia 2011). Since there are ample sources of silicon dioxide closer to the industrial centers where it would be processed, it is unlikely that the Caballos novaculite will become an economically viable source for this mineral.

Consequently, we believe that the degree of threat from destruction, modification, or curtailment of habitat and range is relatively minor.

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

The evidence of the threat of illicit and unscrupulous collection to both *E. v. davisii* and *E. minima* is clear; both species have been extirpated from their type locations on a publicly-accessible highway ROW – a site well-known to cactus collectors for decades. These cactus species are offered for sale over the internet (B & T World Seeds 2011a, 2011b; High Country Gardens 2011a, 2011b), presumably cultivated legally and ethically from propagated seed or tissue culture rather than seeds or plants collected from the wild. We have no information on the current extent of illicit collection from the remaining wild populations. The restricted access to these remote sites and the vastness of the landscape may provide the best possible protection from this threat.

Therefore, we determine that the threat of over-collection for commercial and recreational purposes constitutes the major threat to these species.

2.3.2.3 Disease or predation:

Weniger (1979a, 1979b) found no evidence of disease or predation in the wild populations of *E. v. davisii* and *E. minima*. We have received no other information regarding threats from disease or predation to these cactus species. However, insect and rodent herbivores are a major threat to other federally-listed cactus species, including *Sclerocactus brevihamatus* ssp. *tobuschii* (Tobusch fishhook cactus; U.S. Fish and Wildlife Service 2010b) and *Astrophytum asterias* (star cactus; Janssen et al. 2009). We consider that herbivory by insects, rodents, and perhaps other animals constitutes a potential threat to *E. v. davisii* and *E. minima*, and recommend periodic monitoring of their wild populations to determine the degree of this threat.

2.3.2.4 Inadequacy of existing regulatory mechanisms:

The ESA does provide some legal protection for federally-listed plants on land under federal jurisdiction. Federally-listed plants occurring on private lands have very limited protection under the ESA, unless also protected by State laws; the State of Texas also provides very little protection to listed plant species on private lands. The populations of *E. v. davisii* and *E. minima* that occurred on public highway ROW have been extirpated. The remaining populations, including any undocumented populations that might exist, almost certainly occur exclusively on private land. Therefore, the species' remaining populations and habitats are not subject to federal or state protection unless there is a federal nexus, such as provisions of the Clean Water Act or a federally-funded project.

Chapter 88 of the Texas Parks and Wildlife Code lists plant species as state-threatened or endangered once they are federally-listed with these statuses. *Echinocereus v. davisii* and *E. minima* were both listed as endangered by the State of Texas on April 29, 1983. The State prohibits taking and/or possession for commercial sale of all or any part of an endangered, threatened, or protected plant from public land. 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 for scientific or educational 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.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

According to the Intergovernmental Panel on Climate Change (IPCC) (2007) "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." It is very likely that average Northern Hemisphere temperatures were higher during the second half of the 20th century than during any other 50-year period in the last 500 years; it is also likely that average temperatures during this period were the highest in at least the last 1,300 years (IPCC 2007). It is very likely that over the last 50 years, cold days, cold nights and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent (IPCC 2007). It is likely that heat waves have become more frequent over most land areas, and also that the frequency of heavy precipitation events has increased over most areas (IPCC 2007).

The IPCC (2007) predicts that changes in the global climate system during the 21st century are very likely to be larger than those observed during the 20th century. For the next two decades a warming of about 0.2°Celsius (C) (0.4° Fahrenheit [F]) per decade is projected (IPCC 2007). Afterwards, temperature projections increasingly depend on specific emission scenarios (IPCC 2007). The range of emission scenarios suggest that by the end of the 21st century, average global temperatures may increase from 0.6°C to 4.0°C (1.1°F to 7.2°F) with the greatest warming expected over land (IPCC 2007). Localized projections suggest that the southwestern U.S. may experience the greatest temperature increase of any area in the lower 48 States (IPCC 2007). The IPCC says it is very likely that hot extremes, heat waves, and heavy precipitation will increase in frequency (IPCC 2007). There is also high confidence that many semi-arid areas like the western United States will suffer a decrease in water resources due to climate change (IPCC 2007). Milly et al. (2005) project a 10 to 30 percent decrease in precipitation in mid-latitude western North America by the year 2050 based on an ensemble of 12 climate models.

We do not know whether the climate changes that have already occurred have affected the populations or distribution of *E. v. davisii* and *E. minima*, nor can we predict how the species might be affected by the type and degree of climate changes forecast by the range of models. While many species have adapted to previous climate changes by migrating in latitude or elevation, these cactus species are endemic to a unique geologic formation where there is very little variation in the range of latitude or elevation. Changes in temperature and rainfall amounts and patterns could alter the species' competitive advantages in the unique micro-habitats they occupy. Regardless of how these changes may affect their autecology, the altered synecology may be far more significant. For example, these cactus species might benefit from higher winter temperatures that extend their growing seasons. Conversely, they might face new threats from a migration of tropical cactus parasites and pathogens into their habitat. At present, we cannot predict how the infinitely complex aggregation of climate changes will affect the synecology of these species and their habitat. Therefore, we will adapt our recovery and management strategies when necessary to address the changing conditions; however, our ability to make sound decisions will depend on periodic, verifiable monitoring of the species' statuses.

2.4 Synthesis

Very little new information has emerged regarding *Echinocereus viridiflorus* var. *davisii* and *Escobaria minima* since they were federally listed in 1984. Systematic botanists continue to recognize both as valid taxa even though they do not concur on their classifications. Both species have been successfully propagated, primarily by cactus collectors and vendors, and conservation seed banks have been established at Desert Botanical Gardens and the National Seed Storage Laboratory. Illicit collection is the major threat to both species; the very small portion of the natural populations of both species that is publicly accessible has been wiped out, apparently by illicit collection. We know nothing about the status of remaining populations on private land. Anecdotal information indicates that at least some local landowners are aware of these unique resources and do protect them on their lands. A single unverifiable report indicates that both species may be more abundant and widespread than previously known, occurring in other portions of the Caballos novaculite geological formation. If this information could be independently verified, it might warrant downlisting to a threatened status, or de-listing, of one or both species. This, however, raises a fundamental conundrum: The lack of access to the privately-owned habitats prevents confirmation that these populations persist, but may also be their most effective protection from the very significant threat of illicit collection.

The wording of recovery outline item 2 of the recovery plans (listed in section 2.2.3) is unfortunate and misleading: "Obtain management rights for existing populations… Protect occupied suitable habitat presently in private ownership." This language may be misinterpreted, particularly by landowners in west Texas who are traditionally protective of their property rights. The Endangered Species Act does not give the government the authority to obtain management rights or to protect habitats of federally-listed plants on private land without the landowner's voluntary approval. The USFWS does, however, work cooperatively with many private landowners in Texas who request assistance in the conservation of rare plants on their land.

Some Texas landowners have taken the initiative to conserve rare plant populations on their land. For example, in 1989 an individual landowner began to promote the conservation of *Styrax platanifolius* ssp. *texanus* (Texas snowbells), an endangered shrub species endemic to the Edwards Plateau. This effort has now grown to an informal group of 24 landowners who protect and restore Texas snowbells on their own land (Bamberger, pers. comm. 2010; Bamberger Ranch 2011). At the group's request, USFWS and TPWD have provided technical and financial assistance. A section 6 grant supported an ecological investigation of the wild populations where landowners had granted permission (Fulton 2010), and the USFWS Partners for Fish and Wildlife Program has supported reintroduction efforts. These landowners who are dedicated to the conservation of natural heritage have brought Texas snowbells back from the verge of extinction. Similarly, the continued existence of *Echinocereus viridiflorus* var. *davisii*, *Escobaria minima*, and the other endemic plants of the Caballos novaculite formation also depends entirely on the interests and initiative of private landowners. The USFWS is grateful for any efforts they may have taken to conserve these resources, and will welcome any request to assist them in this effort.

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 Numbers: No change. *Echinocereus viridiflorus* var. *davisii:* to remain as 3; *Escobaria minima* to remain as 2.

Brief Rationale:

The Recovery Priority Number for *E. v. davisii* remains 3, meaning that it is a subspecies (or variety) with a high degree of threat and a high recovery potential.

The Recovery Priority Number for *E. minima* remains 2, meaning that it is a full species with a high degree of threat and a high recovery potential.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The most important recovery actions during the next five years include, but are not limited to, the following:

- Revise the recovery plans and recovery criteria for both species to incorporate the most recent recovery planning guidance (National Marine Fisheries Service 2007). Treat both species in a single recovery plan, and include recovery criteria that are specific, measureable, attainable, realistic, and time-referenced.
- Explore means to monitor the species and their habitats that are acceptable to landowners in the Marathon Basin as well as scientifically verifiable. Specific objectives should include a more complete determination of the species' ranges, distributions, population sizes, demographic trends, and threats.
- Support conservation of wild populations on private lands with willing landowners through the USFWS Partners for Fish and Wildlife Program, section 6-funded grants, cooperative efforts with Natural Resources Conservation Service, or non-governmental partners. Establish a private landowner support group for conservation of the Caballos novaculite rare plants, similar to the group now actively working to conserve Texas snowbells *(Styrax platanifolius* ssp. *texanus*).
- Support continued research on the population dynamics, reproductive biology, and genetic structure of the wild populations.

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PHOTOGRAPHIC CREDITS

Cover photograph of Davis's green pitaya: Jackie M. Poole, TPWD.
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Figure 1.1: Dale and Marian Zimmerman.
Figure 1.2: Jackie M. Poole, TPWD.
Figure 1.3: Jackie M. Poole, TPWD.
Figure 1.4: Chris Best, USFWS.
Figure 1.5: Jackie M. Poole, TPWD.

ABBREVIATIONS OF SCIENTIFIC UNITS

Abbreviation	Scientific Unit
ac	acres
° C	degrees Celsius
cm	centimeter
° F	degrees Fahrenheit
ft	ft
ha	hectares
in	inches
km	kilometers
m	meters
mi	miles

GLOSSARY OF TECHNICAL TERMS

Anthesis	The period when a flower is receptive to fertilization.
Areole	Specialized axillary bud or short shoot in cactus species; the spine cushion, producing leaves, spines, and flowers (Anderson 2001)
Autecology	Ecology of individual species.
Callus	A mass of undifferentiated cells.
Chert	A microcrystalline or cryptocrystalline sedimentary rock material composed of SiO_2 (Geology.com 2011).
Chloroplast	A double-membrane organelle found in higher plants in which photosynthesis takes place.
Chromosome	A threadlike linear strand of DNA and associated proteins in the nucleus of eukaryotic cells that carries the genes and functions in the transmission of hereditary information (Farlex, Inc. 2010).
Clade	The scientific classification of living and fossil organisms to describe a monophyletic group, defined as a group consisting of a single common ancestor and all its descendants (Wikipedia 2011).
Club-moss	A family of primitive vascular plants, Lycopodiaceae, bearing spores on specialized structures of the shoot apex (Wikipedia 2011).
Endemic	An organism restricted to a specific habitat or geographic range.
Ex vitro	Cultured outside of a controlled, sterile environment (literally, not within glass).
Flavonoid	A class of plant secondary metabolites or yellow pigments having a structure similar to that of flavones (Wikipedia 2011).
Genetic structure	Any pattern in the genetic makeup of individuals within a population (Wikipedia 2011).
Geoendemic	Endemic to a specific geological formation.
Geosyncline	A major trough or downwarp of the Earth's crust, in which great thicknesses of sedimentary and/or volcanic rocks have accumulated (Geology.com 2011).
Habitat	Ecological or environmental area that is inhabited by a particular species of animal, plant or other type of organism (Wikipedia 2011).
Halictid	A cosmopolitan family of the order Hymenoptera consisting of small (> 4 mm) to midsize (> 8 mm) bees which are usually dark-colored and often metallic in appearance; commonly referred to as sweat bees (Wikipedia 2011).
In vitro	Cultured within a controlled, sterile environment (literally, within glass).
Intergenic spacer	(Internal transcribed spacer). A piece of non-functional RNA situated between structural ribosomal RNAs (rRNA) on a common precursor transcript (Wikipedia 2011).
Interspecific	Between different species.
Intraspecific	Within a single species.
Intron	DNA region within a gene that is not translated into protein (Wikipedia 2011).

Micro-habitat	Very specific or fine-scale portion of a habitat that is occupied by a species.
Micro-propagation	Propagation of individual cells or small groups of cells, such as in tissue culture.
Monophyly	A group of organisms which consists of all the descendents of a single common ancestor.
Novaculite	A form of chert or flint found in the Ouachita Mountains of Arkansas and Oklahoma and in the Marathon Uplift of Texas (Wikipedia 2011).
Paleozoic	Geologic era spanning from roughly 542 to 251 million years ago (Wikipedia 2011).
Paraphyly	A group of organisms which consists of some, but not all of the descendents of a common ancestor.
Perianth	The floral envelopes collectively; usually used when calyx and corolla are not clearly differentiated (Correll and Johnston 1979).
Phenology	Seasonal pattern of plant growth, development and reproduction.
Phylogeny	The study of evolutionary relatedness among various groups of organisms (e.g., species, populations), which is discovered through molecular sequencing data and morphological data matrices (Wikipedia 2011).
Population dynamics	Changes in the size and age composition of populations over time, and the biological and environmental processes influencing those changes (Farlex, Inc. 2011).
Quartzite	A metamorphic rock formed by the alteration of sandstone by heat, pressure and chemical activity (Geology.com 2011).
Recovery team	A team of experts appointed by U.S. Fish and Wildlife Service or National Marine Fisheries Service to make recommendations on the recovery of federally-listed species.
Self-incompatible	Incapable of self-fertilization.
Sensu lato	Broadly defined.
Stamen	Male reproductive structure of the flower, consisting of a filament and anther; the androecium (Anderson 2001).
Subgenus	A subdivision of a genus, comprising one or more species which differ from other species of the genus in some important character or characters (Biology-online.org 2011).
Subspecies	A taxonomic group that is a division of a species; usually arises as a consequence of geographical isolation within a species (Biology-online.org 2011).
Subsume	Reclassify into a broader taxonomic group.
Synecology	Ecology of groups of coexisting organisms.
Systematics	The study of the diversification of life on the planet Earth, both past and present, and the relationships among living things through time, visualized as evolutionary trees (Wikipedia 2011).

Taxon	(Plural, taxa). A natural group of organisms at any rank in the taxonomic hierarchy (Anderson 2001).
Taxonomy	Scientific classification of living organisms.
Tepal	Sterile leaf-like structure of the flower when the perianth parts are not differentiated into sepals and petals (Anderson 2001).
Testa	Seed coat.
Tubercle	A conical or cylindrical outgrowth or protuberance from a cactus stem, usually bearing all or part of the areole; podarium (Anderson 2001).
Type locality	The location where a type specimen was collected.
Ultra-violet light	Electromagnetic radiation with a wavelength shorter than that of visible light, but longer than X-rays, in the range 10 nm to 400 nm, and energies from 3eV to 124 eV (Wikipedia 2011).
Variety	A taxonomic rank below subspecies in botany (Biology-online.org 2011).
Xenogamy	Sexual fertilization between different, unrelated individuals.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of
ECHINOCEREUS VIRIDIFLORUS var. DAVISII* and *ESCOBARIA MINIMA

Current Classification: Both are Endangered.

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change needed for either species

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Chris Best, Austin Ecological Services Field Office.

FIELD OFFICE APPROVAL:

Lead Field Supervisor, U.S. Fish and Wildlife Service

Approve ____________________ Date 8/4/11

REGIONAL OFFICE APPROVAL:

Assistant Regional Director, Ecological Services, U.S. Fish and Wildlife Service

Approve ____________________ Date 2/10/12