

Terlingua Creek Cat's-Eye
(*Cryptantha crassipes* I.M. Johnston)
(*Oreocarya crassipes* (I.M. Johnst.) Hasenstab & M.G. Simpson, comb. nov.)

5-Year Review:
Summary and Evaluation



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

5-YEAR REVIEW
Terlingua Creek Cat's-Eye
(*Cryptantha crassipes* I.M. Johnston)
(*Oreocarya crassipes* (I.M. Johnst.) Hasenstab & M.G. Simpson, comb. nov.)

1.0 GENERAL INFORMATION

1.1 Reviewers.

Lead Regional Office: Southwest (Region 2)

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Cooperating Field Office: n/a

1.2 Methodology used to complete the review.

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(TPWD) Natural Diversity Database (TXNDD), monitoring reports, section 6-funded projects, scientific publications, unpublished documents, personal communications from botanists familiar with the species, and Internet web sites.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 the Austin Ecological Services Field Office.

1.3 Background.

U.S. Fish and Wildlife Service (USFWS) listed Terlingua Creek cat's-eye as endangered without critical habitat on September 30, 1991. The State of Texas listed it as endangered on March 30, 1993.

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 33–37. For convenience, the first uses of scientific units are spelled out, and are also summarized on page 32.

Photographic credits are on page 32. This is the first status review since the species was listed (1991) and the recovery plan was prepared (1994). For convenience, we include brief summaries under each topic of the information known at those times.

Recommended citation:

U.S. Fish and Wildlife Service. 2020. Terlingua Creek cat's-eye (*Cryptantha crassipes* I.M. Johnston) five-year review: Summary and evaluation. Austin Ecological Services Field Office, Austin, Texas. 38 pp.

1.3.1 FR Notice citation announcing initiation of this review.

March 20, 2008 (73 FR 14995) and July 26, 2019 (84 FR 36113).

1.3.2 Listing history.

Original Listing

Federal Register notice: 56 FR 49634.

Date listed: September 30, 1991.

Entities listed: *Cryptantha crassipes*.

Classification: Endangered; critical habitat was not designated.

Critical Habitat Designation: n/a.

1.3.3 Associated rulemakings. n/a

1.3.4. Review History

No previous 5-year review has been conducted for Terlingua Creek cat's-eye. Other review documents include:

Poole, J.M. 1987. Status report on *Cryptantha crassipes*.

1.3.5 Species' Recovery Priority Number at start of 5-year review.

Prior to this review, the Recovery Priority Number for Terlingua Creek cat's-eye was 5C. This indicates that the degree of threat was high, the recovery potential was low, the taxon was a species, and the species is, or may be, in conflict with construction or other development projects or other forms of economic activity.

1.3.6 Recovery Plan or Outline.

Name of plan or outline: Terlingua Creek Cat's-eye (*Cryptantha crassipes*) Recovery Plan.

Date issued: April 5, 1994.

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 Does this species have a final, approved recovery plan?

Yes (USFWS 1994).

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?

The recovery criteria should be updated to include: 1) an estimate of minimum viable population (MVP) size and minimum numbers of viable populations that are consistent with our treatments of other plants species; 2) a delineation of the population centers upon which the criteria are based; 3) a protocol for delineating populations; and 4) descriptions of acceptable measures of protection.

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 sources.

Recovery Plan Criteria

Executive Summary (p. iii): “Develop and implement plans that insure the long-term protection and stability of a minimum of three population centers. There should be a total of at least 20 viable populations across the three population centers with each population comprised of no fewer than 1000 plants and being capable of long-term, self-perpetuating reproduction.”

Part II.A (p. 20): “If additional populations are discovered or sufficient suitable habitat is available and establishment of new populations proves to be feasible, *Cryptantha crassipes* could be considered for delisting when a minimum of three population centers containing a total of at least 20 viable populations with each population comprised of no fewer than 1000 plants are protected.”

Discussion. The plan re-defines population centers as metapopulations. Section II.C.1. (the narrative outline of recovery actions) further defines the protection of populations:

“...Thus every site needs protection. At present all known populations are on private land. Because land ownership and subsequent management practices often change through time, protection of such sites is somewhat more difficult. However, by using management agreements, conservation easements, and other tools, plans can be developed that are beneficial to the landowners as well as the species. Landowner cooperation is an integral component in the recovery of this species. Owners of property that the species occupies and the resort development [Terlingua Ranch Resort] should be encouraged to protect the species and commended for their efforts.”

Terlingua Creek cat’s-eye is currently known from 10 extant Element Occurrences (EOs); in addition, 8 new sites were reported in 2012 and 2016 that are either extensions of existing EOs, or may represent new EOs (Table 2; Figure 4). Only two populations have been surveyed in the last 10 years. Warnock (2012) observed 8,700 and 999 individuals at O2 Ranch and Field Lab, respectively, indicating that population size criteria have been met at those sites. One population (EO 1138) declined from 2000 individuals in 1985 to 100 in 2001. Seven populations have not

been monitored since the late 1980s. Since we have no recent monitoring or census data from most known populations, and since most of the potential habitat has never been surveyed, we cannot judge the extent that recovery criteria have been met. All populations occur on private land, and none have been formally protected by any of the measures described in the recovery plan.

If plant surveyors can obtain permission to access, monitor, and census the species' documented populations and potential habitats, determinations of recovery criterion fulfillment will depend on how populations and population centers are delineated. For example, all 8,700 individuals reported by Warnock at O2 ranch could be combined into one population that far exceeds the criterion of 1,000 individuals. Conversely, this number could be split into as many as 7 population sites, with as few as one, or perhaps all, meeting the size criterion. However, the recovery plan does not describe how populations and population centers should be delineated.

2.3 Updated Information and Current Species Status.

2.3.1 Biology and Habitat.

2.3.1.1 Description, taxonomic classification, and phylogenetics.

Summary of prior information (Higgins 1971; Poole 1987; USFWS 1994).

Cryptantha crassipes was described as a new species of the Borage Family (Boraginaceae) by I.M. Johnston (1939) from specimens collected by V.L. Cory in 1936. This perennial, herbaceous plant has basal rosettes of silvery, densely pubescent leaves, each up to 6 centimeters (cm) (2.4 inches (in)) long and 0.7 cm (0.3 in) wide, that emerge from a caudex (woody rootstock). Unbranched, pubescent flower stalks, up to 25 cm (10 in) tall, bear capitate inflorescences (rounded heads of flowers) at their tips and upper leaf nodes. Flower corollas have 5 white lobes bearing conspicuous yellow knobs. Flowers are dimorphic (occurring in two distinct forms) and heterostylous: some have long styles and short stamens, and others have short styles and long stamens. Fruits consist of 4 oval, flattened nutlets (seeds) 2.8–3.8 millimeters (mm) (0.11–0.15 in) long and 2.5–3.0 mm (0.10–0.12 in) wide. The upper surface of nutlets is finely wrinkled, while the lower surface is smooth. *C. crassipes* is most closely related to *C. palmeri* and *C. paysonii*, and is distinguished by its thickened, woody caudex, capitate inflorescence, shorter floral tube, and flattened nutlets.

New information.

Hasenstab-Lehman and Simpson (2012) investigated the phylogeny of *Cryptantha* s.l. and several related genera, based on herbarium and vouchered field collections of 45 species. They used parsimony, maximum likelihood, and Bayesian inference analyses of genes sequenced from the nuclear ribosomal ITS gene and the chloroplast *trnL_{UAA}* intron region. This revealed that *Cryptantha* s.l. is polyphyletic, and consists of 6 major clades: *Eremocarya*, *Greeneocharis*, *Johnstonella*, *Oreocarya*, *Cryptantha* s.s.1 and *Cryptantha* s.s.2. The investigators used the genetic data to reconstruct a phylogeny based on relevant morphological characters. The data supports resurrecting the genus *Oreocarya*, characterized by perennial life span, persistent basal rosettes, relatively large flowers, persistent calyces, and relatively large nutlets with sub-apical

ventral grooves and smooth, rugulose, or roughened sculpturing. The resurrected genus *Oreocarya* has 21 species, including Terlingua Creek cat's-eye (*O. crassipes* (I.M. Johnst.) Hasenstab & M.G. Simpson). Both *Cryptantha crassipes* and *Oreocarya crassipes* are listed as acceptable names in Tropicos (2020a, 2020b), but the updated classification has not yet been indicated in the PLANTS database (NRCS 2020a) or the Integrated Taxonomic Information Service (ITIS 2020). The Flora of North America (FNA) treatment of Boraginaceae (Volume 15) has not yet been published. However, since Hasenstab-Lehman and Simpson are the authors of the genera *Oreocarya* and *Cryptantha*, respectively, in the as-yet unpublished FNA volume, it is likely that FNA will adopt the revised classification, and that PLANTS and ITIS will then follow suit. Additionally, the phylogenetic analysis cited here is convincing and is the best available scientific information. Therefore, we recommend revising the scientific name of Terlingua Creek cat's-eye to *Oreocarya crassipes*.

2.3.1.2 New information on the species' biology, life history, habitat, and ecosystem.

Summary of prior information (56 FR 49634; Poole 1987; USFWS 1994).

Terlingua Creek cat's-eye flowers from late March to early June, and fruits have been observed from April to July. A preliminary study found that it is pollinated by small, possibly endemic bees. The dimorphic, heterostylous flowers occur in a 1:1 ratio; heterostyly is a morphological mechanism that enhances outcrossing. Germination trials have ranged from 0 to 75% germination, and may be stimulated by cool night temperatures (14–17° C; 58–62° F). No seedlings or juvenile individuals had been observed in the wild. Propagated plants flowered in the greenhouse after two years. The species occurs only on a unique soil type, the Fizzle Flats Lentil, composed of sparsely vegetated, highly fractured gypseous shale or limestone. This soil type occurs within the Badlands-Vieja soil association, which is found in outcrops of the upper Cretaceous Boquillas geological formation. Vegetated cover is less than 10 percent; associated plants are shown in Table 1. Annual precipitation in this arid, subtropical climate averages 23.4 cm (9.2 in), with a peak in late summer.

New information.

Reproduction.

Warnock (2012) investigated populations at two private ranches (discussed in section 2.3.1.3). During the spring of 2010, a year of near-normal precipitation, individuals in sample units averaged 4.8 capitate inflorescences each, inflorescences averaged 13 flowers each, and flowers averaged 0.75 seeds each (p. 12). From this information we deduce that individuals produced an average of 46.8 seeds each; combined with the small number of recruits observed and low survival (pp. 13, 17), we conclude that the species has extremely low fecundity, compared to plants in general. During an extreme drought the following year, flower and seed production declined by 51 percent (p. 17). These investigators documented floral visitation to an inflorescence by an unidentified species of Lepidoptera (butterfly) and two unidentified species of Hymenoptera, an ant and a bee or wasp (pp. 11, 17; Figures 1.b, 1.c). However, although a viable seed was produced by this inflorescence, this study did not determine whether any of these visitors effectively pollinated the species.

Cohen (2016, pp. 7–9, 15–16; also discussed in 2.3.1.3) investigated the floral morphology and breeding system of Terlingua Creek cat's-eye. The ratio of long-style and short-style flower morphs was close to 1:1 in each of 4 populations; this is an important indicator of population health of heterostylous plants, because fertilization could decline if one morph becomes overdominant. Although style lengths were continuously variable among flower morphs, anther lengths were dimorphic, and style-stigma separation was consistent among morphs, confirming that the species is functionally heterostylous. Pollen tube growth and fruit set were observed in experimental crosses between and among flower morphs as well as self-pollinated flowers; this data provisionally indicated that the species reproduces through both outcrossing and self-fertilization (pp. 8–9, 15). Although most heterostylous species are obligate outcrossers, other heterostylous species of *Oreocarya*, such as *O. flava*, are also capable of outcrossing and self-fertilization. However, Cohen (2019, p. 1315) later determined that the species is primarily allogamous (requires fertilization between different floral morphs), and described the breeding system of *O. crassipes* as reciprocal herkogamy: the anthers of each morph are the same height as the stigmas of the other morph, which enhances inter-morph fertilization.

Wells (2009–2020) provided photo-documentation of Terlingua Creek cat's-eye in flower at The Field Lab 5 times in the months of March and April, as well as January 1, 2013, February 2, 2017, February 29, 2012, and October 1, 2016. This demonstrates that moderate temperatures and rainfall can stimulate the species to flower outside the typical flowering season.

Habitat.

Warnock (2012) investigated habitat characteristics of Terlingua Creek cat's-eye populations at two sites. Analyses of soil samples collected within populations of this species (pp. 14–16) had gypsum concentrations ranging from 1.25–26.34 percent (average 7.36 percent), confirming that the occupied soils have high gypsum levels. Samples collected at the margins and beyond the margins of populations had gypsum concentrations ranging from 0.81–2.17 percent and 0.80–1.88 percent (averages 1.58 and 1.30 percent), respectively. This suggests that high gypsum levels are a specific habitat requirement for this species. Population sites also had slightly higher pH values, saturation percentages, and clay content than margins and beyond margins. The occupied soils had a lighter yellow color than surrounding soils (p. 17). The population sites averaged 10 percent vegetative cover, and Terlingua Creek cat's-eye was the dominant species (p. 12); associated species are listed in Table 1. Individuals occurred on slopes of random aspect ranging from 1–7 percent on alluvial fans or fan piedmont land forms of small hills (p. 17).

Ecology.

Williams *et al.* (2011) reported that Terlingua Creek cat's-eye tissues contain high levels of the toxic pyrrolizidine alkaloids lycopsamine-N-oxide and intermedine-N-oxide. These and similar alkaloids occur in many *Cryptantha* species that grow in arid regions, and may serve as protection against insect herbivory. Warnock (2012) hypothesized that the high levels of pyrrolizidines may help protect the species from fungal pathogens (p. 12) or may protect its proteins and membranes from high concentrations of salts (p. 19).

Table 1. Plant species associated with Terlingua Creek cat's-eye, reported by multiple observers.

Family	Genus	Species ¹	Common Name	Poole 1987, Poole <i>et al.</i> 2007, USFWS 1994	TXNDD 2019	Warnock 2012
Acanthaceae	<i>Stenandrium</i>	<i>barbatum</i>	Shaggy Stenandrium	x	x	
Anacardiaceae	<i>Rhus</i>	<i>microphylla</i>	Desert Sumac		x	
Apocynaceae	<i>Amsonia</i>	<i>longiflora</i>	Tubular Bluestar	x	x	
Asparagaceae	<i>Yucca</i>	<i>torreyi</i>	Torrey Yucca		x	
Asteraceae	<i>Baileya</i>	<i>multiradiata</i>	Desert Baileya		x	
Asteraceae	<i>Chrysactinia</i>	<i>mexicana</i>	Damianita	x	x	
Asteraceae	<i>Isocoma</i>	<i>pluriflora</i>	Southern Goldenbush			x
Asteraceae	<i>Thelesperma</i>	<i>longipes</i>	Longstalk Greenthread	x		
Asteraceae	<i>Xylorhiza</i>	<i>wrightii</i>	Gyp Machaeranthera	x	x	x
Boraginaceae	<i>Cryptantha</i>	<i>palmeri</i>	Palmer's Cryptantha			
Boraginaceae	<i>Tiquilia</i>	<i>hispidissima</i>	Rough Tiquilia	x	x	
Boraginaceae	<i>Tiquilia</i>	<i>mexicana</i>	Mexican Crinklemat		x	
Brassicaceae	<i>Physaria</i>	<i>gordonii</i>	Gordon's Bladderpod		x	
Brassicaceae	<i>Stanleya</i>	<i>pinnata</i>	Desert Princeplume		x	
Brassicaceae	<i>Thelypodium</i>	<i>texanum</i>	Texas Thelypodium		x	
Cactaceae	<i>Ariocarpus</i>	<i>fissuratus</i>	Living Rock Cactus		x	
Cactaceae	<i>Echinocactus</i>	<i>horizonthalonius</i>	Eagle-Claw Cactus		x	
Ephedraceae	<i>Ephedra</i>	<i>aspera</i>	Rough Jointfir		x	
Ephedraceae	<i>Ephedra</i>	<i>sp.</i>	Ephedra	x		
Euphorbiaceae	<i>Chamaesyce</i>	<i>acuta</i>	Pointed Sandmat		x	
Euphorbiaceae	<i>Chamaesyce</i>	<i>perennans</i>	Perennial Spurge	x	x	
Euphorbiaceae	<i>Chamaesyce</i>	<i>theriaca</i>	Terlingua sandmat		x	
Fabaceae	<i>Acacia</i>	<i>schottii</i>	Schott's Acacia	x	x	
Fabaceae	<i>Dalea</i>	<i>formosa</i>	Feather Dalea	x	x	
Hydrophyllaceae	<i>Nama</i>	<i>hispidum</i>	Rough Nama		x	
Krameriaceae	<i>Krameria</i>	<i>erecta</i>	Range Ratany	x	x	
Krameriaceae	<i>Krameria</i>	<i>glandulosa</i>	Littleleaf Rattany		x	
Liliaceae	<i>Dasyilirion</i>	<i>leiophyllum</i>	Green Sotol		x	
Loasaceae	<i>Mentzelia</i>	<i>mexicana</i>	Mexican Blazingstar			x
Nyctaginaceae	<i>Acleisanthes</i>	<i>longiflora</i>	Angel's Trumpets		x	
Nyctaginaceae	<i>Anulocualis</i>	<i>leiosolenus v. lasianthus</i>	Chihuahua Ringstem	x	x	x
Poaceae	<i>Aristida</i>	<i>pansa</i>	Wooton's threeawn			x
Polygalaceae	<i>Polygala</i>	<i>lindheimeri v. parvifolia</i>	Shrubby Milkwort		x	x
Polygonaceae	<i>Eriogonum</i>	<i>havardii</i>	Havard Wild Buckwheat	x	x	x
Polygonaceae	<i>Eriogonum</i>	<i>suffruticosum</i>	Bushy Wild Buckwheat	x	x	
Scrophulariaceae	<i>Castilleja</i>	<i>rigida</i>	Rigid Indian Paintbrush			x
Solanaceae	<i>Lycium</i>	<i>berberoides</i>	Downy Desert-Thorn		x	
Solanaceae	<i>Lycium</i>	<i>berlandieri</i>	Berlandier's Wolfberry		x	
Zygophyllaceae	<i>Larrea</i>	<i>tridentata</i>	Creosote Bush	x	x	

1. Botanical classifications conform to NRCS 2020b.

Figure 1. Photographs of Terlingua Creek cat's-eye.



- a. Terlingua Creek cat's-eye in typical gypseous limestone substrate.
- b. Floral visitor.
- c. Floral visitor.
- d. Plants in propagation trial at Sul Ross State University.

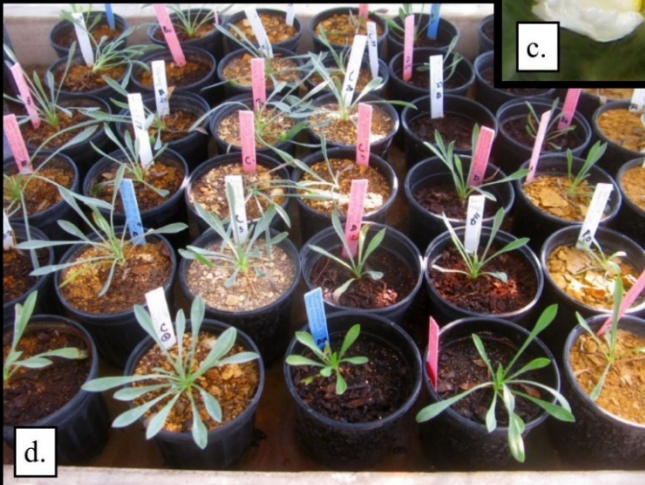


Figure 1. Photographs of Terlingua Creek cat's-eye.

2.3.1.3 Trends in abundance, number and spatial distribution of populations, estimate of minimum viable population, population delineation, and demographic trends.

Summary of prior information (56 FR 49634; Poole 1987; USFWS 1994).

Ten population sites occur in an area about 20 kilometers (km) (12 miles (mi)) wide along upper Terlingua Creek, in Brewster County, Texas. Unconfirmed reports include Big Bend National Park and a site east of Lajitas. A specimen collected in 1946 in Otero County, New Mexico was identified as *C. crassipes*, but was later determined to be a closely-related species, *C. paysonii* (note that the PLANTS database (NRCS 2020a) incorrectly includes Otero County, New Mexico within the species' range). Sites range from 2 to 202 hectares (ha) (5 to 500 acres (ac)), and populations range from 50 to 2,000 individuals. The total of all populations is 4,554 individuals covering about 500 ha (1,236 ha).

New Information.

Documented populations and demographic trends.

We received the most recent update of the Terlingua Creek cat's-eye EO Report from the Texas Natural Diversity Database (TXNDD 2019), summarized in Table 2. One EO (4749) is a historic record of unknown size and imprecise geographic location (represented by a large open circle in Figure 3). In addition, we received new population reports (Warnock 2012; Cohen 2016) that are not yet included in the TXNDD report. Six new sites, listed as O2a through O2f in Table 2, are collectively within 1 km of EO 3817 and will likely be combined with that EO (see discussion on population delineation in Section 2.3.1.3). Similarly, two new sites, listed as FL1 and FL2 in Table 2, are less than 1 km from EO 2231, and will likely be combined with it.

Alex *et al.* (2006) conducted a 3-year search for 207 sensitive plant species at Big Bend National Park, but documented no occurrences of Terlingua Creek cat's-eye at the park.

Warnock (2012, pp. 6, 12) mapped populations of Terlingua Creek cat's-eye at the O2 Ranch, where the investigators found two new populations, and the John Wells Terlingua Ranch (also known as The Field Lab), where one new population was found. Their census detected about 8,700 individuals at the former property and 999 at the latter. The nearly 10,000 individuals counted at just two EOs is more than twice the previously estimated total population for all EOs. In 2010, from 2 to 16 seedlings were observed in each "stand" of the species (an undefined term we presume indicates a cluster of individuals or subpopulation) (p. 13). From September 29, 2010, until February 9, 2012, the study sites received only 2.94 cm (1.16 in) of precipitation; many of the seedlings may have died during this period of extreme drought (p. 17). The investigators established 3 permanent monitoring plots intended to detect population changes over time.

Most of the EOs in the TXNDD (2019) have only been visited once; EO 1138 declined from about 2000 individuals in 1985 to 100 in 2001. The discovery of almost 10,000 new individuals in two areas increases the known population size. Nevertheless, it is not possible to determine any overall demographic trends for this species due to the very limited amount of data.

Table 2. Summary of Element Occurrence records from the Texas Natural Heritage Database (TXNDD 2019, pp. 1–23) and recent surveys (Warnock 2012, Cohen 2016). Population sizes represented by an “A” total to 999 plants and by a “B” total to 8700 plants.

Element Occurrence or Source ID	Site Name or description	First Reported	Most Recent Observation	Most Recent Pop Size	Max Pop Date	Max Pop Size
EO1; ID3966	Confluence of Terlingua and Alamo de Cesario creeks; type locality.	1936	1986	500	1985–1986	500
EO2; ID4749	NW of Big Bend National Park (Historic)	1936	1936	unk.		
EO3; ID1138	Terlingua Creek N of Panther Mtn.	1985	2001	100	1985	2000
EO4; ID6546	Near Panther Mtn E of Terlingua Creek	1986	1986	620	1986	620
EO5; ID4177	NW of Paint Mtn	1986	1986	84	1986	84
EO6; ID2231	NNE of Panther Mtn	1986	2012	A	2016	A
EO7; ID4343	Fizzle Flat	1987	1987	500	1987	500
EO8; ID1604	NW of Whistler Mesa	1988	1988	100	1988	100
EO9; ID7782	NNW of Whistler Mesa	1988	1988	100	1988	100
EO10; ID7783	N of Fizzle Flat near Terlingua Creek	1988	1988	500	1988	500
EO11; ID3817	S of Long Hills along Terlingua Creek	1988	2012	B	2012	B
Cohen 2016	Within EO ID 2231	2012	2016	A	2012	A
Warnock 2012	275 m NW of EO ID 2231	2012	2012	A	2012	A
Cohen 2016	750 m NE of EO ID 3817	2012	2016	B	2012	B
Cohen 2016	930 m N of EO ID 3817	2012	2016	B	2012	B
Cohen 2016	1,200 m NE of EO ID 3817	2012	2016	B	2012	B
Warnock 2012	1,000 m SW of EO ID 3817	2012	2012	B	2012	B
Warnock 2012	940 m SW of EO ID 3817	2012	2012	B	2012	B
Warnock 2012	930 m SW of EO ID 3817	2012	2012	B	2012	B
Total Plants					12,303	14,253

Conservation genetics and genomics.

Cohen (2016, pp. 11–16; Cohen 2019, all) used Single Nucleotide Polymorphism (SNP) and microsatellite DNA data to investigate the genetic structure and demographics of 4 populations of Terlingua Creek cat’s-eye. These populations, designated Field Lab (FL) and O2 Ranch 1, 2, and 3, are shown in table 2 and the map in Figure 3. The 4 geographic populations grouped into 3 genetic populations, designated FL, O2-1, and O2-2 plus O2-3. From 81 to 90 percent of genetic variation was among individuals, and 5 to 10 percent was among populations (Cohen 2019, p. 1320–1321). Although there were indications of inbreeding and relatively recent genetic bottlenecks in all populations, gene flow had occurred within and among all populations. A model of gene flow revealed that it likely occurred in a stepping stone pattern from O2-1 to O2-2, from O2-2 to both O2-3 and FL, and from FL to O2-3. Population sizes appear to have remained stable. These populations of *O. crassipes* had less inbreeding and greater population

structure than two closely related species of gypsum-endemic *Oreocarya*, *O. paradoxa* and *O. revealii* (Bresowar and McGlaughlin 2014), indicating that *O. crassipes* has sufficient genetic resources for long-term persistence and viability (Cohen 2019, p. 1326).

Geographic distribution of populations and estimate of potential habitat.

We used the ESRI ArcMap software to analyze the geographic distribution of Terlingua Creek cat's-eye. The species' range extent is 17.5 km (10.9 mi) north to south and 12.9 km (8.0 mi) east to west; if represented as a rectangle, the range would cover an area of 226 km² (87 mi²). However, the species is only known from portions of that range. We created a polygon, using the outermost known populations as its vertices, to represent the species' occupied range (Figures 2 and 3), which covers an area of 4,178 ha (41.8 km²; 10,324 ac; 16.1 mi²).

All known populations occur on privately owned land, and it is very likely that all existing populations (including unknown extant populations) occur on private land. While some landowners have granted access to monitor and study the populations on their land, many of the known populations occur on a large number of subdivided properties whose owners do not live in the area and who have not been contacted (many are unknown) or have not granted access. Thus, it is not possible to monitor many of the known populations to confirm their current status, or to survey extensively to determine the species' actual range and number of populations.

We created a potential habitat model to estimate the extent and geographic distribution of habitats where the species might be found. This model is based on known habitat requirements that are represented in available digitized geographic data. These data layers are:

- Soils. We overlaid Terlingua Creek cat's-eye locations, obtained from TXNDD (2019) and new locations reported by Warnock (2012) and Cohen (2016), on digitized maps of soil types for Brewster County (NRCS 2020c). The species is a geo-endemic that is strongly associated with high-gypsum soils, such as the Fizzle Flats loam. However, these very specific soils are not indicated in the available soil maps, due to their relatively small, fragmented areas that occur within larger soil map units. The known populations overlie one or more of the following soil map units (numbers of populations are in parentheses): Geefour silty clays complex (9); Rock outcrop-Mariscal complex (4); Cheosa and Loyplace (2); Mariscal rock outcrop complex (2); Mariscal very channery loam (2); Riverwash-Pantera complex (2); Cesario and Fizzle Flat loams (1); Musgrave gravelly clay loam (1); and Study Butte rock outcrop complex (1). We created a new polygon shapefile from the source data composed only of these 9 soil map units.
- Geology. We overlaid the known populations on a U.S. Geological Survey digitized geology map (Stoeser *et al.* 2005). The known populations overlie one or more of the following geological formations (numbers of populations are in parentheses): Pen (13); Boquillas (8); Devils Graveyard volcanic rocks (4); and Aguja (2). We created a new polygon shapefile from the source data composed only of these 4 geological formations in Brewster County.
- Elevation. We overlaid the known populations on a digital elevation model (DEM; USGS 2020) covering the species' known range. The known populations occur at a range of 940 to 1,089 m (3,084 to 3,573 ft) elevation. We created a new polygon

shapefile from the source data composed of polygons between 900 and 1,100 m (2,953 and 3,609 ft) elevation.

- Slope. Known populations of Terlingua Creek cat's-eye occur where slopes range from 0 to 7 percent (Warnock 2012, p. 17). We used the ArcMap Spatial Analyst slope tool to create a raster file of slopes from the DEM described above, and then created a polygon shapefile consisting only of polygons where slope ranged from 0 to 10 percent.

We used the ArcMap Intersect tool to create a shapefile of polygons that occur within all 4 of the data layers described above (Figure 3). The areas identified by this model should not be interpreted as consisting solely of the specific gypseous habitats of Terlingua Creek cat's-eye; rather, the model indicate places where the specific habitats may exist within a mosaic of other soil types. The model identified 843 potential habitat areas, ranging from 1 to 1,118 ha (2.5 to 2,763 ac) in size (average 20.6 ha (50.9 ac)), totaling 17,380 ha (42,946 ac). The model also identified 15,910 potential habitat areas less than 1 ha in size, totaling 820 ha (2,026 ac). This distinction in size of habitat area could be important, since small, isolated areas may not be able to sustain viable populations; conversely, large numbers of small habitats may sustain viable populations if they are geographically clustered. This model did not evaluate areas within Big Bend National Park. However, it does appear that a small amount of potential habitat could occur in the extreme northwest area of the park; as mentioned previously, plant surveys have never detected the species at the park.

Recovery Units.

To conserve the full range of the species' genetic diversity and ecological adaptation, it must be conserved throughout its geographic range. The recovery plan (USFWS 1994, p. 20) establishes a recovery criterion of a minimum of 3 population centers (metapopulations), but does not indicate the geographic distribution of these metapopulations. Based on genetic variation among populations, Cohen (2016, p. 16; 2019, p. 1324) identified two evolutionarily significant units, Field Lab and O2 Ranch, but did not collect data from other populations. We have provisionally identified 3 recovery units in the upper Terlingua Creek, lower Terlingua Creek, and Alamo de Cesario Creek portions of the species' geographic range (figure 4) that will contribute to recovery planning and the conservation of its genetic diversity. These recovery units may be revised if new data on the species' populations and genetics indicate more logical delineations.

Estimate of Minimum Viable Population size.

MVP refers to 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. Determinations of MVP usually take into account the effective population size (n_e), rather than the total number of individuals (n); 10 genetically identical individuals (for example, clones) would have an effective population size of 1.

MVP or Population Viability Analysis have not been calculated for Terlingua Creek cat's-eye, nor do we possess all the baseline demographic and life history data needed to perform these calculations. Table 3 is an adaptation of a method for estimating plant MVPs published in Pavlik

(1996, p. 137). Species with traits that all fall under column A would have MVPs of about 50 individuals. Those with traits that all ascribe to column C would have MVPs around 2,500 individuals. We added an intermediate column (B) to Pavlik's table, corresponding to an MVP of 1,000 individuals, to account for species with intermediate or unknown traits. The bold letters in the table indicate values, if known, for Terlingua Creek cat's-eye. Two factors require fewer individuals (perennial lifespan and climax successional status); although the gypseous, flaky limestone substrate is sparsely vegetated, we interpret the plant community as a climax ge-endemic community. Two factors are intermediate (unknown survivorship and longevity of seed viability). Five factors require more individuals (outcrossing breeding system, herbaceous growth form, low fecundity, no ramet production, and high environmental variation). The relatively small number of seeds produced and limited recruitment (Warnock 2012, pp. 13, 17) indicate low fecundity, compared to plants in general. High environmental variation is due to the wide variation in annual precipitation. The estimated MVP for Terlingua Creek cat's-eye is:

$$((2 \times 50) + (2 \times 1,000) + (5 \times 2,500)) / 9 = \text{approximately } 1,600 \text{ individuals.}$$

Table 3. Minimum viable population guidelines applied to Terlingua Creek cat's-eye (adapted from Pavlik 1996, p. 137).

Factor	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.
Lifespan	Perennial		Annual
Breeding System	Selfing		Outcrossing
Growth Form	Woody		Herbaceous
Fecundity	High		Low
Ramet Production	Common		Rare or None
Survivorship	High	Unknown	Low
Longevity of Seed Viability	Long	Unknown	Short
Environmental Variation	Low		High
Successional Status	Climax		<u>Serial</u> or <u>Ruderal</u>

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 juveniles that die before they reproduce 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 the proportion of surviving seedlings; thus, basing MVP on mature individuals will also make it easier to judge when the level has been attained.

Delineation of populations.

In order to determine the sizes, numbers, and distribution of populations, it is necessary to delineate populations. As used here, a population consists of groups of individuals within which gene flow, by means of seed dispersal or pollination, occurs often. Metapopulations refer to two or more populations between which gene flow is infrequent. Separate groups of individuals between which gene flow does not occur constitute separate populations. Viable populations of rare plants often consist of metapopulations of numerous small colonies that migrate (by means of mortality in one area and recruitment in another) through areas of contiguous habitat, or between patches of suitable habitat within mosaics of different habitat types, periodically merging or dividing over spans of many years. We hypothesize that Terlingua Creek cat's-eye may also follow this pattern.

Gene flow of Terlingua Creek cat's-eye occurs through pollination and seed dispersal. However, we do not currently know what the effective pollinators are or what their forage ranges might be, nor do we have any information on this species' seed dispersal. In cases where specific data on gene flow is not available, TXNDD employs the default minimum separation distances between plant EOs developed by NatureServe: 1 km (0.6 mi) for gaps of unsuitable habitat or unoccupied suitable habitat and 0.5 km (0.3 mi) for gaps of cultural vegetation (i.e., planted by humans; NatureServe 2002, p. 26). We are provisionally adopting this estimate for delineating populations of Terlingua Creek cat's-eye to maintain standards that are consistent with our state partner agency.

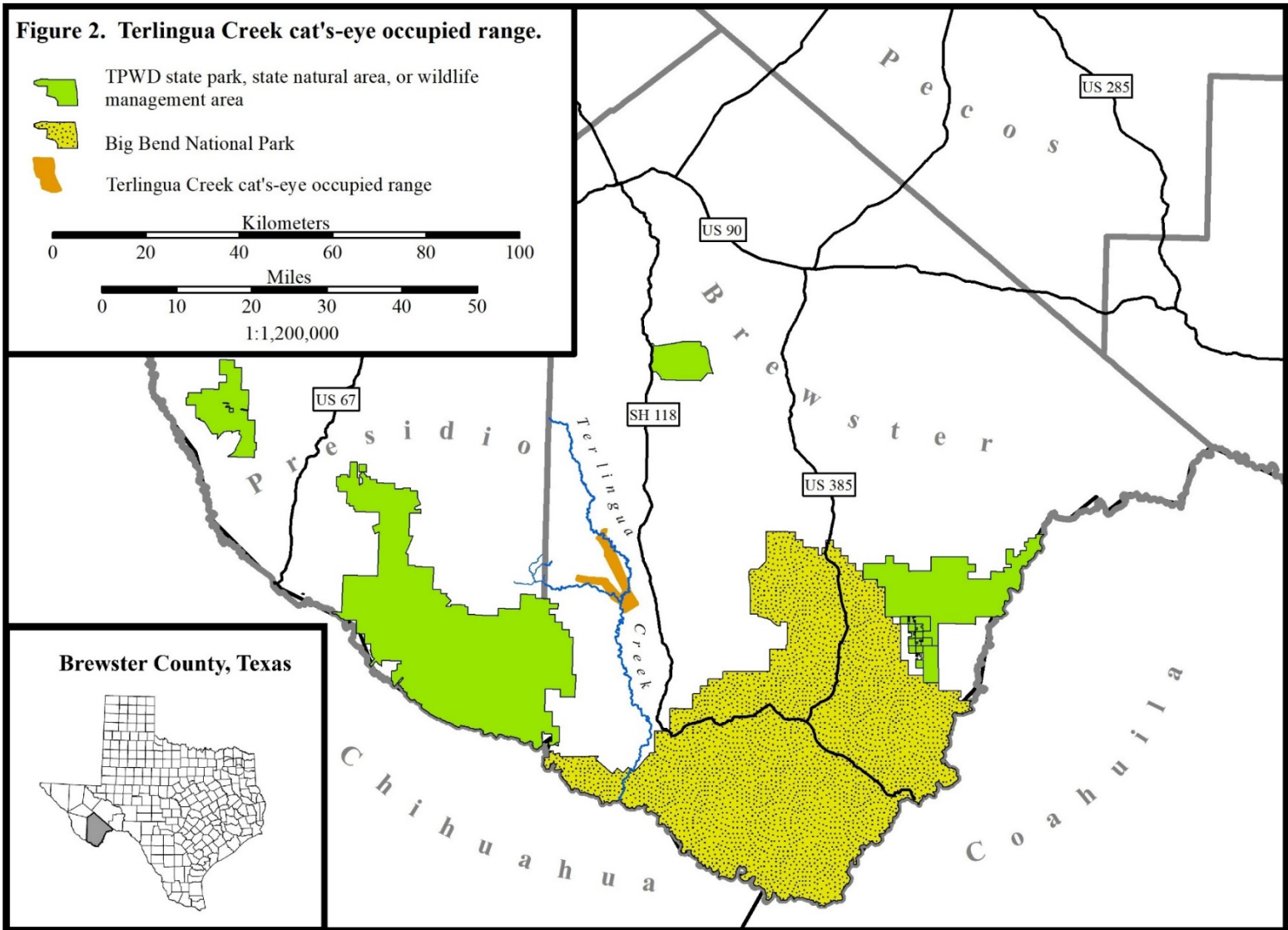


Figure 2. Terlingua Creek cat's-eye occupied range.

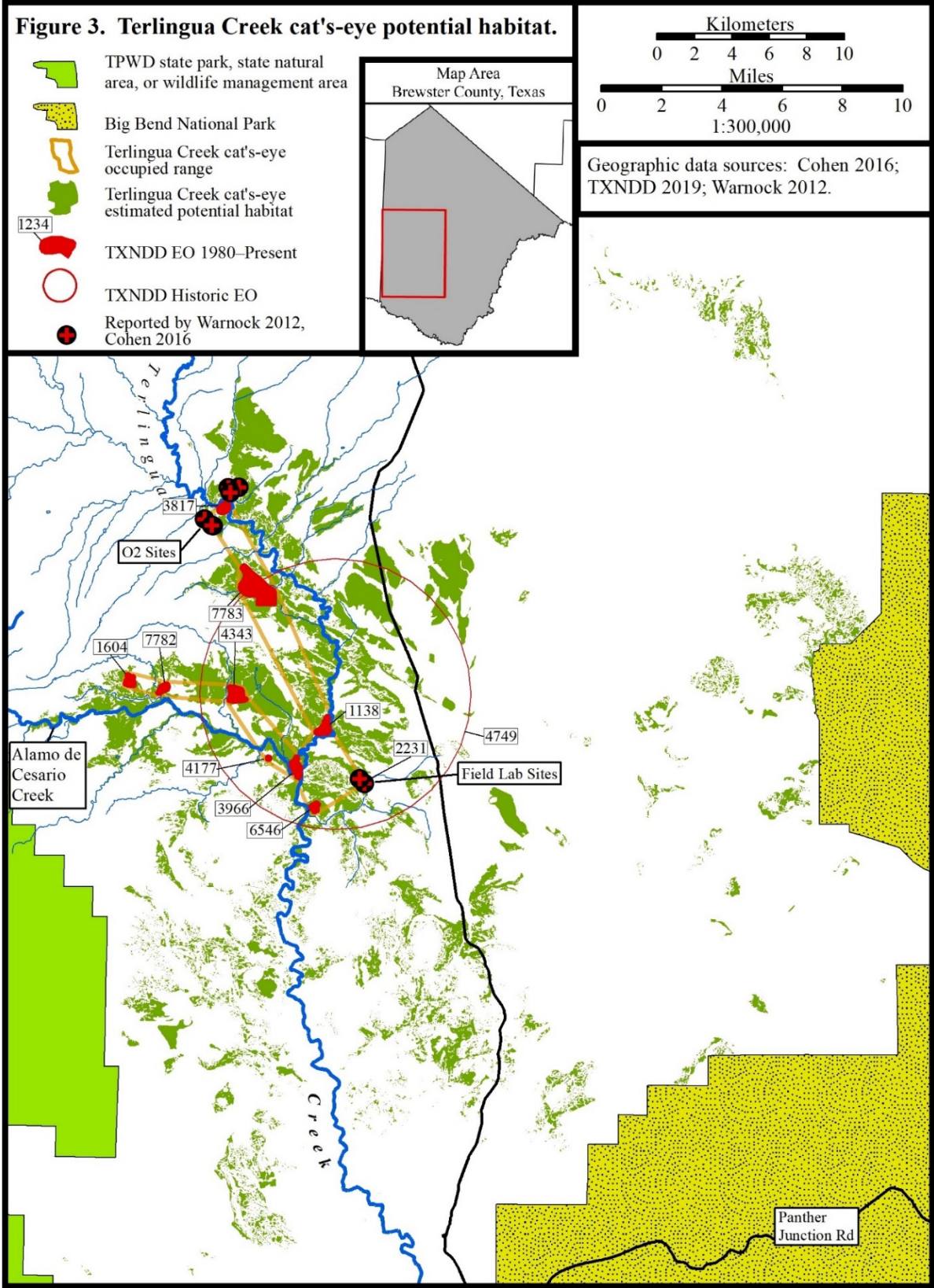


Figure 3. Terlingua Creek cat's-eye potential habitat.

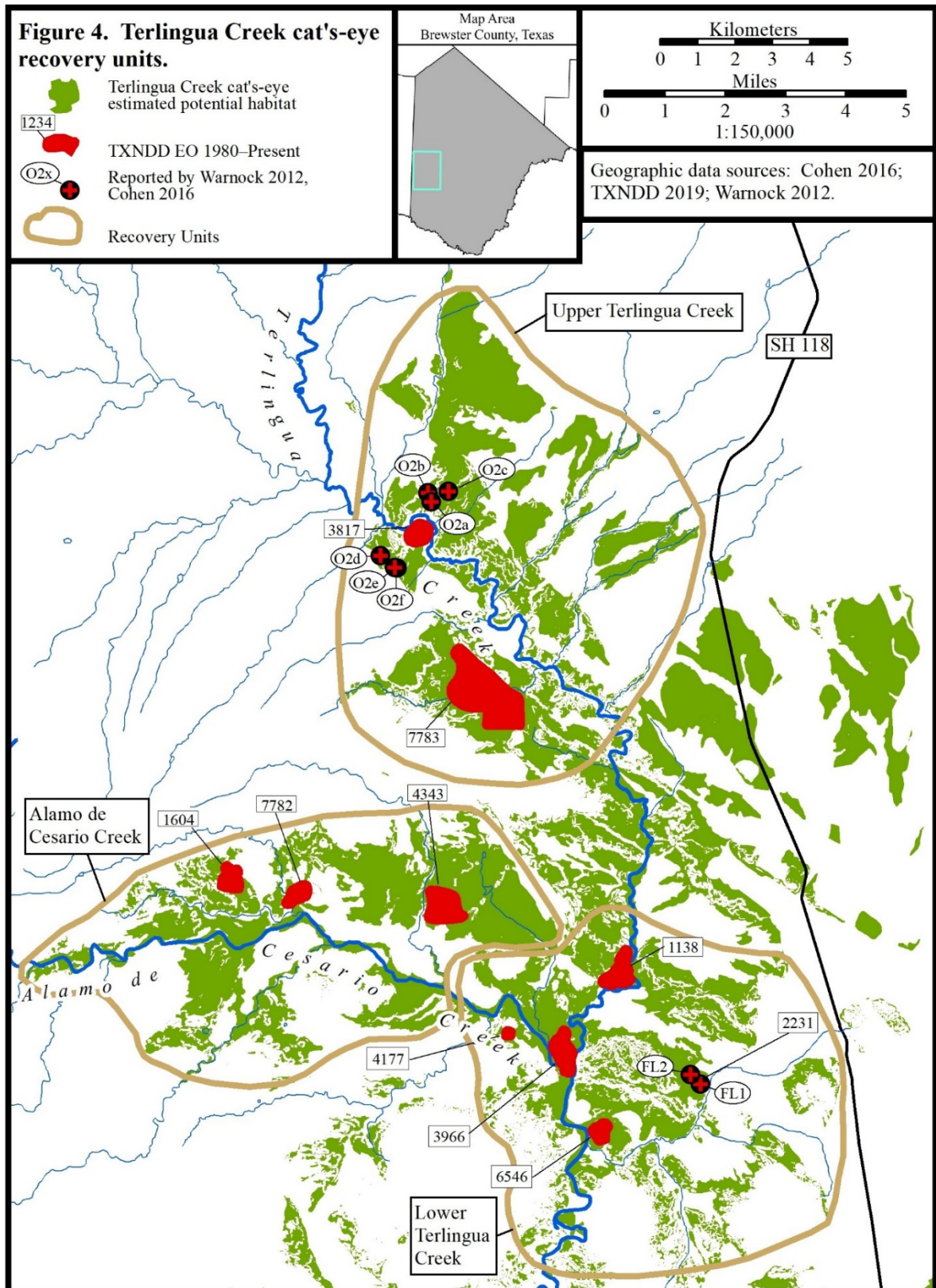


Figure 4. Terlingua Creek cat's-eye recovery units.

2.3.1.4 Conservation.

Summary of prior information (USFWS 1994).

Terlingua Creek cat's-eye seeds were collected and stored in seed banks at the National Seed Storage Lab, Ft. Collins, CO, and the Desert Botanical Garden, Phoenix, AZ.

New information.

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).

Two section 6-funded projects, described below, have contributed most of the new information about Terlingua Creek cat's-eye as well as most conservation actions.

Grant No. TX E-113-R-1, “Population biology, habitat description and delineation and conservation of Terlingua Creek Cat's-eye (*Cryptantha crassipes*)” (Warnock 2012), implemented conservation actions at two population sites, the O2 Ranch and Field Lab. This project addressed 13 recovery actions listed in the recovery plan. This included construction of an environmentally friendly access road to populations at the O2 Ranch (p. 6) and construction of a fence between O2 and adjacent private property to prevent off-road vehicle trespass (p. 13). The investigators observed a black, apparently pathogenic fungus on about 10 percent of the individuals, and sent samples for analysis to the Southwest Center for Natural Products Research at the University of Arizona; the analysis detected 9 unidentified fungal strains, but could not determine whether these were pathogenic, symbiotic, or both (p. 12). Three new populations were discovered and mapped (pp. 7–10, 14). A total of 1,873 seeds were collected and sent to the Desert Botanical Garden in Phoenix, AZ for seed banking (pp. 12, 17). The investigators propagated the species from wild-collected seeds and compared four growth media: pure native soil, commercial potting soil, a 1:1 potting soil and native soil mix, and a 1:1 native soil and sand mix (p. 12). The germinated plants had the poorest growth and survival in pure native soil, the highest survival in potting soil, the greatest number of leaves in the native soil-potting soil mix, and the tallest growth in the native soil-sand mix. This trial resulted in 27 established seedlings, of which 26 had survived for two full years at the Sul Ross State University greenhouse (p. 17; Figure 1.d). Finally, county property records were used to create a database of properties and landowners of sites where potential habitat exists (p. 17).

Grant no. TX E-160-R (F13AP00689), “Conservation genetics and genomics, pollination biology and phenology of *Cryptantha crassipes* I.M. Johnst., Terlingua Creek cat's-eye” (Cohen 2016), addressed 4 recovery actions listed in the recovery plan. The accomplishments of this project are described in sections 2.3.1.2 Reproduction and 2.3.1.3 Conservation genetics and genomics.

Two additional section 6-funded projects, described below, contributed nominally to Terlingua Creek cat's-eye conservation.

Terlingua Creek cat's-eye is one of 5 species addressed in Grant no. TX E-1-12, "Rare plants, birds, mammals in the Trans-Pecos Ecoregion of Western Texas" (McKinney 2001). The investigator monitored one population of over 400 individuals from April through June of 3 years (1998–2000). Unfortunately, this report does not provide any new information about the species or data from the monitored sites.

Grant no. TX E-112, "Seedbanking the rare plants of Texas" (Kennedy and Strong 2012), provides additional documentation of seeds collected by Warnock (2012) and sent to Desert Botanical Garden for long-term storage. Desert Botanical Garden records included in this report (pp. 17–35) indicate that they received from Warnock a total of 2,901 seeds collected from 458 parent plants in 9 sites. Curiously, Warnock claims to have sent only 1,873 seeds.

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

Table 4 (below) summarizes and compares actual and potential threats to Terlingua Creek cat's-eye described in the status report (Poole 1987), federal listing (56 FR 49634), the recovery plan (USFWS1994), and our current understanding of threats.

Summary of prior information (Poole 1987; 56 FR 49634; USFWS 1994).

Factor A. The present or threatened destruction, modification, or curtailment of its habitat or range.

Subdivision of a large ranch into numerous ranchettes has caused a proliferation of access roads that disturb and fragment previously undisturbed habitats, and may have destroyed some individuals. Although unpalatable to livestock, grazing may impact plants and habitats through trampling and soil disturbance. Recreational activities, including off-road vehicles (ORVs), mountain bikes, horseback riding, and hiking creates persistent tracks in fragile soils. Bentonite mining occurs near the population sites, and if expanded, could impact some populations.

Factor E. Other natural or man-made factors affecting its continued existence.

The extreme habitat specialization, limited range, and the demographic and genetic consequences of small population sizes increase vulnerability to threats. The species is likely to be an obligate outcrosser that is dependent on specific pollinators, and is therefore vulnerable to pollinator declines.

New Information.

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

Cohen (2016, p. 16) observed frequent off-road vehicle use near populations. Warnock (2012) constructed a fence to prevent trespass and ORV damage to populations at O2 Ranch.

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

Over-collection for any purpose has not been reported, and is unlikely.

2.3.2.3 Disease or predation.

Warnock (2012, p. 12) observed an unidentified black fungus growing on about 10 percent of individuals at O2 Ranch and Field Lab. Cohen (2016, p. 16) also observed this fungus on some individuals of Terlingua Creek cat's-eye. However, we have no other information about the extent, frequency, or effect this fungus has on the species.

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; however, the known populations of Terlingua Creek cat's-eye occur almost entirely on privately-owned land (as well as a small amount of state highway and county road rights-of-way). Federally-listed plants occurring on private lands have limited protection under the ESA, unless they are protected by state laws; the State of Texas also provides very little protection to listed plant species on private lands. It is reasonable to assume that any undiscovered populations are also likely to be privately-owned. Therefore, none of the species' populations and habitats are subject to federal protection unless there is a federal nexus, such as provisions of the Clean Water Act, or a federally-funded project, for example, a new highway or water treatment plant.

Chapter 88 of the Texas Parks and Wildlife Code lists plant species as threatened or endangered in the state that are federally listed with these statuses. The State of Texas listed Terlingua Creek cat's-eye as endangered on March 30, 1993. 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. Texas Parks and Wildlife Department 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. For example, State law prohibits the destruction or removal of any plant species from State lands without a Texas Parks and Wildlife Department permit.

2.3.2.5. Other natural or manmade factors affecting its continued existence.

Demographic and genetic consequences of small population sizes.

Small populations are less able to recover from losses caused by random fluctuations in recruitment (demographic stochasticity) or variations in rainfall (environmental stochasticity) (Shaffer and Stein 2000, pp. 308-310). In addition to population size, it is likely that population density and distribution also influence population viability, since successful sexual outcrossing—necessary to maintain genetic diversity in populations—requires genetically distinct individuals to be in sufficiently close proximity for cross-pollination to occur.

Small, reproductively isolated populations are also susceptible to the loss of genetic diversity, to genetic drift, and to inbreeding depression.

The deficiency of genetic diversity may reduce the ability of a species or population to resist pathogens and parasites, to adapt to changing environmental conditions, or to colonize new habitats. Conversely, populations that pass through a genetic bottleneck may subsequently benefit through the elimination of harmful alleles. Nevertheless, the net result of the loss of genetic diversity is likely to be a loss of fitness and lower chance of survival of populations and of the species.

Genetic drift is a change in the frequencies of alleles in a population over time (Barrett and Kohn 1991, pp. 3-30). Genetic drift can arise from random differences in founder populations and the random loss of rare alleles in small, isolated populations. Sexual reproduction is the principal mechanism of genetic drift, but mortality within small populations also contributes to changes in allele frequencies. Genetic drift may have a neutral effect on fitness, but is also a cause of the loss of genetic diversity in small populations. Genetic drift may also result in the adaptation of an isolated population to the climates and substrates of specific sites, leading to the development of distinct ecotypes and to speciation.

Inbreeding depression is the loss of fitness among progeny arising from sexual reproduction between closely related individuals. The probability of sexual reproduction between closely related individuals increases in small, isolated populations. However, plant species vary greatly in response to inbreeding. We do not know if Terlingua Creek cat's-eye is susceptible to inbreeding depression, but if so, this factor could affect the species' viability.

Finally, the combined demographic and genetic consequences of small population sizes may reduce population recruitment, leading to an extinction vortex of even smaller populations, greater isolation, decreasing genetic diversity, and loss of viability. These factors may already have contributed to the restriction of Terlingua Creek cat's-eye to its current state of extreme endemism in a small portion of Brewster County, Texas.

These threats of small population sizes could be mitigated through facilitated population augmentation or reintroduction into secure sites.

Climate change.

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2013) projects the following changes by the end of the 21st century, relative to the 1986 to 2005 averages. It is virtually certain that most land areas will experience warmer and/or fewer cold days and nights; it is virtually certain that most land areas will experience warmer and/or more frequent hot days and nights; it is very likely that the frequency and/or duration of warm spells and heat waves will increase in most land areas; it is very likely that the frequency, intensity, and/or amount of heavy precipitation will increase in mid-latitude land masses; it is likely that the intensity and/or duration of droughts will increase on a regional to global scale. The magnitude of projected changes varies widely, depending on the assumptions of future greenhouse gas emissions used by different models. For example, the RCP2.6 model projects an

increase of global mean surface temperatures of 0.3° to 1.7° C (0.5° to 3.1° F) by the end of the 21st Century. Under the RCP8.5 model the increase would range from 2.6° to 4.8° C (4.7° to 8.6° F). The report also states, “In many mid-latitude and subtropical dry regions, mean precipitation will likely decrease...” However, these models do not simulate well the projected patterns of regional precipitation (IPCC 2013, p. 11).

We do not know whether the climate changes that have already occurred have affected the populations or distribution of Terlingua Creek cat’s-eye, 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, it is unlikely that this species could migrate, due to its extreme endemism to specific soil types and a very restricted range. Changes in temperature and rainfall amounts and patterns could have multiple effects that alter the species’ fitness in opposing ways. For example, hotter summers could increase mortality from drought, but warmer winters could extend the growing season, benefit seedling establishment, and stimulate greater recruitment. Wells (2020) reported that many individuals at the Field Lab were damaged by hard freezes during the winter of 2010–2011, but the population was not greatly affected by the record drought of that year. Regardless of how these changes may affect its autecology, the altered synecology may be more significant. For example, more frequent or more severe droughts could reduce populations of the species’ pollinators, leading to reduced seed production and recruitment. Conversely, frequent, severe droughts could reduce competition from other plants in the area, allowing Terlingua Creek cat’s-eye to expand into areas that are now only marginally suitable. At present, we cannot predict how the infinitely complex aggregation of climate changes will affect the synecology of Terlingua Creek cat’s-eye populations and habitats. Therefore, we will continue to monitor the species’ status and will adapt our recovery and management strategies when necessary to address the changing conditions.

We conclude that Terlingua Creek cat’s-eye populations continue to face immediate threats of habitat loss from access road construction and habitat degradation from recreational ORVs, and the potential threat of habitat loss from bentonite mining. The subdivision of large properties into many small lots does not directly threaten the species, but makes private landowner outreach and conservation more difficult. These known threats are potentially exacerbated by the species’ extreme endemism to a very restricted soil type, its limited geographic range, and the demographic and genetic consequences of small population sizes. Livestock grazing is a potential threat, but appears to have very little impact on Terlingua Creek cat’s-eye populations. The effect of a black fungal parasite is unknown. Climate changes may exacerbate existing threats in the coming decades; however, it is currently not possible to project the extent of those changes or their net effects on Terlingua Creek cat’s-eye.

Table 4. Factors affecting the survival of Terlingua Creek cat's-eye.

Factor	Poole 1987; 56 FR 49634; USFWS 1994	This 5-year review
A. The present or threatened destruction, modification, or curtailment of its habitat or range.	Habitat loss from property subdivision and access road proliferation; Habitat degradation from ORVs; Potential damage from livestock grazing; Potential habitat loss from bentonite mining.	Habitat loss access road proliferation; Property subdivision is primarily a complicating factor rather than a direct threat; Habitat degradation from ORVs; Potential habitat loss from bentonite mining; Livestock appear to have little effect on the species and its habitats.
B. Overutilization for commercial, recreational, scientific, or educational purposes.	Not documented.	Not documented.
C. Disease or predation.	Not documented.	A fungal parasite has been observed, but its frequency and effect on the species is unknown.
D. The inadequacy of existing regulatory mechanisms.	Not previously protected by any state or federal regulations.	ESA confers very limited protections to listed plants on private land.
E. Other natural or man-made factors affecting its continued existence.	The extreme habitat specialization and limited range intensify other adverse effects; Potentially vulnerable to pollinator decline.	The extreme habitat specialization and limited range intensify other adverse effects; Threatened by the demographic and genetic consequences of small population sizes; Potentially threatened by climate change.

2.4 Summary and Synthesis.

Terlingua Creek cat's-eye is a valid, distinct species; a recent phylogenetic analysis reveals that it should be classified in the genus *Oreocarya*. Although the species most often flowers from March to June, flowering can also occur from October through February if weather is favorable. It reproduces primarily or entirely by outcrossing, and has low fecundity and recruitment. It is very narrowly endemic to unique, nearly barren, high-gypsum soils found in a small part of western Brewster County, Texas. The 10 known populations (EOs) occupy a range of 41.8 km² (16.1 mi²), and the potential habitats are distributed over a range of 182 km² (70.3 mi²). Most genetic variation occurs among individuals rather than among populations, and there is gene flow between populations. The populations have undergone a genetic bottleneck in the past, but are currently stable and have less inbreeding and more genetic structure than other gypsum-endemic *Oreocarya* species.

Eight new population sites were discovered in 2012 and 2016, bringing the total known population size to over 12,000 individuals. The new sites are near two existing EOs and may or may not be combined with them. All known populations are on private land, and none are legally protected, but a fence was constructed in 2012 to curtail trespass by ORVs into several population sites. A database of landowners was created to aid communication and outreach with owners of potential habitats. Sul Ross State University had 26 live propagated plants, and Desert Botanical Garden has 1,873 seeds in a long-term seed bank. The recovery criteria call for 20 protected populations, with at least 1,000 individuals each, within 3 population centers (metapopulations). However, the recovery plan does not describe how populations and metapopulations should be delineated. Most populations have not been observed for more than 30 years, and most of the potential habitat has not been surveyed; hence, we cannot determine the extent that recovery criteria have been met.

We recommend amending the existing recovery plan to clarify the recovery criteria, using an approach that is consistent with other recent plant recovery plans. For this purpose, we estimate that Terlingua Creek cat's-eye has an MVP size of about 1,600 mature, reproductive individuals. We have provisionally adopted NatureServe's default minimum EO separation distances of 1 km (0.6 mi) for gaps of unsuitable habitat or unoccupied suitable habitat and 0.5 km (0.3 mi) for gaps of cultural vegetation. We provisionally identified 3 recovery units that will contribute to recovery planning and the conservation of its genetic diversity.

In synthesis, although there have been important efforts to address the recovery actions, we cannot demonstrate that the recovery criteria have been met. The principal threats remain unchanged, and may be exacerbated by climate changes in the coming decades. Consequently, we have no information that would justify a change in the species' status, and recommend that Terlingua Creek cat's-eye continue to be classified as endangered.

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

No change is needed

3.2 New Recovery Priority Numbers:

5C (no change).

Brief Rationale:

Prior to this review, the Recovery Priority Number for 5C. This indicates that the degree of threat was high, the recovery potential was low, the taxon was a species, and the species is, or may be, in conflict with construction, development projects, or other forms of economic activity. Although 8 new population sites have been discovered near two existing EOs, most populations have not been monitored for more than 30 years. The threat level remains high due to endemism to a very limited habitat, habitat degradation from ORV use, potential habitat loss from bentonite mining, small population sizes, and potential effects of climate changes. Two private landowners have allowed access to monitor populations, but most landowners have not been contacted. The species has been propagated, but has not been successfully reintroduced. Hence, the recovery potential remains low. Terlingua Creek cat's-eye is currently recognized as a valid species of the genus *Oreocarya*. The species' recovery may still be in conflict with bentonite mining, road construction, and residential development. Therefore, the Recovery Priority Number should remain 5C.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS.

1. Amend the recovery plan to clarify the recovery criteria. Use the MVP level and population delimitation distances described in this review as components of recovery criteria that address resilience and redundancy. Adopt the provisional recovery units discussed in this review to develop recovery criteria that address the species' ecological and genetic representation.
2. Promote awareness and conservation of Terlingua Creek cat's-eye in western Brewster County.
3. Contact landowners of sites within the potential habitat area, and seek permission to survey and monitor populations on private land.
4. Conduct up-to-date censuses of the accessible populations and revise the TXNDD EO records.
5. Work cooperatively with private landowners who are interested in conserving and managing the species on their lands. Seek voluntary measures to confer long-term protection for populations on private lands, such as conservation agreements and conservation easements.
6. Propagate the species, using seeds at the Desert Botanical Garden seed bank, to establish seed production plots, renew the seed bank, and reintroduce populations in appropriate sites that can be protected.
7. Obtain additional support for conservation actions from the Cooperative Endangered Species Conservation Fund (Section 6) or other grant sources.

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Abbreviations of scientific units.

<u>Abbreviation</u>	<u>Scientific Unit</u>
ac	acres
cm	centimeters
ft	feet
ha	hectares
in	inches
km	kilometers
m	meters
mi	miles
mm	millimeters

Acronyms.

ESA	Endangered Species Act
IPCC	Intergovernmental Panel on Climate Change
ITIS	Integrated Taxonomic Information Service
MVP	Minimum viable population
NRCS	Natural Resources Conservation Service
RCP	Representative concentration pathway
TPWD	Texas Parks and Wildlife Department
TXNDD	Texas Natural Diversity Database
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Glossary of Scientific and Technical Terms.

Term	Definition
Alkaloid	An organic compound whose structure includes nitrogen (although simple aliphatic amines and aminoacids are usually considered separately) (Robinson 1980, p. 281).
Allele	Alternate forms of a gene.
Allogamy	Sexual reproduction between different, unrelated individuals (out-crossing).
Anther	The pollen-bearing part of the stamen. (Correll and Johnston 1979).
Autecology	Ecology of individual species.
Bayesian Inference	"A method of statistical inference in which Bayes' theorem is used to update the probability for a hypothesis as more evidence or information becomes available." (Wikipedia 2020).
Breeding System	The ability of a plant species to reproduce via outcrossing, self-fertilization, apomixis, or a combination (Wikipedia 2015).
Calyx	The external whorl of a flower (Correll and Johnston 1979, p. 1747); the sepals, collectively.
Caudex	(Pl. caudices). The woody base of an otherwise herbaceous perennial (Correll and Johnston 1996).
Chloroplast	A double-membrane organelle found in higher plants in which photosynthesis takes place.
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 2013).
Corolla	The inner perianth of a flower (Correll and Johnston 1979, p. 1749); the petals, collectively.
Cretaceous	Geologic period and system from 145 ± 4 to 66 million years (Ma) ago (Wikipedia 2016).
Critical habitat	"...(i) the specific areas within the geographical area occupied by the [threatened or endangered] species, at the time it is listed in accordance with the provisions of section 4 of [the ESA], on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 4 of [the ESA], upon a determination by the Secretary that such areas are essential for the conservation of the species." U.S. Congress 1988.
Demography	Scientific study of populations.
Ecotype	A genotype that is specifically adapted to a particular ecological area.

Term	Definition
Element Occurrence	An area of land and/or water in which a species or natural community is, or was, present (NatureServe 2002).
Endangered	"...any species which is in danger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta determined by the Secretary to constitute a pest whose protection under the provisions of this Act would present an overwhelming and overriding risk to man." U.S. Congress 1988.
Endemic	An organism restricted to a specific habitat or geographic range.
Evolutionarily Significant Unit	A population of a taxon that is genetically distinct, locally adapted, and geographically or reproductively isolated from other populations (see Wikipedia 2019).
Gene flow	The transfer of alleles or genes from one population to another (Wikipedia 2013).
Genetic bottleneck	An event that greatly restricts an organism's genetic diversity.
Genetic drift	A change in allele frequencies within a population over time.
Genetic structure	Any pattern in the genetic makeup of individuals within a population (Wikipedia 2011).
Gypseous	Containing gypsum (calcium sulfate dihydrate, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$).
Habitat	Ecological or environmental area that is inhabited by a particular species of animal, plant or other type of organism (Wikipedia 2013).
Herkogamy	The reduced incidence of self-pollination through the spatial separation of anthers from stigmas in flowers of hermaphroditic plants (Luo and Widmer 2013).
Heterostyly	Plant species whose flowers have styles of different lengths (Correll and Johnston 1979, p. 1753).
Inbreeding	Sexual reproduction between closely related individuals.
Inbreeding depression	The reduction of fitness caused by mating between relatives (Edmands 2007, p. 464).
Inflorescence	A plant structure bearing two or more flowers.
Internal Transcribed Spacer (ITS)	Spacer DNA (non-coding DNA) situated between the small-subunit ribosomal RNA (rRNA) and large-subunit rRNA genes (Wikipedia 2015).
Intron	DNA region within a gene that is not translated into protein (Wikipedia 2011).
Maximum likelihood estimation	"[A statistical] method of estimating the parameters of a probability distribution by maximizing a likelihood function, so that under the assumed statistical model the observed data is most probable." (Wikipedia 2020).

Term	Definition
Metapopulation	A group of spatially separated populations of the same species that interact at some level (Wikipedia 2013).
Microsatellite DNA	Repeating sequences of 2 to 6 base pairs in DNA that may be used as genetic markers in kinship and population studies (Wikipedia 2012).
Minimum viable population	The fewest individuals required for a specified probability of survival over a specified period of time (Pavlik 1996; Mace and Lande 1991); see Population Viability Analysis.
Nuclear DNA	DNA contained within the nucleus of a Eukaryotic organism.
Nut	"A hard-shelled and one-seeded indehiscent fruit derived from a simple or compound ovary." (Correll and Johnston 1979, p. 1757).
Nutlet	"Diminutive of <i>nut</i> ; applied to any small and dry nutlike fruit or seed. Thicker-walled than an achene." (Correll and Johnston 1979, p. 1757).
Outcross	In plants, sexual fertilization involving the union of gametes from different individuals.
Parsimony analysis	A mathematical technique for resolving genetic trees into the simplest possible clades.
pH	A measure of the acidity or basicity of a solution approximately equal to $p[H]$, the negative logarithm (base 10) of the molar concentration of dissolved hydronium ions (H_3O^+). (Wikipedia 2010).
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 2013).
Polyphyly	A group of organisms whose last common ancestor is not a member of the group (Wikipedia 2009).
Population Viability Analysis (PVA)	Statistical models used to predict the probability of extinction of a population after a specified period of time.
Ramet	An individual, genetically identical plant reproduced as a clone of the parent plant.
Recovery unit	"...a special unit of the listed entity that is geographically or otherwise identifiable and is essential to the recovery of the entire listed entity." (NMFS and USFWS 2010).
Recruitment	Addition of new individuals to a population.
Rosette	A radially-symmetrical whorl of leaves formed at the base of a plant stem, usually during a vegetative (non-reproductive) growth phase.
Rugulose	Slightly wrinkled (Correll and Johnston 1979, p. 1760).
Section 6	Cooperative Endangered Species Conservation Fund (Section 6 of the ESA). (USFWS 2009)

Term	Definition
Sensu lato (s.l.)	Broadly defined.
Sensu stricto (s.s.)	Strictly defined.
Shapefile	A digital geospatial vector data storage format developed by Esri. (Wikipedia 2015).
Single Nucleotide Polymorphism (SNP)	A substitution of a single nucleotide at a specific locus in the genome of an organism (Wikipedia 2020). SNPs provide useful data for investigating population genetics.
Speciation	The evolutionary process by which new biological species arise (Wikipedia 2015).
Stamen	Male reproductive structure of the flower, consisting of a filament and anther: the androecium (Anderson 2001).
Stigma	The receptive part of the pistil on which the pollen germinates. (Correll and Johnston 1979).
Stochastic	Random.
Style	A narrowed, often elongate portion of a pistil between the stigma and ovary (Correll and Johnston 1979).
Subtropical	Climatic region intermediate between tropical and temperate, where freezing temperatures occur infrequently and are of limited duration and intensity.
Synecology	Ecology of groups of coexisting organisms.
Taxon	(Plural, taxa). A natural group of organisms at any rank in the taxonomic hierarchy (Anderson 2001).
<i>trnL-F</i>	A region of chloroplast DNA that is useful for supra-generic phylogenetic analysis (Richardson <i>et al.</i> 2000, p. 1310).

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of
***Cryptantha crassipes* (Terlingua Creek Cat's-Eye)**

Current Classification: Endangered.

Recommendation resulting from the 5-Year Review:

- Downlist to Threatened
- Uplist to Endangered
- Delist
- No change needed

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

FIELD OFFICE APPROVAL:

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

Approved _____ Date _____