

Arizona Hedgehog Cactus
(*Echinocereus arizonicus* ssp. *arizonicus*)
5-Year Status Review:
Summary and Evaluation



Credit: K. Robertson

U.S. Fish and Wildlife Service
Arizona Ecological Services
Phoenix, Arizona
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5-YEAR REVIEW

Species reviewed: Arizona hedgehog cactus (*Echinocereus arizonicus* ssp. *arizonicus*)

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5-YEAR REVIEW
Arizona hedgehog cactus (*Echinocereus arizonicus* ssp. *arizonicus*)

1.0 GENERAL INFORMATION

1.1 Reviewers:

Lead Regional or Headquarters Office:

Southwest Region, Region 2, Albuquerque, NM
Janess Vartanian, Recovery Biologist, (505) 248-6657

Lead Field Office:

Arizona Ecological Services Office, Phoenix, AZ
Kathy Robertson, Fish and Wildlife Biologist, (602) 889-5957
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Cooperating Field Office(s):

N/A

Cooperating Regional Office(s):

N/A

1.2 Purpose of 5-Year Reviews:

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

1.3 Methodology used to complete the review:

The Service conducts status reviews of species on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.12) as required by Section 4(c)(2)(A) of the ESA (16 U.S.C.1531 et seq.). The Service provided notice of this status review via the Federal

Register (87FR5834) requesting information on the species. This review was co-authored by Ethan Seavey and Kathy Robertson, Fish and Wildlife Biologists for the Arizona Ecological Services Field Office. A considerable amount of new information has become available on this species since it was listed in 1979. We conducted a review of past and recent literature and data, the listing rule, and several draft recovery plans. Interviews and fieldwork alongside conservation partners were conducted to clarify or obtain specific information. We prepared a preliminary draft that was reviewed by biologists within the Arizona Ecological Services Field Office. Sections of this 5-year review were also sent out for review to conservation partners with the Desert Botanical Garden and Tonto National Forest. These partners have been essential to our efforts in monitoring, conserving, and restoring Arizona hedgehog cactus throughout their range.

1.4 Background:

1.4.1 FR Notice citation announcing initiation of this review:

Federal Register, Volume 83, pages 25034- 25038, May 31, 2018

Federal Register, Volume 87, pages 5834- 5838, February 2, 2022

1.4.2 Listing history:

Original Listing

FR notice: Federal Register, Volume 44, pages 61556-61558

Date listed: October 25, 1979

Entity listed: Subspecies

Classification: Endangered

Revised Listing, if applicable

FR notice: N/A

Date listed: N/A

Entity listed: N/A

Classification: N/A

1.4.3 Associated Rulemakings:

N/A

1.4.4 Review History:

This is the first review conducted on this taxon since its listing.

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

The Recovery Priority Number is 3, which indicates that the degree of threat and recovery potential is high, and the taxonomic entity is a subspecies.

1.4.6 Recovery Plan or Outline

Name of plan or outline:

1984 – Recovery Plan for the Arizona Hedgehog Cactus, Agency Review Draft (Fletcher 1984)

2013 – Draft Recovery Plan for *Echinocereus arizonicus* subsp. *arizonicus* (Baker 2013)

Date issued: Not applicable, neither recovery plan was finalized.

Dates of previous plans/amendment or outline, if applicable: Not applicable.

2.0 REVIEW ANALYSIS

Section 4 of the ESA (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species meets the definition of “endangered species” or “threatened species.” The ESA defines an “endangered species” as a species that is “in danger of extinction throughout all or a significant portion of its range,” and a “threatened species” as a species that is “likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” The ESA requires that we determine whether a species meets the definition of “endangered species” or “threatened species” due to any of the five factors described below.

Section 4(a) of the ESA describes five factors that may lead to endangered or threatened status for a species. These include: A) the present or threatened destruction, modification, or curtailment of its habitat or range; B) overutilization for commercial, recreational, scientific, or educational purposes; C) disease or predation; D) the inadequacy of existing regulatory mechanisms; or E) other natural or manmade factors affecting its continued existence.

The identification of any threat(s) does not necessarily mean that the species meets the statutory definition of an “endangered species” or a “threatened species.” In assessing whether a species meets either definition, we must evaluate all identified threats by considering the expected response of the species, and the effects of the threats—in light of those actions and conditions that will ameliorate the threats—on an individual, population, and species level. We evaluate each threat and its expected effects on the species, then analyze the cumulative effect of all of the threats on the species as a whole. We also consider the cumulative effect of the threats in light of those actions and conditions that will have positive effects on the species—such as any existing regulatory mechanisms or conservation efforts. The Service recommends whether the species meets the definition of an “endangered species” or a “threatened species” only after conducting this cumulative analysis and describing the expected effect on the species now and in the foreseeable future.

2.1 Distinct Population Segment (DPS) policy (1996):

Not applicable.

2.2 Updated Information and Current Species Status

2.2.1 Biology and Habitat

2.2.1.1 New information on the species’ biology and life history:

The Arizona hedgehog cactus is a dark-green, succulent perennial in the Cactaceae or cactus family. Individual plants may be single stemmed or have multiple stems joined at the base forming a loose cluster (e.g., caespitose growth form) (Figure 1). Numbers of stems vary but commonly range from 4 to 20 stems with occasionally an individual having 50 to over 100 stems (Cedar Creek Associates, Inc. 1996, Arizona Rare Plant Committee 2001) (Figure 2). Stems range in height from 6.4 to 40 centimeters (cm) (2.5 to 16 inches (in)) (Phillips et al. 1979). Stem diameter ranges from 1 to 14.5 cm (0.4 to 5.7 in) with an average diameter of 8 to 8.5 cm (Cedar Creek Associates, Inc. 1996, Arizona Rare Plant Committee 2001, Baker 2006). Each stem has 7 to 11 tuberculate strong ribs, with an average of 9 ribs (Table 1) (Cedar Creek Associates, Inc. 1996, Baker 2006). Each stem is a clonal copy of the maternal plant.



Figure 1. Arizona hedgehog cactus, Top of the World, Gila County Arizona. Credit: USFWS, 2021.

Table 1. Number of tuberculate ribs observed from 1,141 Arizona hedgehog cactus. (Adapted from Cedar Creek Associates, Inc. 1996).

Rib Number	Number Observed	Percent
7	20	1.75%
8	252	22.09%
9	722	63.28%
10	140	12.27%
11	7	0.61%
Total	1,141	100%
Average	8.88	N/A

Spines are smooth, straight to slightly curved, not angled, and up to 3.6 cm (1.4 inches) in length. There are 1 to 3 central spines with the largest deflexed, gradually tapering with minute striations (Zimmerman and Parfitt 2003). Radial spines number 5 to 12, generally 9 that are slightly curved, pinkish-tan in color and shorter than central spines (Phillips et al. 1979, Baker 2006). Cedar Creek Associates (1996) noted that spine length, number, and diameter are highly

variable within the Arizona hedgehog cactus, but tend to be stouter than other similar appearing taxa (Figure 2 and Figure 3) (Cedar Creek Associates, Inc. 1996).

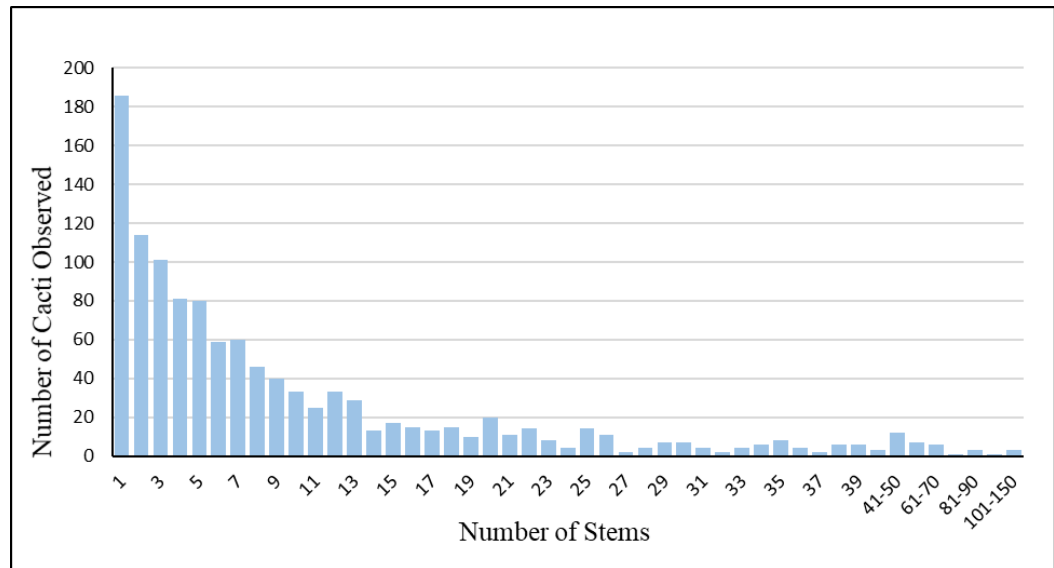


Figure 2. Number of stems observed from 1,150 Arizona hedgehog cactus individuals in the vicinity of the Carlota Copper Mine, Gila County, Arizona. Reprinted with permission, Cedar Creek Associates, Inc. (1996).

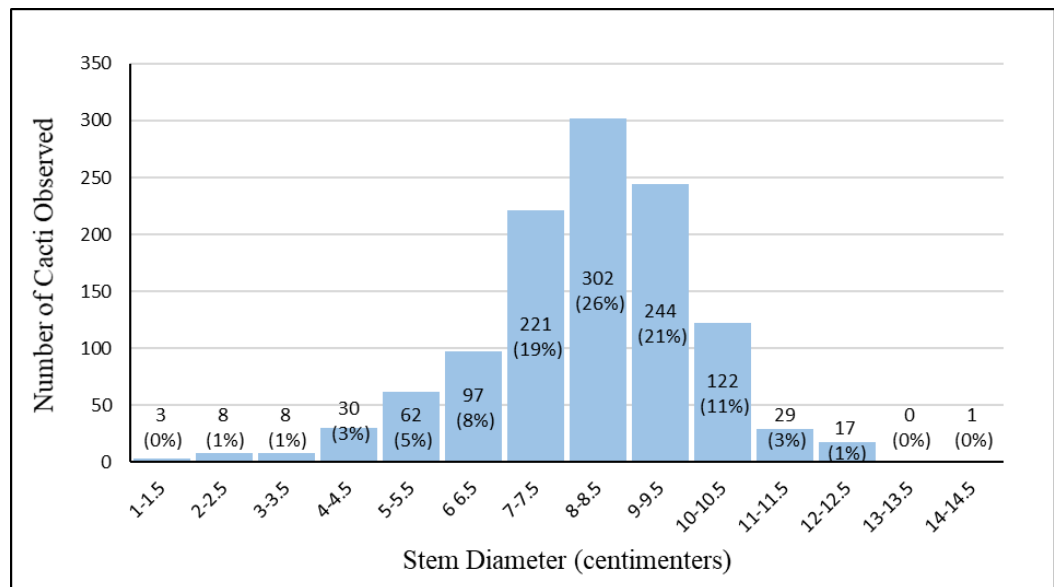


Figure 3. Diameter of the largest stem and percentage of observations measured from 1,144 Arizona hedgehog cactus individuals. Reprinted with permission, Cedar Creek Associates (1996).

Flowering occurs in early April until mid-May (Fletcher 1984, Aslan 2015). Flowers are brilliant red to crimson red, claret-cup shaped with red or purple anthers and green stigma lobes (Figure 4). Floral buds erupt through the

epidermis from the upper one-third of the stem, a trait distinguishing the Arizona hedgehog cactus from other red-flowered hedgehog cacti below elevations of 2000 meters (m) (6,561 feet (ft)) (Phillips et al. 1979, Arizona Rare Plant Committee 2001, Sánchez et al. 2014). Flowers are broad, about 5 cm in diameter (2 in), 7.4 cm (3 in) in length; the floral tube is 25 to 35 mm (0.9 to 1.3 in) long with short spines and hairs (Cota 1993, Blum et al. 1998, Zimmerman and Parfitt 2003).



Figure 4. Flowering Arizona hedgehog cactus. Credit: USFWS, 2009.

Flowers are perfect, having both male (stamens) and female (carpel) reproductive structures (Baker 2006). Flowers open for 3 to 5 days, opening in the morning and closing at night, during cloudy weather, and possibly during warmer parts of the day (Taylor 1985, Cota 1993, Aslan 2015). The period from bud set to wilting is approximately 10 to 14 days (Aslan 2015). The total number of flowers and fruit produced varies by individual Arizona hedgehog cacti.

Fruits are 2.5 cm (0.9 in) in diameter, globose, and spiny; green color turning brownish tinged at maturity (Blum et al. 1998) (Figure 5). Fruiting generally occurs from May through June, but may occur through late July (Fletcher 1984, Arizona Rare Plant Committee 2001) (Figure 6). Seeds of the Arizona hedgehog cactus are small and encased in a fleshy fruit covered with spines. At maturity, the side of the fruit splits open (e.g., dehiscence) releasing numerous black seeds. Reported seed numbers from a single fruit range from 53 to 1,466, with reported averages of 379 seeds per fruit (Siegwarth 2014) to 424 seeds per fruit (Aslan 2015). Seed germination occurs in mid-summer (Arizona Rare Plant Committee 2001). However, despite the numerous seeds produced, seedling establishment is low (Rojas-Arechiga and Vazquez-Yanes 2000, Ortiz-Martinez et al. 2021).



Figure 5. Developing fruit on an Arizona hedgehog cactus, Pinto Creek, Arizona. Credit: USFWS, July 2017.

Successful germination and seedling establishment generally depends on soil moisture, sunlight, and temperature (Rojas-Arechiga and Vazquez-Yanes 2000). In response to less favorable environmental conditions such as low water availability and temperature extremes, seeds of many plant species, including cactus species, enter a dormancy period (Muro-Pérez et al. 2012). This evolutionary adaptation ensures higher probability of survival for the individual plant, although dormancy may occur even in ideal conditions (Rojas-Arechiga and Vazquez-Yanes 2000). We assume that Arizona hedgehog cactus seeds enter into a dormancy period from December, January, and February based on findings of other *Echinocereus* species and results of a seed viability test (Muro-Pérez et al. 2012) (Figure 6). We also assume that seeds remain viable in the soil as a seed bank (Sivinski 2007, Bruns and Amos 2015) and therefore may require an after-ripening period to break dormancy.

Life Stage	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Flowering												
Fruits Mature												
Seed												
Germination												
Dormancy												

Figure 6. Estimated phenological calendar of the Arizona hedgehog cactus. Flowering period may vary in response to weather conditions and extend into June based on fruiting observed in July. Timing of germination and dormancy is assumed based on general life history traits of other cactus species.

In 2013, Cedar Creek Associates had 20 Arizona hedgehog cactus seeds tested for viability after they observed disparity between relatively low natality (germination) and high fruit yields in their monitoring plots. A tetrazolium (TZ)

test (used to quickly determine the number of viable seed from a sample with the potential to produce a normal plant under suitable germination conditions) showed 70% (14 of 20) of the Arizona hedgehog cactus seeds were capable of germinating. A separate germination test (used to test seed viability, but requiring a longer time period) showed that the seeds had a 15% germination rate under suitable germination conditions (Colorado Seed Laboratory 2013). Usually, the results of both tests should be similar. Several factors can cause discrepancies between results, one of which is seed dormancy.

The seed dispersal mechanism for the Arizona hedgehog cactus is unknown. Seed dispersers for many cacti species are birds and small mammals (Willson 1993, Anderson 2001), which likely facilitate dispersal for the Arizona hedgehog cactus (Crosswhite 1992a). Cedar Creek Associates (1996) observed a small number of Arizona hedgehog cacti growing adjacent to riparian areas or in canyon bottoms suggesting that their establishment was likely from birds or small mammals eating the fruit and distributing seeds into these areas. The cactus is typically located within rock crevices or cliff faces where only small mammals and birds would be able to access the fruit (Cedar Creek Associates, Inc. 1996).

Arizona hedgehog cactus is self-incompatible, requiring pollen from a genetically different plant to produce seed. Pollinators include native bees (*Halictidae*), honeybees (*Apis mellifera*), and three different species of hummingbirds: Anna's hummingbird (*Calypte anna*), broad-billed hummingbird (*Cynanthus latirostris*), and black-chinned hummingbird (*Archilochus alexandri*) (Aslan 2015). Native bees are the most common pollinator of the Arizona hedgehog cactus. Hummingbirds, however, are equally important pollinators. While they were found to visit flowering individuals less frequently than native bees, hummingbirds visit more flowers and contribute more to seed set (pollination resulting in seed growth) compared to bees. Hummingbird visitation boosts seed set by 168% on average while bee or insect visitation set on average 37.3% seeds per flower (Aslan 2015). The elongated floral tube, wide cup-shaped opening, unscented, and red color of Arizona hedgehog cactus flowers promote hummingbird pollination (Cota 1993) (Figure 7). Arizona hedgehog cactus can also be propagated vegetatively in a greenhouse setting.



Figure 7. Red claret cup flower on an Arizona hedgehog cactus that is adapted to hummingbird pollination. Credit: M. Taylor, Tonto National Forest, 2017.

2.2.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, birth rate, seed set, germination rate, age at mortality, mortality rate, etc.), or demographic trends:

Range-wide surveys have not been completed due to the remote, steep, and rugged terrain supporting the Arizona hedgehog cactus. Most records that report on the Arizona hedgehog cactus are from site-specific areas located within proposed Federal projects under the Section 7 of the ESA. Survey data is typically submitted to the Arizona Heritage Data Management System (HDMS) within the Arizona Game and Fish Department (AZGFD). However, submission of data to HDMS is voluntary and therefore not every detected cactus is documented in this database.

There are several caveats in trying to estimate the total number of Arizona hedgehog cactus across its range. Errors in the HDMS records such as confusion with other species of red-flowered hedgehog cacti, mislabeling, and issues with different surveyors recording the same plant at different times have confounded the accuracy of the taxon's population size. Additionally, due to the remote and rugged conditions of the landscape and some populations occurring on private lands and therefore inaccessible without landowner permission, access to a large portion of the taxon's range is limited and unsurveyed. At times abundance has been overstated without adequate documentation (i.e., extrapolation based on a

density count) and incorrectly published. These have resulted in the reported abundance counts fluctuating between years (Thomas et al. 2019). A history of abundance estimates and how we derived the current estimate are described below.

An estimated population size was not described at the time of listing. Fletcher (1984) approximated 1,500 to over 14,000 individuals based on surveys he completed. NatureServe listed the range-wide population between 250 to 1,000 individuals but did not reference a source for the estimate. According to the HDMS, surveyors observed 1,302 cacti between 1979 and 2009 on the Tonto National Forest. Some of those records were anecdotal, overgeneralized, or were believed accurate at the time but are now confirmed to be for a different red-flowered hedgehog cacti, the Santa Rita hedgehog cactus (*Echinocereus santaritensis*), that overlaps in habitat with the Arizona hedgehog cactus.

The majority of Arizona hedgehog cactus occurrence data is reported by WestLand Resources, Inc. (WestLand) who conducted numerous surveys for compliance with the ESA on behalf of the Tonto National Forest and Resolution Copper for the Resolution Copper Mine project. Surveys occurred in 2004, 2007, 2008, 2010, 2012, 2015, 2017, and 2019 and were located on the Globe Ranger District and focused along U.S. Forest Service (Forest Service) roads, proposed project areas including drill pad locations, and proposed corridors on federal, state, and private land. WestLand recorded a total of 165 Arizona hedgehog cacti from project-related surveys within the proposed project footprint area. An additional 1,962 individuals were located outside the project footprint but within the action area (Thomas et al. 2019, SWCA Environmental Consultants (SWCA) 2020, USFWS 2020).

In 2013, WestLand submitted a Microsoft Access database to the Arizona Ecological Services Field Office incorporating all known Arizona hedgehog cacti that they observed in surveys from 2010 through 2012. Their database contains records of 4,035 individuals. WestLand acknowledged that genetic analysis did not occur, and taxonomic status of the individual plants counted was uncertain. Thus, morphological and genetic studies completed in later years would reveal that some of the documented Arizona hedgehog cacti reported by WestLand Resources are Santa Rita hedgehog cacti (Taylor 2017). However, some of their data points did not have location coordinates for each plant so it is not possible to map the plants in ArcGIS and field verify their locations. The AZGFD HDMS also reviewed the Access database. Approximately 2,300 georeferenced points reported by WestLand cannot be validated and will need to be field verified. Because some records lacked certain attributes such as observer and observer date that enabled data verification and accuracy, the points are included in HDMS but are not included in the total abundance count. Records that could be verified through data submitted by the Tonto National Forest were included in the abundance count. The total of 4,035 Arizona hedgehog cactus individuals are not reported elsewhere in WestLand survey

reports and therefore, this count is not considered reliable until plants can be field verified.

A survey conducted by Marc Baker in 2013 within the range of the Arizona hedgehog cactus included approximately 2,000 georeferenced (GPS) points collected by WestLand. In total, Baker reported 6,010 georeferenced points that were submitted to HDMS. This data was used by the Service and the Tonto National Forest as the best estimate of the taxon's rangewide abundance. Examination of his data later found it included other *Echinocereus* species in Arizona. Even though 5,849 points were the Arizona hedgehog cactus, the 6,010 estimated had already become the baseline estimate for future surveys to add upon. In 2017, the Forest Service reported a total of 6,679 plants based on their review of all Arizona hedgehog cactus records in HDMS (Arizona Public Service 2018). The Forest Service acknowledge that this number may include hybrid plants and the total numbers of individuals, numbers of populations, and population sizes/robustness are not completely clear.

Surveys by Arizona Public Service and WestLand in 2017 and 2019, respectively, located an additional 420 and 810 Arizona hedgehog cacti, respectively north of US Highway 60 (Archaeological Consulting Services, Ltd. 2017, Westland Resources, Inc. 2019, HDMS 2022). Some of the records from the two datasets overlap with GPS points recorded by Baker in 2013 while others are in close proximity to a previous recorded point. Therefore, several Arizona hedgehog cacti were likely recorded during multiple surveys and reported by different surveyors but represented the same plant. In 2019, USGS reported 6,769 records for the Arizona hedgehog cactus, later corrected to 6,679 (Thomas et al. 2019, K. Thomas, USGS, personal communication 2022). Building on this estimate, the Tonto National Forest estimated an overall abundance of 7,302 Arizona hedgehog cactus for the Resolution Copper Mine project; 2,087 cacti were actually counted in the project area but the number was extrapolated to include all plants rangewide (SWCA 2020).

In 2021 and 2022, the Service worked with AZGFD to re-examine the Arizona hedgehog cactus data records. Baker's 2013 data was re-examined and any datum errors, non-listed, red-flowered cacti, and data lacking attributes were removed. The data removed from the 2021-2022 re-examination included the approximately 2,300 points that were included in WestLands Access database and in Baker's 2013 data set (HDMS 2022). These points are included in the dataset for Arizona hedgehog cactus but are not included in the abundance estimate. HDMS had several scattered points that were considered outliers because of their location beyond the species known elevation range. These points were located north of Globe near Apache Peak, Timber Camp, and turned out to be Santa Rita hedgehog cacti. In some cases, data points submitted by the Tonto National Forest for other surveyed Forest Service species were included and named as Arizona hedgehog cactus data.

Given the more recent re-assessment of existing data, the population estimate for the Arizona hedgehog cactus through 2020 is approximately 5,998 individuals (HDMS 2022). As described above, additional plants that may occur within the range of the species, but their locations in the field need verification. As of 2022, we believe that there are less than 5,998 individuals due to the Telegraph Fire in 2021 that burned across Arizona hedgehog cactus habitat south of US 60 adversely affecting many plants. This fire eventually merged with the Mescal Fire at El Capitan where several hundred Arizona hedgehog cacti were previously documented. A full survey post-fire of occupied areas that were previously surveyed including the population at El Capitan has not been completed. See Section 2.1.2 (Factor A) below for a discussion on wildfires.

Based on the survey history of the species, it will be necessary to continue to verify or reconcile existing records to get a clearer picture of the Arizona hedgehog cactus population pre-Telegraph fire. It is also important to reiterate that most formal surveys conducted for the cactus were required for compliance with the ESA for projects involving actions that were permitted, funded, or carried out by the federal government. Therefore, it will be critical to expand survey efforts beyond these action areas throughout its range to better understand baseline conditions for the species.

2.2.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Two related studies examined the genetic relationships within and among populations of the Arizona hedgehog cactus and other closely related red-flowered hedgehog cacti, *Echinocereus arizonicus* ssp. *nigrihorridispinus*, scarlet hedgehog cactus (*E. coccineus*), Santa Rita hedgehog cactus, and kingcup cactus (*E. triglochidiatus*) (Fehlberg 2013, Fehlberg et al. 2013). Sampling sites for the Arizona hedgehog cactus occurred in central Arizona between the towns of Superior, Miami, and Globe and included thirteen populations. Additional sampling sites occurred in California, Colorado, Utah, and New Mexico. For each focal species, the researchers collected spine or floral tissue samples, and information on morphological characteristics, abundance, habitat, and any observed threats. Preliminary results of the genetic analyses found that Arizona hedgehog cactus populations (referred in the study as individuals within a site location) maintain a moderately high level of genetic diversity. Specifically, 89% of the observed genetic variation was attributed to differences within populations and 11% of the observed genetic diversity was attributed to differences among populations (Fehlberg et al. 2013). This likely reflects healthy levels of cross-pollination, large effective population sizes, and an absence of inbreeding, isolation, and genetic drift despite the taxon's rarity and limited distribution. The preliminary results also indicated that the Arizona hedgehog cactus populations appear connected by high levels of gene flow and/or dispersal (Fehlberg et al. 2013).

The genetic analysis identified a few individuals in the diploid Arizona hedgehog cactus population having more than two alleles per microsatellite region. These tetraploid individuals are located within the El Capitan, West Fork Pinto Creek, Copper Creek, and Six Shooter Canyon populations. Following additional genetic analyses, the results revealed that populations along West Fork Pinto Creek, Copper Creek, and Roger's Trough were Santa Rita hedgehog cacti; those at Six Shooter Canyon were Arizona hedgehog cactus (Fehlberg 2013). Tetraploid individuals in the El Capitan population may indicate the presence of both the diploid Arizona hedgehog cactus and the tetraploid Santa Rita hedgehog cactus co-occurring together, Santa Rita hedgehog cacti with more variable morphological traits, or individuals that display intermediate or mixed morphological characters between an Arizona hedgehog cactus and Santa Rita hedgehog cactus (Fehlberg et al. 2013). Fehlberg et al. (2013) recommended further chromosome, genetic variation, and floral characteristic studies be conducted along the periphery of the Arizona hedgehog cactus' distribution to resolve the taxonomic identities of individuals with intermediate morphological characters.

2.2.1.4 Taxonomic classification or changes in nomenclature:

The Arizona hedgehog cactus has a complex taxonomic history. Fletcher (1984) provides a brief summary about the difficulties identifying the Arizona hedgehog cactus from other red-flowered cactus that are similar in appearance. We expand on additional taxonomic studies completed after 1984 to the current taxonomic classification of the Arizona hedgehog cactus.

The Arizona hedgehog cactus was first collected in July 1922 by Charles Russell Orcutt at Top-of-the-World, Arizona, a census designated place located along the U.S. 60 highway at the Gila and Pinal county line (Benson 1982). Orcutt sent the cactus to the New York Botanical Garden where J. N. Rose recognized it as a new cactus species and assigned the name *Echinocereus arizonicus*. Although Rose never published an official description of the species, the name was validated in 1926 when Orcutt published a description of *Echinocereus arizonicus* in *Cactography*, a little-known journal of the time (Crosswhite 1992b).

Between 1940 and 1950, taxonomist Lyman D. Benson placed the Arizona hedgehog cactus (*Echinocereus arizonicus*) in synonym with *Echinocereus poycanthus* that occurs in Mexico; then ten years later named the cactus a variety of *E. triglochidiatus*. In 1963, the cactus (*E. arizonicus*) was again treated as a synonym of *E. polycanthus* (Cedar Creek Associates, Inc. 1996). Lastly in 1969, with the publication of *The Cacti of Arizona*, Benson named the Arizona hedgehog cactus *Echinocereus triglochidiatus* var. *arizonicus* (Rose ex Orcutt) (Benson 1969). This taxonomic treatment of the Arizona hedgehog cactus circumscribed all robust, red-flowered hedgehog cacti in Pinal and Gila Counties adjacent to the type locality of Miami/Superior under the species; and

this circumscription is the classic presentation that was accepted by the Service for listing the taxon in 1979 (USFWS 1979a). Additionally, Benson circumscribed all red-flowered hedgehog cacti in the United States under the species *E. triglochidiatus*. This resulted in the species, comprised of eight varieties including var. *arizonicus*, being considerably variable in the extremes of morphological character traits (i.e., stem number and size, spine number, size, and angle) and their broad geographic distribution (Benson 1982, Taylor 1985).

Ferguson (1989) reexamined the various species of the *Echinocereus triglochidiatus* group resulting in revisions to their taxonomy. Ferguson realigned several varieties of red flowered hedgehog cacti into two species *Echinocereus triglochidiatus* and *Echinocereus coccineus*. He treated the Arizona hedgehog cactus as a variety of *E. coccineus* (*E. coccineus* var. *arizonicus*) suggesting that the taxon is more widespread than plants at the type locality but included other red-flowered populations (*Echinocereus triglochidiatus* var. *neomexicanus* and *E. triglochidicatus* var. *polycanthus*) with robust stems and thick spines. The inclusion of these additional populations defined the range of the Arizona hedgehog cactus from central and southeastern Arizona to southwestern New Mexico, and into Mexico (Ferguson 1989, Crosswhite 1992b, Cedar Creek Associates, Inc. 1996).

From the 1970s through 1990s, morphological and cytological studies (e.g., study of chromosome numbers for classification) documented chromosome levels of taxa within the genus *Echinocereus* as an attempt to understand taxonomic problems (Pinkava et al. 1977, 1985, Weedin and Powell 1978, Pinkava and Parfitt 1982, Cota and Philbrick 1994). Chromosome counts revealed that several varieties of *E. triglochidiatus* (Benson 1982) included both diploid (two homologous copies of each chromosome) and tetraploid (four homologous copies of each chromosome) species. These studies led to separations of species based on ploidy levels (e.g., the number of copies of the complete genetic information) which correlated with morphology, geographic distribution, and floral dimorphism (Baker 2006). As a result, diploid varieties are treated as either *E. triglochidiatus* or *E. arizonicus*. The tetraploid varieties are recognized as *E. coccineus* (Taylor 1985, Zimmerman and Parfitt 2003).

Chromosome counts on the Arizona hedgehog cactus (named *E. coccineus* var. *arizonicus* by Ferguson) were conducted in 1991 by Parfitt and Christy (1992). They determined that red-flowered hedgehog cacti at low elevations (1,219-1372 m [4000-4500 ft.]) near Globe, are diploid and therefore could not be a variety of the tetraploid *Echinocereus coccineus* as Ferguson proposed; they classified these cacti as the Arizona hedgehog cactus, with the name *Echinocereus triglochidiatus* var. *arizonicus* (Parfitt and Christy 1992). They also concluded that the other populations of red-flowered hedgehog cactus in southeastern Arizona, New Mexico, and Mexico (*E. triglochidiatus* var. *neomexicanus* and *E. triglochidicatus* var. *polycanthus*) were not the Arizona hedgehog cactus.

In 1998, the Arizona hedgehog cactus was classified as a subspecies of *Echinocereus arizonicus* based on chromosome numbers, elevational range, and geographic distribution (Blum et al. 1998, Zimmerman and Parfitt 2003, Baker 2006). This taxonomic treatment is accepted by the Flora of North America (Zimmerman and Parfitt 2003) which treats *Echinocereus arizonicus* as a distinct species and regards the subspecies *arizonicus* as “known only from central Arizona” and of “conservation concern” in Arizona. However, the Flora of North America does not classify the “infraspecific taxa within *E. arizonicus*” formally because “their taxonomic boundaries remain controversial”.

Baker (2006) summarizes the current taxonomy of *Echinocereus* section *Triglochidiatus* for populations in the west including *E. arizonicus* in Arizona. He provides descriptive statistics of select morphological characters within and among the studied *Echinocereus* populations and establishes a field identification key to distinguish the Arizona hedgehog cactus from *E. arizonicus* ssp. *nigrihorridispinus*.

In 2021, we published a final rule revising the taxonomic name of the Arizona hedgehog cactus from *Echinocereus triglochidiatus* var. *arizonicus* to *Echinocereus arizonicus* ssp. *arizonicus* (USFWS 2021). This taxonomic name change does not affect the range or endangered status of the Arizona hedgehog cactus. This taxonomic treatment has been adopted by the Flora of North America (Zimmerman and Parfitt 2003) and the Integrated Taxonomic Information System.

2.2.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, pollinator availability, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species’ within its historic range, etc.):

At the time of the listing, the range of the Arizona hedgehog cactus was conservatively delineated as a narrow corridor between the town of Superior to the town of Miami (Fletcher 1984). The total known range was roughly estimated to be four to five square miles with about 90% on Federal land and 10% on private land (USFWS 1979b). The final listing rule also noted an Arizona hedgehog cactus population in the Mescal Mountains. However, at the time, taxonomic identification was uncertain, and it is unclear whether this population was included within the listed entity. The Mescal Mountains Arizona hedgehog cactus population has since been verified and is described in more detail below.

Between 1988 and 1991, rangeland staff on the Globe Ranger District, Tonto National Forest discovered populations of red-flowered hedgehog cacti at four distinct sites, as well as in five canyons, and along several Forest Service roads (Widner 1989). Since there was confusion with accurately identifying the Arizona hedgehog cactus, they recorded any red-flowered hedgehog cactus as

the Arizona hedgehog cactus. These surveys expanded the taxon's range beyond Top of the World to include locations near West Fork Pinto Creek, Six Shooter Canyon in the Pinal Mountains (Figure 8), 10 miles northeast of Globe on Apache Peak, and approximately 40 miles east of central Phoenix at Iron Mountain in the Superstition Wilderness (Widner 1989). In 1997, Forest Service staff on the Mesa Ranger District discovered a large population of red-flowered hedgehog cacti assumed to be the Arizona hedgehog cactus in the Superstition Wilderness.

From 1989 to 2001, other red-flowered hedgehog cacti discovered in eastern Arizona expanded the species' range further but only temporarily. In 1989 and 1995, several hundred red-flowered hedgehog cacti displaying similar morphological characters as Arizona hedgehog cactus were documented in Graham and Greenlee counties on the Bureau of Land Management (BLM), Apache-Sitgreaves National Forest, and privately owned lands (SWCA 1995). However, their taxonomy was difficult to identify because morphology of some cacti in eastern Arizona either overlapped with morphology of known Arizona hedgehog cacti at the type locality or exhibited a wide variation of distinct characters.

These surveys led to distribution of the Arizona hedgehog cactus expanding beyond Top of the World to include the Pinal and Mescal Mountains south of Globe as well as the Dripping Springs Mountains approximately 6 miles northwest of the town of Winkelman, north to include the Superstition Mountains. A few scattered plants were discovered on Apache Peak and approximately 22 miles northeast of Globe in the Timber Camp Mountains. Using all available distribution and ecological data, Cedar Creek Associates (1996), estimated that the Arizona hedgehog cactus occupied approximately 18,900 acres (30 square miles) of habitat.

For compliance purposes with the ESA, we considered cacti in eastern Arizona to be the Arizona hedgehog cactus while emphasizing their taxonomic uncertainty. By 2001, a preliminary morphometric analysis (Baker 2001) provided sufficient evidence and validated earlier morphological studies (Blum et al. 1998, Bellsey and Mount 2000) that these plants were a different subspecies of *Echinocereus arizonicus* than the Arizona hedgehog cactus. Baker's final morphometric analysis of the Arizona hedgehog cactus (Baker 2006) provided additional refinement of its distribution reverting back to the currently accepted range in central Arizona.

Various livestock grazing projects and surveys for Federal project clearance by environmental consultants located additional Arizona hedgehog cactus north of U.S. Highway 60, in additional canyons not previously documented, the Pinal Mountains, and El Capitan Mountains near Mescal Mountains.

The current range of the Arizona hedgehog cactus was refined in 2021 to include approximately 141,747 acres from the Superior-Globe region in Gila and Pinal counties of central Arizona (Figure 8). This range was determined by a species distribution model developed by USFWS staff using vetted occurrence data from HDMS, environmental covariates such as elevation, percent slope, vegetation communities, minimum temperature, and average annual precipitation comprising suitable habitat components of the cactus, and a 500-meter buffer. Additionally, locations where the taxonomy of the Arizona hedgehog cactus was questionable or contained the wrong habitat features (i.e., locations outside of the elevation range, dense grass, deep soils, lack of rocky substrate) were verified and removed. For example, field investigations of Apache Peaks and Timber Camp in 2020 found the plants were Santa Rita hedgehog cacti. Locations along U.S. Highway 60 near Picketpost Mountain and north of U.S. 60 near Whitlow Dam were mislabeled points.

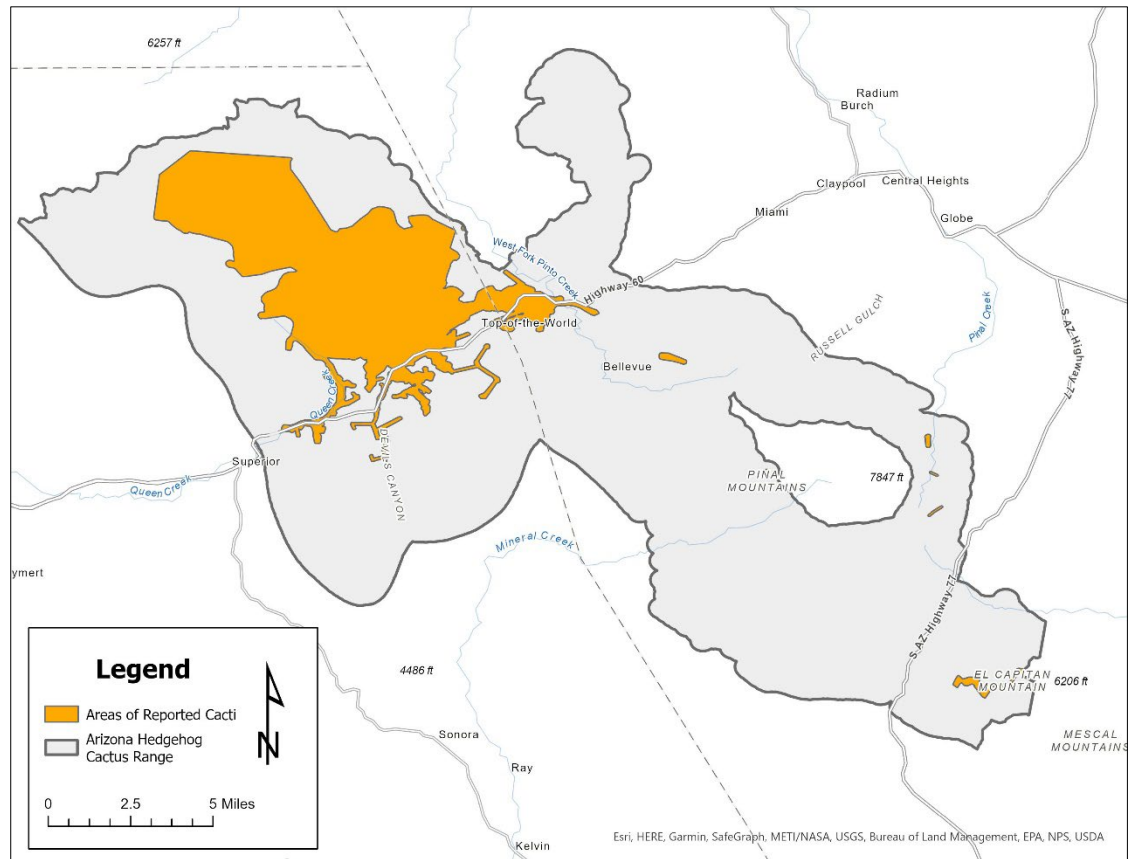


Figure 8. Current range of the Arizona hedgehog cactus represented in gray. Yellow shaded represents generalized areas of reported Arizona hedgehog cacti in Pinal and Gila counties. Not all areas in yellow have been surveyed. Areas surveyed for Arizona hedgehog cactus with negative survey results are not reported in HDMS.

The entire range is not equivalent to total distribution; it incorporates developed areas such as the towns of Superior and Top of the World, buildings, roads, and infrastructure associated with industry. The cactus is not evenly distributed

within its availability of suitable habitat. Where suitable habitat exists, the cactus has a clumped distribution surrounded by a few scattered plants. Despite the availability of habitat, most appears unoccupied.

2.2.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

The Arizona hedgehog cactus is a narrow endemic cactus in the Superior- Globe region, Gila and Pinal counties in central Arizona. The species occurs from approximately 975 to 1615 m (3,200 to 5,300 ft) in the transition area where floristic elements of Interior Chaparral, Madrean Evergreen Woodland, and the Arizona Upland subdivision of the Sonoran Desert plant communities merge (Fletcher 1984).

The Arizona hedgehog cactus is found on slopes of 20 to 90 degrees in rocky and boulder terrain with northerly and easterly exposures (Crosswhite 1992a, Cedar Creek Associates, Inc. 1996), but many plants grow on flatter and more open slopes (Cedar Creek Associates, Inc. 1996). The cactus prefers a resistant stable rock matrix primarily in the form of exposed bedrock, stabilized boulders, cracks, fissures, and rock fields, with or without a small layer of shallow soil present. Its roots invade cracks in exposed rock or narrow soil pockets between boulders and within bedrock that exhibit sufficient fracturing or rock interstices for establishment (Cedar Creek Associates, Inc. 1996). These rocky areas provide the roots with the necessary anchoring medium, channel rainwater, retain periodic moisture, and provide shade (Nobel et al. 1992). Shallow soil pockets and cracks seem to provide the roots with the necessary anchoring medium and periodic moisture, whereas, deeper exposed and moist soils, when exposed to higher temperatures, may harbor pathogenic bacteria and fungi known to cause death in cacti (Crosswhite 1992a, Cedar Creek Associates, Inc. 1996). The Arizona hedgehog cactus also roots in shallow, sandy cobbled loam, and gravelly loam soils over bedrock or in bare ground next to boulders. Although less numerous, some Arizona hedgehog cacti grow in deeper soils or on scree/rubble slopes and scattered rock habitats typically below bedrock controlled upper slopes (Figure 9). These types of areas are potentially unstable and individuals that become established may not survive over time (Cedar Creek Associates, Inc. 1996).

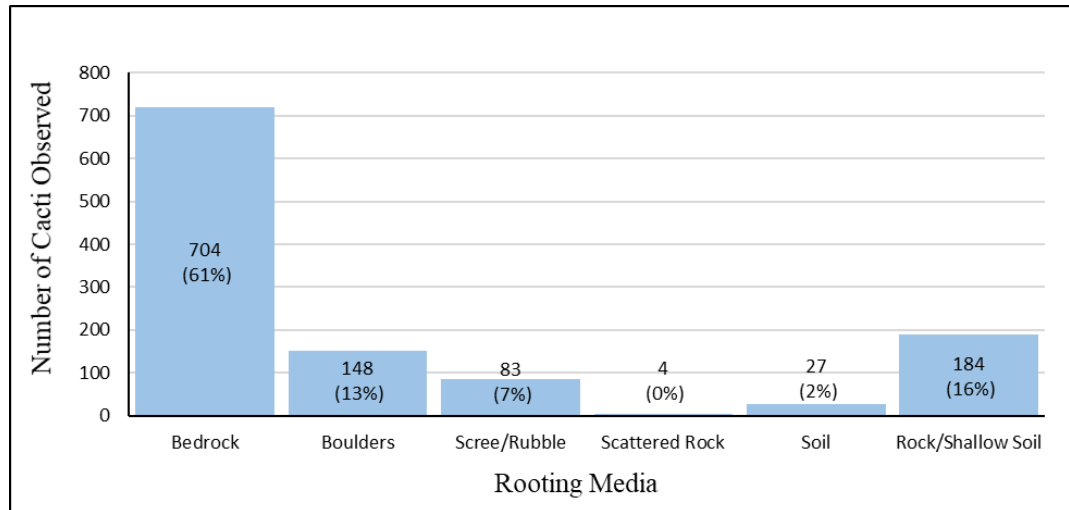


Figure 9. Percentage of 1,150 Arizona hedgehog cacti observed growing on different rooting media. Reprinted with permission from Cedar Creek Associates, Inc. (1996).

High quality Arizona hedgehog cactus habitat, which is habitat supporting most plants, is formed of resistant stable rock, either bedrock or entrenched boulders. Moderate habitat is composed of significant but often unstable rock; and poor habitat consists of a shallow but stable soil matrix with occasional scattered surficial rock. Non-habitat includes active colluvial rock and either erodible or deeper, more productive soils (Cedar Creek Associates, Inc. 1996).

While the Arizona hedgehog cactus can tolerate full sun and compete shade, the cactus prefers conditions that offer some shade. Nurse plants are beneficial by providing shade during daytime high temperatures that reduces evapotranspiration, reduce surface temperatures, increase soil-nutrient availability, and may increase seed germination and seedling survival (Mandujano et al. 2002, Godínez-Álvarez et al. 2003). In a quantitative analysis by Cedar Creek Associates (1996), the majority of plants grow in conditions that offer 30 to 70% sun exposures, with 50% sun exposure the most preferable (Figure 10). Different species of perennial shrubs, trees, and grasses or boulders ledges can act as a nurse plant or nurse rock by providing some canopy cover to the Arizona hedgehog cactus growing beneath or adjacent to neighboring plants or rocks. Cedar Creek Associates (1996) documented 45% of Arizona hedgehog cacti occur adjacent to herbaceous vegetation, 40% next to scattered shrubs, 8% in barren areas, 4% under trees, and 3% under moderately dense shrub cover (Figure 11).

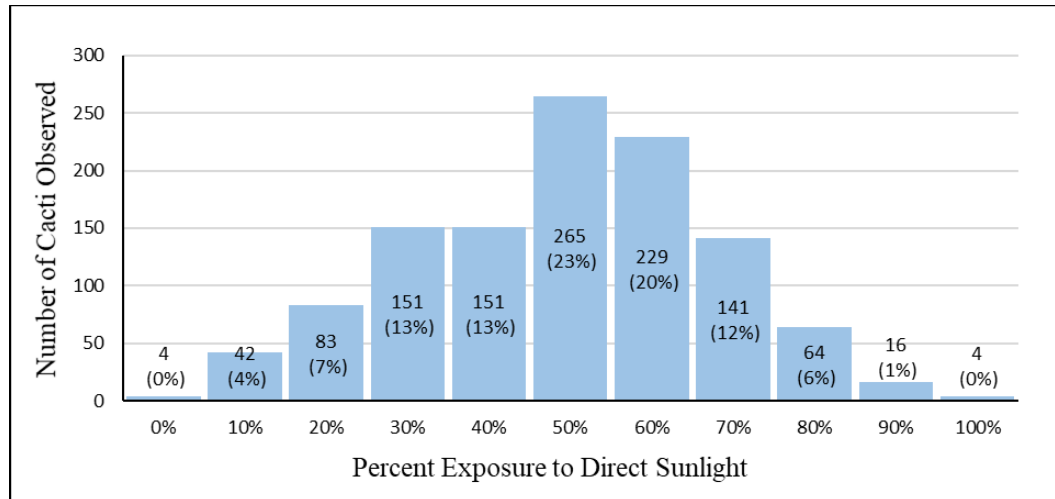


Figure 10. Observations of 1,150 Arizona hedgehog cacti grow in full shade (0%) to full sun (100%). Reprinted with permission from Cedar Creek Associates, Inc. (1996).

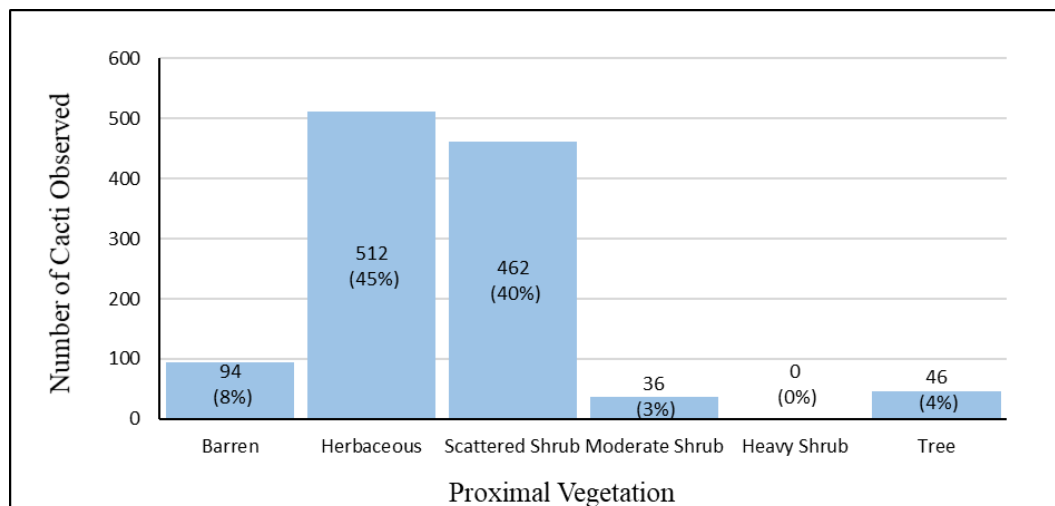


Figure 11. Percentage of 1,150 Arizona hedgehog cacti observed growing adjacent to chaparral plants. Reprinted with permission from Cedar Creek Associates, Inc. (1996).

Dominant species associated with Arizona hedgehog cactus habitat include shrub live oak (*Quercus turbinella*), Emory oak (*Q. emoryi*), manzanita (*Arctostaphylos pungens*), bear grass (*Nolina spp.*), Wright's silk tassel (*Garrya wrightii*), golden flowered century plant (*Agave chrysantha*), and mountain mahogany (*Cercocarpus montanus*). Other species in the associated plant communities include hedgehog cactus (*Echinocereus fasciculatus*), common sotol (*Dasylirion wheeleri*), Wright's buckwheat (*Eriogonum wrightii*), catclaw mimosa (*Mimosa aculeaticarpa* var. *biuncifera*), prickly pear cactus (*Opuntia polyacantha*), *Penstemon* spp., muttongrass (*Poa longiligula*), sugar bush (*Rhus ovata*), skunk bush (*Rhus trilobata*), and banana yucca (*Yucca baccata*). Alligator juniper (*Juniperus deppeana*) and piñon pine (*Pinus edulis*) occur at the upper elevation limits of the Arizona hedgehog cactus range (Pase and Brown 1982, Fletcher 1984, Cedar Creek Associates, Inc. 1996) (Figure 12).



Figure 12. An example of an interior chaparral plant community associated with Arizona hedgehog cactus. Credit: E. Seavey, USFWS, 2023.

The Superior-Globe region lies between the Central Highlands Transition Zone and the southern Basin and Range physiographic landforms. The Transition Zone is characterized by variably dissected alluvial basins and large mountain ranges, which are capped by erosional remnants of the Colorado Plateau (Briggs 2022). The Basin and Range Province includes the northwest and southeast portions of Arizona. It is characterized by series of northwest to northeast trending mountain ranges, the “sky islands” separated by broad alluvial valleys and lowland deserts (Pearthree and Youberg 2000, Briggs 2022).

Much of the Arizona hedgehog cactus habitat is overlain by volcanic rocks consisting of lava, tuff, fine-grained intrusive rock, and diverse pyroclastic rocks that include dacite and rhyolite (Middle Miocene dating 11-38 million years ago [Ma]). Based on a study and observations of 2,000 individuals the observed optimal Arizona hedgehog habitat occurs within two principal rock types, the Tertiary Apache Leap Tuff (dacite) and the Cretaceous or Tertiary Schultze Granite (Cedar Creek Associates, Inc. 1996). To a lesser extent, two additional formations offer variably favorable habitat for the Arizona hedgehog cactus: the Precambrian Apache Group Pioneer quartzite and the Precambrian Pinal Schist (Figure 13).

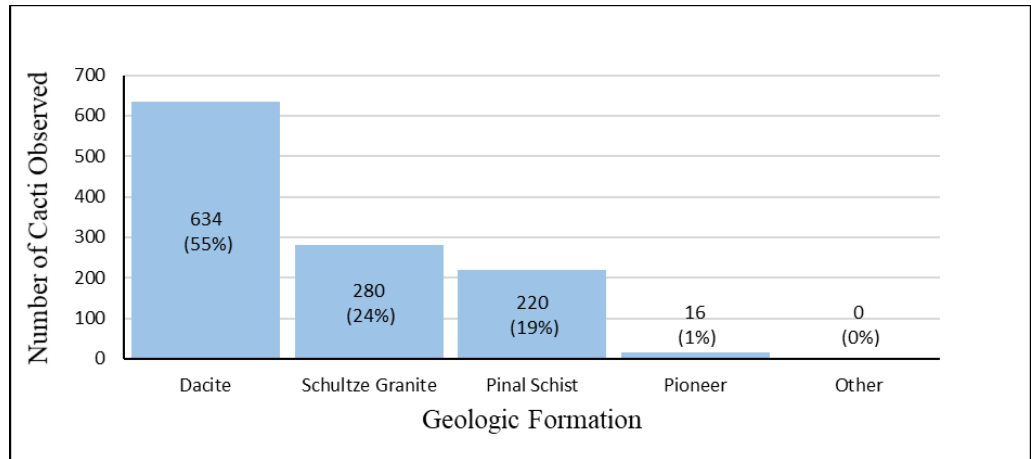


Figure 13. Percentage of 1,150 Arizona hedgehog cacti observed growing in several geologic formations. Reprinted with permission from Cedar Creek Associate, Inc. (1996).



Figure 14. Steep, vertical cliffs composed of Apache Leap tuff and rhyolite. Cracks, fissures, and interstices within the bedrock provide rooting media for the Arizona hedgehog cactus. Credit: K. Robertson, USFWS, 2022.

Apache Leap tuff, named for Apache Leap, a prominent west-facing escarpment, is a welded tuff of volcanic ash flow (Peterson 1969, Tonto National Forest 2021). It is very stable, resistant to weathering and forms ridges of boulder outcrops and/or cliff faces east of Superior to Top of the World (Arizona Geological Survey (AZGS) 2022, Briggs 2022) (Figure 14).

Schultze Granite, dating Late Cretaceous to Early Tertiary granitic rocks (50-82 Ma) are exposed at Top of the World, near the Pinal-Gila County line, east to Miami (AZGS 2022, Briggs 2022). Schultze Granite weathers slowly into large, exfoliated boulders forming rock outcrop-boulder fields with little soil

development (Cedar Creek Associates, Inc. 1996). Large copper deposits are located in this region and are associated with porphyritic granitic rock and therefore named "porphyry copper deposits" (AZGS 2022).

Pinal Schist, dating Early Proterozoic Metasedimentary rocks (1600-1800 Ma), is poorly exposed within the range of the Arizona hedgehog cactus, specifically northeast of Pinto Creek where it may be overlain by Apache Leap tuff (Briggs 2022). It is found in outcrops, cliff faces, or exposed parent material in close proximity to Schulze Granite. In some areas, supporting the Arizona hedgehog cactus, Pinal Schist is exposed as fractured but relatively stable bedrock whereas in other areas that do not support the cactus it weathers easily forming soil material (Cedar Creek Associates, Inc. 1996).

A smaller number of Arizona hedgehog cacti occur on Pioneer Formation (Middle Protozoic sedimentary rocks dating 700-1300 Ma) consisting of limestone, red-brown or black shale, sandstone, and quartzite (AZGS 2022). The Pioneer Formation is exposed in limited areas of the cactus' distribution, forming cliff faces or highly resistant ridges (Cedar Creek Associates, Inc. 1996). Cedar Creek Associates estimated that 1.39% of the Arizona hedgehog cactus population they observed occurred on Pioneer Formation.

2.2.1.7 Other:

When the Arizona hedgehog cactus was listed, accurate identification was difficult, and the taxonomic status of this entity had not been completely resolved; multiple varieties of *Echinocereus triglochidiatus* were taxonomically difficult to separate. The October 25, 1979, final listing rule states: "Different varieties within the species *Echinocereus triglochidiatus* intergrade extensively with one another. Mixed populations showing extensive variation but with some affinities toward var. *arizonicus* are not to be considered classical var. *arizonicus* and therefore will not be subject to the protection and restrictions of the ESA ... Again, until further data is available (chromosome counts, etc.) only known populations of this variety will be subject to the ESA." The 1979 listing also goes on to describe the proportion of the range where the cactus is listed as "entire" [U.S.A. Arizona]. Thus, the 1979 listing, consistent with the ESA requirement that a threatened or endangered species be protected wherever found, protected all Arizona hedgehog cactus, if able to be classified as such.

In 2008, however, language within the Status of the Species section of a Biological Opinion (BO) (USFWS 2008) stated, "These populations (main and two subpopulations) are "classical var. *arizonicus*" and are the only populations of the [Arizona hedgehog cactus] subject to the protection and restrictions of the ESA." This language does not describe the endangered status of the Arizona hedgehog cactus accurately as it does not make clear that any Arizona hedgehog cactus, properly classified as such, wherever found in its range would be subject to the protections of the ESA pursuant to the 1979 listing and requirements of

the ESA that the species itself is protected, not the range. Despite the inaccuracy, this language has been recycled in subsequent BO's as recent as 2018 (USFWS 2018). Prior to 2008, in line with the 1979 listing rule and requirements of the ESA, the USFWS described the listing status of the Arizona hedgehog cactus as endangered "rangewide." Similarly, according to the Code of Federal Regulations, 50 CFR 17.12, the listing for this species is "Wherever found". To clarify this issue in this SSA, USFWS emphasizes here that the 1979 listing rule did not state that only certain known populations or subpopulations of Arizona hedgehog cactus are subject to the protection and restrictions of the ESA. Rather, any population or plants identified as var. *arizonicus* are subject to the protections of the ESA.

2.2.1.8 Conservation Measures:

State and federal agencies, subject matter experts, and consultants have implemented and are currently investigating actions that can directly or indirectly conserve, reduce, or minimize effects to Arizona hedgehog cactus and its habitat. Since the species was listed, the Service has consistently advised action agencies to survey for cacti and mark their locations prior to any land or vegetation disturbance activities to avoid destroying individuals. Several road improvement projects along US Highway 60 precipitated the development of species-specific methodology for salvaging, propagating, and transplanting Arizona hedgehog cacti by SWCA Environmental Consultants, Arizona Department of Transportation, USFWS, Forest Service, and Desert Botanical Garden (USFWS 2008, 2014, 2018, Siegwirth 2014, Raschke et al. 2022). Implementation of these methods have included:

- 1) Salvaging and relocating whole plants outside of action areas
- 2) Collecting stems from a mother plant to propagate in a greenhouse setting a year or more prior to transplantation
- 3) Collecting and storing seeds from both greenhouse-pollinated and naturally occurring plants for conservation banking and future propagation and outplanting

The existing methodology identifies selection of microhabitats prior to transplanting as critical for planting success. Transplanting, while not a guarantee for plant survival, enables plants to remain within their native habitat and contribute genetic material through pollination to other individuals within the population. Although most individuals planted within the last three years appear to have survived transplantation, with some even producing flowers and fruits, it is still too soon to claim that the method in question results in long-term success, as cacti can live on energy reserves in existing tissue for long periods of time without fully establishing at a new site (Butler 2023). Desert Botanical Garden, Forest Service, and USFWS staff will continue to monitor and maintain ongoing transplanted populations to refine these conservation measures.

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

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

Mining and Associated Infrastructure

Mining in the Miami-Globe Region has occurred for more than 150 years. This region is a part of Arizona's "Copper Triangle," a region in northeast Arizona known for its concentration of large copper deposits. Arizona produces more copper than any other state (Geoscience News and Information 2020) and as of December 31, 2020, cumulative copper production from Arizona's Copper Triangle totaled 37.3 billion pounds, representing an estimated 13.6% of the total reported historic U.S. production. Additional unmined mineral resources within the Miami-Globe region total ~ 85.1 billion lbs. of copper (Briggs 2022).

There are 167 sites associated with mining on the Tonto National Forest that occur within the Arizona hedgehog cactus range. The status of these mineral sites is not complete, with some no longer active, while some are associated with mineral claims. Populations of Arizona hedgehog cacti occur adjacent to the footprint of the OMYA Mine near exploratory drill sites, and within the Resolution Copper Mine and Carlota Copper Mine, now known as the Quadra Mine (Figure 15) (Thomas et al. 2019).

Construction of the most recent Resolution Copper Mine project, which partly encompasses the Oak Flat Campground, is an underground operation that is anticipated to remove 165 to 249 Arizona hedgehog cactus and result in 823 acres of habitat loss throughout the life of the mine and upon its inevitable collapse. In total, there will be 14,950 acres of disturbance, which includes the footprint of the mine itself, in addition to the tailings storage facility, the tailings conveyance pipeline, and the powerline corridor. The tailing storage facility will be approximately 9,611 acres, with about 4,002 acres of disturbance within its footprint. The tailings will remain in the storage facility in perpetuity (USFWS 2020).

In summary, mine construction, development of associated operational and support facilities and resulting tailings waste piles permanently remove Arizona hedgehog cactus habitat and can impact or destroy established plants. Mining activities and road construction associated with mining and mineral exploration has resulted in the loss of individual Arizona hedgehog cactus and the loss, degradation, and fragmentation of its habitat (USFWS 1996, 2020). Habitat disturbance from construction and vehicle traffic can increase establishment of invasive grasses into remaining habitat which can increase wildfire potential and exclude establishment of native species (see Wildfire and Invasive Species below).

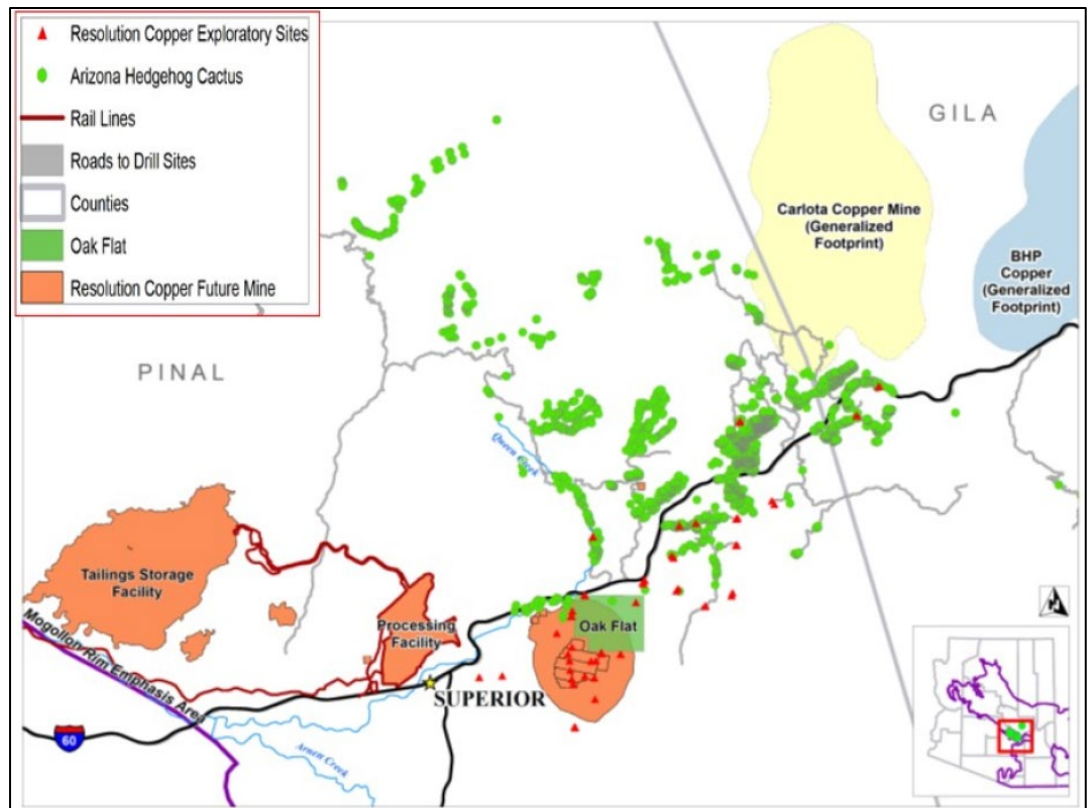


Figure 15. General locations of reported Arizona hedgehog cacti in Pinal and Gila counties and associated mine exploration sites and proposed facilities for the Resolution Copper Mine as of 2019 (Thomas et al. 2019). Arizona hedgehog cactus habitat occurred in the Carlota Copper Mine footprint prior to mine construction. Many cacti were translocated within the project area but outside of the construction zone for conservation purposes. Please note, not all detected cacti as of 2023 are represented in this map.

Roads, Transmission Lines, and Pipeline Corridors

The construction of roads, transmission lines, and pipeline corridors, regardless of whether they are directly related to mining operations, appreciably alter Arizona hedgehog cactus habitat. The most notable projects within this scope of impact have included several improvements and enhancements to US Highway 60 (USFWS 2008, 2014, 2018) and infrastructure related to the Carlota and Resolution copper mines (USFWS 1996, 2020). In some cases, large areas of occupied habitat in chaparral vegetation are cleared to construct and maintain these corridors into the future. Any Arizona hedgehog cactus growing in these areas are removed (salvaged to a botanical institution or transplanted near the project site but outside construction zone) and the existing seed bank is likely removed or destroyed. These activities permanently alter the habitat rendering it no longer suitable for future reestablishment. In addition, some of these corridors are accessible to the public and may contribute to the loss or damage

to individual plants associated with illegal off-road motor-vehicle activity or increased access for illegal collection.

Wildfire and Invasive Species

At the time of listing, wildfire was of limited concern and was not well-studied enough to be considered a primary threat to the species (Phillips et al. 1979, Fletcher 1984, Cedar Creek Associates, Inc. 1996, Baker 2013). However, current fire regimes are drastically different from historical patterns, and climate change and increased fire suppression over the past 100 years have driven the Southwest into a fire deficit compared to historic fire levels (Yocom et al. 2022). Current wildfire ignition and habitat alteration trends as well as existing wildfire history within the current range for the Arizona hedgehog cactus indicate that wildfire poses a considerable threat to its recovery.

The state of Arizona has been in some stage of drought since 1994 (Arizona Department of Water Resources 2023). However, record low precipitation in northeast Arizona from June through September 2020 resulted in extreme drought from 2020 to 2021 (Hoell et al. 2022), resulting in turn with record-breaking wildfire years. In years of infrequent summer rains, the resulting dry thunderstorms can contribute to an extended, widespread summer wildfire season, when vegetation is most flammable and strong winds drive fire spread (Schmid and Rogers 1988, Arizpe et al. 2020). The remoteness of lightning-driven wildfires, especially within Arizona hedgehog cactus habitat, may render them inaccessible and lessen the possibility of a rapid discovery resulting in more expansive fires (Schmid and Rogers 1988). Human ignited wildfires are also on the rise in the United States, with one study indicating that between 1992 and 2012, human-ignited fires accounted for 84% of all fires and 44% of total area burned, and resulted in fire seasons three times longer than lightning-ignited fire seasons (Balch et al. 2017).

Interior chaparral, where the Arizona hedgehog cactus is most abundant, is adapted to infrequent high-severity fire which may recur at intervals as long as 50 to 100 years (Pase and Brown 1994, Lata 2019), with most dominant native woody shrubs in this ecosystem easily resprouting from remnant root crowns following fire (Pase and Brown 1994, Schmutz 1994). Increased fire suppression in addition to domestic grazing and road construction (which can function as firebreaks in wildfire suppression), have contributed significantly to a reduction in wildfire frequency in interior chaparral (Rogers 1986). In some parts of the Tonto National Forest, fire suppression in chaparral vegetation resulted in an 86% increase in woody cover, with contiguous woody fuels present over larger areas than what would typically be present under a natural fire regime (Lata 2019). This shift in the natural fire regime for this ecosystem carries the potential to increase fire frequency, severity, and total land cover impacted (Westerling et al. 2006).

High-severity wildfire also has the ability to affect soil erosion rates by eliminating vegetation which would otherwise prevent erosion (Brooks et al. 2004). During a March 2023 visit to an Arizona hedgehog cactus population in Upper Pinto Creek, Forest Service, USFWS, and Desert Botanical Garden staff observed that runoff from the 2021 Telegraph Fire had resulted in significant erosion along the canyon walls. The 2022 post-fire monitoring surveys indicated that several individual Arizona hedgehog cacti were not detected and were believed to be lost due to soil erosion (Bruner 2022). Due to the isolation of many Arizona hedgehog cactus populations, it is uncertain to what extent post-wildfire soil erosion will impact the cacti and their habitats in the long-term.

It is widely accepted that invasive species can increase fuel load, influence wildfire regimes, out-compete native species for resources, and alter soil properties (Brooks and Pyke 2001, Brooks et al. 2004, Brooks and Chambers 2011, Underwood et al. 2019, St. Clair et al. 2023). Invasive fountain grass (*Pennisetum setaceum*), Mediterranean grass (*Schismus spp.*), red brome (*Bromus rubens*), cheatgrass (*B. tectorum*), rabbitfoot grass (*Polypogon monspeliensis*), Boer lovegrass (*Eragrostis chlromelas*), weeping lovegrass (*E. curvula*), Lehmann's lovegrass (*E. lehmanniana*) and wild oat (*Avena fatua*) are present within the Arizona hedgehog cactus range on the Tonto National Forest (Baker 2013, Bruner 2023b). Fountain grass, red brome, rabbitfoot grass, and wild oat have been identified as potential drivers for increased wildfire risk. Fountain grass is present at Queen Creek Canyon, and Devil's Canyon and Pinto Creek are likely vulnerable to fountain grass infestation (Bruner 2023b). While interior chaparral is characterized by low-density vegetation communities composed primarily of woody shrubs and fire-resistant grasses (Schmutz 1994), the introduction of more fire-prone invasive bromes and bunch grasses has introduced horizontal fuel continuity across the landscape in many ecosystems, in some cases allowing fire to spread across greater areas where it previously would have been unable to spread (Brooks and Pyke 2001, Brooks et al. 2004). This change in vegetation continuity is of particular concern for the recovery of the Arizona hedgehog cactus, given that invasive bromes and other grasses can invade open slopes, cracks, crevices, and between boulders on stable rock formations where Arizona hedgehog cactus typically occur. One study of nylon hedgehog cacti (*Echinocereus viridiflorus* var. *viridiflorus*) reported high mortality post-fire, with exception to areas where the cacti either occurred in unburned refugia or survived fire by resprouting (Rideout-Hanzak et al. 2009). Similarly, microhabitat sites for the Arizona hedgehog cactus are thought to provide some protection during wildfires, and it is possible that the encroachment of invasive fire-prone invasive plant species would carry fire into some of these previously fire-resilient areas (Baker 2013).

The 2021 Telegraph Fire, which burned 180,757 acres in total, impacted approximately 3,730 acres of known Arizona hedgehog cactus habitat (Peterson 2022) (Figure 16). The fire extended south of Highway 60, including the Pinal Mountains and El Capitán, which in large part has not yet been surveyed for the

species due to rough terrain. Previously, 1,578 individuals had been mapped within the fire perimeter, which presents a unique opportunity to study the impacts of fire on the cactus. Biologists and volunteers with the Tonto National Forest and Desert Botanical Garden found that many cacti were seemingly unharmed by the fire even in areas of high vegetation burn severity, likely influenced by the rocky habitat on which they occur providing some natural fire protection. Of the 223 Arizona hedgehog cactus, 55 Santa Rita hedgehog cactus, and 50 *Echinocereus* spp. individuals thought to be a mix of the two species surveyed during the initial survivorship assessment following the fire in 2021, overall survivorship was 74%. In a 2022 follow-up survey of 169 *Echinocereus* individuals, it was found that more cacti were trending toward healthy (i.e., less than approximately 10% damage and/or discoloration present on all stems combined, stems generally robust and vibrant in color, and flowering when mature) than dead (i.e., senesced stems and no viable remaining tissue and/or chlorophyll). The cacti which occurred within the 9.8-acre fire retardant drop zone did not appear to show any negative effects as of 2022 and appeared to have more fruit and flowers present than cacti which were not exposed to retardant. The Tonto National Forest selected 169 individuals across four monitoring sites for long-term monitoring, which will help in determining whether these trends will continue long-term or are anomalies (Bruner 2022).

While studies of the long-term impacts of fire on Arizona hedgehog cactus are still ongoing, fire impact studies have been conducted for several other species in the genus *Echinocereus*. One study found that a 1992 natural wildfire in juniper savanna resulted in high mortality in a population of Kuenzler's hedgehog cactus (*Echinocereus fendleri* var. *kuenzleri*) due to its proximity to highly flammable fuels, such as grasses. After a 1999 post-fire survey indicated that the density of Kuenzler's cactus was approximately one-third the density of that in unburned habitat, researchers speculated that low density patches of the cactus may not have a sufficient soil seed bank to fully recover to pre-fire numbers and may be highly dependent on seed dispersal to recover (Sivinski 2007). Similarly, in a fire impact study of several species of cactus, including lace hedgehog cactus (*Echinocereus reichenbachii*), researchers found that the smaller cactus species were more susceptible to fire damage than taller species, with 94% mortality of lace hedgehog cactus individuals three years post-fire (Bunting et al. 1980). High-temperature fire can cause epidermal cell death and high-density spines can carry fire up the cactus to the apex, inhibiting growth post-fire and ultimately making some species of hedgehog cacti more vulnerable to damage from insects, freezing, and drought (Rideout-Hanzak et al. 2009). Even if cacti can resprout post-fire, they are more vulnerable to mortality from recurring fire because resources are translocated from the roots to the resprout, meaning they have little reserves left to establish new shoot material after recurring fires (Brooks and Pyke 2001).

The 2021 Telegraph Fire is not an exceptional event within the recent fire history for the cactus's range. In 2017, the Pinal Fire, which occurred within the

footprint of the Telegraph Fire consumed a total of 7,851 acres, impacting 2,749 acres of interior chaparral habitat (Lata 2017). In 2019, the Woodbury Fire burned a total of 129,121 acres, impacting 14,326 acres of interior chaparral habitat. However, the overlap between the Woodbury Fire perimeter and the Arizona hedgehog cactus range was small in comparison to the Telegraph Fire (Figure 16). Red brome and Mediterranean grass were particularly pervasive throughout the burned area (Lata 2019). In both the Pinal and Woodbury Fires, decadent and contiguous woody materials (a result of high winds and summertime temperatures) contributed to the extent and severity of the fires, as did the legacy of fire suppression on the Tonto National Forest and adjacent lands. Again, due to rough terrain impeding large-scale baseline monitoring of Arizona hedgehog cactus, it is unknown to what extent these fires impacted potential unknown populations.

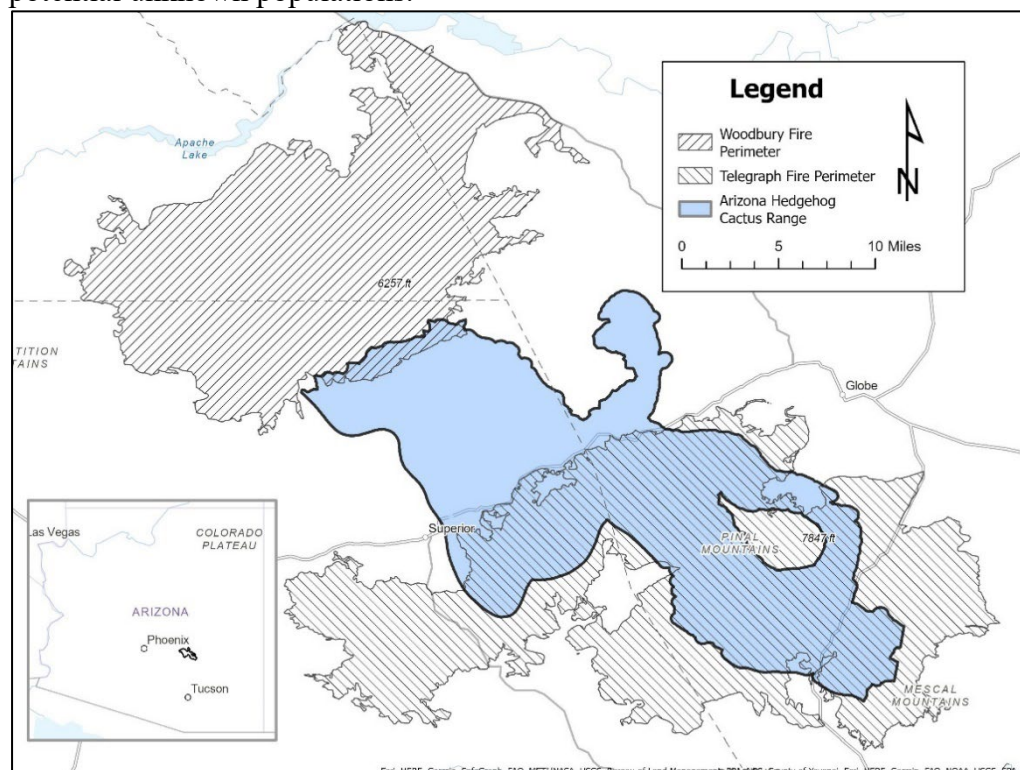


Figure 16. Fire perimeters for the Telegraph and Woodbury Fires and their overlap on Arizona hedgehog cactus habitat. The Pinal Fire perimeter is not reflected on this map, as it occurred completely within the footprint of the Telegraph Fire. Note that the range for the Arizona hedgehog cactus is inflated by a 500-meter buffer and includes areas that are unoccupied or unsurveyed but contain suitable habitat (see section 2.2.1.5).

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

In recent years, the cactus trade has expanded considerably. Plant nurseries saw a soar in popularity of cacti and other succulents during the COVID-19 pandemic due to their promotion on social media. The illegal cactus trade has

also grown in recent years, as collectors are especially attracted to the exclusivity of rare and endangered cacti (Nuwer 2021, Cornelius 2022). Prosecutions for illegal cactus collection in Arizona continue to be prevalent, with collectors eyeing both domestic and international markets (McGivney 2019, Rohrlach and Schlanger 2019, Cornelius 2022). In a survey conducted in 2020 of cacti hobbyists, 11.2% of 418 respondents self-reported non-compliance with the Convention on International Trade in Endangered Species of Wild Fauna and Flora rules (Margulies et al. 2022).

The 1979 federal listing indicated that illegal collection was considered a threat to the Arizona hedgehog cactus (USFWS 1979a). There are anecdotal reports as well as data discrepancies which may indicate illegal collection. It was reported that a nursery east of Phoenix may propagate Arizona hedgehog cactus, although the nursery claims that the plants were collected prior to its listing in 1979, and thus far these claims have gone unverified (Camden Bruner, U.S. Forest Service, personal communication 2023a).

In the past, concerns have been raised that Arizona hedgehog cacti along major travel corridors may make individuals more vulnerable to illegal collection (Cedar Creek Associates, Inc. 1996). WestLand Resources, Inc. (WestLand) was retained by Resolution Copper to conduct surveys for Arizona hedgehog cactus in compliance with monitoring requirements of the Resolution Copper Mining Pre-feasibility Activities Plan of Operations (Resolution Copper Mining 2010) and the Tonto National Forest's Finding of No Significant Impact (Tonto National Forest 2010). In a 2018 survey conducted along several forest roads and drill pads on the Tonto National Forest, surveyors located 425 live cacti tagged during surveys conducted between 2010 and 2016, while 28 tagged during the same survey were not detected (Westland 2010, Westland 2013, Westland 2014, Westland 2016). It is uncertain whether these cacti were simply missed during the survey, or if they were taken from the area.

Existing data on the illegal collection (or lack thereof) of Arizona hedgehog cactus is insufficient to discern long-term impacts to the species and its recovery. Because habitat for the cactus is often remote and rough terrain prevents or greatly hinders access to some populations, documentation and enforcement of potential poaching activities is unlikely in the future. However, illegal collectors typically value and target cactus species with unique features, and Arizona hedgehog cactus produces claret cups like other members of the genus *Echinocereus*. The large size of mature Arizona hedgehog cacti may also present a barrier to illegal collection, as it has been observed that collectors favor small, single stem species that are easy to transport, such as the federally endangered Acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) (Steve Blackwell, Desert Botanical Garden, personal communication 2023).

2.2.2.3 Disease or predation:

There have been several reports of insect damage to Arizona hedgehog cactus stems. In the 1984 draft recovery plan for the cactus, Fletcher (1984) included insect damage as a threat, stating it has been observed on the species, but no studies had been conducted at that time. Phillips et al. (1979) noted insects consumed many of the fruits produced in a population they studied in June but they were not able to identify the insect species. A native insect in the Coreidae family, commonly known as leaf-footed bugs, was observed extracting juices from dead stems of a living plant and it was unknown if this caused those stems to die (Phillips et al. 1979).

Coreid bugs of the genus *Chelinidea*, known generally as cactus coreids, have been observed to leave evidence (feeding marks) on Arizona hedgehog cactus specimens across nearly the entire known distribution of the cactus (Cedar Creek Associates, Inc. 1996). In 2021, staff at the Desert Botanical Garden captured a photo of *Chelinidea vittiger* (Hemiptera, Coreidae) on an Arizona hedgehog cactus in Queen Creek Canyon (Figure 17). Desert Botanical Garden staff observed this species in several Arizona hedgehog cactus populations within its range; the damage was not severe, but when the number of insects feeding on a single stem was high, staff observed yellowing of stems (Puentes-Martinez and Butler 2023). Cactus coreids typically favor *Cylindropuntias* (chollas) and *Opuntia* species (prickly pears) as host plants (Mann 1969, Herring 1980).

Cedar Creek and Associates (1996) cited evidence of the native *Moneilema* beetles, commonly known as cactus longhorn beetles, feeding on apical meristems of the cactus, occasionally resulting in the death of the meristem and subsequent re-growth of a new shoot. While the species of longhorn beetle was not specified in this case, the range of *Moneilema gigas* overlaps with that of Arizona hedgehog cactus and larvae from *M. gigas* have been observed feeding on *Echinocereus polyacanthus*. Despite this observation, *M. gigas* demonstrates a preference for *Cylindropuntias*, particularly *Opuntia fulgida* (Mann 1969). However, a noted cactus expert, Alan Zimmerman, believes that increased warming in recent decades facilitates longer breeding cycles and more reproduction in cactus longhorn beetles (Rutman 2007), possibly increasing impact from herbivory on cacti populations.



Figure 17. *Chelinidea vittiger* on stem of Arizona hedgehog cactus individual in Queen Creek Canyon. Photo by R. Puente-Martinez, Desert Botanical Garden, 2021.

In 1996, Cedar Creek Associates (1996) cited evidence that, while herbivory by cactus coreids and longhorn beetles occurs, it was not occurring at the extent to which could jeopardize the recovery of the species. However, more current information is needed to verify these observations. It is unknown if the extent of herbivory has increased to a level that could impact Arizona hedgehog at a species level, however there is little recent documentation of mortality by insect herbivory of any kind. It is important to note that insect herbivory may not directly result in mortality but may compound other threats or circumstances related to mortality. For example, a cactus compromised by wildfire may be more susceptible to mortality due to insect damage (Bunting et al. 1980, Rideout-Hanzak et al. 2009).

Moneilema larvae have been observed damaging Arizona hedgehog cactus stems through boring, which in turn introduces pathogenic bacteria and fungi identified generally as “soft-rot of cactus” (Cedar Creek Associates, Inc. 1996). Desert Botanical Garden staff noted that, while they have never observed *Moneilema* larvae on Arizona hedgehog cacti, blue larvae from an unknown insect and accompanying rot were previously observed in the roots of stem cuttings which were being propagated in a greenhouse setting for 5-6 months (Puente-Martinez and Butler 2023). A 2017 unpublished briefing on Arizona hedgehog cactus biology (Taylor 2017) identified *Erwinia carnegieana*, a bacteria that causes cactus soft rot, as a potential threat to the cactus. Commonly known to impact adult saguaros compromised by threats such as sub-normal water uptake, lesions, or herbivory (Steenbergh 1970), two plants in Queen Creek Canyon were observed with circular, black wounds similar to *E. carnegieana*, which showed damage to about 30% of the stems (Puente-Martinez and Butler 2023). *E. carnegieana* has been shown to be pathogenic to other plants, including at least two other species of hedgehog cactus, *Echinocereus engelmannii* (Graf 1965) and *Echinocereus arizonicus* ssp. *nigrihorridispinus* (Puente-Martinez and Butler 2023). In addition to bacterial

infection, internal soft rot in several species of *Echinocereus* can be caused by the fungal pathogen *Helminthosporium*, although there is no evidence that *Helminthosporium* affects Arizona hedgehog cactus (Kelly and Olsen 2011).

Earlier in its listing history, several sources indicated that javelina (*Pecari tajacu*) were observed feeding extensively on Arizona hedgehog cactus and therefore may be of concern to the recovery of the species (Fletcher 1984, Cedar Creek Associates, Inc. 1996). While javelina have the metabolic ability to eat many species of cactus, they appear to prefer prickly pears due to their abundance, fewer and less rigid spines, and high ratio of succulent-to-woody tissue (Neal 1959, Crosswhite 1984). While javelina may consume Arizona hedgehog cactus, very few observations of javelina consuming Arizona hedgehog cactus have been made, no recent follow-up monitoring has been conducted, and it remains uncertain what impact javelina herbivory may have on the hedgehog cactus throughout its range. However, field observations throughout its listing history note that javelina have dug up whole cacti on numerous occasions and this behavior may be cause for concern. Further monitoring and documentation of existing cactus will be important to determine to what extent javelina activity are impacting the recovery of the species.

2.2.2.4 Inadequacy of existing regulatory mechanisms:

There are state, Federal, and international regulations and conventions providing some protection to Arizona hedgehog cactus. Arizona hedgehog cactus are protected by the Arizona Native Plants Law, A.R.S. Chapter 7, Sec. 3-901 et seq. which prohibits collection without obtaining a permit on all public lands and directs that plants may not be moved off private property without contacting the Arizona Department of Agriculture. Forest Service regulation 36 CFR 261.9 (c)(d) explicitly prohibits damaging or removing any plant that is classified as a threatened, endangered, sensitive, rare, or unique species. Given the expansive range of the hedgehog cactus and rough terrain preventing access by law enforcement, this regulation is likely difficult to enforce. All native cacti are listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora. However, this convention only regulates export of cacti, and therefore does not regulate internal trade in cacti or habitat destruction.

2.2.2.5 Other natural or manmade factors affecting its continued existence:

Human activities have contributed to changes in global climate. For the last four decades, each decade has been successively warmer than the preceding one (Intergovernmental Panel on Climate Change (IPCC) 2021). Increases in hot extremes, drought, the frequency and intensity of heavy precipitation events, and tropical storms, as well as declines in cold weather extremes, have been documented (IPCC 2021). Such trends are predicted to continue; future global

predictions include further rises in temperature, changes in precipitation patterns, and increasing weather extremes and events, among others (IPCC 2021).

Even though cacti are adapted to conditions of aridity, direct sunlight, high daytime temperatures and periods of drought may surpass the species' environmental tolerances resulting in plant mortality, reduced reproductive capacity, and range contractions. In one study modeling the impact of climate change on habitat suitability for 408 cactus species, researchers found that the majority of cacti will experience a reduction in favorable climate, with about one quarter of species projected to be exposed to environmental conditions outside of their average habitat conditions in over a quarter of their current distribution (Pillet et al. 2022). It is important to note that there is very little species-specific information analyzing impacts of climate change on Arizona hedgehog cactus, therefore in some cases we are reviewing literature for related species in the genus *Echinocereus*.

The National Climate Assessment indicates that the southwestern United States will continue to get hotter and drier into the future (Garfin et al. 2014 pp. 464–466). Based on statewide precipitation patterns, Arizona is experiencing a long-term drought, which is currently in its 27th year (Frankson and Kunkel 2022). According to the Arizona Climate Summary, temperatures in the state have risen about 2.5 degrees Fahrenheit (°F) (1.4 degrees Celsius [°C]) since the beginning of the 20th century. Since 1995, the number of days with a maximum temperature of 100°F or higher have been near to above average, reaching a record high from 2015 to 2020. The number of nights with a minimum temperature of 80°F or higher has been trending upward since 1995, also reaching a record high from 2015 to 2020 (Frankson and Kunkel 2022).

Climate within the range of the Arizona hedgehog cactus is semi-arid, characterized by hot, dry summers and cold, dry winters. From 2000 to 2020, average temperatures for northeastern Arizona have differed from the long-term average by an increase of 1.6 to 1.8°F. In addition, the region has been abnormally dry, experiencing increased moderate to severe drought conditions (EPA 2023). It is important to note that annual precipitation does vary short-term from year-to-year, depending on whether the region is experiencing an El Nino (wet) or La Nina (dry) year. However, the region of interest is likely to experience changes to weather which will result in increased risk of wildfires, where warm spring and summer temperature are already strongly associated with reduced winter precipitation (Westerling et al. 2006). Climate data collected from Miami, Arizona from 1961 to 1990 reported annual mean precipitation of 19.7 inches, and annual mean maximum and minimum temperatures of 76.1°F and 49.6°F (24.5°C and 9.8°C) respectively. Climate data from 1981 to 2010 reported annual mean precipitation of 18.38 inches, and annual mean maximum and minimum temperatures of 78.1°F and 51.8°F (25.6°C and 11°C) respectively (Western Regional Climate Center (WRCC)

n.d.). These trends clearly indicate a decrease in average annual precipitation and increase in average annual temperature over time. Because seeds require moisture to germinate, it is possible that these precipitation trends may negatively impact Arizona hedgehog cactus seed germination in the long-term.

Under all emissions scenarios, soil moisture is expected to decrease (IPCC 2021 p. 22). In *Echinocereus engelmannii*, root growth was influenced by soil moisture preserved closest to or under rocks (Nobel et al. 1992). The Arizona hedgehog cactus prefers narrow soil pockets between boulders or larger cracks within bedrock, which provide shelter from higher temperatures of exposed soil (Cedar Creek Associates, Inc. 1996). Given the relationship between greenhouse gas emissions and decrease in soil moisture and the fact that rocky environments, such as those suitable for Arizona hedgehog cactus habitat, exacerbate the effects of drought due to limited available soil (Pimienta-Barrios et al. 2002), it is possible that climate change may impact soil moisture, and therefore degrade habitat suitability, for the Arizona hedgehog cactus.

The impact of climate change in the desert southwest has been evident for several decades. Declines in vegetative cover including cacti in desert habitats are predicted due to climate change (Munson et al. 2013). One study documented high mortality of desert plants, including one species in the genus *Echinocereus*, in the Grand Canyon over a 100-year period, with mortality and recruitment attributed to drought and unusual precipitation, respectively (Bowers et al. 1995). Still et al. (2015) noted that several species in the genus *Echinocereus* are likely vulnerable to such effects. We therefore conclude that increased severity and frequency of drought associated with climate change predictions will likely reduce the long-term survivorship of the Arizona hedgehog cactus.

It is possible that climate change could affect Arizona hedgehog cactus physiologically. While there is evidence to support that succulent plants can quickly acclimate to elevated atmospheric carbon dioxide, especially in conditions where humidity is high and temperature is relatively low (Pimienta-Barrios et al. 2002, Larios et al. 2020), increases in atmospheric carbon dioxide and climate warming have been shown to affect photosynthetic processes (Huxman and Scott 2007, Aragón-Gastélum et al. 2014). Phenology, the timing of a plant's life cycle events, would also have to adapt to be in sync with unpredictable climatic changes (Walther et al. 2002). Plants may not be able to adjust their phenology or photosynthetic mechanisms rapidly enough to maintain viability while experiencing rapidly changing climatic conditions.

The 1979 final ruling and 1984 draft recovery plan for the cactus cites livestock grazing as a potential threat to the recovery of the species (U.S. Fish and Wildlife Service 1979a, Fletcher 1984). However, one survey indicated observations of physical damage to individual cacti due to cattle occurred at an estimated rate of about one individual in 400 to 500 observations, with one

observation of a cactus that appeared to be crushed by livestock (Cedar Creek Associates, Inc. 1996). Despite this, it is important to note that approximately 81% of the Arizona hedgehog cactus range occurs within Tonto National Forest grazing allotments (Figure 18). During a planting trip in April 2023 near Pinto Creek, USFWS, Forest Service, and Desert Botanical Garden staff observed a fishhook pincushion cactus (*Mammillaria viridiflora*) which appeared stepped on by livestock, as indicated by hoof prints directly beside the cactus (Figure 19). The specimen was approximately 9 cm (3.5 in) tall while still intact. Young Arizona hedgehog cacti (less than three years of age) have been observed to measure between 4 and 4.5 cm (1.6 to 1.8 in) in diameter and less than 10 cm (4 in) tall (Cedar Creek Associates, Inc. 1996). Much like the way *Erwinia carnegieana* causes soft rot in the lesions of saguaro cacti, damage from livestock may potentially increase the susceptibility of young and mature Arizona hedgehog cacti to disease (Steenbergh 1970). While the presence of cattle is heavily dependent on topography as a factor in grazing suitability, and it has been observed that many Arizona hedgehog cacti grow in cracks and crevices in suitable bedrock (Cedar Creek Associates, Inc. 1996), more research is needed to determine to what extent livestock presence impacts the recruitment and long-term survival of young cacti.

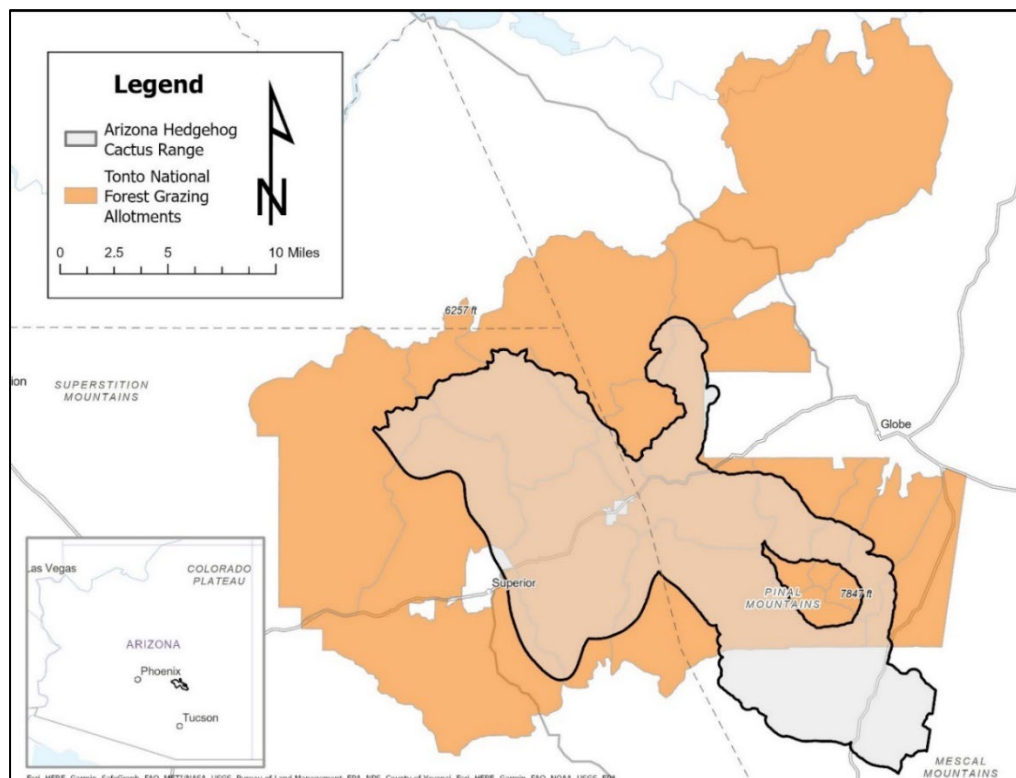


Figure 18. Tonto National Forest grazing allotments that overlap with Arizona hedgehog cactus habitat.



Figure 19. Fishhook pincushion cactus specimen trampled by livestock, observed March 9, 2023. Note the hoof print to the left of the cactus. Credit: E. Seavey, USFWS, 2023.

2.3 Synthesis

The Arizona hedgehog cactus is a narrow endemic cactus in the Superior-Globe region, Gila and Pinal counties in central Arizona. The species occurs from approximately 975 to 1615 m) (3,200 to 5,300 ft in the transition area where floristic elements of Interior Chaparral, Madrean Evergreen Woodland, and the Arizona Upland subdivision of the Sonoran Desert plant communities merge.

Several recovery plans have been drafted since its listing, however, none have been finalized. Discrepancies in field identification (for example, mistaking Arizona hedgehog cactus with Santa Rita hedgehog cactus (*Echinocereus santaritensis*) or other red-flowered hedgehog cacti), as well as varying methodologies for baseline inventory surveys and corresponding data collection, have resulted in a high level of uncertainty as to the exact range-wide population and distribution of the species. While numbers of known individuals remain relatively low, and threats are continuing and in some cases compounded by new or increasing threats such as wildfire, climate change, and invasive species, without this environmental baseline we are unable to track the population trends over time. Based on the information available, including population estimates and threats, the current listing for the Arizona hedgehog cactus is still appropriate.

Even without a finalized recovery plan, conservation measures have been developed in response to projects involving both road construction/realignment and mining operations since the species was listed. The Desert Botanical Garden, Forest Service, Arizona Department of Transportation, and other conservation partners have worked alongside the USFWS to make concerted efforts to identify and implement species-specific propagation, transplantation, and seed collection methodology. Transplanting, while not a guarantee for

plant survival, enables plants to remain within their native habitat and contribute genetic material through pollination to other individuals within the population. Monitoring of these transplant populations is ongoing, and we have yet to understand the long-term success rate of such methods.

Despite ongoing conservation measures, however, threats to the cactus have changed drastically since it was listed in 1979. In the 1984 draft recovery plan, it was suggested that threats to the cactus included: (1) illegal collection of seeds; (2) habitat loss to road construction/realignment, mining, and mining exploration (including road construction); (3) herbivory by livestock and wildlife; and (4) freeze damage. While there is some concern for illegal collection of cacti, and some losses have occurred due to road construction, this 5-year review has shown that wildfire, invasive species, and climate change, in addition to mining, may pose serious threats to the recovery of the species.

We believe that there are still many unanswered questions and much needed research pertaining to the species population and distribution, as well as the specific impacts of individual or combined environmental factors on the population, reproduction, and germination of the species. The best available information indicates that the number of known individuals remains relatively low, the range for the species is spatially limited, and threats such as mining, infrastructure development, nonnative invasion, climate warming, and wildfire remain present or increasing. For these reasons, we recommend that *Echinocereus arizonicus* var. *arizonicus* remain classified as endangered.

3.0 RESULTS

3.1 Recommended Classification:

- No change is needed

3.2 New Recovery Priority Number (indicate if no change; see 48 FR 43098):

No change recommended.

Brief Rationale:

The Arizona hedgehog cactus is a subspecies, threats persist or are increasing, and the recovery potential is considered high. Currently, we do not have enough information to determine a baseline population or long-term population trends since the species listing. There is evidence to support that threats to the cactus have persisted and increased both spatially and temporally since the species' listing. Although more information on long-term population trends and the success of conservation measures is needed, conservation actions to mitigate threats are being implemented and we and our partners are committed to increasing efforts to investigate and implement conservation planning, population and habitat restoration, and fuels reduction projects to aid species recovery.

3.3 Listing and Reclassification Priority Number, if reclassification is recommended (see 48 FR 43098):

Reclassification (from Threatened to Endangered) Priority Number: N/A
Reclassification (from Endangered to Threatened) Priority Number: N/A
Delisting (Removal from list regardless of current classification) Priority Number: N/A

Brief Rationale:

N/A

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Based on recent discussions with conservation partners, we recommend the following future actions:

Conservation Planning

- Continue to verify or reconcile existing records to better determine the Arizona hedgehog cactus population pre-Telegraph Fire.
- Aggregate verifiable records from HDMS, conservation partners, and action agencies into one database to clarify existing spatial and temporal trends to track naturally occurring populations and recovery actions over time.
- When workloads permit, conduct a Species Status Assessment to guide the development of a finalized recovery plan.
- Work with partners to improve species census data across identified suitable habitat using standardized protocols. Continue to update range map as more information becomes available.
- When feasible utilize novel survey techniques such as drone surveys during flowering season.
- Work with Tonto National Forest and other partners to create a habitat suitability model for Arizona hedgehog cactus based on elevation, vegetation type, and geology.
- Work with Tonto National Forest botanists and biologists to create a protected botanical area that limits habitat disturbance in perpetuity.

Restoration

- Work with conservation partners to improve and restore Arizona hedgehog cactus habitat at transplant sites and, if resources are available, in select areas that have been previously impacted by unnatural disturbance (wildfire, construction, mining, etc.).
- Continue to monitor and maintain transplanted Arizona hedgehog cactus populations for up to five years, including monitoring of parent plant populations (plants from which transplants were cut) to determine whether the removal of cuttings negatively impacts parent plants. Based on monitoring outcomes, work with partners to adjust extraction, harvest, and transplantation protocols accordingly.
- Support partners and researchers investigating the viability of seed collection, banking, and propagation for future restoration plantings.

Fire Monitoring and Management

- Support Tonto National Forest and Desert Botanical Garden with post-wildfire monitoring of Arizona hedgehog cactus populations and their habitat.
- Support Tonto National Forest and other land management practitioners with invasive species and other wildfire fuels treatment and reduction in Arizona hedgehog cactus habitat to reduce the risk of unnaturally large and intense wildfires. This would likely include increasing native plant diversity at restoration sites and monitoring the effects of both prescribed and wildfires for adaptive management of occupied habitat.

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U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW of Arizona Hedgehog Cactus

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service, Arizona Ecological Services Office

Approve _____