

**ARIZONA GAME AND FISH DEPARTMENT
HERITAGE DATA MANAGEMENT SYSTEM**

Plant Abstract

Element Code: PDCAC0E010
Data Sensitivity: YES

CLASSIFICATION, NOMENCLATURE, DESCRIPTION, RANGE

NAME: *Pediocactus bradyi*
COMMON NAME: Brady Pincushion Cactus, Brady's Plains Cactus
SYNONYMS: *Toumeyia bradyi* W.H. Earle
FAMILY: Cactaceae

AUTHOR, PLACE OF PUBLICATION: Benson, L. 1962. Cactus and Succulent Journal 34:163-168.

TYPE LOCALITY: Near Marble Canyon of the Colorado River, Coconino County, Arizona.

TYPE SPECIMEN: POM 16807. Benson, E.L. and L. Benson. 21 April 1961.

TAXONOMIC UNIQUENESS: Eight species of *Pediocactus*, defined primarily by unique capsule dehiscence, occurring from the Columbia River Basin, Great Basin, Rocky Mountains and Colorado Plateau. Seven of these species, including *P. bradyi*, are restricted endemics. *P. winkleri*, a rare cactus from Wayne County, Utah (200 km (33 miles) to the north), is the closest relative to *P. bradyi*. *P. winkleri* has peach-colored flowers and fewer radial spines (9-11) which are less pectinate than *P. bradyi*. There are no recognized varieties of *P. bradyi*.

DESCRIPTION: Small cactus of one or sometimes two semiglobose stems, to 6.5 cm (2.6 in.) long, and to 5.0 cm (2.0 in.) wide. **Areoles elliptic** and densely white or yellow-villous. Usually **no central spine**, but rarely 1 or 2. **Radial spines 14 to 15**, each 3.0-6.0 mm (0.12-0.23 in.) in length, white or yellowish, smooth, cartilaginous, semi-flexible (not sharp) and somewhat pectinate (comb-like with closely set teeth or divisions). Flowers straw-yellow in color, to 2.5 cm (1.0 in.) in diameter. Fruit green and top-shaped, the base constricted into a short stalk; turning brown at maturity.

AIDS TO IDENTIFICATION: Young individuals of *Coryphantha vivipara*, especially in the 10.0-20.0 mm (0.4-0.8 in.) diameter range, may resemble *P. bradyi*. These small *C. vivipara* have 10 to 25 radial spines. The greater number of radial spines give *C. vivipara* a matted appearance which distinguishes it from *P. bradyi*. The red to brown central spines characteristic of larger *C. vivipara* are lacking in small individuals.

ILLUSTRATIONS: B&W photo (Benson 1962: Fig.108, p.167).
B&W photo (Benson 1982: Fig.791, p.756).
Line drawing (Benson 1982: Fig.792, p.757).
B&W photo (Benson 1982: Fig.793, p.757).
B&W photo (Benson 1982: Fig 794, p.757).
Line drawing (USFWS).
Color photo: NatureServe 2019
Photos:

https://repository.arizona.edu/bitstream/handle/10150/555916/dp_21_02-013-0.pdf?sequence=1

TOTAL RANGE: Marble Canyon, Coconino County, Arizona. Scattered populations along both sides of the rim of Marble Canyon and tributary canyons for a distance of about 25 km in length (north to south) and varies in width from 1.6 to 6.6 km (USFWS 2012) from below

Lee's Ferry to the vicinity of Bedrock Canyon on the west side of Marble Canyon, to Tanner Wash on the east side of Marble Canyon, Coconino County, Arizona. Plants may be found from one to three miles from canyon rims. Total potential habitat has been estimated to be 17,000 acres, though only 10-20% appears to be occupied.

RANGE WITHIN ARIZONA: See "Total Range."

SPECIES BIOLOGY AND POPULATION TRENDS

GROWTH FORM: Globose Perennial Succulent

PHENOLOGY: Flowers late March to April; fruits mature late May to early June.

BIOLOGY: Flowers and fruit are produced by plants over 15 mm in diameter. Larger stemmed plants are more likely to produce multiple flowers; up to five flowers have been observed on one stem (Spence 1992). On sunny days, flowers open mid-morning and close in the evening, and may open for four or five successive days (Spence 1992). A mature fruit may contain 150 seeds; the total number of seed produced by a single plant over its life is relatively small. Hughes (1991) found that up to 76% of monitored adult plants produced fruit in some years; the lower the precipitation during the months preceding fruiting, the lower the fruit production. Recruitment dropped during the dry years of 1988 and 1990. Under cool temperatures and wet conditions, the *P. bradyi* is highly susceptible to root rot. Hughes (1991) stated that depredation by rodent herbivory is the single largest killer of the cactus, especially under drought conditions. Drought and frost heaving has contributed to loss of some plants.

Mycorrhiza are associated with the roots of this cactus. The fungus is acquired from the parent plant (the seed germinating immediately alongside the parent plant) or from the roots of grasses.

The 5-Year Review (USFWS 2012) including other "new" information (i.e., knowledge that was not presented in the 1985 Recovery Plan):

Although an estimate of 10-15 years lifespan was included in the 1985 Recovery Plan, there was no actual data to back this up. However, because there are still some of the original cactus on the 1985 BLM plots still living, we now know that lifespans can be as long as 20 years.

Pediocactus bradyi has the ability to retract below the ground during periods of stress or drought. Hughes (2005) documented a tagged cactus that retracted and reappeared after seven years. Retraction should be considered when comparing population data.

The study by Tepedino et al (2000) documented that *P. bradyi* is self-incompatible, and must be cross-pollinated. They also found the cactus to be insect-pollinated, and sweat bees (*Dialictus* spp.) were observed to be the primary pollinators. Vegetative reproduction has not been documented.

HABITAT: Grows in gravelly alluvium on gently sloping benches and terraces with very specific soil characteristics; with sparse vegetation characterized by scattered low shrubs (*Atriplex*, *Gutierrezia*, *Ephedra*) grasses (*Bouteloua*, *Sporobolus*), and annuals (*Sphaeralcea*, *Eriogonum*).

ELEVATION: 3,860 to 4,490 feet (1,177 – 1,369 m.), per the 5-Year Review (USFWS 2012).

EXPOSURE: Open, exposed, sunny situations; gently sloping; generally north-facing.

SUBSTRATE: Kaibab limestone chips overlaying soil derived from shale, mudstone, and siltstone of the Moenkopi Formation. Chert and quartz pebbles eroded from the Shinarump Conglomerate Member of the Chinle Formation are also present at some sites.

Hughes (2005) reports that *P. bradyi* grows on three different soil types: the Pennell sandy loam, gravelly loam, the Kinan Pennell complex, and the Disterheff/ Houserock complex. The one soil character that seems to indicate the possible presence of this cactus is the white rock chips that overlay the soil. These indicator chips have an abundance of clear crystalline coatings and a whitish color that appears to be the distinct property on which the cactus is found.

PLANT COMMUNITY: Great Basin Desertscrub. Associated plants include shadscale (*Atriplex confertifolia*), snakeweed (*Gutierrezia sarothrae*), Mormon tea (*Ephedra viridis*), and Desert Trumpet (*Eriogonum inflatum*).

The dominant vegetation types along the canyon rims are saltbush and desert grasslands according to Hughes 2005. The saltbush type is dominated by shadscale (*Atriplex confertifolia*), four-wing saltbush (*Atriplex canescens*), ephedras, with grasses being quite frequent in places. The desert grasslands are dominated by galleta (*Hilaria jamesii*), black grama (*Bouteloua eriopoda*), blue grama (*Bouteloua gracilis*), sand dropseed (*Sporobolus cryptandrus*), and Indian ricegrass (*Oryzopsis hymenoides*).

Roth (2008) described the 2005 survey season as difficult to monitor due to the excessive amount of annual exotic plants covering the plots during the survey period. Roth attributed the increase in annuals to the unusually high amount of rainfall (7.7 cm or 3.03 in) recorded at Lee's Ferry in February of 2005. Observations of shrub and cactus cover by Spence (2008) indicate the total shrub-succulent canopy cover has declined from a mean of 19.8 percent in 1993 to 8.3 percent in 2005. Spence stated that there has been an overall decline in native annuals which he states is not significant; however, a statistically significant change in exotic annuals from a mean count of 32 individuals in 1993 to 93 in 2005 is a 300 percent increase (5-Year Review, USFWS 2012). The significant change in exotic annuals recorded by Spence (2008) and observed changes by Roth (2008) could affect the germination and seedling establishment of *P. bradyi* through competition, although there are no data available to suggest this impact has yet occurred.

POPULATION TRENDS: Although all three agencies (BLM, NPS, NN) have been conducting long-term monitoring, there are differences in data collection and this inconsistency makes it difficult to compare trends across all landscapes and ownerships. The fact that *P. bradyi* has the ability to retract underground for several years at a time, also confounds annual counts (USFWS 2012).

There is not enough information to make a reliable estimate of the total population between all land owners. Surveys of potential habitat and possible additional populations still need to be completed, even though this effort has advanced. At this time (2012) the only reliable counts are from the monitoring plots and these figures are 268 (BLM), 148 (NPS) and 60 (NN) for a total of about 475 (USFWS 2012). To this number, another 108 can be added based on the results at the new "Cave" monitoring site reported by Hazelton 2014. Both Roth (in 2004) and Spence (2008) suggest their maximum populations could be about 1000 each on Navajo and Park Service lands. Butterworth and Porter (2013) believe there are less than

2,500 individuals in total. NatureServe (2019) list the species as critically imperiled, with only between 8-13 occurrences (some may no longer be extant).

BLM data described an upward trend for both size classes (0-15mm and 16-30mm) from 1994 to 1999. Starting in 2000, however, the larger class continued to increase, but there was a significant drop in the smaller class (0-16mm), which defined diminishing recruitment. This gap continued through 2009. Both NPS and BLM data demonstrates a peak in recruitment in 1994 and 1995 (respectively). This seemed to be an episodic reproductive success event. On the Navajo Nation lands, the population trend from counts on the monitoring plots not only shows a decline, but the R^2 value of .84 shows a close representation of the population trend. There have been some significant disturbances on these plots. There have been only 21 new recruits in 16 years of monitoring. The NPS population lies within a one-mile strip on the west side of Marble Canyon. There are four monitoring plots. After a modest increase between 1992 and 1994, the longer term trend has been a steady decline. This population occurs in the lowest, hottest, and driest part of the Brady pincushion cactus' overall range, and the trends of this population, if related to climate change, may suggest the beginning of a larger population-wide decline for the species. Spence (2008) notes that, at least on NPS lands "the major demographic problem in the population is the lack of seedling recruitment rather than juvenile or adult mortality" (USFWS 2012).

Data from the BLM plots, collected since 1985, probably provides the best representation of long-term environmental influences on the species. Although the population appears to be slowly increasing, there are also very significant fluctuations. The low R^2 value (.21) shows a low correlation with the population trend, and probably reflects a stronger correlation with environmental influences. Rodent depredations significantly reduced the population numbers between 1989-1991, but the population made a major recovery by 1997. This seems to show the ability for *P. bradyi* to be able to recover from a major mortality event. Between 1986 and 2004, the populations showed positive population dynamics (a total of 561 plants recruited vs 356 mortalities (USFWS 2012).

NatureServe states that the short-term trend is a decline of 10-30%. During the last five years (2010-2015), there has been a decline in the population that is likely attributed to a continuation of lower than average annual precipitation and snowfall rates, and increased temperatures that began in the late 1990s. If these environmental trends continue, recruitment is likely to decrease, ultimately driving the population towards a downward trend that may not be recoverable (USFWS 2012). Shryock et al (2014) also reported a similar conclusion. They used a matrix model to calculate stochastic population growth rates. Population growth was equally influenced by fecundity and survival and significantly correlated with increased annual precipitation and higher winter temperatures. They believe *Pediocactus bradyi* may be vulnerable to increases in the frequency and intensity of extreme climatic events, particularly drought. Biotic interactions resulting in low survival during drought years outweighed increased seedling establishment following heavy precipitation. Climatic extremes beyond historical ranges of variability may threaten rare desert species with low population growth rates and therefore high susceptibility to stochastic events.

SPECIES PROTECTION AND CONSERVATION

ENDANGERED SPECIES ACT STATUS:

LE (USDI, FWS 1979)

[PE USDI, FWS 1975]

STATE STATUS:

Highly Safeguarded (Arizona Native Plant)

OTHER STATUS:

Law, 1993)
Not Forest Service Sensitive (USDA, FS
Region 3 1999)
[Forest Service Sensitive USDA, FS Region
3 1990]
Group 2 (NNDFW, NESL 2000, 2008)
Near-Threatened (IUCN Red List 2013)
Sensitive (BLM, Arizona 2017)

MANAGEMENT FACTORS: *Pediocactus bradyi* faces a number of threats. It is highly desired for its ornamental value in the cactus and succulent trade, but very difficult to cultivate. Highway maintenance and road alignment (US 89A) has affected at least one population. Livestock grazing has had local impacts due to trampling. Additional threats include off-highway vehicles (OHVs) and impacts from dispersed recreation. Threats from mining activities (including uranium leasing) appear minimal at this time. Several new threats were identified in the 5-Year Review (USFWS 2012): climate change, rodent depredation and invasive exotic plant species. The overall threat impact is considered to be very high-high (NatureServe 2019). The very limited distribution of this endemic species, and the small number of populations, makes this cactus vulnerable to extinction.

The 5-Year review (USFWS 2012) analyses and summarizes the impacts of the identified threats:

OHVs. Damage from off highway vehicles has been identified as a threat. On BLM lands, improvements were made through road closures, and monitoring reports (2002, 2004, and 2007) did not document any OHV activity that resulted in damage to *P. bradyi* (Hughes 2009). For the NPS, the location of *P. bradyi* near the Lee's Ferry road suggests that the potential for OHV damage could exist; however, there is no current monitoring or documentation of such occurrence. Unauthorized vehicle access to *P. bradyi* habitat on the NN has been a problem in the past. In 2008, the NDFW installed a low running cable to prevent vehicle access to the area. Provided the cable on the NN is effective and additional road closures on BLM lands remain in place, we believe the threat from OHVs to *P. bradyi* is low and are no longer considered significant.

Uranium Mining. No active uranium mining occurs within *P. bradyi* habitat and the Secretary of the Interior has approved a withdrawal of approximately one million acres of public land surrounding Grand Canyon National Park from mineral entry for 20 years. Uranium mining has become an insignificant threat to the species and is not expected to occur in the foreseeable future.

Livestock Grazing. On BLM lands, livestock trampling transects on the Kane Ranch Allotment (completed in 2001, 2002, and 2003) identified a total of 15 cacti that were stepped on, but only one of those resulted in a mortality (Hughes 2005). Although livestock trampling is still possible, the BLM recognizes that the occurrence is infrequent to uncommon (BLM 2007). So as long as grazing continues where *P. bradyi* occur, the threat from livestock will remain but the severity of impact is considered low and is not anticipated to increase in the foreseeable future if current management practices on BLM lands are maintained. On the NN, grazing practices continue to occur and all *P. bradyi* populations are potentially impacted by livestock trampling. The exposure of *P. bradyi* to livestock in these areas may have significant effects because there is no grazing plan and livestock may remain in the area year round (Roth 2004). For this reason, livestock grazing on NN lands remain a significant threat

to *P. bradyi*. As of 1992, the NPS lands were not grazed by cattle, and no sign of livestock activity was seen in the area (Spence 1992). Livestock grazing on NPS lands should continue to be an insignificant threat to *P. bradyi*.

Collection. Annual monitoring of the cactus indicates collection is rare on BLM and NPS lands (Hughes 2005 and Spence 2008) and Roth (2008) indicates illegal collection appears to be a minor threat on NN lands. The USFWS considers the threat from collection to be low and no longer considered a significant threat to *P. bradyi*.

Recreational ORVs. Off-road vehicle recreational use has been reduced to a minimum on BLM and NPS lands but NN lands may continue to have violations if the low running cable to deter vehicles in *P. bradyi* habitat is ineffective.

Filming Crews and Movie Set Locations. On the NN, the Navajo Office of Broadcasting Services (Navajo Nation Department of Parks and Recreation [NDFW]) regularly gives out permits for filming along the picturesque rims of Marble Canyon. These permits do not require film crews to clear an area through biological assessments or evaluations. Without resolutions or changes in communication between the two departments, and threats from filming crews will likely continue in the future. These ground disturbing activities resulted in mortality and in soil compaction which restricts recovery and seedling recruitment. Recreational and commercial filming activities are having and will continue to have detrimental impacts on *P. bradyi* on the NN.

Disease or Predation. Disease is not mentioned as a new threat; however, there have been instances where predation by rodents has impacted populations during times of drought. The potential threat from rodents is significant and is likely to have adverse impacts to populations of *P. bradyi* in the future, particularly under drought conditions, when other sources of moisture for rodents become scarcer.

Inadequacy of existing regulatory mechanisms. The applicable laws and management plans for BLM and NPS have provided good protection for the species. We believe the regulations and management plans for BLM and NPS will continue to provide protections for *P. bradyi* in the future. However, the habitat on NN lands is not protected by any existing regulations. This inadequacy of regulatory mechanisms on NN lands is a moderate threat and is likely to continue in the future.

Climate Change. Overall effects from climate change to *P. bradyi* are unknown, but diminished seedling recruitment and overall population numbers described above could be exacerbated by temperature increases and precipitation decreases. Depending on the specialization of the native bee pollinators of this cactus, changes in climate could also alter the blooming and foraging timing between the cactus and its insect pollinators, leading to changes in pollination occurrence and efficiency, and ultimately, impacts to sexual reproduction. Although the effects of climate change are not clearly understood at this time, the impacts to the populations of *P. bradyi* could be severe in the future.

Invasive Plant Species. The rapid increase in the exotic Mediterranean grass (*Schismus barbatus*) in the locality occupied by *P. bradyi* may have been triggered by recent changes in climate. Spence (2008) states the proliferation of this exotic grass could negatively affect soil moisture within suitable habitat for *P. bradyi*, and increase the potential for fire in high density years. This information described by Spence (2008) is anecdotal and speculative in theory and there are no current data available to confirm or dispute the potential influences of exotic grasses to cacti at this time. The impacts from altered pollinator behavior and a

reduction of soil nutrients and water could adversely affect *P. bradyi* populations, but the extent of these impacts is unknown at this time. At this time (2012) the threat is judged to be low to moderate and may continue to affect *P. bradyi* in the future.

Although specific information on the genus *Pediocactus* and fire adaptations are unknown, we expect the invasion of annual, non-native species will likely increase the frequency and severity of fire beyond historical conditions within the *P. bradyi* habitat. The threat from non-native grasses and the potential for increased fire behavior is a severe threat to *P. bradyi* and is likely to increase in the future.

Small Population Size and Limited Genetic Mixing. Although the specific reasons for small population sizes are unknown, the isolated distribution could create conditions of lowered connectivity between *P. bradyi* locations and decreased genetic diversity. The small populations and potentially limited genetic mixing are likely a severe threat to *P. bradyi*. Genetic studies would be useful for the long-term management of this species.

CONSERVATION MEASURES TAKEN: There has been considerable effort devoted to the conservation of *Pediocactus bradyi*. The major milestones have been:

- The species was listed as endangered under the ESA in 1979.
- A recovery Plan was completed in 1985.
- BLM developed a habitat management plan in 1986.
- The BLM created the Marble Canyon Area of Critical Environmental Concern (ACEC) in 1992 and completed the MC ACEC management plan in 1994.
- BLM established permanent monitoring plots beginning in 1980 and others since 1984; as of 1992 there are four BLM monitoring plots.
- Surveys were conducted on the Navajo Nation in 1991 and 1992. Monitoring plots established in 1991 by the Navajo Natural Heritage Program at Jackass Canyon.
- Monitoring plots established in 1992 at Glen Canyon National Recreation Area, NPS.
- Biological Opinion on Kane Ranch Allotment Management Plan was issued by USFWS in 2001. This resulted in moving livestock watering points, closing areas to vehicles and monitoring to determine livestock trampling effects on the cactus.
- 5-Year Review 2012
- Proposed Amendment 1 to Recovery Plan 2018.

The 5-Year Review (2012) summarizes the progress that has been made per the 5 steps outlined in the Recovery Plan:

1. Remove threats to *Pediocactus bradyi* by enforcement of existing regulations and management of the habitat for protection of the species. The species is protected by many laws and regulations (see above). Habitat and species protection is augmented by management plans and monitoring programs implemented by the principle agencies (BLM, NPS, NN). Results of actions taken:

Collection: although all agencies note the threat potential of illegal collecting, monitoring and status reports note that there is little to no evidence on BLM and NPS populations, and if it is occurring on NN lands, it is minimal.

OHVs: Monitoring reports (2002, 2004, and 2007) did not record any OHV activity that resulted in effects to *P. bradyi* (Hughes 2009). The NPS population grows within a few hundred meters of the Lee's Ferry road. There were vehicle tracks near the plants, but no damage was noted. NN has had some issues with compliance but keeps trying new remedies.

Uranium Mining: At this time no active uranium mining occurs within *P. bradyi* habitat. In addition, in 2011, the Secretary of the Interior approved a withdrawal of approximately one million acres of public land surrounding Grand Canyon National Park from mineral entry for 20 years.

Livestock Grazing: BLM recognizes that injury or mortality of *P. bradyi* by livestock trampling is possible, but documentation of this occurrence is infrequent to uncommon and has only occurred in less than three percent of study plots (BLM 2007). Recent monitoring suggests rodent depredation is more prevalent than livestock trampling (Hughes 2009). NPS lands are not grazed by cattle. On the NN, all populations are potentially impacted by livestock trampling. The exposure of *P. bradyi* to livestock in these areas may have significant effects because no grazing plan exists and livestock may remain in the area year round.

2. Sustain healthy populations in their natural habitat at the existing sites. The USFWS states that the current regulations and protections (Federal, state, tribal, and International Trade regulations), and ongoing management plans identified all work toward sustaining a healthy population of *P. bradyi* in their natural habitat.

3. Develop a comprehensive trade management plan (CTMP) for all cacti. To date (2012) a CTMP has not been developed for *P. bradyi* or any other cacti. Monitoring reports from BLM, NPS, and NN have not noted the collection of *P. bradyi* for trade as a significant factor in the decline of the species. Collections have been made on some of the study sites, but with the implementation of the existing regulations and management plans, the USFWS does not believe the development of a CTMP for *P. bradyi* is a critical need at this time.

4. Develop public awareness, appreciation, and support for the preservation of *Pediocactus bradyi*. According to the 5-Year review (2012) the NN does not seem to have support from the public for preservation of *P. bradyi* at this time. Hughes (2005) attributes the successful protection of *P. bradyi* along a portion of the Marble Canyon rim on BLM lands to the addition of educational signs to a fencing project that deters vehicles from driving over the cactus. He also states that the public living in the Marble Canyon area has been helpful and cooperative.

5. Develop propagation techniques to provide nursery stock for possible reintroductions to its historic range. Artificial propagation of *P. bradyi* is extremely difficult and research in the area of propagation is limited. Roberts (2006, in USFWS 2012), says this cactus and others in this genera generally require a separate hot house; a completely dry period from April 15 to July 30; and cool summer nights to survive in cultivation. In fact, cool nighttime temperatures are required to allow a specific type of photosynthesis called crassulacean acid metabolism (CAM) to occur. The initiation of CAM through cool temperatures opens the stomata and allows the carbon dioxide requirement to grow.

As shown in steps one through five above, significant efforts have been made to protect the known habitat on BLM, NPS, and NN lands. What is still lacking, however, is a complete survey of *P. bradyi* populations. Without an evaluation of the extant population that exists on suitable habitat on all three land management agencies, it cannot be determined if down-listing requirement of 75 percent of the habitat protected has been met.

In spite of the efforts made over the past 30 years, the overall population trend for this endangered species is still declining. In the 5-Year Review, the USFWS (2012) did change the recovery priority number from a 2 (high degree of threat and high recovery potential) to a 5 (high degree of threat and low recovery potential).

A new monitoring area, “The Cave” was established on the east rim of Marble Canyon by the NNHP in 2009. A 5-Year Monitoring Report was prepared by Hazelton in 2014. On the seven plots, a total of 159 cacti were recorded. The plots were divided into two groups referred to as the Ridgeline and Campsite. The Ridgeline populations exhibited a steady decline over the 5-years, averaging a loss of 7.4 cacti per year. The Campsite populations were essentially steady with a slight increase. The causes of mortality could not be determined for the majority of lost cacti, but were ascribed to drought conditions. There were 51 mortalities recorded during the five year period. Hazelton does point out that this limited set of five year data for this new monitoring area might not describe an actual trend. Shryock et al (2014), working with longer term data demonstrated that 14 years of data was required to achieve a reasonable statistical confidence interval. This probably derives from the fact that *P. bradyi* and many other non-clonal cacti in the region are known to recruit only sporadically, in response to exceptional precipitation events. Nonetheless, Hazelton concludes that regardless of the length of the data sets, all data point to a decline in numbers of this species, and the causes are not completely clear. Recruitment appears to be a problem, and mortality is uncomfortably high and not always connected to measurable or controllable threats.

In 2018, the USFWS issued a proposed amendment to the 1985 Recovery Plan. Their proposal seeks to both clarify and add to the original recovery plan. First, they add two definitions:

Population: Groupings or single plants within 2 km of each other within areas of suitable habitat (NatureServe 2004). Based on these criteria, the USFWS believes there are seven populations of Brady pincushion cactus.

Disturbance: Destruction of the biological crust and modification of microwatersheds (as defined by Wallace and Romney [1981], cited in USFWS 2018) that negatively impacts individuals, the seedbank, and the successful re-establishment of the species.

Second, in addition to the down-listing criterion of “permanent protection of 75 percent of the known habitat” stated in the original recovery plan, the amendment proposes implementing actions in order to determine when the plant should be down-listed as follows:

Inventory the amount of Brady pincushion cactus habitat that has permanent protection in place (addresses all five-factor threats). Compare the amount of cactus habitat known to the amount of habitat that has had permanent protections put in place. The BLM has designated most, if not all, of the habitat on BLM-administered lands as an ACEC, providing extra management protections to the cactus in perpetuity. The amount of habitat existing on Tribal land needs to be added to the cumulative total of habitat in order to determine if the ACEC accounts for 75 percent of the known habitat for Brady pincushion cactus.

- Conduct census of land ownership and habitat protections implemented. Compile maps of landownership and determine what special management protections have been implemented to permanently conserve Brady pincushion cactus habitat. Define what constitutes permanent protection and what actions can be taken, or have been taken, to ensure permanent protection for the cactus’ habitat.
- Propose down-listing of Brady pincushion cactus. If 75 percent of the cactus’ habitat has been permanently protected, then we should propose down-listing to threatened.

Third, the amendment proposes de-listing criteria for the first time:

1. Maintain populations at a level that demonstrates stable or increasing plant abundance and maintain the current distribution of locations within each population. Plant abundance

(measured by the number of plants) may fluctuate within locations and populations, but the defined populations should be stable or increasing over a consecutive 10-year period.

2. Ensure no more than 20 percent of the occupied Moenkopi shale and sandstone habitat (as defined in the Recovery Plan and final rule to list the species: 44 FR 61784) within each of the populations is disturbed over a consecutive 10-year period.

And fourth, the proposed amendment includes implementing actions for recovery criteria:

Conserve known extant Brady pincushion cactus populations and their habitat (addresses all five-factor threats). The primary threat to the cactus is the loss of habitat, mostly associated with mining activities. Surveys have located the cactus only in Kaibab limestone chips overlying soil derived from Moenkopi shale and sandstone outcrops in northern Coconino County, Arizona. Preserving and enhancing these soils and habitat in this area is essential to the conservation of this species.

- Manage for and enhance habitat using available mechanisms like land acquisition programs, conservation agreements, management agreements, etc. Working in partnership with the BLM, use the BLM's administrative processes to amend ACEC plans to provide adequate protection to cactus habitat from mining activity. ACECs provide special management for habitat and the plants and wildlife within them. Work with the Navajo Nation to develop a habitat management plan to reduce threats to populations on tribal lands.
- Maintain all Brady pincushion cactus populations. Working in partnership with the BLM and Navajo Nation, use long-term management agreements, management plans, land designations, and other potential methods to ensure that all populations of cacti have stable or increasing plant numbers for 10 consecutive years to ensure populations are established and stable or increasing in size.
- Reclaim Disturbed Brady pincushion habitat. For a location to continue to count as Brady pincushion cactus habitat, the responsible land manager must reclaim any disturbed site through: 1) the collection and planting of cacti and associated native plant seeds and plants in disturbed areas using standard habitat restoration techniques, 2) transplanting, following tested protocols, of cactus individuals that cannot be avoided by disturbance, 3) collection of cactus seed, using approved techniques, to be saved for conservation in a designated seed storage facility, and 4) monitoring for 10 consecutive years to ensure populations are established and stable or increasing in size.
- Continue to monitor Brady pincushion cactus populations to determine long-term population trends with a minimum of 10 years of consecutive monitoring. All large populations should be monitored annually in order to establish a trend and determine whether or not cactus populations are stable or increasing in order to delist the species. Populations should be stable or increasing over a 10-year period beginning with the implementation of the recovery plan and this implementation strategy.
- Develop a standardized monitoring plan and protocol. In partnership, develop a cohesive plan for acquiring the quality and quantity of information required to detect population trends for this species. The monitoring plan should provide information regarding both plant abundance and population trend as well as habitat conditions. Monitoring protocols should include randomized monitoring plots across an area sufficient to detect population trends. Additionally, monitoring should include methods that will determine seedling survivorship. Use results from past monitoring efforts to inform improved monitoring protocols with the aim of facilitating consistency of data collection and analysis on a rangewide basis. Plant abundance and population trend will help determine if the cactus is remaining stable or increasing as monitoring continues over time.

SUGGESTED PROJECTS: The implementation of current management plans and the monitoring of established plots should be continued. Additional surveys should be conducted until all possible habitat has been identified so the total habitat area can be determined. To date (2012) it is not clear as to whether the 75% threshold of protected habitat has been met and the species qualifies for down-listing.

The 5-Year Review (USFWS 2012) includes the following recommended actions:

- The 1985 Recovery Plan should be updated with recovery criteria that reflect current threats to *P. bradyi*. Objective, measurable criteria for down-listing and de-listing should be established.
- Studies should be conducted to evaluate the climate data for each plot or plots at various elevations. Studies should focus on site specific climate changes such as precipitation, snowfall, and temperature that influence reproduction, retraction, and seed germination.
- Appropriate climate gauges should be installed throughout *P. bradyi* habitat within BLM, NPS, and NN lands.
- Studies should be conducted to evaluate the effectiveness of seed germination and seedling establishment, and if new populations can be established by seed or require transplanting of already established plants (Spence 2008).
- Studies should be conducted to evaluate the pollination ecology of *P. bradyi* and evaluate if the species is pollinator limited due to its early flowering (Spence 2008).
- Identify and implement the control or eradication of nonnative species where needed.
- Improve coordination and communication between the NDFW and Navajo Office of Broadcast Services for actions permitted within *P. bradyi* habitat.
- Establish consistent monitoring protocols that allow comparison of data for population trend analyses.
- Work with the NN to develop a grazing plan within *P. bradyi* habitat.
- Construct fencing exclosures with educational signage around *P. bradyi* populations that appear to be more exposed to film sets or that need protection from OHV use.
- Studies specific to genetics or trends in genetic variation should be completed.

LAND MANAGEMENT/OWNERSHIP: BIA - Navajo Nation; BLM - Arizona Strip Field Office; NPS - Glen Canyon National Recreation Area; Arizona State Highway right-of ways.

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ADDITIONAL INFORMATION: Heil et al. (1981) speculated that *P. bradyi* may have occurred further to the northeast along the Colorado River, but Glen Canyon Dam and the filling of Lake Powell behind it would have destroyed any populations that might have occurred there.

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