

Brady Pincushion Cactus
(*Pediocactus bradyi*)

5-Year Review:
Summary and Evaluation



Photo by Ryan Gordon, USFWS

**U.S. Fish and Wildlife Service/
Arizona Ecological Service Field Office
Phoenix, Arizona**

5-YEAR REVIEW

Brady Pincushion Cactus/*Pediocactus bradyi*

1.0 GENERAL INFORMATION

1.1 Reviewers

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

The U.S. Fish and Wildlife Service (Service) is required by section 4(c)(2) of the Endangered Species Act (Act) to conduct a status review of each listed species at least 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 Act. 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 U.S. Fish and Wildlife Service (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 Endangered Species Act (Act) (16 U.S.C. 1531 et seq.). We provided notice of this status review via the Federal Register (73 FR 14995) requesting information on the status of the Brady pincushion cactus (*Pediocactus bradyi*). A status review dated June 5, 2008, was provided by John Spence of the National Park Service (NPS) for the Glen Canyon National Recreation Area. No additional comments from the public were received. This 5-year review was completed using the best available information contained in Service files including the Brady Pincushion Cactus Recovery Plan (USFWS 1985), survey/monitoring reports compiled since the taxon's listing in 1979, and other technical reports and peer-reviewed journal articles. We used this information to provide a historical context of the species' status, a synopsis of its status and threats, and as a basis for our final status recommendation.

1.4 Background:

1.4.1 FR Notice citation announcing initiation of this review:

73 FR 14995, March 20, 2008

1.4.2 Listing history

Original Listing

FR notice: 44 FR 61784

Date listed: October 26, 1979

Entity listed: Brady pincushion cactus (*Pediocactus bradyi* L. Benson)

Classification: Endangered

1.4.3 Associated rulemakings: None

1.4.4 Review History: None

1.4.5 Species' Recovery Priority Number at start of 5-year review: 2

The recovery priority number of 2 indicates that an entity meets the taxonomic conditions for a species, with a high degree of threat and a high recovery potential.

1.4.6 Recovery Plan or Outline

Name of plan or outline: Recovery Plan for the Brady Pincushion Cactus
Pediocactus bradyi L. Benson

Date issued: March 28, 1985

Dates of previous revisions, if applicable: None

2.0 REVIEW ANALYSIS

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

2.1.1 Is the species under review a vertebrate?

☐ Yes
☒ No

2.2 Recovery Criteria

2.2.1 Does the species have a final approved recovery plan?

☒ Yes
☐ No

2.2.1.1 Does the recovery plan contain objective, measurable criteria?

☒ Yes
☐ No

The Brady Pincushion Cactus Recovery Plan includes one objective, measurable criterion to downlist the species from endangered to threatened. When the recovery plan was finalized in 1985, there were limited data available to quantify the total population abundance or other biological and ecological requirements on the species; therefore, criteria for delisting the species were not established.

2.2.2 Adequacy of recovery criteria.

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat?

☐ Yes
☒ No

The downlisting criterion was developed at the time the Brady Pincushion Cactus Recovery Plan was written in 1985 and does not reflect any new information that has become available since that date. In addition, new threats that are relevant to the species and its habitat have been identified and should be incorporated and addressed in a revised recovery plan.

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

☐ Yes
☒ No

Although recovery criteria are not specifically addressed, the downlisting criteria and step-down outline evaluate elements within each of the five listing factors. A list and discussion of these elements are found in section 2.2.3 below. Existing and new threats that should be considered are related to regional climate change, rodent depredation, and invasive species.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:

The Brady Pincushion Cactus Recovery Plan includes one measurable criterion to downlist the species from endangered to threatened, which is *permanent protection of 75 percent of the known habitat*. This criterion has been partially met. Management plans and monitoring agencies covering habitats where the cactus is known to occur are protecting these populations; until the species has been entirely surveyed to determine the

total area of habitat, it is not clear as to whether the 75 percent threshold of protected habitat has been met.

The five steps outlined in the plan to attain this criterion and actions taken to address them are listed below.

1. *Remove threats to Pediocactus bradyi by enforcement of existing regulations and management of the habitat for protection of the species.*

Pediocactus bradyi is currently protected by the following Federal, state, tribal, and International Trade regulations.

- Endangered (44 FR 61784, October 26, 1979)
- Endangered (Navajo Tribal Code Title 17, Subchapter 507)
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
- Arizona Native Plant Law (ARS 3-901B)
- Lacey Act (as amended 1981)
- Bureau of Land Management Regulation (43 CFR 6010.2)
- National Park Service Regulation (36 CFR 2.20)

Protection of *P. bradyi* habitat has been and is currently implemented through monitoring programs and management plans under the purview of the Bureau of Land Management (BLM), National Park Service (NPS), and Navajo Nation (NN). Monitoring plots for *P. bradyi* were established by BLM (1985), NPS (1992), and NN (1991). A Recovery Plan for *P. bradyi* was finalized in 1985. Within the Recovery Plan, BLM was tasked with and completed a Habitat Management Plan (HMP) (BLM 1986) for the Arizona Strip District Office. The BLM also completed an Area of Critical Environmental Concern (ACEC) Plan (BLM 1994), which includes management prescriptions for *P. bradyi* on BLM lands. In addition, the NPS developed a monitoring program for the Glen Canyon National Recreation Area (Spence 1992).

Management actions that work toward elimination of threats and/or the protection of *P. bradyi* and its habitat are identified and implemented through the various management plans listed above. The threats identified in the Recovery Plan include collection, off-highway vehicles (OHVs), uranium mining, and livestock grazing. Each threat is discussed in detail below along with the status of each action implemented to date.

Collection

Threats related to collection of *P. bradyi* were discussed in reports from BLM, NPS, and NN. The BLM's HMP (1986) states that collection occurs; although, monthly observations by BLM (from October 1984 to December 1985) did not find any sign of collecting. Hughes (2005) later concluded that there is little evidence to suggest any scale of collecting on BLM lands. For the NPS, Spence (1992) identified illegal collection as a threat; however, no unequivocal sign of such activities were observed during the initial assessment nor was it suggested as a significant threat to the population in the 2008 status report (Spence 2008). The NN survey results documented two plants removed at the survey site in 2008 (Roth 2008). Roth (2008) concludes that illegal

collection appears to be a minor threat but documentation and enforcement is difficult considering the area is remote.

Off-Highway Vehicles

The BLM identified OHV activity as being random and sparse due to the remoteness of the area (BLM 1986). In 1987 and 1988 three and two tagged cacti, respectively, were killed as a result of OHVs. Hughes later states in the 2005 monitoring report that compliance with closed roads and overlook points to Marble Canyon is good and that grass has over grown several of the old roads, and two locations have *P. bradyi* growing in the old vehicle tracks (Hughes 2005). More recent monitoring reports (2002, 2004, and 2007) did not record any OHV activity that resulted in effects to *P. bradyi* (Hughes 2009).

For the NPS, Spence (1992) mentions that of the three anthropogenic threats to the Lee's Ferry population, the most immediate threat at the time was OHV traffic. The population grows within a few hundred meters of the Lee's Ferry road, and there were vehicle tracks near the plants but no damage was noted.

The population on NN seems to have the most difficulty with compliance. Roth (2004) states that the main threats on the NN are a multitude of old and new access roads and associated OHV use ultimately leading to increased potential for habitat destruction. In late 1993 and early 1994 a film crew severely disturbed the monitoring site (Marble Canyon), decreasing the number of plants from 114 to 97. In 1995, a fence was constructed by the Navajo Department of Fish and Wildlife (NDFW) to prevent access by the general public and a locked gate was installed to allow access for the local land user and the NDFW personnel. The following year the fence post and fence were lifted to allow unauthorized public vehicles to pass through and by 1997 the gate was torn out allowing access to vehicle traffic once again (Roth 2008). The fence was replaced in 2001 and a new sign was erected explaining the reason for the closure. The gate remained unlocked to prevent further vandalism. But in 2001 a stunt jumper attempted to jump across a tributary to Marble Canyon bringing increased traffic to the monitoring site. In 2006, funding was provided from the Partners for Fish and Wildlife program which allowed the NDFW to install a low running cable between the road and the rim of the canyon in 2008. At the time of the 2008 review, it was too early to tell if the cable had prevented any further damage to the plants within the monitoring plots (Roth 2008).

Uranium Mining

No active uranium mining has been reported and no permits have been requested for NN and NPS lands. 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 (BLM and Forest Service (FS)) surrounding Grand Canyon National Park from mineral entry for 20 years. Only those claims that can produce valid existing rights will be approved for mining operations and, as a result of this, only four mines are anticipated to be developed, one of which was operational prior to the mineral withdrawal. Additionally, one of the anticipated mines is on FS land south

of Grand Canyon National Park. None of these anticipated mines occur in the House Rock Valley and these mines will not impact *P. bradyi* or its habitat.

Livestock Grazing

Livestock grazing occurs on BLM land and is in or near *P. bradyi* habitat. In the 2007 Environmental Impact Statement, BLM recognized the impacts of livestock grazing could lead to long-term changes to the soil and vegetation community that may ultimately affect rare plant species; however, studies in this area are inconclusive (BLM 2007). BLM also 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 indicates that rodent depredation is more prevalent than livestock trampling (Hughes 2009, 2010). The establishment of BLM's 1992 ACEC and subsequent 1994 plan included management prescriptions for *P. bradyi* on BLM lands. In 2001, a biological opinion on the Kane Ranch Allotment Management Plan was issued, which set into place a number of implemented actions to protect the cactus in addition to the ACEC plan. Detailed actions included moving livestock waters, closing areas to vehicles, and monitoring to determine livestock trampling effects on the cactus (Hughes 2005). Hughes (2005) documents only two cacti that were found killed by trampling since 1986. However, on the Kane Ranch Allotment, livestock trampling transects were completed in 2001, 2002, and 2003. A total of 15 cacti were stepped on but 14 of those were not injured. Only one cactus was found killed by livestock trampling where the soil was wet and the hoof prints were deep in the soil (Hughes 2005).

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 there is no grazing plan and livestock may remain in the area year round (Roth 2004).

As of 1992, the NPS lands were not grazed by cattle, and no sign of livestock activity was seen in the area (Spence 1992). There is no additional information available to suggest that the status of livestock activity in the area has changed to date.

1. Sustain healthy populations in their natural habitat at the existing sites.

We believe the current regulations and protections (Federal, state, tribal, and International Trade regulations), and management plans identified above all work toward sustaining a healthy population of *P. bradyi* in their natural habitat. Many improvements, such as BLM's completion of the HMP, the installation of the low running cable in 2008 on NN lands, and monitoring by all three agencies, have contributed to the protection of the populations through addressing each of the threats identified as collection, off-road vehicles, uranium mining, and livestock grazing.

2. Develop a comprehensive trade management plan (CTMP) for all cacti.

To date a CTMP has not been developed for *P. bradyi* or any other cacti. Monitoring reports from BLM, NPS, and NN have not recorded the collection of *P. bradyi* for trade as a significant factor in the decline of the species. Collection has been recorded on some of the study sites but with the implementation of existing regulations and management

plans identified in recovery criteria one above, we do not believe the future development of a CTMP for *P. bradyi* is a critical need at this time.

3. *Develop public awareness, appreciation, and support for the preservation of Pediocactus bradyi.*

As discussed above, the NN does not seem to have support from the public for preservation of *P. bradyi* at this time. The installation of the vehicle barrier cable and public awareness signs have not been in place long enough to show if they are effective or not. For the NPS, there is no information available to suggest that public outreach for the cactus has been completed to date.

Hughes (2005) attributes the successful protection of *P. bradyi* along a portion of the Marble Canyon rim 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 with the closures and that some local residents have become guardians for *P. bradyi* at their favorite locations (Hughes 2005).

4. *Develop propagation techniques to provide nursery stock for possible reintroductions within its historic range.*

Artificial propagation of *P. bradyi* is extremely difficult and research in the area of propagation for *P. bradyi* is limited. Roberts (2006), says this cactus and others in this genera generally require a separate hot house; a completely dry period from April 15 through July 30; and cold 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 (Roberts 2006). To date, development of an artificial propagation program to reduce collecting pressure on wild populations and provide nursery stock has not occurred; however, a study design has been prepared to collect data on several aspects of *P. bradyi* ecology. This study plan will be submitted for consideration of a Section 6 grant in 2012 and has seven primary objectives:

- Complete surveys in potential habitat to provide a reasonable estimate of the total population size;
- Characterize the invasive exotic plant species associated with known *P. bradyi* populations;
- Develop a uniform integrated monitoring program that follows the fates of individuals across the species' range;
- Conduct additional biological work on pollination ecology, herbivory and predation, and seed viability;
- Establish one or more new populations through seed transplant experiments;
- Compile existing and new data and prepare a status report;
- Provide data to the Service to support completion the 5-year status review.

Summary

As shown in steps one through five above, significant efforts have been made to protect the known habitat on BLM, NPS, and NN lands; however, a complete analysis of *P. bradyi* populations has not occurred. Without an evaluation of the extant population that exists on suitable habitat on all three land management agencies we cannot determine if 75 percent of the habitat is protected.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

Pediocactus bradyi is a small, semiglobose cactus with single stems (although rare, 2 to 4), 3.2 to 6.2 centimeters (cm) long and 2.6 to 4 cm in diameter. The spines are dense (typically no central spine) with each elliptic areole (white or yellow-villous) numbering 13 to 16 radial spines, 3 to 5 millimeters (mm) long (white or yellowish tan). The straw-yellow flowers are 2 cm long and 1.5 cm in diameter and its smooth green fruit (7 to 10 mm long and 10 mm diameter) turns reddish-brown at maturity. The fruit is top-shaped and constricted at the base, the apex slightly convex, dehiscing by a vertical slit. Seeds are brownish black, 2.8 mm long and 1.7-2.0 mm wide (Heil and Porter 2001).

Pediocactus bradyi is restricted to habitat composed of Kaibab limestone chips overlying soil derived from Moenkopi shale and sandstone outcrops. Chert and quartzite pebbles eroded from the Shinarump member of the Chinle Formation are also present at some sites (USFWS 1985). The rock chips that overlay the soil have clear crystalline coatings and a whiter color that appears distinct from the adjacent brown limestones where few or no *P. bradyi* occur (Hughes 2005). The cactus occurs between 1,177 and 1368 meters (m) (3,861 and 4,488 feet [ft]) in elevation, which is the altitude of the Kaibab Formation (USFWS 1985).

In the summer and winter months, *P. bradyi* spends most of its time below ground level covered by loose limestone fragments along the Marble Canyon plateaus of the Colorado River. The cacti typically respond to summer rainfall events by expanding above the soil (Heil et al. 1981). If the conditions are favorable the cacti will flower typically between March and April (Spence 2008). By May the cactus responds to drought conditions and rising temperatures by retracting into the soil.

The number of flowers range between one and five with a strong correlation between flower number and stem diameter (Spence 1992). Spence (1992) recorded flowers opening between 0900 and 1000 hours and closing in the evening, repeating the cycle over a four or five day period.

The vegetation where *P. bradyi* occurs is generally open and sparse, and characterized by low shrubs, grasses, and annuals. The biotic community is the Great Basin Desert Scrub. Dominant plant species include shadscale (*Atriplex confertifolia*), snakeweed (*Gutierrezia sarothrae*), Mormon tea (*Ephedra viridis*), and desert trumpet (*Eriogonum inflatum*).

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

Longevity. The longevity of *P. bradyi* was not clearly understood in 1985. Information provided in the Recovery Plan indicates the cactus has a lifespan of 10 to 15 years (USFWS 1985). However, we could not find any data in the Recovery Plan or literature to support this estimate. Since 1985, each land management agency has set up permanent monitoring plots (1985 on BLM lands, 1991 for NN, and 1992 for NPS) to evaluate long-term trends for the species. These data collection efforts by BLM, NN, and NPS have given the agencies enough information to describe *P. bradyi* as a long-lived species. Spence (2008) describes the species as long-lived and suggests recruitment occurs perhaps once every 10 to 20 years. Roth estimates the cactus may live approximately 20 years; however, age estimates can only be determined based on the original cactus found since their initial survey date (Daniela Roth, NN, pers. comm. March 2, 2009). In 1985, BLM set up permanent plots in four locations (Badger Creek with two plots, Soap Creek, and North Canyon) where each cactus was given a tag, mapped, and measured; therefore, our best estimate for longevity of the cactus currently relies on BLM data. Hughes (Lee Hughes, BLM, pers. comm. April 15, 2010) stated that there are still cacti in the permanent plots that were originally found and tagged in 1985. Based on the BLM long-term plot data, previous longevity estimates by Roth and Spence appear accurate, and may be even longer.

Retractability. *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. Because the species' emergence depends on drought conditions, we believe it may take several years to establish baseline data within a plot; therefore, retraction should be considered when comparing population data.

Reproduction. Breeding biology for the cactus has become more clearly understood since 1985. The NPS 1992 Monitoring Program Final Report states *P. bradyi*'s breeding biology appears to be typical for the family and suggests the species is self-incompatible (Spence 1992), meaning the pollen transferred between flowers on the same plant will not self-fertilize. Later, Tepedino (2000) summarized the reproductive characteristics in a study of 26 species of rare plants. The study results document the *P. bradyi* breeding system as cross-pollinated and self-incompatible. Tepedino (2000) 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 in literature reviewed.

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

Cactus Growth and Population Trends. Growth and population trends are documented by BLM, NPS, and NN in their annual monitoring reports or status updates. When conducting surveys, it is important to keep in mind the cactus's ability to retract below ground and thus the possibility that the plant may still be alive but undetectable, especially if drought conditions are prevailing. Each agency has monitoring plans that are set up to track specific trends in each of their populations. However, there are differences in data collection and this inconsistency makes it difficult to compare trends across all landscapes and ownerships. For example, the NPS began monitoring in 1992; they have a 5 year data gap between 1998 and 2002; their plots are circles 10 m (32.8 ft) in diameter; and size classes, starting with class 1, are arranged in 10 millimeter (mm) (0.39 inches [in]) increments in width. The NN started monitoring in 1991 and the size classes are arranged starting with 0-0.99 cm (0-0.39 in) to 1-1.99 cm (0.39-0.78 in) and ending at 5.99 cm (2.36 in). No plot sizes were provided in the annual reports. The BLM has four plots; two measuring 32 by 30 m (105 by 98.4 ft), one 28 by 30 m (92 by 98.4 ft), and one 10 by 120 m (32.8 by 393.7 ft). The BLM started surveys in 1985 and cactus individuals were classified into four different size classes measured in width rather than height between 1985 and 1988 but into five different size classes between 1990 and 1993. An additional and final change in 1994 was implemented to reflect the juvenile (0 to 15 mm [0 to 0.59 in]), adult (16 to 31 mm [0.63 to 1.22 in]), and greater than 31 mm [1.22 in]) size classes.

Shifts in Population Demographics. One notable change that is documented in the BLM population is where the 0 to 15 mm and 16 to 30 mm size classes makes a significant shift (Figure 1). Between 1994 and 1999 the two size classes maintained a similar upward trend in numbers; however, in 2000 the 16 to 30 mm size class continued on with the upward trend while a significant drop in the 0 to 15 mm size class occurred, reflecting a diminishment in recruitment. This gap between the two size classes has continued through 2009.

Recruitment. The BLM and NPS did identify that their long-term monitoring data show isolated trends in recruitment that could be influenced by periodic environmental conditions that are conducive to germination (Hughes 2008, 2009, 2010; Spence 2008). Monitoring by the NPS documented a peak in recruitment (1 to 10 mm size class) in 1994. In 1995, Hughes recorded a measurable increase in the 0 to 15 mm size class (from 90 cacti in 1995 to 138 in 1996) in one of the four plots (Badger Creek Plot) (Hughes 2001). He records this as being the only time in 15 years of monitoring that the small size class has been dominant and believes this occurrence is the result of an episodic reproductive event that may occur one year in 20. Hughes (2001) attributes the shift as a result of a good germination year when many small young cacti appeared. Although there are documented peaks in recruitment, the reason and the timing of such events are unknown.

Demographic Trend. Spence (2008) summarized site specific information in his status report. Spence (2008) notes that, on NPS lands “the major demographic

problem in the population is the lack of seedling recruitment rather than juvenile or adult mortality.” Spence (2008) used transition data from 1992 to 1997 and various stage-based transition models to look at the long-term trends in four plots. Based on the 1994 cohort, scenario one looked at mean survivorship and recruitment rates and scenario two looked at the best seedling recruitment and survivorship. In the first modeled scenario, Spence found population declines to less than 5 individuals in 86 years, and in the second scenario even if the seedling recruitment was 100 percent (based on observed number of seedlings), the population would still decline to less than 5 individuals in 90 years. Spence estimates the overall half-life of the 1994 cohort is 17 years.

Total Population Size. There is not enough information to make a reliable estimate of the total population between all land owners. The Recovery Plan states that “further studies are needed to determine the approximate numbers of individuals in the various populations,” and “the total estimated abundance may approach 10,000 plants” (USFWS 1985). At this time the only reliable number is based on the current monitoring data documented by each agency in Figure 2.

Monitoring plots for each agency identified 268 cacti for BLM (2009), 148 cacti for NPS (2005), and 60 cacti for NN (2006). These numbers are restricted to monitoring plots and to date total population abundance is still unknown. Roth (2004) states that “despite extensive surveys throughout the habitat, *Pediocactus bradyi* remains a rare and threatened species on Navajo Nation lands.” Roth believes the population estimate in the Recovery Plan may be a serious overestimate, at least when considering the low numbers on Navajo Nation land which is likely less than 1,000. Spence (2008), states that the total population on NPS lands has not been determined but that in 1992 the population was estimated to be between 750 and 1,000 individuals. Estimates of population abundance on BLM lands have not been evaluated, and without reliable estimates from all three agencies we cannot determine if the original estimate of 10,000 plants is accurate.

The one piece of information that was consistently tracked by NN, NPS, and BLM was the number of cacti found within their monitoring plots. We combined all the data available from each agency and plotted the number of cacti found each year to compare population trends (Figure 2). In addition we analyzed the specific data from each agency’s status and monitoring reports to identify specific population trends, demographic features, or trends with the information that was available. We provide a summary of our analysis for each agency below.

Bureau of Land Management (BLM)

We believe the plot sizes, number of individuals within each plot, and the 24 plus years of data collection (available through 2009) on BLM lands give us the best representation of long-term environmental influences on the *P. bradyi* population. Figure 2 shows the significant fluctuations in population size for BLM since 1985. Since 1985, the population appears to be increasing as shown by the linear regression line. However, because of the significant variations in the population

we included the R^2 value of the linear regression line. The R^2 value tells us how much of the variance in the independent variable (year) is explained by the dependent variable (number of cacti) on the population. The R^2 value for the linear regression line is 0.21, which is low and indicates a weak correlation with the population trend. Given the low R^2 value and the population changes seen in Figure 2, we believe the BLM plots and data indicate a correlation with environmental influences.

Although a direct correlation has not been determined, we identified climate condition as one significant factor that is influencing the population. Figures 3 and 4 show notable spikes and trends related to precipitation and temperature that could individually or in combination translate to yearly population changes seen in Figure 2. The timing and/or combination of population changes likely influence emergence, flowering, and seed production within the population. Between 1990 and 1999, a general increase in precipitation, several spikes in snowfall, and a steady rise in average maximum temperature parallel with an increasing population. Post 1999, temperatures above the median and a lack of snowfall most likely caused a sharp decline in the population. The population recovered slightly in 2002 but within the last three years the population has started to decline again. This trend is most likely attributed to a sharp increase in average maximum temperatures, a decrease in average precipitation, and a continuation of little to no snowfall since 1999 (Figures 3 and 4).

Depredation has also affected the population on BLM lands (Figure 5). In 1988, the North Canyon Plot had an unexplained population increase which was later affected by rodent predation reducing the population by 16 in 1989, 81 in 1990, and 40 in 1991. The mortality data tracked by BLM show that depredation by rodent herbivores is the single largest killer of *P. bradyi* (Hughes 1991). By 1992 the total population in the North Canyon Plot was reduced to 22 and it was not until 1997 that the North Canyon Plot approached 100 individuals. Despite the setback to the population, *P. bradyi* was still able to recover after a significant mortality event. In total, the cactus on BLM plots is described as having positive population dynamics occurring where recruitment (561 total) between 1986 and 2004 was higher than mortality (365 total) (Hughes 2005).

National Park Service (NPS)

In 1992, a long-term monitoring study was implemented by the NPS within Glen Canyon National Recreation Area. The NPS population consists of small patched and scattered plants along a one-mile strip on the west side of Marble Canyon (Spence 2008). Between 1998 and 2002 and again in 2004, no survey data were collected for the NPS. When monitoring started, the initial cohort consisted of 180 plants (in 4 plots). In 1994 after an initial peak of 207 individuals, the cactus has steadily declined (Figure 2). The last year of monitoring was in 2005, and only 148 plants were recorded in the four plots. In 2007 and 2008 most plants did not emerge or flower because of very dry conditions (Spence 2008). Spence (2008) does emphasize the significance that the NPS 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 in the species.

Beginning in 1998, noticeable climate changes resulted in above average temperatures followed by a decrease in precipitation and snowfall (Western Regional Climate Center 2010). As discussed previously, *P. bradyi* is known to retract out of sight during dry years, making monitoring results less conclusive. Because of the gaps in data collection, we believe the population numbers in 2003 and again in 2005 may not truly represent the total population. Population numbers were likely influenced by climate changes resulting in mortality and/or retraction, making it difficult to accurately evaluate the population trend on NPS lands.

Navajo Nation (NN)

The NN has seven plots that were monitored annually from 1991 to 1994 and again since 1997 (Roth 2008). In Figure 2, the linear trend for the NN shows a decline in the population since surveys began and the significance of the R^2 value 0.84 is more closely representative of the population trend. On the NN, disturbance from film crews combined with drought have decreased the population to 60 cacti in all seven plots. The NN plots contain only small numbers of cacti with the total population at 106 individual cacti in 1991. Roth (2008) notes that by 2008, 51 percent of the original population died and only 21 new plants were recruited in the monitoring plots in 16 years of monitoring.

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

Studies specific to genetics or trends in genetic variation have not been evaluated. The study described above does not address genetics, specifically; however some genetic data will likely be collected as a result of this study. A study specific to genetics of this plant would help in the long-term management of the species.

2.3.1.4 Taxonomic classification or changes in nomenclature:

The taxonomy and nomenclature of *P. bradyi* have not changed since the 1985 Recovery Plan.

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

The distribution of the species has not changed, and comprises an area approximately 23 kilometers (km) (15 miles [mi]) in length, north to south, and varies in width from 1.6 km (1 mi) to 4.58 km (3 mi). The range of *P. bradyi* is

limited to plateaus on both sides of the Colorado River along both rims of Marble Canyon, on specific soil types (See section 2.3.1.6 for more information on soils). “The populations of the Brady pincushion cactus on BLM land occur just south of Lee’s Ferry, on the rims of Badger Creek Canyon, along the Marble Canyon rim down to Soap Creek Canyon and on the rims of Ryder and North Canyons. On the NN, *P. bradyi* has been found from the Lee’s Ferry area across from Cathedral Wash to two miles north of Sheep Springs Wash. The Brady pincushion cactus occurs sporadically along the canyon rims with dense populations alternating with areas of no Brady pincushion cactus” (Hughes 2005). On NPS land, the cactus is found along a one mile strip on the west side of Marble Canyon (Spence 2008).

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

The cactus grows on sloped benches in exposed, sunny locations occurring between 1,170 and 1,360 m (3,861 – 4,488 ft) in elevation of the Kaibab Formation (USFWS 1985). It is an edaphic specialist found in association with Kaibab limestone pieces atop soil derived from Moenkopi shale and sandstone (USFWS 1985).

Specific soil formations and edaphic conditions that produced specific soil characterization where *P. bradyi* reside are described in the 2010 Soil Survey for the Glen Canyon National Recreation Area (USDA 2010). The characteristics of soil formation and specific factors that influence the development of each soil profile are determined by five soil-forming factors: the type of parent material, living organisms, climate, topography, and time (USDA 2010). The parent material, as described in the Glen Canyon National Recreation Area, is determined by the chemical and mineralogical composition of the soil and is classified into four types: residuum (material derived from weathered bedrock), colluvium (unsorted, unconsolidated material deposited by mass movement or gravitational action), eolian (material that is transported and deposited by wind), and alluvium (material that is transported by water). These parent materials, combined with living organisms and physical and chemical changes through climatic conditions (water, wind, and temperature), act together slowly forming a soil profile that has genetically related horizons that are defined through topography and time (USDA 2010).

Hughes (2005) described three soil conditions (or soil profiles) in which *P. bradyi* are found. These soils are characterized as Pennell sandy loam, gravelly loam Kinan Pennell complex, and Disterheff/Houserock complex. Within these soil types Hughes (2005) describes what he believes is the possible indicator of *P. bradyi* presence as white rock chips with abundance of crystalline coatings that overlay the soil. The Recovery Plan (USFWS 1985) mentions the presence of chert and quartz pebbles, eroded from the Shinarump member of the Chinle Formation, at some sites.

Pediocactus bradyi grows in the biotic community of the Great Basin Desert Scrub (Brown and Lowe 1980) with the dominant vegetation types being saltbush and Desert Grasslands (Hughes 2005). Plants associated with these two biomes include: shadscale (*Atriplex confertifolia*), four-wing saltbush (*Atriplex canescens*), mormon tea (*Ephedra viridis*), desert trumpet (*Eriogonum inflatum*), galleta grass (*Hilaria jamesii*), black grama (*Bouteloua eriopoda*), blue grama (*Bouteloua gracilis*), sand dropseed (*Sporobolus cryptandrus*), and Indian ricegrass (*Oryzopsis hymeniodies*) (Hughes 2005). As far as suitability of the habitat surrounding Brady pincushion cactus, 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 (Spence 2008).

2.3.1.7 Other:

Exotic Annual Plants. As mentioned above in 2.3.1.6, an increasing trend of exotic annual plants has been noted in *P. bradyi* habitat. 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. Roth further noted that germination and seedling establishment by exotic species may be particularly stimulated by high rainfall conditions, although the precise relationships between exotic plant fecundity and climate are not clear (Roth 2008). A 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; however, there are no data available to suggest an increase of exotics has affected the *P. bradyi* population.

Climate. Other natural factors that are shown to influence populations of *P. bradyi* are precipitation and temperature. The average temperature calculated from 1944 to 2009 at nearby Lee's Ferry is 77.5 degrees Fahrenheit (F) (Western Regional Climate Center 2010). Figure 3 shows a steady increase in temperature from 1991 to 2004. In 1999, the temperature rose past the median and for six consecutive years thereafter had annual maximum temperatures ranging from one to six degrees above average. This temperature trend continued until there was a sharp decline in 2005. Figure 4 records the amount of annual precipitation and snowfall near the BLM populations. Spence (2008) stated that most mortality occurs after extremely dry winters. No snowfall was recorded in the area between 1998 and 2007. Beginning in 1998 the annual precipitation started in a downward trend through 2009 except for two spikes in 2000 and 2004. Overall the steady increase in temperature, combined with declining precipitation and snowfall since

1998, may have contributed to the decline in the Badger Creek (beginning in 1996) and Soap Creek (beginning in 1998) populations (Figure 5).

In section 2.3.1.2 we discussed the 1999 size class shift in the BLM population where the 16 to 30 mm size class increased in numbers over the 0 to 15 mm size class. The shift was recorded in three of the four BLM plots (Badger Creek, and North Canyon East and West). The timing of this correlates with the temperature, precipitation, and snowfall changes mentioned above but the exact reason for the shift is unknown at this time.

The data for Soap Creek document the 16 to 30 mm size class as the dominant size class (Figure 1). There is no information available to explain how the Soap Creek population may or may not have been influenced by climate changes. Because *P. bradyi* is long-lived, continued monitoring and evaluation of the potential long-term impact of the size class shift in Badger Creek, and the North Canyon East and West plots is needed to see if the shift reverts to pre-1998 conditions after periods of more favorable climatic conditions.

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

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range (Factor A):

Off-highway vehicles, uranium mining, and livestock grazing are all threats identified in the Recovery Plan that could potentially impact *P. bradyi* through the destruction, modification, or curtailment of its habitat or range. These threats were discussed in detail under section 2.2.3 above. Although the enforcement of existing regulations and management of the habitat for protection of the species by BLM, NPS, and NN has been successful, a few isolated threats continue to occur.

Off-highway Vehicles. Several reports discuss the current or potential threat from OHV use on BLM, NPS, and NN lands. Historically, the threat from OHV activity was described by BLM as random and sparse (BLM 1986); Spence (1992) mentions that the most immediate threat at the time was OHV traffic on NPS lands; and since the early 1990s NN has documented unauthorized public vehicles accessed in areas where *P. bradyi* and its habitat occur (Roth 2008).

For BLM, improvements were made through road closures, and monitoring reports (2002, 2004, and 2007) have not documented any recent OHV activity that resulted in effects 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. Historically, uranium mining and exploration were considered potential threats due to a number of exploration and mining permits near *P. bradyi* populations that were submitted for review in the mid-1980s (USFWS 1985). As stated previously, no active uranium mining occurs within *P. bradyi* habitat and 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 (DOI 2012). No mines will occur in the House Rock Valley and, therefore, will not pose a threat to *P. bradyi*. Thus, we believe uranium mining has become an insignificant threat to the species and is not expected to occur in the foreseeable future.

Livestock Grazing. Historical livestock use, prior to the 1930s, on the BLM's Portion of the Kane Ranch was estimated to have about 3,000 head of cattle until the Grand Canyon Cattle Company became the operators and the herd was increased to 20,000 head. By 1934, the Taylor Grazing Act set into motion public lands grazing regulations (BLM 1999). Currently, management actions such as the 1992 ACEC plan and subsequent 1994 plan, and the Biological Opinion for the Kane Ranch Allotment Management Plan provided actions to protect *P. bradyi*, including moving livestock waters, closing areas to vehicles, and monitoring to determine livestock trampling effects on the cactus (Hughes 2005). The most recent RMP (BLM 2007) provides management actions for special status plants (including *P. bradyi*) where disturbance, injury, or mortality of such plants from livestock grazing will be minimized or eliminated through the implementation of conservation measures. As discussed previously in section 2.2.3, livestock trampling transects on the Kane Ranch Allotment (completed in 2001, 2002, and 2003) identified a total of 15 cacti that were stepped on and only 1 of those resulted in mortality (Hughes 2005). Although livestock trampling is possible, BLM recognizes that the occurrence is infrequent to uncommon (BLM 2007). Thus we believe 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 considered to increase in the foreseeable future due to current management practices on BLM lands.

Livestock grazing practices by the Navajos began during the late seventeenth century when livestock, mainly sheep and goats, were introduced by the Pueblos (Lieder 1993). 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 we believe 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). There is no additional information available to suggest that the status of livestock activity in the area has changed to date. Thus we believe livestock grazing on NPS lands will continue to be an insignificant threat to *P. bradyi*.

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes (Factor B):

Collection. Threats related to collection of *P. bradyi* were discussed in reports from BLM (HMP 1986), NPS (Spence 1992), and the Recovery Plan (USFWS 1985). Historically collections were considered a serious threat; however, 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. Thus we believe the threat from collection is low and is no longer considered a significant threat to *P. bradyi*.

Recreational Off-highway Vehicles. 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. As stated previously, 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 a significant threat.

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. Because of the short timeframe of the filming activities and the remoteness of the habitat, the NDFW may not be aware of all ground-disturbing activities in the habitat of *P. bradyi* (Daniela Roth, former NN botanist, summary of email communication, July 27, 2010). At this time we are not aware of any resolutions or changes in communication between the two departments, and threats from filming crews will likely continue in the future. As stated previously (section 2.2.3) disturbance occurred in 1993 and 1994 from a film crew and in 2001 from a stunt jumper. These ground disturbing activities resulted in mortality and in soil compaction which restricts recovery and seedling recruitment. We conclude that recreational and commercial filming activities are having and will continue to have impacts on *P. bradyi* on the NN.

2.3.2.3 Disease or predation (Factor C):

Disease is not mentioned as a new threat; however, there have been instances where predation by rodents has impacted populations during times of drought. Significant mortality attributed to rodents reduced the total population in the North Canyon plot (on BLM lands) from 240 individual cacti in 1989 to 81 in

1990 with an additional 40 cacti removed through predation in 1991. Future interactions with climate could increase the likelihood of predation for the cactus. We believe 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.

2.3.2.4 Inadequacy of existing regulatory mechanisms (Factor D):

The applicable laws and management plans for BLM and NPS have provided good protection for the species. Section 2.2.3 describes how the regulations have influenced protections of the cactus since 1985. 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 are not protected (Roth 2004) by any existing regulations. Although the Endangered Species Act is in place, “the inadequacy of regulatory mechanisms is one of the largest threats to endangered plants on Navajo lands because the Endangered Species Act does not protect plants on tribal lands unless there is a Section 7 nexus” (Daniela Roth, former NN botanist, email communication, July 27, 2010). In addition to inadequate regulations, the NN continues to have problems with not receiving the appropriate permit requests from the Navajo Office of Broadcasting Services (Daniela Roth, former NN botanist, pers. comm., March 2, 2009) for ground disturbing activities in or near *P. bradyi* habitat. As stated previously (section 2.2.3) disturbance occurred in 1993 and 1994 from a film crew and in 2001 from a stunt jumper. These ground disturbing activities resulted in *P. bradyi* mortality and in soil compaction which restricts recovery and seedling recruitment. Although a low running cable was installed to prevent vehicle access to the area where *P. bradyi* grow, illegal ground disturbing activities may still occur. Thus, we believe the inadequacy of regulatory mechanisms on NN lands is a moderate threat and is likely to continue in the future.

2.3.2.5 Other natural or manmade factors affecting its continued existence (Factor E):

Climate Change. Based on the unequivocal evidence of warming of the earth’s climate from observations of increases in average global air and ocean temperatures, widespread melting of glaciers and polar ice caps, and rising sea levels recorded in the Intergovernmental Panel on Climate Change Report (IPCC 2007), climate change is now a consideration for Federal agency analysis (GAO 2007). The earth’s surface has warmed by an average of 0.74 C (1.3 F) during the 20th century (IPCC 2007) and, since 1960, the annual average temperature across the United States has increased by more than 2 F (1.1C) (Global Climate Change Impacts in the United States [GCCIOUS] 2009). The IPCC (2007) projects that there will very likely be an increase in the frequency of hot extremes, heat waves, and heavy precipitation events as a result of climate change.

The IPCC projects there will be an increase in the frequency of extreme weather events that are temporally and spatially more variable as a result of climate change (IPCC 2007).

Climate change also involves an increase in atmospheric carbon dioxide which is commonly associated with increased temperatures and the greenhouse gas effect. Since 2000, the observed emissions of greenhouse gases, which are a key influence on climate change, have been occurring at the mid- to higher levels of the various emissions scenarios developed in the late 1990s and used by the IPCC for making projections (e.g., Raupach et al. 2007, Manning et al. 2010, Pielke et al. 2008). This increased carbon dioxide directly affects plant photosynthesis (Huxman and Scott 2007). At the plant level, adapting to drought involves the ability to balance carbon sequestration (the uptake and storage of carbon) and carbon respiration (efflux back into the atmosphere), and to maintain sustainable evapotranspiration rates (Huxman and Scott 2007). Adaptation would also require a plant to change its phenology (timing of life cycle events) to coincide successfully with extreme shifts in temperature, precipitation, and soil moisture (Walther et al. 2002) which are all part of the evapotranspiration equation. The potential for rapid climate change, which is predicted for the future, could pose significant challenges for plants because they may not be able to adjust their phenology or photosynthetic mechanisms quickly enough.

The 2002-2003 drought spanning southwestern North America was anomalously dry with unusually high temperatures (Breshears et al. 2005). In the Arizona Drought Preparedness Plan, the long term drought status, for the Little Colorado River Watershed is rated as abnormally dry (ADWR 2011). At a local level, Spence (2008) evaluated the changes in temperature and precipitation and considered the potential affects to the population. He stated that “the climate of Lee’s Ferry has changed significantly based on the re-constructed record extending back to 1944. Minimum temperature has increased more than mean and maximum temperatures. Since 1944 the mean annual minimum temperature has increased from ~48F to ~50 F, or 2 degrees F. Mean annual precipitation has also increased, from ~6.2 inches in 1944 to ~6.9 inches in 2007, or about 13 percent.”

Overall effects from climate change to *P. bradyi* are unknown, but diminished seedling recruitment and overall population numbers described above could be exacerbated by recent temperature increases and precipitation decreases. Depending on the specialization of the native bee pollinators of this cactus, changes in climate could alter the blooming and foraging phenologies between the cactus and its insect pollinators, leading to changes in pollination occurrence and efficiency, and ultimately, impacts to sexual reproduction. Interactions among population demographics should be monitored in conjunction with climate changes to understand and track the status of this cactus. Although the effects of climate change are not clearly understood at this time, we believe the impacts to the populations of *P. bradyi* could be severe in the future.

Invasive Plant Species. The spread of nonnative invasive species is considered the second largest threat to imperiled plants in the United States (Wilcove et al. 1998). Invasive plants—specifically exotic annuals—negatively affect native vegetation, including rare plants. One of the most substantial effects is the change in vegetation fuel properties that, in turn, alter fire frequency, intensity, extent, type, and seasonality (Menakis et al. 2003, Brooks et al. 2004, and McKenzie et al. 2004). Shortened fire return intervals make it difficult for native plants to reestablish or compete with invasive plants (D’Antonio and Vitousek 1992).

Invasive plants can exclude native plants and alter pollinator behaviors (D’Antonio and Vitousek 1992, DiTomaso 2000, Mooney and Cleland 2001, Levine et al. 2003, Traveset and Richardson 2006). For example, nonnative invasive grasses outcompete native species for soil nutrients, water (Melgoza et al. 1990, Aguirre and Johnson 1991, Brooks 2000), and space, and may even alter the soil conditions for germination. Invasive forbs can modify the activity of pollinators through producing different nectar compared to nectar from native species (Levine et al. 2003), or by attracting nonnative pollinators (Traveset and Richardson 2006). Introduction of nonnative pollinators or production of different nectar can lead to disruption of normal pollinator interactions for *P. bradyi*.

The rapid increase in the exotic species Mediterranean grass (*Schismus barbatus*) in the locality *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. But, as we describe above, other nonnative invasive grasses outcompete native species for soil nutrients and water (Melgoza et al. 1990, Aguirre and Johnson 1991, Brooks 2000) and we expect that Mediterranean grass could have the same impact to *P. bradyi*. The impacts from altered pollinator behavior and a reduction of soil nutrients and water could adversely affect *P. bradyi* populations; however, the extent of these impacts is unknown at this time. Thus, we believe the threat is low to moderate and may continue to affect *P. bradyi* in the future.

The potential for increased fire frequency and severity is a significant threat to *P. bradyi* since the habitat in which they reside is not fire adapted. Invasions of annual, nonnative species are well documented to contribute to increased fire frequencies (Brooks and Pyke 2002, Grace et al. 2002, Brooks et al. 2003). The disturbance caused by increased fire frequencies creates favorable conditions for increased invasion by nonnative grasses. The end result is a downward spiral where an increase in invasive species results in more fires, more fires create more disturbances, and more disturbances lead to increased invasive species densities. The risk of fire is expected to increase from 46 to 100 percent when the cover of cheatgrass (*Bromus tectorum*) increases from 12 to 45 percent or more (Link et al.

2006). The invasion of nonnative grasses into the Mojave Desert of western North America poses similar threats to fire regimes, native plants, and other federally protected species (Brooks et. al. 2004). Brooks (1999) also found that high interspace biomass of nonnative grasses resulted in greater fire danger in the Mojave Desert. Brooks (1999) goes on to state that the ecological effects of nonnative grass-driven fires are significant because of their intensity and consumption of perennial shrubs. Although *P. bradyi* does not grow in the Mojave Desert, the studies above include Mediterranean grass. Furthermore, the Great Basin Desert Scrub community that *P. bradyi* occur in does not receive much more rainfall; therefore, the effects of Mediterranean grass on *P. bradyi* are anticipated to be similar to those described in the Mojave Desert.

Although specific information on the genus *Pediocactus* and fire adaptations are unknown, we expect the invasion of annual, nonnative species will likely increase the frequency and severity of fire beyond historical conditions within the *P. bradyi* habitat. For example, the Paradine plain cactus (*Pediocactus paradine*) was impacted by the Warm Fire in 2006. The area burned experience high vegetation mortality and the Forest Service expects many of the cacti were killed since surveys did not produce any live cacti (USDA 2007). It was suggested that the modification of historical management practices resulted in vegetation changes and the spread of nonnatives that altered the fire behavior from low intensity to more severe fires (USDA 2007). Thus, we believe the threat from nonnative 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. The species' low population level, restricted gene pool, and geographic limitations were described as natural factors affecting the population in the Recovery Plan (USFWS 1995). Although the reason for small population sizes and the potentially limited genetic mixing between *P. bradyi* has not been confirmed or evaluated, Benson (1982) suggests that the species of *Pediocactus* we have today are relicts of a more variable group of plants that once occupied suitable intervening sites between the present areas of distribution. For these relictual populations, the structural differences, extremely disjunct distribution, together with the lack of special means of seed dispersal and the physiological limitation of each species to a specific underlying rock or soil type, indicate long evolutionary periods of isolation.

Although the specific reasons for small population sizes are unknown, the isolated distribution could create conditions of lowered connectivity among *P. bradyi* locations and depauperate genetic diversity. Thus, we believe small populations and potentially limited genetic mixing are likely a severe threat to *P. bradyi*; however, additional research is needed to determine the extent of the threat.

The study proposed by Spence (section 2.2.3) does not address genetics, specifically; however, under the monitoring protocol each plant will be measured

for diameter, flower, fruits and estimated seed set to develop fecundity values. This type of research is needed along with a study specific to genetics of this plant to help with the long-term management of the species.

2.4 Synthesis

We acknowledge that the BLM, NPS, and NN have made significant efforts to conserve *P. bradyi*. They have used their authorities to implement the appropriate actions outlined within the Recovery Plan, HMP, RMP, ACEC, and monitoring plans. Because of these actions, we believe the threats related to off-road vehicles, uranium mining, and livestock grazing have been significantly reduced in some areas, with other threats currently appearing to be nonexistent, such as collection. Management plans and monitoring agencies covering habitats where the cactus is known to occur are protecting these populations; however, until the species has been entirely surveyed to determine the total area of habitat, it is not clear as to whether the 75 percent threshold of protected habitat has been met.

Over the past 24 years of monitoring, the BLM population has shown resilience and the potential to rebound after a significant decrease in population size from environmental or natural factors. However, the last five years document 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 (Figure 3 and 4), recruitment is likely to decrease, ultimately driving the population towards a downward trend that may not be recoverable. Because *P. bradyi* is long-lived, threats associated with specific environmental or natural factors such as regional climate change, rodent depredation, and invasive species that were not previously considered in the Recovery Plan have a much greater impact to the population and are considered additional threats.

Although *P. bradyi* has shown resilience over time, the overall numbers of known individuals are low, and *P. bradyi* continues to meet the definition of endangered, which is a species in danger of extinction throughout all or a significant portion of its range. Therefore, it is critical that BLM continue to monitor the population to track the population's response to continued threats, take measures such as fence construction around occupied habitat, and develop and install educational signage to actively conserve the species. We believe there are still many unanswered questions and much needed research pertaining to the specific impacts of individual or combined environmental factors on the declining population, reproduction, retraction, and seed germination of the species. For these reasons, *P. bradyi* should remain classified as endangered.

3.0 RESULTS

3.1 Recommended Classification: Remain as endangered.

☐ Downlist to Threatened

☐ Uplist to Endangered

☐ Delist:

☐ *Extinction*

☐ *Recovery*

☐ *Original data for classification in error*

☒ No change is needed

3.2 New Recovery Priority Number: 5.

Brief Rationale: We recommend the recovery priority number be changed from a 2 (high degree of threat and high recovery potential) to a 5 (high degree of threat and low recovery potential). This change is justified based on evidence that the cactus is long-lived and exhibits relatively low fecundity, which would increase the potential for a genetic bottleneck in conjunction with its isolated and restricted distribution, and limited micro-habitat. As well, conditions to create long-term propagation success are difficult to achieve and development of an artificial propagation program to enhance wild populations and provide nursery stock has not occurred. Our review also indicates that human-caused threats such as OHV use and some grazing continue, while novel threats, such as predation from rodents, invasive plants, and climate change are becoming more apparent. In combination, these factors indicate a low recovery potential is more appropriate for this plant at this time, and support the change from a high to a low recovery potential.

3.3 Listing and Reclassification Priority Number: Not Applicable.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

- The 1985 Recovery Plan should be updated with recovery criteria that reflect current threats to *P. bradyi*. Objective, measurable criteria for downlisting and delisting 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 transplants of already established plants (Spence 2008).
- Studies should be conducted to evaluate the pollination ecology of *P. bradyi* and evaluate whether the species is pollinator limited due to its early flowering (March-April) (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.

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Figures

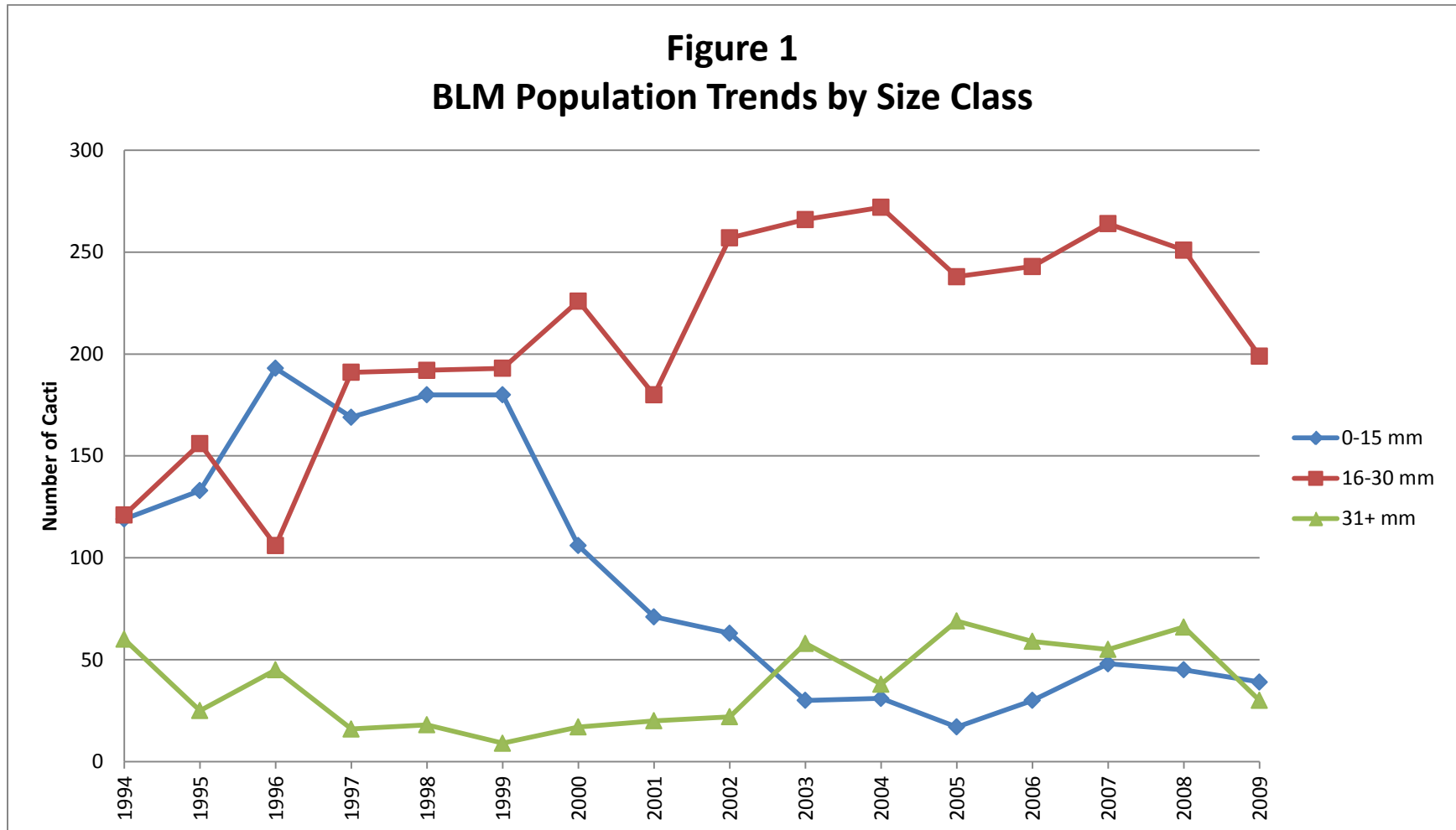


Figure 1. Trends in size class recorded from Soap Creek, Badger Creek, and North Canyon plots between 1994 and 2009 (Hughes 2009). Data prior to 1994 was not included because size classed between 1985 and 1988 included four size class categories and five different size classes were recorded between 1990 and 1993.

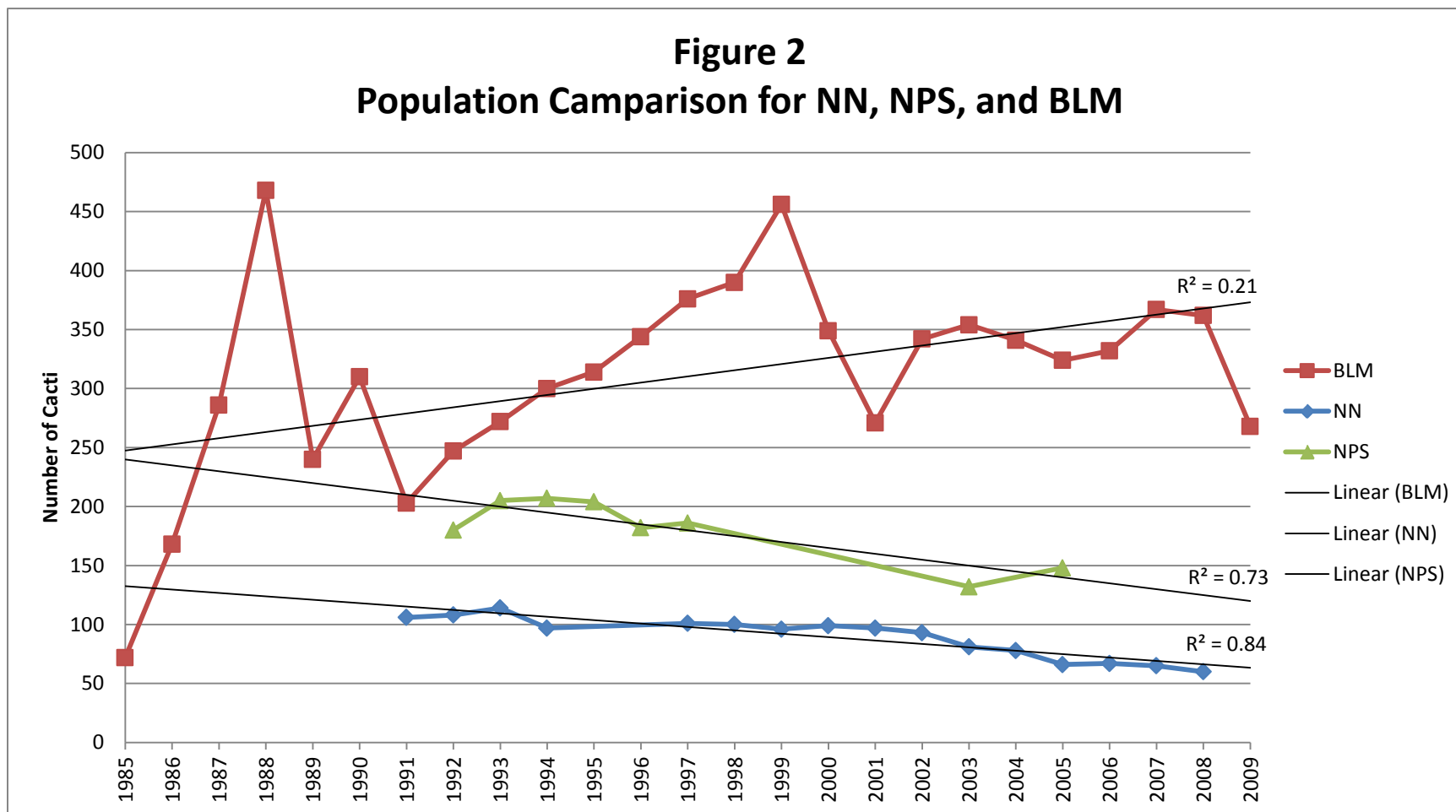


Figure 2. Population data available for each agency (Hughes 2009; Roth 2004 and 2008; Spence 2008). Data are missing for BLM in 1989 (no data recorded for Badger and Soap Creek plots), and 2001 (no data were recorded for North Canyon). For NN, no data recorded for 1995 and 1996. For NPS, no data was recorded between 1998 and 2002, or in 2004.

Figure 3
Climate Data from Lee's Ferry

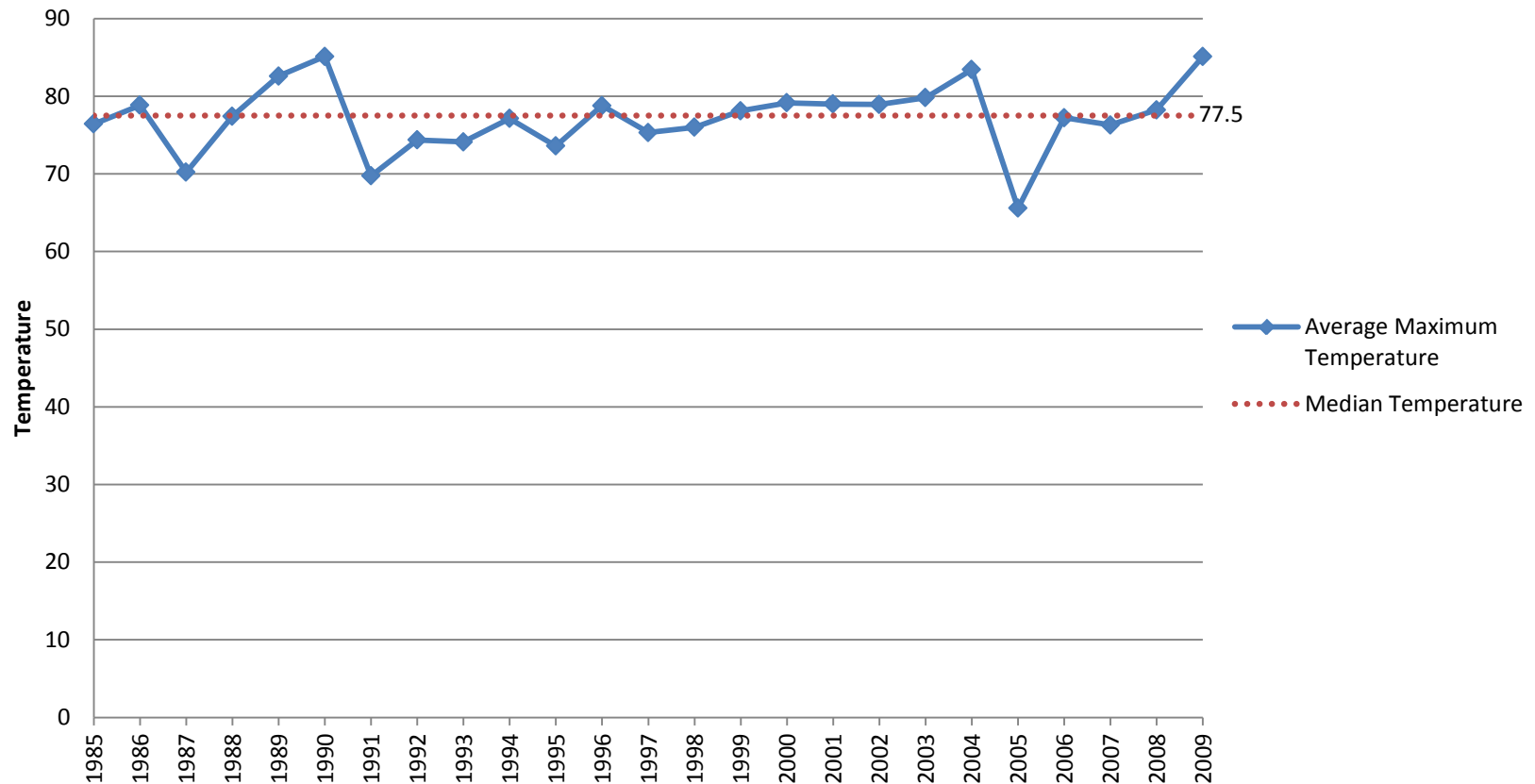


Figure 3. Temperature data recorded from the Western Regional Climate Center, Lee's Ferry, Arizona, between 1985 and 2009 (<http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?azlees>). The median temperature is recorded as 77.5 degrees Fahrenheit.

Figure 4
Average Annual Precipitation
Lee's Ferry

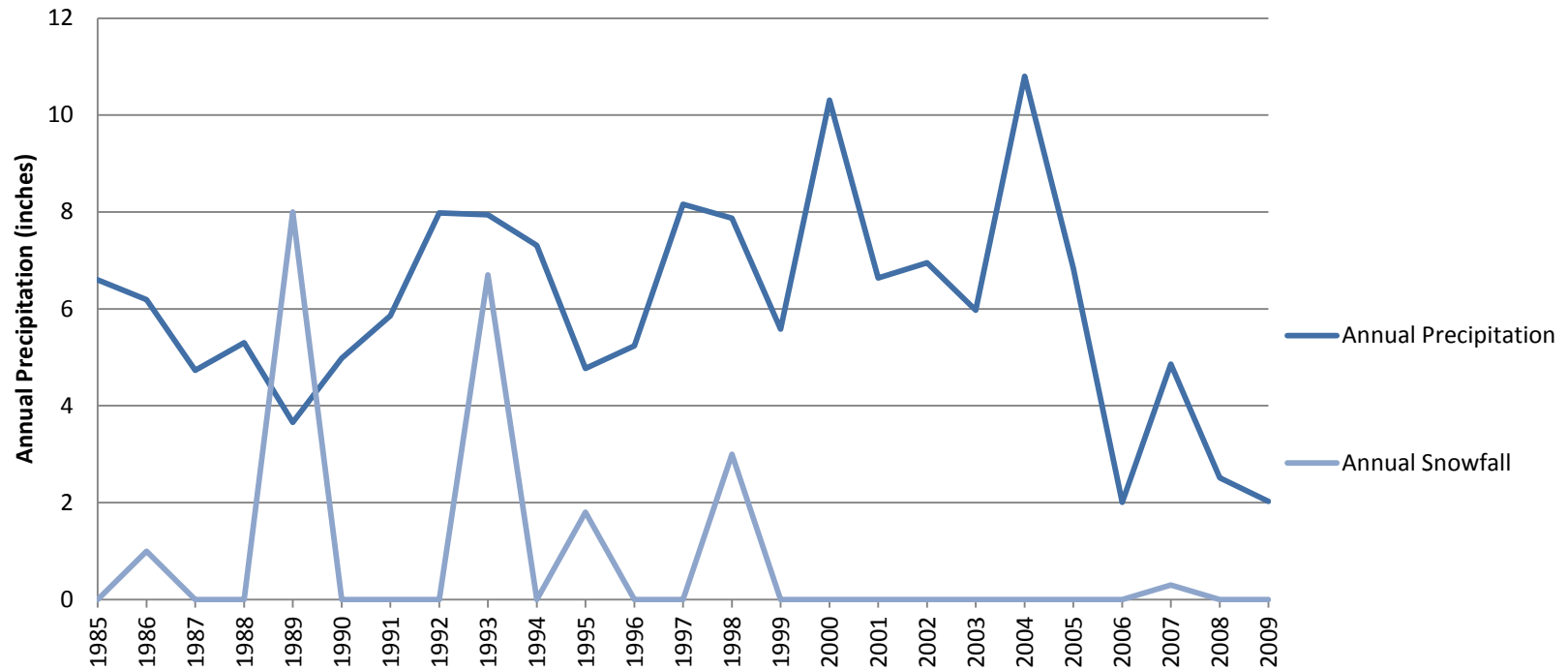


Figure 4. Annual precipitation and snowfall data for Lee's Ferry between 1985 and 2009 recorded at the Western Regional Climate Center, Lee's Ferry, Arizona (<http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?azlees>).

Figure 5
BLM Population Trend for Three Plots

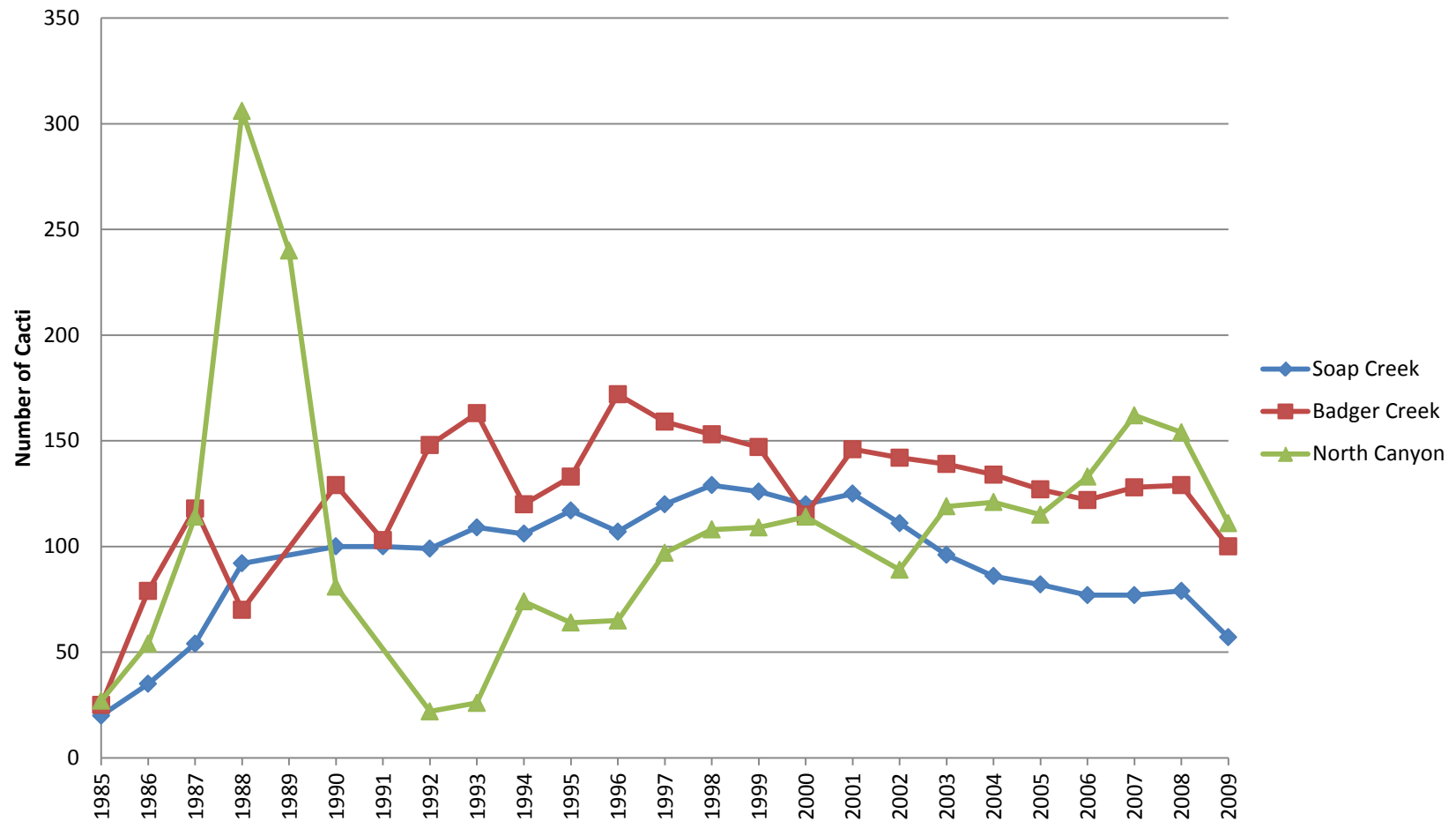


Figure 5. Population data for Soap Creek, Badger Creek, and North Canyon between 1985 and 2009 (Hughes 2009).

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *Pediocactus bradyi*

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

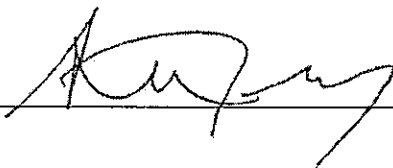
☐ Downlist to Threatened
☐ Uplist to Endangered
☐ Delist
☒ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: Not applicable.

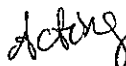
Review Conducted By: Ryan Gordon, Arizona Ecological Services Office, Phoenix, AZ

FIELD OFFICE APPROVAL:

Field Supervisor, Fish and Wildlife Service

Approve:  Date: 7/13/2012

REGIONAL OFFICE APPROVAL:

 **Assistant Regional Director, Fish and Wildlife Service**

Approve:  Date: Aug 31, 2012