Species Status Assessment Report for

Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*)
and
Peebles Navajo cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*)

Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) 5-8-2024 USFWS file photo.

Peebles Navajo cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*) April 2022, K. Olmon-Phillips, with permission.

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EXECUTIVE SUMMARY

This Species Status Assessment (SSA) provides a comprehensive review for Fickeisen plains cactus (FPC) (*Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (PNC) (*P. p*. ssp. *peeblesianus*) through an analytical approach assessing the species needs, current status, and future status using the best available information to provide a thorough account of the overall viability of these cacti subspecies. The FPC was listed Endangered in 2013, and the PNC was listed Endangered in 1979; critical habitat was designated for FPC in 2016. For this assessment, we generally define viability as the ability of FPC and PNC to sustain populations in natural systems over time. The Species Status Assessment framework uses the conservation biology principles of resiliency, redundancy, and representation (collectively known as the "3Rs") as a lens to evaluate the current and future condition of species.

Both FPC and PNC are small spherical cacti that are typically unbranched or with few branches (Heil & Porter 2004 p. 99). A morphometric study did not find distinct differences between the two subspecies in correlation with geography, suggesting treatment as a single subspecies; however, in this document the two are treated as separate subspecies and will be until genetic testing is conducted to prove otherwise. The FPC is endemic to the Colorado Plateau in Coconino and Mohave Counties of northern Arizona and Washington County of southern Utah, where it occurs in disjunct populations that are widely scattered over a broad range. The PNC is an endemic of northern Arizona occurring in three populations in a single area of low hills in the area between Joseph City and Holbrook, Navajo County, Arizona. Both *Pediocactus* subspecies grow in exposed, sunny and arid areas of little slope, often on flat topped mesas and on canyon rims, and on well-drained soil. These areas are within the Plains and Great Basin Grasslands and Great Basin Desertscrub vegetation communities. We are aware of 58 FPC populations and 3 PNC populations. Populations are defined by plant groupings separated by at least 200 meters, which is thought to be the maximum distance their small bee pollinators can travel.

The roots and stems of both FPC and PNC are contractile, allowing the plants to retract into the ground in response to drought, heat, or cold. Plants may shrink down into the soil until the crown sits flush with the soil surface. Some individuals may become completely buried by soil litter or gravel thus limiting the time plants can be found. We estimate there are currently less than 2,500 FPC and less than 300 PNC individuals across the ranges of these cacti. Within all populations of both FPC and PNC with more than a single monitoring event, there has been a decrease in the number of located individuals, which is highly correlated to rainfall. For example, in 2022, in two of four FPC monitoring plots on the Arizona Strip no plants were found, and in 2023, the 284 total PNC found within three populations decreased from as many as 1,000 plants thought to occur in the single known population at the time of listing in 1979. Because these plants retract into the ground in response to climatic conditions, a decrease in numbers of individuals does not necessarily indicate death of all the plants, but instead may indicate a greater lack of emergence due to drier conditions over time.

To be viable, FPC and PNC need multiple resilient populations. Resilient populations are those able to withstand stochastic events arising from spatially and temporally random factors, and that are distributed widely across their ranges, to maintain their persistence into the future and to

avoid extinction. Several factors influence the resiliency of FPC and PNC populations in response to stochastic events. These factors are:

- Number of Individuals per Population - For FPC and PNC populations to be resilient, abundance should be large enough that local stochastic events do not eliminate all individuals, allowing recovery from any one event.
- Number of Populations per Representation Area (RA) - For FPC and PNC RAs to be resilient, abundance of populations should be large enough that local stochastic events do not eliminate all populations, allowing recovery from any one event.
- Recruitment - Resilient FPC and PNC populations must produce flowers and viable seeds to offset individuals killed by drought, herbivory, trampling, removal, and other threats, or natural senescence. We use precipitation as a surrogate for recruitment.
- Level of Disturbance - Resilient FPC and PNC have the greatest potential to thrive when disturbance impacts such as trampling by livestock, people, and off-highway vehicles (OHV), are reduced or eliminated.

To assess population resiliency levels for current condition, we used the previously listed three population factors (Number of Individuals per Population, Number of Populations per Representation Area, and Recruitment / Precipitation) and one habitat factor (Level of Disturbance), as they are the primary factors influencing FPC and PNC for which we have consistent information. For each of the three populations and one habitat factor, we developed condition categories (High, Moderate, Low, Very Low, and Functionally Extirpated) to assess the condition of each factor for each population, to determine overall population resiliency. To further assess current condition of the species, we also considered representation and redundancy. Representation is the ability to adapt to changing environmental conditions as measured by the breadth of genetic or environmental diversity within and among populations. Redundancy is the ability of a species to withstand catastrophic events, measured by the number of populations, their resiliency, and their distribution and connectivity. Genetic analyses of these subspecies have not been conducted within or among populations or representation areas. However, populations within different representation areas are widely separated, making cross-pollination from pollinators unlikely, meaning populations within representation areas form independent units. The species needs and current condition are presented in Table ES-1.

Table ES-1. The needs of Fickeisen plains cactus (FPC, *Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (PNC, *P. peeblesianus* ssp. *peeblesianus*) and the current condition of these subspecies regarding population resiliency: (large populations with good condition habitat able to withstand stochastic events), species representation (genetic and ecological diversity to maintain adaptive potential), and species redundancy: (number, distribution, and connectivity of populations to withstand catastrophic event). RA refers to Representation Areas which are based on geography, annual precipitation, and vegetation community; there are three FPC and one PNC RAs in northern Arizona.

Needs	Current Condition
High abundance of individuals within populations such that the range of environmental conditions is represented	In northern Arizona, 58 FPC populations known to be extant over 3 RAs and 3 PNC populations known to be extant over a single RA.
Multiple populations within each Representation Area	Population numbers range from 29 FPC in RA 3 down to 3 PNC in RA 4.
Recruitment exceeds mortality (we use precipitation as a surrogate for recruitment)	RAs One and Two are in Moderate condition and RAs Three and Four are in Low condition for recruitment / precipitation.

Needs	Current Condition
Low disturbance	No populations are in High condition, eight from RA Three are in Moderate condition, two from RA Four are in Very Low condition, and all 51 other populations are in Low condition.

Our analysis of the past, current, and future influences on what FPC and PNC need for long-term viability revealed that there are several threats to this species including one primary threat which poses the greatest risk to future viability of the two cacti subspecies. This threat is increased drought and temperatures, and potential resulting increase in small mammal predation. This suite of threats leads to increased evapotranspiration, increased stress on individuals, reduced germination, flowering, pollinator visitation, fruiting, and seed set.

This threat plays a large role in the future viability of FPC and PNC. Other identified threats, such as trampling by livestock and humans; mining and energy and infrastructure development; nonnative plant invasion and spread; and illegal collection in some areas may be especially problematic for populations with fewer than 100 individuals. Thus, all these threats are important, in various areas throughout the ranges, when considering population viability. If populations lose resiliency, they are more vulnerable to extirpation, with resulting losses in species representation and redundancy.

While we have data to inform us of the threats that may impact FPC and PNC populations in the future, and we understand how these threats can impact these subspecies, there is uncertainty regarding the exact risk of the threats to each population, such as where and when each threat will occur in the future and exactly which populations may be impacted. We use available data and our best judgement to determine which populations have the greatest likelihood of experiencing these threats. We assumed that all populations have an equally likely probability of experiencing drought, increased temperatures, and small mammal herbivory.

We developed two future scenarios, denoted as Low Effects and High Effects, incorporating the threats that are ongoing or will occur in the future to consider the range of plausible future conditions for the species. For each scenario, we describe the level of impact from the identified threats that would occur in each population. Both scenarios involve some degree of uncertainty; however, they present a range of realistic and plausible future conditions. We assessed a range of conditions over a 30-year period to allow us to consider the species' resiliency, redundancy, and representation. We chose 30 years to allow us adequate time to determine if drought will impact reproduction, growth, and vigor of FPC and PNC.

Table ES–2 provides a summary of our assessment of the current and future conditions of 58 FPC and 3 PNC populations. Under the Low Effects scenario, no FPC or PNC populations would be in High condition, 3 FPC would be in Moderate condition (5.2 percent), 49 FPC populations would be in Low condition (84.5 percent), 4 FPC and 2 PNC would be in Very Low condition (6.9 and 66.7 percent, respectively), and 1 PNC population is Functionally Extirpated (33.3 percent) (Table ES-2). Under the High Effects scenario, no populations would be in High condition, 3 FPC populations (5.2 percent) would be in Moderate condition, 41 FPC populations (70.7 percent) would be in Low condition, 14 FPC populations and 1 PNC population (24.1 and 33.3 percent, respectively) would be in Very Low condition, and 3 FPC and 2 PNC populations

(5.1 and 66.7 percent, respectively) would be in the Functionally Extirpated condition (Table ES-2). Under both the Low Effects and High Effects, redundancy would decrease, and connectivity within RAs would be lost.

Table ES–2. Summary results of FPC and PNC population conditions for current condition and from two future scenarios. Populations within the Very Low category may become extirpated without conservation actions.

Scenario	High condition	Moderate condition	Low condition	Very Low condition	Functionally Extirpated	Total Populations
FPC Current	0	8	50	0	0	58
PNC Current	0	1	0	2	0	3
FPC Low Effects	0	3	51	4	0	58
PNC Low Effects	0	0	0	2	1	3
FPC High Effects	0	3	41	13	1	58
PNC High Effects	0	0	0	1	2	3

Under the Low Effects scenario, we would expect the viability of FPC and PNC to be characterized by a loss of resiliency, representation, and redundancy compared to current condition. We assume impacts from drought, high temperatures, small mammal herbivory; trampling by livestock, people, and OHVs; nonnative plant invasion and spread; illegal collection; and other threats continue to occur on their current trajectory, but also assume the current conservation measures (e.g., monitoring, research, exclosure placement and maintenance, seedbanking, nonnative plant reduction through land management plan implementation) reduce some threats to FPC and PNC. We anticipate that the near future of FPC and PNC is more likely to resemble this scenario, as over the next decade it is more likely than not that any given population will experience large-scale drought, increased temperatures and small mammal predation similar to or worse than the impacts experienced today. The fact that so many populations are in Low, Very Low, or Functionally Extirpated condition even under an optimistic scenario reflects the degradation FPC and PNC have experienced due to severe drought, reduced reproduction, increased herbivory and stress, as well as other threats over the past few decades. Importantly, under this scenario we project no current populations would have high resiliency in 30 years, and three FPC would have moderate resiliency, with all other populations having Low, Very Low, or Functionally Extirpated condition.

Under the High Effects scenario, we would expect the viability of FPC and PNC to be characterized by lower levels of resiliency, representation, and redundancy than under the Low Effects scenario. There would be no populations in High condition and three FPC in Moderate condition; all remaining populations would be in Low, Very Low, or Functionally Extirpated condition. Therefore, we expect the majority of the FPC range outside of the three populations on the Navajo Nation in Moderate condition would be vulnerable to stochastic events that would result in widespread localized extirpations and greatly reduce the spatial extent of the FPC range. If these populations disappeared, it would reduce redundancy for the FPC and PNC to persist in the face of increased drought, temperatures, and herbivory, and could reduce adaptive capacity of these cacti. Such a scenario is more likely toward the end of our future timeframes (i.e., 30 years

from now) given the projected impacts of continued and intensified drought, high temperatures, and alterations in precipitation timing and intensity.

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CHAPTER 1. INTRODUCTION

1.1 Species Status Assessment Framework

The Species Status Assessment (SSA) framework is an analytical approach used by the United States Fish and Wildlife Service (USFWS) to assess the needs, current status, and future status of a species using the best available information (Figure 1.1). The SSA framework uses the conservation biology principles of resiliency, redundancy, and representation as a lens to evaluate the current and future condition of a species. The resulting SSA report that characterizes a species' ability to sustain populations in the wild over time (viability) based on the best scientific understanding of current and future abundance and distribution within a species' ecological settings. The intent is for the SSA to be easily updated as new information becomes available and to support all functions of the USFWS' Endangered Species Program from listing to consultations to recovery. As such, the SSA will be a living document upon which other documents, such as listing rules, recovery plans, and 5-year reviews are based.

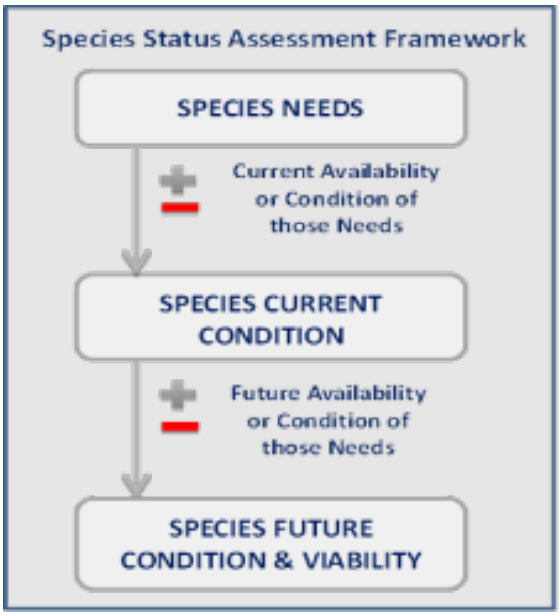


Figure 1.1. Species Status Assessment Framework.

1.2 Context

Fickeisen plains cactus (FPC, *Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (PNC, *Pediocactus peeblesianus* ssp. *peeblesianus*) are succulents of the Cactaceae or cactus family. The USFWS listed the FPC as Endangered under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.; ESA) on October 1, 2013 (U.S. Fish and Wildlife Service 2013a entire). On August 18, 2016, 17,456 acres (7,062 hectares) of FPC critical habitat were designated within six units. The USFWS listed the PNC as Endangered on October 26, 1979 and no critical habitat was designated (U.S. Fish and Wildlife Service 1979 entire).

Both *Pediocactus* subspecies are local endemics occurring in northern Arizona (Figure 1.2). For the purposes of this SSA, we are analyzing impacts to known FPC and PNC Element

FOccurrences (EOs), herein called populations, which are defined as groups of cacti that fall within the distance pollinators can travel, in this case 200 meters (Aslan pers. comm. May 13, 2024). The FPC occurs in 58 populations on well-drained gravel soils derived from Kaibab limestone (Phillips et al. 1982a p. 5). The PNC occurs in three populations on well-drained gravely soils derived from the Shinarump conglomerate of the Chinle Formation or on weakly alkaline, gravelly soils not always of the Shinarump conglomerate (Cockman 2019 p. 7). Both *Pediocactus* subspecies grow in exposed, sunny situations in areas of little slope, often on flat topped mesas and on canyon rims. These areas are characterized by sparse low shrubs, grasses, and annuals, including snakeweed (*Gutierrezia sarothrae*), shadscale (*Atriplex confertifolia*), four-winged saltbush (*A. canescens*), rabbitbrush (*Ericameria nauseosus*), Galleta (*Hilaria jamesii*), and six-weeks fescue (*Vulpia octiflora*).

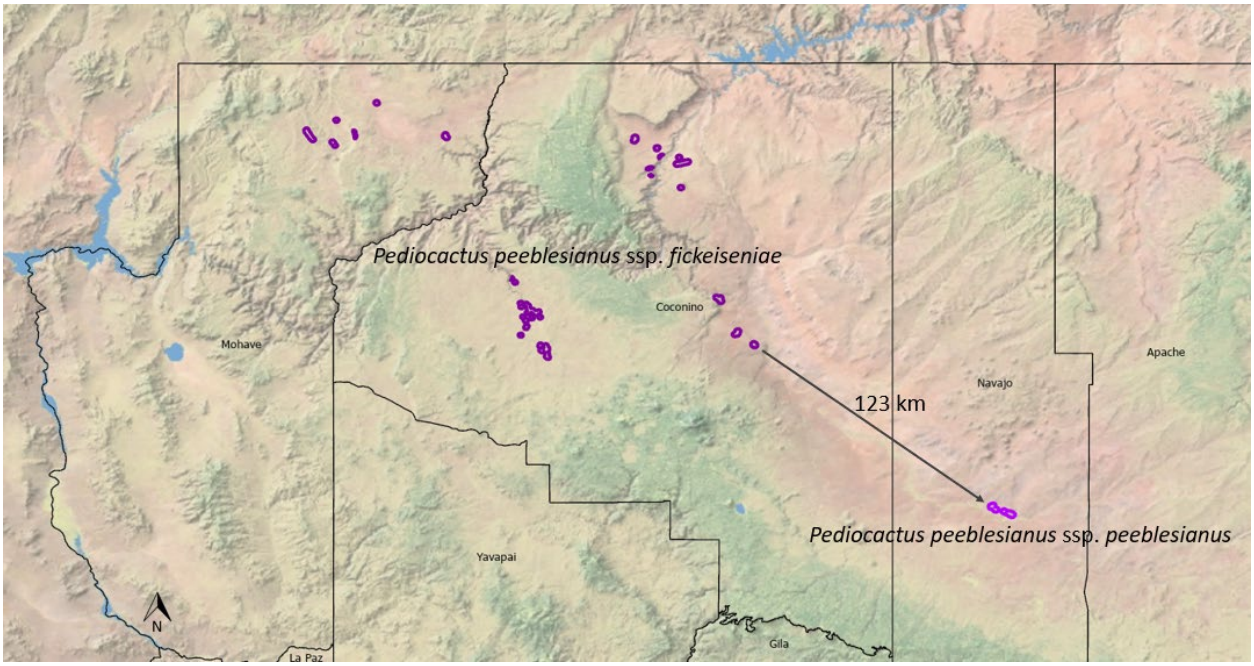


Figure 1.2. General northern Arizona locations of two *Pediocactus peeblesianus* subspecies: Fickeisen plains cactus (*P.p.* ssp. *fickeiseniae*) in the west and Peebles Navajo cactus (*P.p.* ssp. *peeblesianus*) in the east.

Based upon the best available information, this SSA report for FPC and PNC provides a thorough review of the biology and natural history, demographic risks, threats, limiting factors, and conservation measures in the context of determining the viability of these subspecies. The information contained in this SSA report will support the development of a single updated and streamlined recovery plan for both FPC and PNC that complies with the USFWS Recovery Planning and Implementation Guide (U.S. Fish and Wildlife Service 2021 entire). Populations of FPC and PNC range from one observed individual to over three hundred plants. Currently, we are aware of approximately 2,456 extant FPC and 284 extant PNC.

Viability is the ability of a species to maintain populations in the wild over time. To assess viability, we use the conservation biology principles of resiliency, redundancy, and representation (Shaffer & Stein 2000 pp. 308–311). These principles are rooted in ecological theory and empirical studies showing that, all else being equal, larger range, more populations, larger populations, larger habitat areas, sufficient gene flow, and distribution across a variety of

ecosystems all lower extinction risk (Wolf et al. 2015 p. 204). We use definitions of resiliency, redundancy, and representation based on (Smith et al. 2018 pp. 306–307), which were derived specifically for species status assessments. Our definitions are somewhat different than those presented in Shaffer and Stein (Shaffer & Stein 2000 entire) because our focus is on assessing the viability of a particular species rather than their broader focus on ecosystem function and biodiversity. A species with a high degree of resiliency, redundancy, and representation (the 3Rs) is better able to rebound from environmental stochasticity (resiliency), withstand catastrophes (redundancy) and adapt to changes in its biological and physical environment (representation). In general, species viability increases with increases in resiliency, redundancy, and representation (Smith et al. 2018 p. 306).

Resiliency is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature and rainfall), periodic disturbances within the normal range of variation (fire, floods, and storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity) (Redford et al. 2011 p. 40). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions.

We can best gauge resiliency by evaluating population-level characteristics such as: demography (abundance and the components of population growth rate—survival, reproduction, and migration); genetic health (effective population size and heterozygosity); connectivity (gene flow and population rescue); and habitat quantity, quality, configuration, and heterogeneity. For species prone to spatial synchrony (regionally correlated fluctuations among populations), distance between populations and degree of spatial heterogeneity (diversity of habitat types or microclimates) are also important considerations.

Redundancy spreads risk among multiple populations or areas to increase the ability of a species to withstand catastrophes. Catastrophes are stochastic events that cause substantial decreases in population size and can increase extinction risk, even in large populations (Mangel & Tier 1993 p. 1083).

We can best gauge redundancy by analyzing the number and distribution of populations relative to the scale of anticipated species-relevant catastrophic events. The analysis entails assessing the cumulative risk of catastrophes occurring over time. Redundancy can be analyzed at a population or regional scale, or, for narrow-ranged species, at the species level.

Representation was originally conceived as the conservation of species within an array of different environments or ecological settings as part of conserving functioning ecosystems (Shaffer & Stein 2000 pp. 307–308). However, in the context of assessing species viability, representation in different ecological settings is a proxy for adaptive capacity (Smith et al. 2018 p. 306), which is the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. Therefore, we define representation as the ability to adapt to changing environments.

Although representation across the range of ecosystems in which a species occurs is one measure of how a species may be able to withstand or adapt to environmental change, we also use more

direct measures of adaptive capacity to assess representation. Species can adapt to novel changes in their environment by either (1) moving to new, suitable environments or (2) altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change (Nicotra et al. 2015 p. 1270; Beever et al. 2016 p. 132). The latter occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Crandall et al. 2000 pp. 290–291; Sgrò et al. 2011 p. 327).

We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In assessing the breadth of variation, it is important to consider both larger-scale variation (such as morphological, behavioral, or life history differences, which might exist across the range, and environmental or ecological variation across the range) and smaller-scale variation (which might include measures of interpopulation genetic diversity). In assessing the dispersal ability, it is important to evaluate the ability and likelihood of the species to track suitable habitat and climate over time. Lastly, to evaluate the evolutionary processes that contribute to and maintain adaptive capacity, it is important to assess: (1) natural levels and patterns of gene flow, (2) degree of ecological diversity occupied, and (3) effective population size.

To evaluate the biological status of FPC and PNC both currently and into the future, we assessed a range of conditions to allow us to consider the resiliency, redundancy, and representation of these two cacti. This SSA provides a thorough assessment of biology and natural history and assesses demographic risks, threats, and limiting factors in the context of determining the viability and risks of extinction for the species.

The format for this SSA includes:
(1) The taxonomy, morphology, biology, and life history of individual FPC and PNC (Chapter 2);
(2) The historical range and current distribution of FPC and PNC, abundance and demographic trends, and resource needs of individuals (Chapter 3);
(3) Influences on viability including threats and conservation efforts (Chapter 4);
(4) Assessing current conditions of populations (Chapter 5);
(5) Description of species' viability in terms of resiliency, redundancy, and representation into the future (Chapter 6); and
(6) Appendices showing history of population and subpopulation surveys (Appendix One) and an overview of current and future conditions (Appendix Two).

This document is a compilation of the best available scientific and commercial information and a description of past, present, and likely future risk factors to FPC and PNC.

CHAPTER 2. TAXONOMY, MORPHOLOGY, BIOLOGY, AND LIFE HISTORY

The following chapter includes basic biological information about FPC and PNC, including their taxonomy, morphology, biology, and life history.

2.1 Taxonomy

Plants of the genus *Pediocactus* are miniature cacti native to the western United States. The genus has a history of taxonomic confusion at both the genus and species levels (Porter 2010 p. 2). Nine species of *Pediocactus* are typically recognized, six of which are highly restricted endemics to the Colorado Plateau (Benson 1982 p. 179; Porter 2010 p. 3) (Figure 2.1). Although there are great dissimilarities among plants in the genus *Pediocactus*, they are united by their unusual method of fruit dehiscence and deciduous floral remnant (Heil et al. 1981 p. 18). Within *Pediocactus peeblesianus*, two subspecies have been recognized: *P.p*. ssp. *fickeiseniae* and ssp. *peeblesianus* (Heil et al. 1981 p. 29), separated by the presence or absence of a single central and corky spine and variation in number of corky radial spines. In 2010, DNA sequences from the chloroplast trnL-F region were used to infer genetic relationships of nine distinct *Pediocactus* species and two genetic races of *P. peeblesianus* (Porter 2010 p. 2). In 2014, a morphometric study did not find distinct differences between the two subspecies in correlation with geography, suggesting treatment as a single subspecies (Baker 2014 entire). This document treats the two as separate subspecies, recognizing that this may be revisited in the future when further genetic testing is conducted.

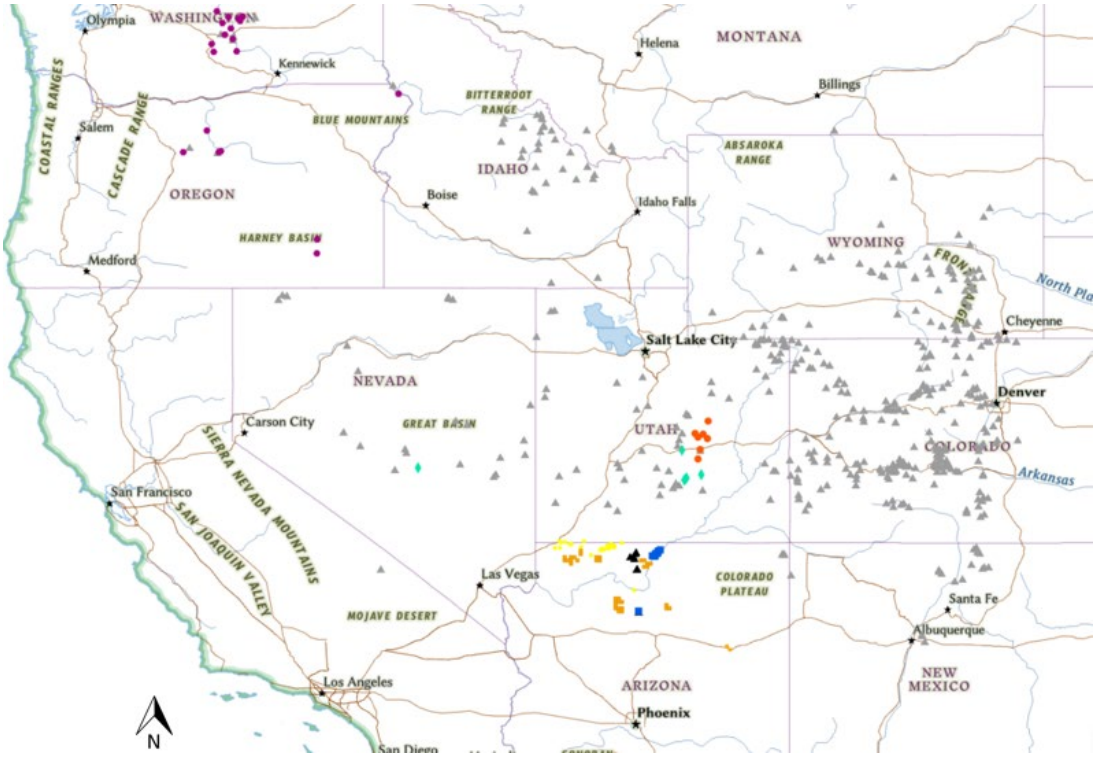


Figure 2.1. Distribution of nine species of *Pediocactus*: *P. brady*i (blue square), *P. despainii* (orange circle), *P. knowltonii* (green triangle), *P. nigrispinus* (maroon hexagon), *P. paradenei* (black triangle), *P. peeblesianus* (orange square), *P. sileri* (yellow circle), *P. simpsonii* (grey triangle), and *P. winkleri* (turquoise diamond). Data from SEINet Portal Network (2024).

2.2 Morphology

The 2014 study of morphology and geography of the two subspecies concluded "Because of the poor geographic correlation with the best morphological grouping of populations, there is little justification to naming subspecific taxonomic groups within *P. peeblesianus*" (Baker 2014 p. 20). The author also notes that stem diameter is correlated with several morphology characteristics allowing that plant maturity may be responsible for at least some morphological variation within *P. peeblesianus* (Baker 2014 p. 19). In addition, soil depth may impact morphology, with populations near canyon edges having more shallow soils (Baker 2014 p. 21). Western populations also have greater precipitation than eastern populations.

Both FPC and PNC are small spherical cacti that are typically unbranched or with few branches (Heil & Porter 2004 p. 99). Either subspecies can grow up to 6.5 cm tall and 5.5 cm wide, but plants of both subspecies are typically smaller (Heil et al. 1981 entire). The spines are soft and corky or spongy and are white to pale gray. Spines can be all radial or with one central spine (1 per areole) which is a key characteristic separating the two subspecies, with ssp. *peeblesianus* having no central spine and ssp. *fickeiseniae* having 0 to 1 central spine. Another key characteristic used to separate the two subspecies is the number of radial spines, with ssp. *peeblesianus* having 3 to 5 and ssp. *fickeiseniae* having 6 to 7 (Heil et al. 1981 entire). Searches of suitable PNC habitat in 2017, 2021, and 2022 resulted in the discovery of 29 plants, 13 of which had characteristics of subspecies *peeblesianus* and 16 of which had characteristics of subspecies *fickeiseniae* – a long central spine and more than four radial spines per areole. This, coupled with plants located in known areas of FPC which when photographed and shown to experts were thought to be PNC, illustrates the difficulty in separating these subspecies morphologically (Figure 2.2).

a) b)

Figure 2.2. a) Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*), USFWS file photo, April 2024 and b) Peebles Navajo cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*. Photo credit: Greg Goodwin, 2005.

Both FPC and PNC flower in April, producing relatively large (2.5 cm (0.98 in)) cream, yellow, or greenish flowers at the apex (top) of the stem. Tepals are slightly to fully toothed with brown-

purple mid-stripes. Fruits are turbinate (top-shaped), and smooth and turn reddish-brown at maturity with dark brown to black seeds that are 3 millimeters (mm) (0.11 in) long, and 2 mm (0.08 in) wide (Arizona Game and Fish Department Heritage Data Management System 2011 entire). The roots and stems are contractile, allowing the plants to retract into the ground in response to drought, heat, or cold (Figure 2.3). Plants may shrink down into the soil until the crown sits flush with the soil surface. Some individuals may become completely buried by soil litter or gravel, thus limiting the time plants can be found (Phillips et al. 1982b p. 4). For example, on May 8, 2024, USFWS researchers found 34 FPC plants in an area that was revisited by the same researchers on May 28, 2024, when fewer than half were re-located. This illustrates how quickly plants can retract into the soil as the temperatures go up and moisture decreases, making individuals difficult to detect.

Figure 2.3. Peebles Navajo cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*) plant showing a stem that is largely underground for much of the year. Photo Credit Museum of Northern Arizona.

2.3 Biology and Life History

The information in this section comes primarily from research on FPC; however, is likely similar between both subspecies. When ambient air temperatures rise in the spring and adequate rainfall occurs, plants emerge from beneath the soil surface to flower from mid-April through mid-May. The flowers of FPC open in the mid-morning for several days (Aslan 2024a p. 4). An entire population generally completes anthesis (the period when the flower is open and functional) in 7 to 14 days (Milne 1987 p. 6). Spring flowering and seed set are believed to be influenced by cold temperatures and precipitation from the preceding winter months (Milne 1987 p. 33; Hughes 2002a p. 3; Phillips & Phillips 2004 pp. 15–16; Navajo Nation 2012 p. 14; Aslan 2024a entire; Arizona Rare Plant Guide Committee n.d. unpaginated) which enables moisture to accumulate in the soil during times when solar evaporation rates are low and may facilitate seedling germination. As the season progresses, plants produce fruit then shrink back into the soil, losing one-half of their height above ground by June. Plants generally remain retracted underground during the remainder of the year; however, some individuals may re-emerge in the autumn following monsoonal rains. The length of time a plant remains retracted can vary between individual plants. Researchers with the Bureau of Land Management (BLM) have documented some FPC plants remaining retracted underground for at least three years but

reported that a plant emerged after remaining retracted after eight years (Hughes 2000 p. 2). Both subspecies are also subject to root rot during very wet years (Phillips et al. 1982a p. 10, 1983 p. 10; Navajo Natural Heritage Program 1994a p. 5). The roots of PNC, and presumably FPC, are heavily colonized by vesicular arbuscular endomycorrhizae (Phillips et al. 1989 p. 9), which may aid in water and mineral absorption and benefit plants, in general.

Flowers of FPC are temperature sensitive, opening for just a few hours each day and providing limited opportunities for pollination (Aslan 2017 p. 2). We lack information supporting whether or not pollination limitation is a factor for FPC and PNC and are pursuing research to understand the relationship between pollinator visits, effective pollination during visits, and the development of fully formed seeds. The flowers of other more abundant forbs and shrubs may outcompete FPC for pollinators; this is especially true when pollinator density is low (Aslan 2017 p. 2). Flowers of neighboring plants may also help attract pollinators (Moeller 2004 p. 3297). Insects observed visiting flowers of FPC include species of hover flies (family Syrphidae) and bee flies (family Bombyliidae), mining bees (family Andrenidae), and sweat bees (family Halictidae) (Milne 1987 p. 21; Navajo Natural Heritage Program 1994a p. 3; Tepedino 2000 p. 7; Aslan 2017 p. 2). The primary pollinators of FPC are believed to be halictid bees from the genera *Lasioglossum, Halictus,* and *Agapostemon,* based on several studied species of *Pediocactus* (U.S. Fish and Wildlife Service 2013a p. 60628). In the spring of 2016, Aslan et al. observed FPC for 52 hours with only two flower visits observed, both performed by bees of the genus *Agapostemon*. In 2023 and 2024, Aslan et al. observed FPC again at the same locations finding visitation by solitary bees and flies in these comparatively wetter years (Aslan 2024b entire). The PNC is an obligate outcrosser, with observed pollinators including the Potter bee (*Anthidium* sp.), sweat bees (*Lasioglossum* sp.), thrips, and ants (*Forelius pruinosus*) (Phillips et al. 2018b p. 10, 2022 p. 4)

The correlation between larger sized individuals and increased fruit production has been found in other *Pediocactus* species (U.S. Fish and Wildlife Service 2013a p. 60628), suggesting that larger, older individuals have a higher reproductive output and contribute more to the population growth rate by potentially having a greater influence on seed output than smaller, younger plants. Population monitoring of FPC suggests that this subspecies has a low reproductive capacity. There have been significant episodes of recruitment within the BLM monitoring plots that occurred 2 to 3 times over a 9-year period from 1986 to 1995. With 30 to 40 seeds per fruit, it is believed that low seed production diminishes any increases in population abundance, even during favorable weather conditions that would support germination (U.S. Fish and Wildlife Service 2013a p. 60628). Similarly, the PNC have long-term monitoring plots that were established in 1985 and have been visited nearly every year since, through 2024. These plot data also show that germination events are strongly associated with rainfall and occur only every few years (Phillips & Phillips 2004 p. 1). This episodic recruitment may impact population health if adult mortality occurs at a high rate between periods of recruitment, lowering the reproductive potential of the populations. Neither FPC nor PNC reproduce vegetatively.

Flowering and fruiting in FPC occur once individual plants reach 16 mm (0.63 in) in diameter, and as the diameter increases more fruit are produced (U.S. Fish and Wildlife Service 2013a p. 66028). Individuals between 20 mm (0.79 in) and 20.9 mm (0.82 in) in diameter produced 1.37 fruit on average (range of fruit produced 1 to 3) compared to individuals at 50 mm (1.97 in) and

larger that produced 3.60 fruits on average (range of fruit produced 2 to 5) (U.S. Fish and Wildlife Service 2013a p. 66028). Similarly, Phillips and Phillips (2004, p. 16) noted slow growth rates in PNC with average reproductive maturity occurring at 8 to 12 years of age. The mechanisms of seed dispersal in FPC have not been investigated and are poorly understood. Most site visits to areas occupied by FPC or PNC that have observed seedlings found them established very close to the adult plant (Milne 1987 p. 34; Navajo Natural Heritage Program 1994b p. 4; Goodwin 2011 p. 6) (Figure 2.4). In PNC, juvenile survival improves if the seedlings survive the first year following germination (Phillips & Phillips 2004 p. 16).

Figure 2.4. Peebles Navajo cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*) adults and seedlings. Photo credit K. Olmon-Phillips May 2024.

CHAPTER 3. DISTRIBUTION AND SPECIES NEEDS

In this chapter, the historical range and current distribution, abundance, and demographic trends, and resource needs of FPC and PNC are considered.

3.1 Historical Range and Current Distribution

It is speculated that FPC and PNC are relicts of a once widespread genus that occupied sites between their present distribution (Benson 1962 p. 163; Rogers 2015 p. 6). Most *Pediocactus* species occur on exposed ledges above rivers in gravelly soils of an alkaline nature (Heil et al. 1981 p. 31). While the availability of correct soils is abundant in northern Arizona, the FPC and PNC are sparsely distributed within these soils. There are thought to be approximately 2,456 FPC and 284 PNC range wide.

The FPC is endemic to the Colorado Plateau in Coconino and Mohave Counties of northern Arizona and Washington County of southern Utah, where it occurs in disjunct populations that are widely scattered over a broad range. As we do not have a location for the few individuals in Utah, our maps in this document do not show this population. On average, these groupings of populations are separated by 78.5 kilometers. The FPC distribution has been described as widespread along the ledges of the Little Colorado and Colorado Rivers to the hills of the lower House Rock Valley (Heil et al. 1981 pp. 30–31). The FPC occur on Navajo Nation, State of Arizona, private, BLM, Havasupai, and U.S. Forest Service lands; the percentage of populations on each are shown in Figure 3.1.

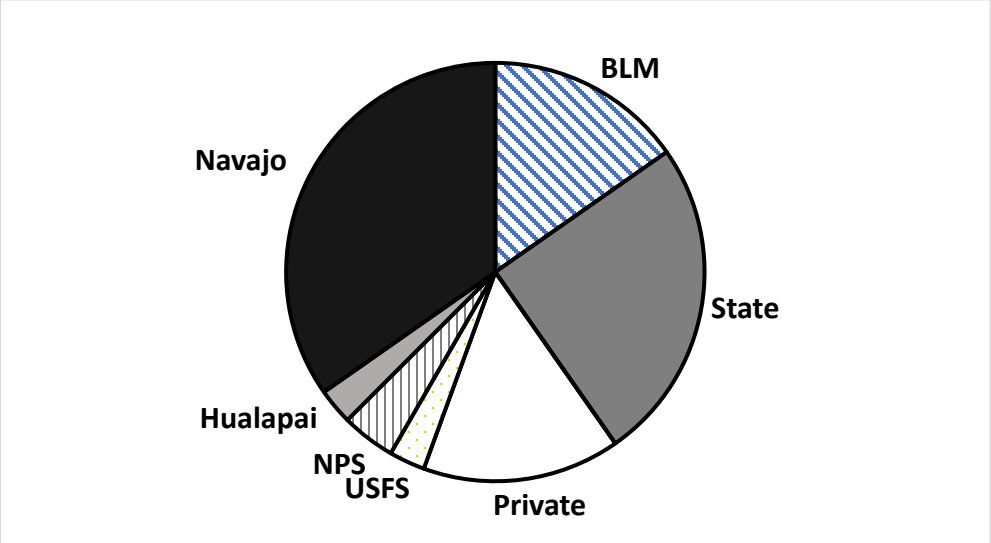


Figure 3.1 Pie chart illustrating the percent of Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) populations occurring on various land jurisdictions.

The PNC is an endemic of northern Arizona occurring in three groupings separated by at least 200 meters (the distance their pollinators can travel) in a single area of low hills in the Navajo Desert between Joseph City and Holbrook, Navajo County, Arizona. The PNC is isolated from FPC by a distance of 123 kilometers. The PNC cacti occur on private, BLM, and possibly State of Arizona managed lands. Most plants occur on a single privately-owned ranch.

3.1.1 Element Occurrences and Source Features

Because it is difficult to determine population boundaries for FPC and PNC, we use instead the National Heritage Program's Element Occurrence (EO) to differentiate groupings, and Source Feature (SF) to differentiate subpopulations of *Pediocactus* plants across the subspecies' ranges.

Element occurrences are a unique identifier number provided by the Natural Heritage Program that describes an area of land and/or water in which a species or natural community is or was present. Element occurrences are separated from other EOs by a distance that is reasonable for conservation, commonly a minimum of 1 kilometer (km, 0.62 miles) which allows for gene flow and movement through cross pollination within EOs (NatureServe 2020 p. 4). In the case of FPC and PNC, EOs are separated by the distance that small pollinators travel, 200 meters.

Source features are the initial mapped spatial component of the Natural Heritage EO Methodology and are developed from discrete units of observation data. A Source Feature is the (interpreted) mapped representation of one or more observations, including the Locational Uncertainty associated with the observation(s) to ensure that the actual on-the-ground location of the underlying observation(s) is captured within the Source Feature (NatureServe 2020 p. 91). Source features are the components from which Element occurrences are developed.

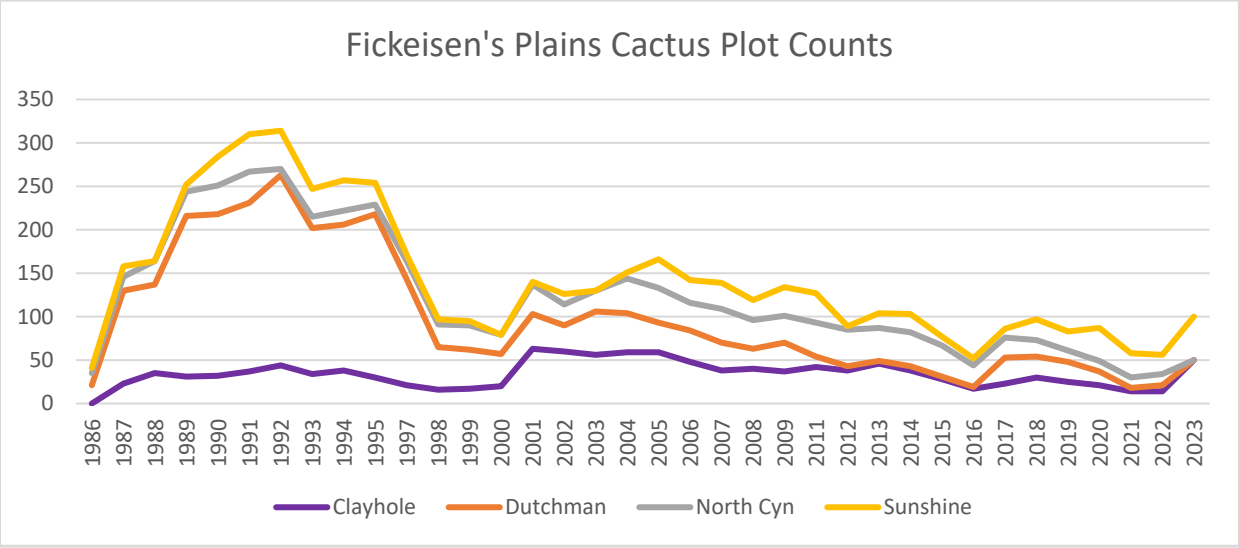
In this document we refer to EOs as populations and SFs as subpopulations and we use EO_ID numbers to differentiate separate populations.

3.2 Abundance and Demographic Trends

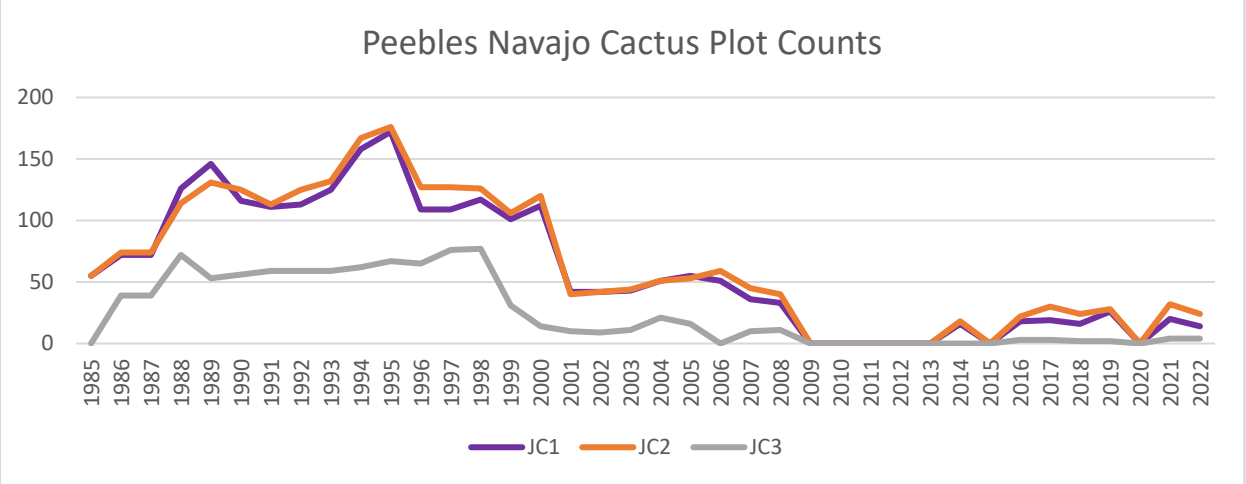
There are 58 known populations of FPC and fewer than 2,500 plants in total (Appendix One). A few populations were recorded as early as 1956, when herbarium specimens were collected near the overlook for the Little Colorado River and the town of Cameron. Most populations were discovered in the 1980s and 1990s, the mid 2000s, and around 2015 (Appendix One). The largest known populations occur on the Navajo Nation, where 75 percent of all known plants occur within 22 populations. The remaining 36 populations occur on the Arizona Strip on U.S. Forest Service and BLM administered lands near the Vermillion Cliffs, and north of Flagstaff on BLM and State of Arizona, and private lands. There are three known populations of PNC, the first having three subpopulations, the second having five subpopulations, and the third having two subpopulations (Appendix One). Among these three populations, we have known of one (EO 13804) since 1940, with the others being discovered in 1980 (EO 8613) and 1992 after the taxon was listed under the ESA (EO 7444). PNC populations occur on private, BLM, and possibly State of Arizona managed lands. Most plants occur on a single privately-owned ranch.

There are four long-term FPC monitoring plots on BLM lands north of the Grand Canyon which were established in the mid-1980s and have been visited in most years since. Beginning in 2013, the USFS has monitored their population on the Kaibab National Forest in this same vicinity. The Navajo Nation has been monitoring two of their largest populations since1989, adding more plots in 2012 and again in 2018 with a total of 10 plots which are monitored annually. The PNC have been monitored by the BLM periodically since 1980, and the Museum of Northern Arizona has monitored different plots nearly every year since 1985. Within all populations of both FPC

and PNC with more than a single monitoring event there has been a decrease in the number of located individuals since peaks in the early 1990s (Figures 3.2 and 3.3). The number of plants located each year appears to be highly correlated with rainfall. For example, the FPC long-term monitoring plots, which were established in 1986, showed recruitment in the 1990s when 314 individuals were counted in one plot and reduction in the years since (Figure 3.2). Since that time, numbers have generally decreased with 50 individuals found in each of two plots in 2022 and no plants found in the remaining two plots that year (Lambeth 2024 entire). Similarly, within long-term monitoring plots of PNC, in 1986 there were 185 individuals counted in the plots, this number reached a peak of 415 individuals in 1995 following several years of high precipitation and decreased to 92 plants in 2001 and 42 plants in 2022 (Phillips et al. 2022 p. 14) (Figure 3.3).



3.2. Monitoring data for four long-term *Pediocactus peeblesianus* ssp. *fickeiseniae* (Fickeisen plains cactus) plots, indicating an increase in the number of individuals following a wet period in the 1990s and an overall decreasing trend since that time.



3.3. Monitoring data for three long-term Peebles Navajo cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*) plots, indicating an increase in number of individuals following a wet period in the 1990s and an overall decreasing trend since that time.

3.3 Resource Needs of Individuals

3.3.1 Elevation

The FPC occurs at elevations from 1,214.6 meters to 1,749.6 meters (3,985 to 5,740 feet), averaging 1,610.3 meters (5,283 feet). The PNC occurs at elevations between 1,494 meters to 1,676 meters (4,900 and 5,500 feet) elevation (Phillips et al. 2022 p. 5). Light green on the map captures the elevation range (1,404 to 1,781) of both subspecies with darker greys being lower elevation and lighter grey and white being higher elevation (Figure 3.4).

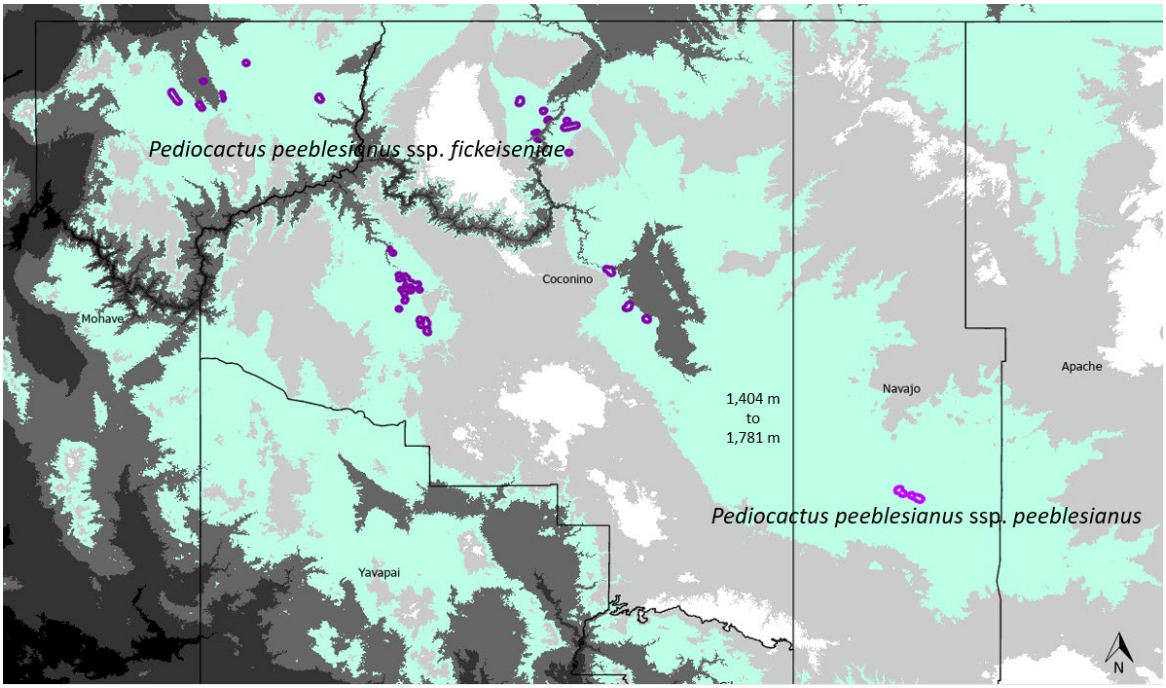


Figure 3.4. Elevation map showing a consistent range of elevations (1,404 to 1,781 meters in green) between nearly all Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (*P. p.* ssp. *peeblesianus*) populations (purple outlines).

3.3.2 Vegetation Community

Both *Pediocactus* subspecies grow in exposed, sunny situations in areas of little slope, often on flat-topped mesas and on canyon rims, and on well-drained soil. These areas are within the Plains and Great Basin Grasslands and Great Basin Desertscrub vegetation communities (Figure 3.5) and are characterized by sparse low shrubs, grasses, and annuals such as snakeweed (*Gutierrezia sarothrae*), shadscale (*Atriplex confertifolia*), four-winged saltbush (*A. canescens*), rabbitbrush (*Ericameria nauseosus*), Mormon tea (*Ephedra* spp.), Beehive cactus (*Coryphantha vivipara*), Galleta (*Hilaria jamesii*), Indian ricegrass (*Achnatherum hymenoides*), and sixweeks fescue (*Vulpia octiflora*). Nonnative plants often inhabit *Pediocactus* habitat, competing for nutrients, water, light, and space, and may alter fire regimes. The most common nonnatives mentioned in reports and which have continued to increase in abundance in areas occupied by FPC and PNC include: Russian thistle (*Salsola tragus*), crane's bill (*Erodium cicutarium*), bur buttercup (*Ceratocephala testiculata*), red brome (*Bromus rubens*), and cheatgrass (*Bromus*

tectorum) (Phillips et al. 2018b p. 9; Ventrella 2024 pp. 7, 15; Aslan 2024c entire). In 2024, it was noted that at one site on the Navajo Nation the FPC are under heavy competition from nonnative plants, which make up 80 percent of the vegetation cover (Ventrella 2024 p. 15).

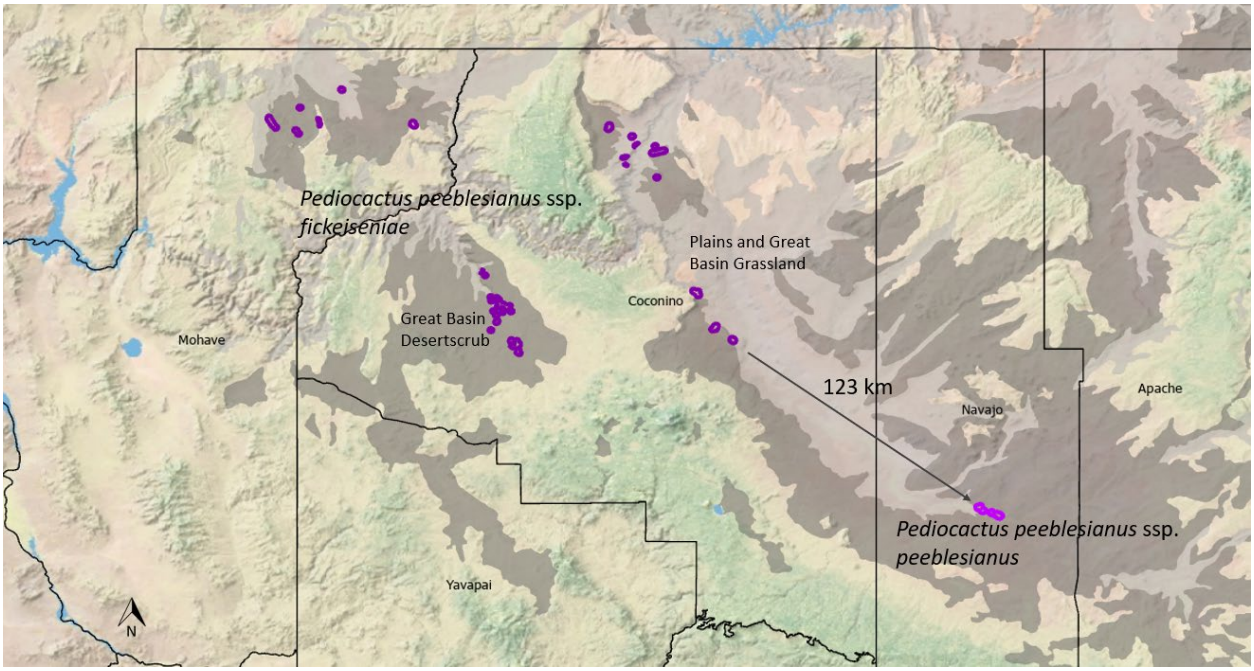


Figure 3.5. Locations of *Pediocactus peeblesianus* ssp. *fickeiseniae* and *P.p.* ssp. *peeblesianus* (purple outlines) in association with the Great Basin Desertscrub (dark grey) and Plains and Great Basin Grasslands (light grey) vegetation communities. Vegetation community spatial data is from The Nature Conservancy's Biotic Communities of the Southwest dataset which is based on the system of Brown and Lowe 1981 (The Nature Conservancy 2004 entire).

3.3.3 Microhabitat

Both subspecies require specialized substrates. The FPC occurs on soils derived from the Kaibab Formation (Figure 3.6). The Kaibab Formation is a Permian aged geologic formation that is fossil rich and was deposited approximately 270 million years ago in oceans (U.S. Geological Survey 2010 unpaginated; Karlstrom et al. 2021 p. 1). The Kaibab Formation is thickest (150 meters [500 feet]) in the western portion of the range and extends and thins eastward to the Holbrook area (Clark 2021 p. iv). The PNC occurs on soils derived from the Shinarump Member of the Chinle Formation or weakly alkaline gravelly soils (Figure 3.6). The Chinle Formation is a geological formation that was deposited over 210 million years ago during the late Triassic Period (National Park Service 2015 unpaginated; Hayes & DeCelles 2022 p. 1207). It is a thick geological layer ranging from 168 meters (550 feet) thick in the west to 226 meters (740 feet) thick in the east and containing many fossils and many subunits called members. The Shinarump Member is the oldest member of the Chinle Formation and was deposited by streams on an alluvial plain (U.S. Geological Survey 2010 unpaginated).

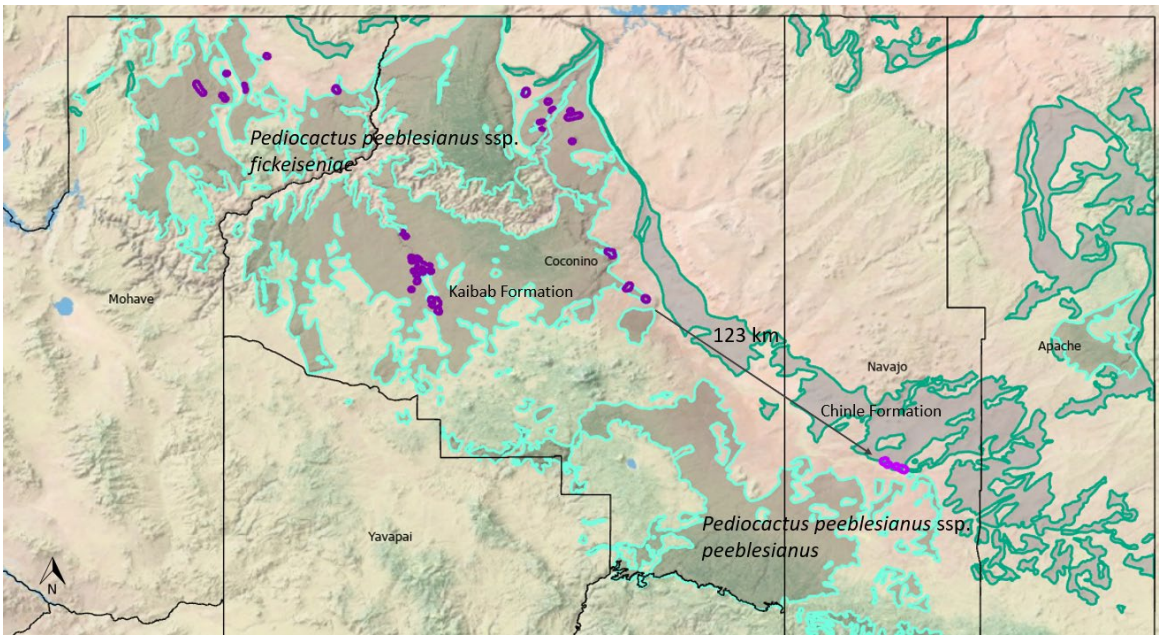
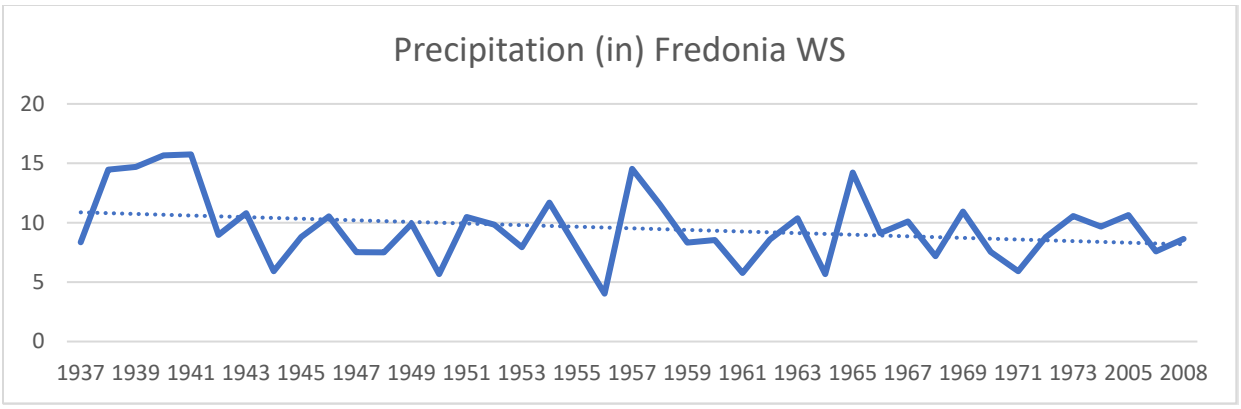


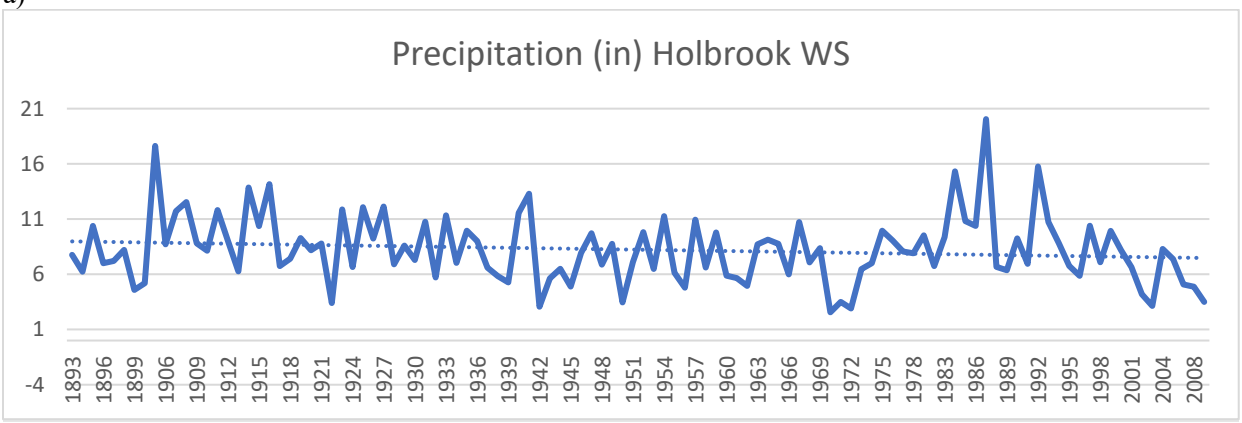
Figure 3.6. Northern Arizona locations of the Kaibab (light green outline) and Chinle (dark green outline) Formations in relation to known Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (*P. p.* ssp. *peeblesianus*) (purple outlines).

3.3.4 Climate

For FPC and PNC to produce flowers and set seed, and for seedling germination and establishment, adequate soil moisture from recharge during the previous winter is necessary (Milne 1987 p. 33; Hughes 2002b p. 3; Phillips & Phillips 2004 pp. 15–16; Navajo Nation 2012 p. 14; Aslan 2024a entire; Arizona Rare Plant Guide Committee n.d. unpaginated). The general soil moisture recharge period across the ranges is from December to March (Travis 1987 p. 3), when temperatures and soil evaporation are low. Accumulated soil moisture is usually depleted by the summer months in which the FPC and PNC will retract underground but may emerge following summer monsoon thunderstorms. In general, the precipitation trends across the ranges of both FPC and PNC have decreased by a few millimeters since records have been kept (Figures 3.7. a and b). Using 30-year normal (1991-2020) precipitation data, it appears the western portion of the ranges receives slightly more precipitation than the eastern portion of the ranges (Figure 3.8). Projected decrease in precipitation, increase in temperature, and increase in evapotranspiration throughout this region [NEED TO ADD REFERENCE HERE] indicate that the reproductive output for the FPC and the PNC may decrease in coming decades.



a)



b)

Figure 3.7. Annual total precipitation in inches for weather stations near the a) Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*; Fredonia Weather Station) and the b) Peebles Navajo cactus (*P.p. peeblesianus*; Holbrook Weather Station) (https://www.wrcc.dri.edu). Only complete annual data from that which is available is shown; note that Fredonia begins in 1937, and Holbrook begins in 1893. A trend line is added to show general decrease in annual precipitation for both weather stations across the periods of record.

3.8. Northern Arizona precipitation in mm using PRISM Climate Group data (https://www.prism.oregonstate.edu) in relation to known Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (*P. p*. ssp. *peeblesianus*). Light tan is <275mm / year and darker tan is 275.01-409 mm / year of precipitation.

The BLM designated vegetative habitat areas (VHA) at Twist Hills (including EO_ID 69, 26683, and 15584) and Upper Clayhole Valley (EO_ID 9267) for the FPC occurring in these areas. Management actions that apply to VHAs include increased emphasis on protection of the species, increased consideration during NEPA analysis, and the ability to modify, mitigate, postpone, or restrict proposed actions to minimize effects to the species. As discussed earlier, the PNC is located on an established BLM ACEC, which requires management in a manner that conserves, protects and enhances the relevant and important values identified during planning, in this case the PNC.

The Navajo Nation lists the FPC as a threatened species. This threatened status provides the plains cactus protection under Navajo Nation Code 17N.N.C. section 507. This section establishes the Navajo Endangered Species List and procedures for updating it, defines "take," and establishes the penalty of a fine for take. Five of the twenty-one FPC populations on the Navajo Nation are, at least partially, in areas designated as a Preserve (EO_IDs 70, 1647, 1806, 1807 and 3068). These areas contain excellent, or potentially excellent, wildlife habitat and are recommended by the Navajo Fish and Wildlife Department for protection from most human-related activities, and in some cases are recommended for enhancement. No new activity or development is allowed within these Preserves, unless it is compatible with management goals for the area. This does not include approved pre-existing activities. The Navajo Nation Fish and Wildlife Department uses the Resource Land Use Clearance Policies (RCP) to protect listed species from development projects. The RCP requires a biological evaluation (BE) to be prepared for any development that is not in a community development zone. The BE must demonstrate that the development activity will not negatively affect any listed species, including the FPC. It does not, however, apply to day-to-day activities of locals (such as livestock herding) and any tourist activities that cannot be easily regulated (i.e. driving and parking at unofficial overlooks). It should be noted that all five of the populations within the Preserve are currently in Moderate condition, our highest ranked condition among all populations.

On the Cataract Ranch, privately-owned parcels occupied by the FPC are under a conservation easement held by The Nature Conservancy (Goodwin 2008 p. 1). These deeded lands prohibit any development activities from occurring on these parcels and protects the inherent value of the land in perpetuity. Daily activities such as livestock grazing and range improvements are permitted. Approximately 14 percent of the FPC population is protected by the conservation easement. On other private or State lands, the PNC has no protections.

In summary, the existing legal or regulatory mechanisms currently in place help protect FPC and PNC habitat from impact associated with development projects that could result in habitat loss or fragmentation. However, they do not protect the habitat from disturbances associated with increases in drought temperature and small mammal predation; potential trampling by livestock, humans, or OHVs; the invasion and spread of nonnative plants and alteration of fire regimes; and other threats. As such, we find that the existing legal or regulatory mechanisms are inadequate to protect the FPC and PNC from habitat impact and this threat is incorporated with our analyses of drought, trampling, nonnative plant invasion and spread, and mining, energy, and infrastructure in the following chapters.

4.2 Conservation Measures

Although there are many threats to FPC and PNC, there are also conservation efforts underway, including seedbanking and grow out, exclosure fencing, land protections, surveys, monitoring, pollination study, and land management planning.

The Desert Botanical Garden collected seed of FPC in 2024; however, the seed was not viable. This institution maintains three individual potted cacti in their collection and plan on future collection attempts for conservation banking. In 2021, the Arboretum of Flagstaff collected 43 seeds from 5 individual PNC plants and maintain them in their conservation collection.

There are four populations of FPC from the BLM Arizona Strip area that occur within areas of increased emphasis on protection of the species. Similarly, within the Navajo Nation FPC populations, five occur on areas of increased protection from most human-related activities. Many of the PNC plants occur on both a BLM conservation area and within exclosures that limit access to livestock and OHV activity.

Surveys for both FPC and PNC occur, typically in association with annual monitoring. In 2024, scent detection dogs were employed to assist with Pediocactus plant detection and showed promising results. Scent detection work will continue in 2025 on FPC and PNC. Annual monitoring on select BLM and Navajo Nation FPC and PNC populations has been ongoing for many years and is anticipated to continue, producing long term datasets useful in determining trends and understanding biology, and useful in making projections.

Researchers with Northern Arizona University have been studying the pollination ecology of FPC since 2015 and have shown correlation of pollinator availability with annual precipitation. Land management planning for both FPC and PNC restricts travel to designated roads and trails, aiding in the prevention of plant loss to OHV activity. Similarly, these plans address the need for nonnative plant prevention and treatment.

While many conservation efforts for the FPC and the PNC are underway, there is more that needs attention. Seedbanking efforts must continue for both subspecies across their ranges to ensure genetic variability and grow out trials are needed. Pollination work should continue, to gain a longer-term picture of pollinator trends and correlation to both the FPC and associated flowering species. Studies of small mammal herbivory and predation are needed, as well as the interrelationships of these cacti to nonnative invasion, dust, trampling, and other threats. The continuation of monitoring is essential to understand the species, the trends, and the projections into the future. The addition of further or larger exclosures when new plants or populations are located, public education, and surveys would be welcomed for the conservation of these cacti.

CHAPTER 5. CURRENT CONDITIONS

5.1 Introduction

In Chapter 3 we discussed the needs of a resilient population and identified and described the population and habitat factors needed for resilient FPC and PNC populations. In Chapter 4, we described the threats affecting FPC and PNC populations. This chapter describes the methodology for assessing the resiliency of each population, describing the status of FPC and PNC. The viability of FPC and PNC populations is inferred over the near term based on demographic and habitat factors. We describe population resiliency levels as High, Moderate, Low, and Very Low, as well as Functionally Extirpated based on three demographic and one habitat factor that are the primary factors influencing FPC and PNC and for which we have the most data. These factors are: (1) number of individuals per population, (2) number of populations per RA (Representation Area), (3) annual precipitation, and (4) disturbances within populations that negatively impact individuals.

The available information indicates that there are 58 known populations of FPC in northern Arizona, with variability in the number of subpopulations from 1 to over 160 at one site on the Navajo Nation. As we have no location or population data for the few FPC found in Utah, we are not evaluating them here. At last count in 2019, there were 1,572 plants on Navajo Nation lands within RA Three (Talkington 2019 p. 1). Although we do not have a complete census of FPC from BLM lands north of Grand Canyon National Park on the Arizona Strip, monitoring plots from four populations indicate a decline in total FPC plants since peaks recorded in the early 1990s. In 2023, a total of 100 plants distributed between two of the four plots, and no plants found within the remaining two plots (Figure 5.1). There are likely additional plants outside of these monitored plots, but we have no complete census; we estimate a few hundred more outside of plots for a total of approximately 300 individuals in RA One. Similarly, we do not have a complete census of FPC from private and State of Arizona lands south of the Grand Canyon near Cataract Canyon, but a 2011 report on FPC from Cataract and Espee Ranch estimated 308 individuals total from this area (Goodwin 2011 p. 8). Since that time additional plants have been found on these ranches in 2024 and more suitable habitat remains to be surveyed. We estimate approximately 500 plants total from RA Two. On Kaibab National Forest lands there were 84 individuals counted in a 2015 census (Dastrup 2025 p. entire). Therefore, the total number of FPC individuals counted across the range is approximately 2,456.

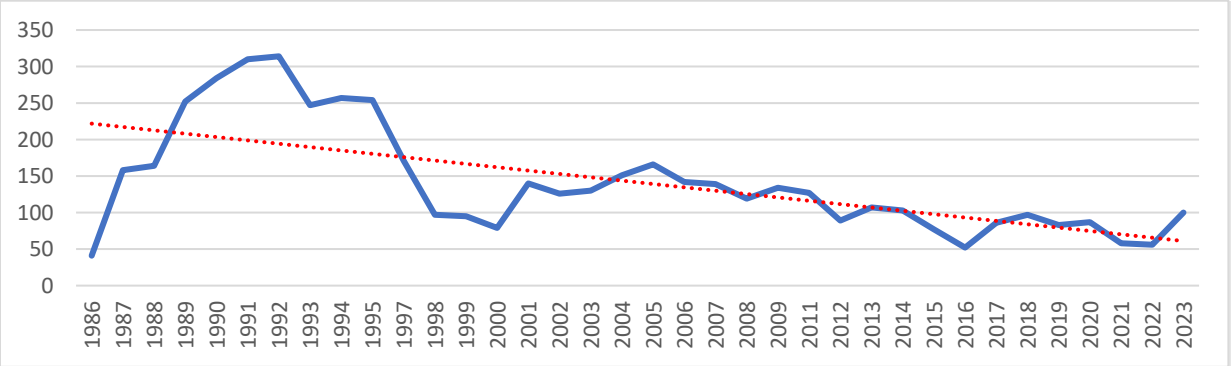


Figure 5.1. Number of individual Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) found within four combined Bureau of Land Management monitoring plots in RA One. Dashed line is general trend.

There are three known populations of PNC, the first having three subpopulations, the second having five subpopulations, and the third having two subpopulations. Based on the best available data, there are currently 284 known PNC among the three populations; this is a reduction from as many as 1,000 plants thought to occur in the single known population at the time of listing (Figure 5.2) (U.S. Fish and Wildlife Service 2022 p. 6).

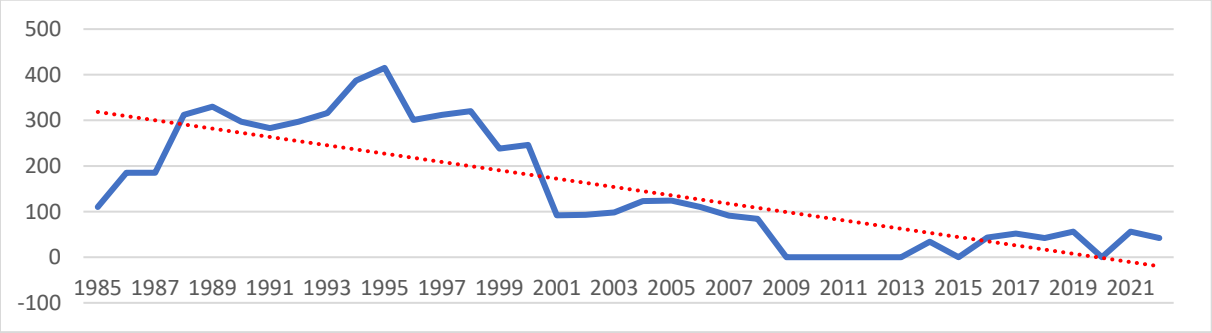


Figure 5.2. Number of individual Peebles Navajo cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*) found within three combined Museum of Northern Arizona monitoring plots within RA Four. Dashed line is general trend.

5.2 Representation Areas

We divide the 58 FPC populations into 3 Representation Areas (RA) based on geography, annual precipitation, and vegetation community (Figure 5.3). A fourth RA encompasses the PNC populations to the southeast (Figure 5.3). RA One includes the populations on the Arizona Strip in Mojave County, including populations found on BLM and State of Arizona lands. RA Two includes populations north and east of the Grand Canyon in Coconino County, including populations found on Havasupai Tribe, private, and State of Arizona lands. RA Three includes all of the populations east of the Grand Canyon in Coconino County; these populations are primarily on Navajo Nation lands, but also on BLM, U.S. Forest Service, National Park Service, private and State of Arizona land. RA Four includes the three PNC populations on BLM, State of Arizona, and private lands.

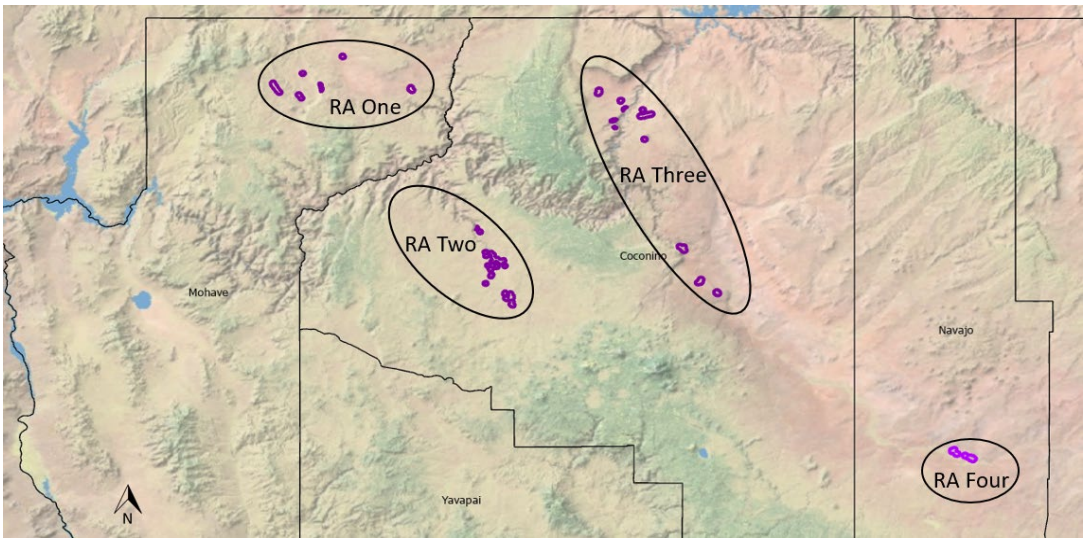


Figure 5.3. Four *Pediocactus peeblesianus* Representation Areas in northern Arizona. Representation Areas One, Two, and Three are *P.p.* ssp. *fickeiseniae*, while Representation Area Four is *P.p. peeblesianus*.

5.3 Current Species Resiliency

Several factors affect the resiliency of FPC and PNC populations. These include demographic factors such as abundance, the number of populations in a RA, and recruitment; as well as habitat factors such as the specialized substrates (Kaibab Formation for FPC and Shinarump Member of the Chinle Formation for the PNC), lack of disturbance that impact individual FPC and PNC, and pollinator presence. For our analysis of population resiliency, we focused on those factors for which we have sufficient data to assess influences on the current condition of FPC and PNC populations. In some instances, surrogates are used when more specific data are lacking.

5.3.1 Demographic Factors

5.3.1.1 Number of Individuals per Population

For FPC and PNC populations to be resilient, abundance should be large enough that local stochastic events do not eliminate all individuals, allowing recovery from any one event. A greater number of individuals in a population increases the chance that it will persist. For rare plants, a minimum population size of 100 is suggested to prevent inbreeding depression and more than 1,000 individuals may be required to maintain evolutionary potential (Jamieson & Allendorf 2012 p. 580; Maschinski & Albrecht 2017 p. 392). These numbers are much higher than can be expected for FPC or PNC populations. From the 58 populations across the range of FPC, there are currently 7 populations with more than 100 individuals and 51 populations with 50 or fewer individuals. From the 3 populations across the range of PNC one has more than 100 individuals and one has 50 or fewer individuals.

The survey data available for FPC and PNC include estimates of individuals from each of the three FPC and one PNC representation areas over time. We used both historical and current FPC count data to determine High, Moderate, Low, Very Low, and Functionally Extirpated condition classes based on natural breaks in the data (Figure 5.3). We are aware of three FPC populations currently with 345 or more individuals that are considered to be in High condition. There are 3 other populations that historically reached more than 150 individuals, so we use 150 individuals as a cutoff for Moderate condition. There are 7 populations historically that had 51 to 149 individuals, therefore we consider populations with 51 to 149 individuals in Low condition. Populations with 50 or fewer individuals are considered Very Low condition. Because individual plants may retract during times of environmental stress, it is possible that in some years few or even no plants may be located. We assume functional extirpation when no plants are detected in three out of the past five monitoring events. As high counts for the 3 PNC populations are 387, 106, and 83 individuals, we use these same criteria to determine PNC condition classes.

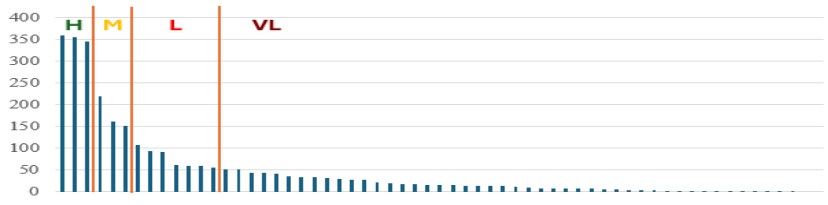


Figure 5.3 Depicting natural breaks in Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) abundance data to determine high moderate, low, and very low condition classes for abundance.

5.3.1.2 Number of Populations per Representation Area

We do not fully understand the interaction of populations within representation areas. We assume a greater number of populations will increase resiliency such that local stochastic events do not eliminate entire FPC or PNC populations. We do not anticipate that populations are close enough to support pollen exchange between groups based on our understanding that small bees typically pollinate these plants and do not travel over 200 meters between plants (Aslan 2024a entire). However, there could be larger bees interacting between populations for which we have no information and there could be more populations than we are aware of connecting plants and pollinators. We also do not anticipate that seeds travel much farther than the parent plant, however, it is possible the wind could carry them more than the 200 meters allotted to differentiate populations. It is possible that threats may impact some populations and not others, even if they are in fairly close proximity. Therefore, for FPC and PNC RAs to be resilient, abundance of populations should be large enough that local stochastic events do not eliminate all populations, allowing recovery from any one event.

Based on the current number of known populations, we determine that High condition for the number of populations within a RA occurs when there are 25 or more populations, Moderate condition occurs when there are 15 to 24 populations within a RA, Low condition occurs where there are 5 to 14 populations within a RA, and Very Low condition occurs when there are fewer than 5 populations in a RA. Again, we assume a Functionally Extirpated condition when no populations are located in three of the past five monitoring events. There are 9 FPC populations within RA One (Low condition), 22 within RA Two (Moderate condition), 29 within RA Three (High condition), and 3 within RA Four (Very Low condition) (Table 5.1).

Table 5.1. Populations within the three Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) Representation Areas and the Peebles Navajo cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*) Representation Area. Representation Areas are placed into condition class based on the number of populations in each location.

Representation Area	Geographic Location	Condition Class (No. Populations)
RA One	Arizona Strip	Low
RA Two	Cataract Canyon	Moderate
RA Three	East of Grand Canyon	High
RA Four (PNC)	Holbrook Area	Very Low

5.3.1.3 Recruitment

Resilient FPC and PNC populations must produce flowers and viable seeds to offset individuals killed by drought, herbivory, trampling, burial, other threats, or natural senescence. In most instances where reproduction has been recorded, only a portion of the plants are flowering or fruiting at any given time. We do not know how long seedbanks are viable. As seedlings are extremely difficult to detect, not all surveys contain seedling counts. We do know that both flower and seed production, as well as seedling survival are closely tied to precipitation. Therefore, we use precipitation as a surrogate for recruitment. In 19 of 82 total precipitation records available for the Fredonia and the Holbrook Weather Stations between 1937 and 2008 (Fredonia) and 1893 and 2009 (Holbrook) the annual precipitation exceeded 350 mm (14 inches). We use 350 mm (14 inches) as the lower cutoff for High condition precipitation. In 18 of 82 records, the annual precipitation was between 279.4 and 355.4 mm (11 and 13.99 inches),

and we use this range as the cutoff for Moderate condition precipitation. In 21 of 82 records, the annual precipitation was between 202.2 and 279.2 mm (8 and 10.99 inches), and we use this range as the cutoff for Low condition precipitation. Very Low condition is recorded in locations with 101.6 to 202.9 mm (4 to 7.99 inches) of precipitation annually, and below 101.6 mm (4 inches) of precipitation is considered Functionally Extirpated.

Since weather station data for the past 15 years are not available, we used annual precipitation PRISM data (https://www.prism.oregonstate.edu/), dividing it into 50 annual precipitation intervals. From this we determined that RA One is almost entirely within the 300 to 350 mm (11.8 to 13.8 inches) range, with two populations being in the 250 to 300 mm (9.8 to 11.8 inches) range. RA Two is almost entirely in the 350 to 400 mm (13.8 to 15.7 inches) range with two populations in the 300 to 350 mm (11.8 to 13.8 inches) range. RA Three in the north is in the 200 to 250 mm (7.9 to 9.8 inches) range but in the south is in the 100 to 200 mm (3.9 to 7.9 inches) range. Finally, RA Four is entirely in the 200 to 250 mm (7.9 to 9.8 inches) range. To compare this with weather station data derived categories, this roughly translates to no RA being in High condition, two in Moderate condition, and two in Low condition. No RAs are in Very Low condition (Table 5.2).

Table 5.2. Populations within the three FPC Representation Areas and the Peebles Navajo cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*) Representation Area are placed into condition class based on annual precipitation in each location.

Representation Area	Geographic Location	Condition Class (Precipitation)
RA One	Arizona Strip	Moderate
RA Two	Cataract Canyon	Moderate
RA Three	East of Grand Canyon	Low
RA Four (PNC)_	Holbrook Area	Low

5.3.2 Habitat Factors

Disturbance

5.3.2.1 *Undisturbed Habitat within the Plains and Great Basin Grasslands and Great Basin Desertscrub vegetation communities*

We are aware of many instances of impacts to the FPC and PNC from trampling, ash deposition, nonnative invasion and spread, and other threats. The FPC and PNC have the greatest potential to thrive when these impacts are reduced or eliminated. We base our habitat factor analysis on the probability of these impacts on each population based on known threats from recent history, in or nearby populations, and look at these impacts on a population-by-population basis. When no information is available, we gave a score within the Moderate condition category. We recognize many impacts occurred in northern Arizona historically; however, we only assess threats documented within the past 30 years going forward in our analyses.

5.3.2.2 Pollinator Presence

FPC and PNC require pollinators for pollen transfer within and between plants, in particular sweat bees (family Halictidae), hover flies (family Syrphidae), bee flies (family Bombyliidae),

and mining bees (family Andrenidae), as well as thrips and ants (*Forelius pruinosus*, and the genera *Pheidole* and *Pogonomyrmex*). Pollination is closely correlated with precipitation and therefore this factor is included within the Recruitment Factor above and will not be assessed separately.

5.4 Population Resiliency Analyses

In this section, we describe our methodology for assessing the resiliency of each FPC and PNC population. We begin with the understanding of what the various condition categories are (i.e., High, Moderate, Low, Very Low, and Functionally Extirpated; Table 5.1) for each analysis factor, as described in the previous sections. To analyze resiliency levels, we used the following factors: Number of Populations; Number of Populations within Representation Areas, Recruitment, and Level of Disturbance (Table 5.3). These factors have available data and provide quantitative measures to assess condition.

Table 5.3. Condition categories for demographic and habitat factors used to evaluate Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*) population resiliency.

Condition Categories	Number of Individuals per Population	Number of Populations per Representation Area	Recruitment (Annual precipitation in inches as determined by weather station and PRISM data for the last 10 year period)	Disturbance (Percent of Habitat Affected -or- Closeness of Impact)
High (3)	≥ 345	≥ 25	≥ 14	<10% impact - or - impacts noted >300 meters away
Moderate (2)	150 to 344	15 to 24	11 and 13.99	<20% impact - or - impacts noted > 200 meters away
Low (1)	51-149	5 to 14	8 to 10.99	<30% impact - or - impacts noted >100 meters away
Very Low (0.5)	≤ 50	<5	5 to 7.99	<40% impact - or - impacts within populations
Functionally Extirpated (0)	No plants found in 3 of 5 of the last surveys	No Plants Found in 3 of 5 Last Surveys	<5	<50% impact - or- impacts within populations

We assigned a numerical value to the condition categories, High=3, Moderate=2, Low=1, Very Low = 0.5, and Extirpated =0, so we could calculate a score for each of the four factors. We averaged all the condition category scores for each population to determine the overall resiliency score. To provide context for this score, we established an overall resiliency scale from 0 to 3 to communicate our understanding of the overall condition of each population. To determine the overall resiliency scale, we first determined the highest score attainable (3) and the lowest score

attainable (0). Within this range, we established five overall resiliency levels based on the number of population and habitat factors in the condition categories:

- High: 2.4-3.0
- Moderate:1.7-2.39
- Low: 1.0-1.69
- Very Low: 0.51-0.99
- Functionally Extirpated: < 0.5

Populations in High condition are anticipated to be highly resilient even in the face significant environmental stochasticity, having high likelihood of persisting in the near term. Those in Moderate condition have experienced some form of degradation that has reduced their resiliency and made them more vulnerable to stochastic events. Still, in the near term we anticipate these populations have a high likelihood of persisting. Low condition indicates populations that have been diminished to the point that they have increased probability of being extirpated in the near term. Those in Very Low face functional extirpation if on-the-ground conservation measures are not immediately implemented. For any population where specific information is not available, we use our best professional judgement (based on experience with the known ecology of congener species) to make assumptions to complete our analysis based on what we do know about this species and similar species, habitat conditions, and the data reported. Systematic, regular surveys have not been conducted throughout the full range of FPC and PNC. Survey information within and among populations varies in timing, data collected, and surveyor.

From the literature, we are aware of specific documented threats to individual populations (Table 5.4). Although many of these threats were detected in single events in the past, we know these threats continue to occur. Therefore, we give a condition class of Low (<30% impact -or- impacts noted within 100 meters) for disturbance category in all populations listed in Table 5.4.

Table 5.4. Populations of Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*) and documented threats, used in our analysis of current conditions.

Population	**Threat Documented**
EO_ID 4443	Rapid increase in *Salsola* sp. throughout the House Rock Valley in 2024
ID 9267:	Three plants were trampled by livestock in 1988
EO_ID 69	Two plants were trampled by livestock in 2000; *Salsola* sp. inside the plot in 2011; nonnative grasses could facilitate spread of fire, undated; plants affected by drivers pulling off designated routes in 2005
EO_ID 1647	Habitat disturbance from feral horses and sheep in 2012
EO_ID 14670	Plants have high risk of trampling in 2001; nonnatives abundant and soil stability low in 2005; nonnatives following fire may contribute to decline in FPC in 2007; unauthorized camping and driving off road in 2007; rapid increase in *Salsola* sp. throughout the House Rock Valley in 2024
EO_ID 228	Potential for illegal collection and trampling
EO_ID 1807	Livestock damage by sheep in 2005, 2008, and 2011
EO_ID 1806	Livestock damage in 2011; presence of nonnative annual grasses in 2007, nonnative grasses could facilitate spread of fire, undated

Population	Threat Documented
EO_ID 982	Livestock hoofprints near plants in 1991 and 1994; possible running over by vehicles in 1991and 1993
EO_ID 9217	Seven plants were trampled by livestock in 2004; nonnatives were abundant and soil stability low in 2005; nonnative grasses could facilitate spread of fire, undated; there are six mines surrounding this population as of 2011
EO_ID 8613	Ash deposition
EO_ID 7444	Ash deposition
All in RAs 1, 2, and 3	For all populations in RAs One, Two, and Three we assume a moderate level of disturbance, that is <20 percent of the land is impacted by common threats such as livestock grazing and nonnative plant invasion

Based on our overall current condition analysis, no populations were found currently to be in High condition, however eight scored as Moderate condition, all from RA Three (Table 5.5). Two populations of PNC in RA 4 were found to be in Very Low condition, with all other populations considered currently in Low condition. No populations are thought to be Functionally Extirpated. Table 5.5 and Appendix Two show the current condition of the 58 FPC and 3 PNC populations. The remaining FPC and PNC populations can be best characterized as having Low condition and are vulnerable to stochastic processes.

Table 5.5. Current Condition of all Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (*P. p.* ssp. *peeblesianus*) populations.

RA	EO_ ID	Number Plants / Population	Number Populations / RA	Recruitment	Disturbance Level	Average	Rank
1	69	0.5	1	2	1	1.1	Low
1	4443	0.5	1	2	1	1.1	Low
1	6099	0.5	1	2	2	1.4	Low
1	9217	0.5	1	2	1	1.1	Low
1	9267	0.5	1	2	1	1.1	Low
1	15584	0.5	1	2	2	1.4	Low
1	15585	0.5	1	2	2	1.4	Low
1	26683	0.5	1	2	2	1.4	Low
1	26721	0.5	1	2	2	1.4	Low
2	18077	0.5	2	2	2	1.6	Low
2	18078	0.5	2	2	2	1.6	Low
2	18079	0.5	2	2	2	1.6	Low
2	18080	0.5	2	2	2	1.6	Low
2	18081	0.5	2	2	2	1.6	Low
2	18086	0.5	2	2	2	1.6	Low
2	18087	0.5	2	2	2	1.6	Low
2	18088	0.5	2	2	2	1.6	Low
2	18089	0.5	2	2	2	1.6	Low
2	20407	0.5	2	2	2	1.6	Low
2	20408	0.5	2	2	2	1.6	Low
2	20409	1	2	2	2	1.8	Low
2	26680	0.5	2	2	2	1.6	Low
2	26685	0.5	2	2	2	1.6	Low
2	26686	0.5	2	2	2	1.6	Low

RA	EO_ ID	Number Plants / Population	Number Populations / RA	Recruitment	Disturbance Level	Average	Rank
2	26687	0.5	2	2	2	1.6	Low
2	26688	0.5	2	2	2	1.6	Low
2	26689	0.5	2	2	2	1.6	Low
2	26690	0.5	2	2	2	1.6	Low
2	26691	0.5	2	2	2	1.6	Low
2	26692	0.5	2	2	2	1.6	Low
2	26693	0.5	2	2	2	1.6	Low
3	14670	0.5	3	1	1	1.4	Low
3	26694	0.5	3	1	2	1.6	Low
3	26695	0.5	3	1	2	1.6	Low
3	26720	0.5	3	1	2	1.6	Low
3	2843	0.5	3	1	2	1.6	Low
3	228	0.5	3	1	1	1.4	Low
3	1250	0.5	3	1	2	1.6	Low
3	70	1	3	1	2	1.8	Moderate
3	982	0.5	3	1	2	1.6	Low
3	771	1	3	1	2	1.8	Moderate
3	1506	0.5	3	1	2	1.6	Low
3	1042	0.5	3	1	1	1.4	Low
3	603	0.5	3	1	2	1.6	Low
3	1540	0.5	3	1	2	1.6	Low
3	1640	1	3	1	2	1.8	Moderate
3	1647	1	3	1	2	1.8	Moderate
3	1806	0.5	3	1	2	1.6	Moderate
3	1807	3	3	1	2	2.3	Moderate
3	1902	0.5	3	1	2	1.6	Low
3	3068	3	3	1	2	2.3	Moderate
3	3866	3	3	1	2	2.3	Moderate
3	3878	0.5	3	1	2	1.6	Low
3	3879	0.5	3	1	2	1.6	Low
3	3928	0.5	3	1	2	1.6	Low
3	3951	0.5	3	1	2	1.6	Low
3	4040	0.5	3	1	2	1.6	Low
3	4165	0.5	3	1	2	1.6	Low
4	8613	0.5	0.5	1	1	0.8	Very Low
4	13804	0.5	0.5	1	2	1.0	Very Low
4	7444	2	0.5	1	1	1.1	Low

5.5 Current Species Representation

All historically known populations within each RA are extant. The FPC range covers a wide area, while the PNC range covers a small area disjunct from the FPC. These populations are likely subjected to different selective pressures due to local conditions; the FPC likely has some degree of adaptive capacity due to the differences in precipitation, soil depth, vegetation community, and other factors from the westernmost to the easternmost populations. The PNC likely has less adaptive capacity due to its small range and similar habitats.

5.6 Current Species Redundancy

There are 58 FPC populations within 3 representation areas and 3 PNC populations within a single representation area in Arizona. Within populations there may be one to many subpopulations, which may aid in reestablishment following catastrophic events; however, seeds are not known to travel far. Thus, even localized redundancy within the scale of populations is limited. Range wide, given its sheer geographic extent, it is unlikely that a single catastrophe would lead to the extinction of the FPC; however, the distribution of PNC is much smaller and may have some likelihood of extinction if a catastrophic event occurred across its range.

CHAPTER 6. FUTURE VIABILITY

In previous chapters we have considered what FPC and PNC need for viability, the threats and conservation measures that are influencing species viability, and the current condition of all populations. We now consider what their future conditions are likely to be by varying the factors from Chapter 5 under two scenarios across a 30-year time step to capture a plausible range of future conditions.

6.1 Scenarios Assessment

We have uncertainty regarding future levels of and effects from: (1) trampling from livestock, OHV, or foot traffic; (2) nonnative plants invasion or treatment; insect herbivory or predation; and (4) the amount of illegal collection which may occur. While we have data to inform us of the threats that are likely to impact FPC and PNC populations in the future, and we understand how these threats can impact these subspecies, there is uncertainty regarding the exact risk of the threats to each population because of limitations of the data, such as where and when each threat will occur in the future and exactly which populations will be impacted. We use available data and our best judgement to determine which populations have the greatest likelihood of experiencing these threats.

We have forecast what FPC and PNC may have in terms of resiliency, redundancy, and representation under two plausible future scenarios over the next 30 years. We chose 30 years to allow us adequate time to determine if drought will impact reproduction, growth, and vigor of FPC and PNC. For each scenario, we describe the level of impact from the identified threats that would occur in each population. Both scenarios involve some degree of uncertainty; however, they present a range of realistic and plausible future conditions. Table 6.1 below summarizes the two scenarios, both of which consider impacts from drought, rising temperatures, and increased herbivory; the development of mines, energy, or infrastructure; trampling from livestock, OHV, or recreation; nonnative plant invasion and spread and the alteration of fire regimes; and illegal collection of individuals. We assumed that all populations have an equally likely probability of experiencing drought, increased temperatures, and small mammal herbivory. Populations with fewer than 100 individuals are assumed to be less resilient to these effects. We labelled our two scenarios as Low Effects versus High Effects, which reflects difference in the severity of future stressors.

Table 6.1. Future Scenario Descriptions for both *Pediocactus peeblesianus* subspecies.

Risk	**Increased Drought, Temperature, and Small Mammal Herbivory**	**Mining, Energy, and Infrastructure Development**	**Effects to Small Populations**
Risk Described	Reduction in available water for growth, flowering, fruiting, and pollinator health; heat increases; small mammal predation increases.	Direct or indirect loss of individuals, subpopulations, or populations from mining, energy, or infrastructure development, erosion, dust, or other related threats.	Trampling by livestock, OHV or recreation; nonnative plant competition; insect herbivory and predation; or illegal collection

Risk	Increased Drought, Temperature, and Small Mammal Herbivory	Mining, Energy, and Infrastructure Development	Effects to Small Populations
Scenario 1: Low Effects	Available water, drought, and temperature increase continue at the same level as in the past 10 years or improve; Emissions scenario 4.5	One development added in next 30 years	Impacts remain stable or improve, impacting individuals and not populations.
Scenario 2: High Effects	Available water is reduced, and drought and temperatures worsen; Emissions scenario 8.5	More than one development added in the next 30 years	Increase in livestock, OHV, or recreation; increase in insect herbivory or predation; or increase in illegal collection

6.2 Scenarios

The Drought, Temperature, and Small Mammal Herbivory Low Effects Scenario includes no further departure from the current drying and increased temperatures of the current RCP 4.5 emissions scenario and there are no changes to current small mammal predation. The Low Effects Development scenario would maintain the current level or increase by one, the number of mines, energy infrastructure, roads, and transmission lines in or nearby populations of either FPC or PNC. The Low Effects to Small Populations Scenario includes suitable livestock management; no or a reduction in off designated road OHV activity; similar to present levels of insect herbivory, predation, or illegal collection; and the prevention of nonnative plant invasion and treatment of larger nonnative infestations. The Low Effects scenario would include regular monitoring and restoration as applicable.

The Drought, Temperature, and Small Mammal Herbivory High Effects Scenario approaches the RCP 8.5 emissions scenarios and involves decreases in available water for FPC and PNC and associated pollinator plants, increased temperatures that stress plants and reduce growth, flowering, or fruiting, and increased small mammal predation. The High Effects Development scenario would increase by more than one the number of mines, energy infrastructure, roads, or transmission lines developed in or nearby populations. The High Effects to Small Populations Scenario involves increased pressure to FPC and PNC from trampling by livestock, OHV, or recreation; nonnative plant invasion and spread, insect herbivory or predation; or illegal collection.

To assess the level of impact from a threat to a population, we developed Impact Categories (Table 6.2). In the Low Effects Scenario, drought, increased temperatures, and small mammal herbivory have the greatest impact to FPC and PNC as illustrated in section 4.1 and is given the highest impact score of -0.15. As all populations are equally likely to have these threats, this deduction is taken equally among populations.

Loss of individuals, subpopulations, or populations to mining (uranium, gravel, etc.), energy or infrastructure development are impactful, if realized. The populations with the nearest mining activity currently are EO_ID 9217, EO_ID 14670, EO_ID 228, EO_ID 2843, and EO_ID 1250

of FPC, and EO_ID 7444 and EO_ID 13804 of PNC. Also, the two PNC populations closest to the Cholla Electric Plant, EO_ID 8613 and EO_ID 7444, whose tailings ponds heavily impact the PNC and its habitat, are included here. These particular populations are given an impact score of -0.10 under the Low Effects Scenario.

Effects to small populations are least likely to impact large numbers of FPC and PNC individual; however, this category includes many threats including livestock and human trampling, OHV activity, insect predation and herbivory, nonnative competition, and illegal collection, and therefore also receives a score of -0.1, although these effects can be detrimental on small scales. We assume that the populations in both RA One and RA Three have equal probability of impacts from livestock grazing, OHV activity, recreation, insect predation, and illegal collection, whereas those in RA Two are less likely to be impacted by livestock grazing and OHV activity threats due to current management and remoteness of locations. We assume the FPC population at the LCR overlook has a higher probability of illegal collection, but this is already accounted for in the baseline score. We also assume the PNC populations have the least likelihood of most of these impacts due to the presence of exclosures which protect many of the PNC within two of the three populations. We rounded the final scores to the nearest tenth. The deductions for each category are doubled for the High Effects Scenario.

We use the same scale as in section 5.3.3 to determine High, Moderate, Low, Very Low, or Functionally Extirpated classes in the Low Effects and High Effects future scenarios (High: 2.4-3.0; Moderate:1.7-2.3; Low: 1.0-1.6; Very Low:0.51-0.99, Functionally Extirpated: < 0.5). Functionally Extirpated is defined as populations which will only remain extant if conservation actions are implemented to reduce threats or augment populations.

Table 6.2. Impact Category Scores represent the level of impacts to Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (*P. p.* ssp. *peeblesianus*) populations from drought, temperatures, and herbivory; mining, energy, and infrastructure development; and effects to small populations. These values represent the anticipated direction and magnitude of change from current conditions and are deducted on a population-by-population basis.

Scenario	Drought, Temperatures, and Herbivory	Mining, Energy, and Infrastructure Development	Effects to Small Populations	Total Possible Reduction
Low Effects	-0.15	-0.1	-0.1	-0.35
High Effects	-0.3	-0.2	-0.2	-0.7

The Overall Resiliency categories are the same as those used for Current Condition. Similarly, we averaged all of the condition category scores for each population for each scenario at the 30-year time step to determine the overall resiliency score. We examined the resiliency, representation, and redundancy of FPC and PNC under each of these plausible scenarios. Resiliency of populations depends on future availability of appropriate habitat and population elements. We projected the expected future resiliency, representation, and redundancy of FPC and PNC based on the events that would occur under each scenario. As a general rule, when a population condition reaches the Very Low category, the population is at greater risk of being lost due to stochastic environmental variation.

6.2.1 Resiliency, Representation, and Redundancy

We used the best available information to forecast the likely future condition of FPC and PNC. Our goal was to describe the viability of the FPC and PNC in a manner that will address the needs of these cacti in terms of resiliency, representation, and redundancy. We considered the two possible future conditions of these cacti that include important influences on their status. Our results indicate possible future condition and where FPC and PNC populations are likely to persist into the future.

Under the Low Effects scenario, no FPC or PNC populations would be in High condition, 3 FPC would be in Moderate condition (5.2 percent), 49 FPC populations would be in Low condition (84.5 percent), 4 FPC and 2 PNC would be in Very Low condition (6.9 and 66.7 percent, respectively), and 1 PNC population would be Functionally Extirpated (33.3 percent) (Table 6.3). Under this scenario, redundancy would decrease from the current condition, because 5 populations would be reduced from Moderate condition to Low condition, 4 FPC populations and 1 PNC population would be reduced from Low condition to Very Low condition, and 1 Very Low condition would be reduced to Functionally Extirpated. Further, the potential loss of 4 FPC populations and all 3 PNC populations in Very Low or Functionally Extirpated condition classes would reduce connectivity. Overall, under the Low Effects scenario, 49 FPC populations would retain current condition levels, and the remaining 9 FPC populations would have reduced condition relative to current conditions, while 1 of 3 PNC populations would retain current condition and 2 of 3 PNC would have reduced condition relative to current conditions (Table 6.3 and Appendix Two).

Table 6.3 Current and Low Effects Future condition of Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (*P. p.* ssp. *peeblesianus*) populations.

RA	EO_ ID	Current Condition	Rank Current Condition	Low Effects (-0.15) Drought Temperatures Small Mammal Herbivory	Low Effects (-0.10) Mines, etc.	Low Effects (-0.1) Small Pops	Total Deduction Low Effects	New Score Low Effects	Rank Low Effects
1	69	1.1	Low	0.15	0.00	0.10	0.25	0.9	Very Low
1	4443	1.1	Low	0.15	0.00	0.10	0.25	0.9	Very Low
1	6099	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low
1	9217	1.1	Low	0.15	0.10	0.10	0.35	0.8	Very Low
1	9267	1.1	Low	0.15	0.00	0.10	0.25	0.9	Very Low
1	15584	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low
1	15585	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low
1	26683	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low
1	26721	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low
2	18077	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	18078	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	18079	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	18080	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	18081	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	18086	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	18087	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low

RA	EO_ ID	Current Condition	Rank Current Condition	Low Effects (-0.15) Drought Temperatures Small Mammal Herbivory	Low Effects (-0.10) Mines, etc.	Low Effects (-0.1) Small Pops	Total Deduction Low Effects	New Score Low Effects	Rank Low Effects
2	18088	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	18089	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	20407	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	20408	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	20409	1.8	Low	0.15	0.00	0.00	0.15	1.6	Low
2	26680	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	26685	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	26686	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	26687	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	26688	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	26689	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	26690	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	26691	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	26692	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
2	26693	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low
3	14670	1.4	Low	0.15	0.10	0.10	0.35	1.0	Low
3	26694	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	26695	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	26720	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	2843	1.6	Low	0.15	0.10	0.10	0.35	1.3	Low
3	228	1.4	Low	0.15	0.10	0.10	0.35	1.0	Low
3	1250	1.6	Low	0.15	0.10	0.10	0.35	1.3	Low
3	70	1.8	Moderate	0.15	0.00	0.10	0.25	1.5	Low
3	982	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	771	1.8	Moderate	0.15	0.00	0.10	0.25	1.5	Low
3	1506	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	1042	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low
3	603	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	1540	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	1640	1.8	Moderate	0.15	0.00	0.10	0.25	1.5	Low
3	1647	1.8	Moderate	0.15	0.00	0.10	0.25	1.5	Low
3	1806	1.6	Moderate	0.15	0.00	0.10	0.25	1.4	Low
3	1807	2.3	Moderate	0.15	0.00	0.10	0.25	2.0	Moderate
3	1902	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	3068	2.3	Moderate	0.15	0.00	0.10	0.25	2.0	Moderate
3	3866	2.3	Moderate	0.15	0.00	0.10	0.25	2.0	Moderate
3	3878	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	3879	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	3928	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	3951	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	4040	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low
3	4165	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low

RA	EO_ ID	Current Condition	Rank Current Condition	Low Effects (-0.15) Drought Temperatures Small Mammal Herbivory	Low Effects (-0.10) Mines, etc.	Low Effects (-0.1) Small Pops	Total Deduction Low Effects	New Score Low Effects	Rank Low Effects
4	8613	0.8	Very Low	0.15	0.10	0.00	0.25	0.5	Function-ally Extirpated
4	13804	1.0	Very Low	0.15	0.10	0.00	0.25	0.8	Very Low
4	7444	1.1	Low	0.15	0.10	0.00	0.25	0.9	Very Low

Under the High Effects scenario, no populations would be in High condition, 3 FPC populations (5.2 percent) would be in Moderate condition, 41 FPC populations (70.7 percent) would be in Low condition, 14 FPC populations and 1 PNC population (24.1 and 33.3 percent, respectively) would be in Very Low condition, and 3 FPC and 2 PNC populations (5.1 and 66.7 percent, respectively) would be Functionally Extirpated (Table 6.4). Under this scenario, redundancy would decrease from the current condition, because 5 FPC populations would be reduced from Moderate condition to Low condition, 13 FPC populations and 1 PNC population would be reduced from Low condition to Very Low condition, and 1 FPC and 2 PNC populations would be reduced from Very Low condition to Functionally Extirpated. Further, the potential loss of 17 FPC and all 3 PNC populations in Very Low or Functionally Extirpated condition classes would reduce connectivity. Overall, under the High Effects scenario, 39 FPC populations would retain current condition levels, and the remaining 22 FPC populations would have reduced condition relative to current conditions, while all 3 PNC populations would have reduced condition relative to current conditions (Table 6.4 and Appendix Two).

Table 6.4 Current and Low Effects Future condition of Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) and Peebles Navajo cactus (*P. p.* ssp. *peeblesianus*) populations.

RA	EO_ ID	Current Condition	Rank	High Effects (-0.3) Drought, Temperatures, Small Mammal Herbivory	High Effects (-0.20) Mines, etc.	High Effects (-0.2) Small Pops	Total Deduction High Effects	New Score High Effects	Rank High Effects
1.0	69	1.1	Low	0.3	0	0.2	0.5	0.6	Very Low
1.0	4443	1.1	Low	0.3	0	0.2	0.5	0.6	Very Low
1.0	6099	1.4	Low	0.3	0	0.2	0.5	0.9	Very Low
1.0	9217	1.1	Low	0.3	0.2	0.2	0.7	0.4	Functionally Extirpated
1.0	9267	1.1	Low	0.3	0	0.2	0.5	0.6	Very Low
1.0	15584	1.4	Low	0.3	0	0.2	0.5	0.9	Very Low
1.0	15585	1.4	Low	0.3	0	0.2	0.5	0.9	Very Low
1.0	26683	1.4	Low	0.3	0	0.2	0.5	0.9	Very Low
1.0	26721	1.4	Low	0.3	0	0.2	0.5	0.9	Very Low
2.0	18077	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	18078	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	18079	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	18080	1.6	Low	0.3	0	0	0.3	1.3	Low

RA	EO_ ID	Current Condition	Rank	High Effects (-0.3) Drought, Temperatures, Small Mammal Herbivory	High Effects (-0.20) Mines, etc.	High Effects (-0.2) Small Pops	Total Deduction High Effects	New Score High Effects	Rank High Effects
2.0	18081	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	18086	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	18087	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	18088	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	18089	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	20407	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	20408	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	20409	1.8	Low	0.3	0	0	0.3	1.5	Low
2.0	26680	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	26685	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	26686	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	26687	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	26688	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	26689	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	26690	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	26691	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	26692	1.6	Low	0.3	0	0	0.3	1.3	Low
2.0	26693	1.6	Low	0.3	0	0	0.3	1.3	Low
3.0	14670	1.4	Low	0.3	0.2	0.2	0.7	0.7	Very Low
3.0	26694	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	26695	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	26720	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	2843	1.6	Low	0.3	0.2	0.2	0.7	0.9	Very Low
3.0	228	1.4	Low	0.3	0.2	0.2	0.7	0.7	Very Low
3.0	1250	1.6	Low	0.3	0.2	0.2	0.7	0.9	Very Low
3.0	70	1.8	Moderate	0.3	0	0.2	0.5	1.3	Low
3.0	982	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	771	1.8	Moderate	0.3	0	0.2	0.5	1.3	Low
3.0	1506	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	1042	1.4	Low	0.3	0	0.2	0.5	0.9	Very Low
3.0	603	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	1540	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	1640	1.8	Moderate	0.3	0	0.2	0.5	1.3	Low
3.0	1647	1.8	Moderate	0.3	0	0.2	0.5	1.3	Low
3.0	1806	1.6	Moderate	0.3	0	0.2	0.5	1.1	Low
3.0	1807	2.3	Moderate	0.3	0	0.2	0.5	1.8	Moderate
3.0	1902	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	3068	2.3	Moderate	0.3	0	0.2	0.5	1.8	Moderate
3.0	3866	2.3	Moderate	0.3	0	0.2	0.5	1.8	Moderate
3.0	3878	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	3879	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	3928	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	3951	1.6	Low	0.3	0	0.2	0.5	1.1	Low

RA	EO_ ID	Current Condition	Rank	High Effects (-0.3) Drought, Temperatures, Small Mammal Herbivory	High Effects (-0.20) Mines, etc.	High Effects (-0.2) Small Pops	Total Deduction High Effects	New Score High Effects	Rank High Effects
3.0	4040	1.6	Low	0.3	0	0.2	0.5	1.1	Low
3.0	4165	1.6	Low	0.3	0	0.2	0.5	1.1	Low
4.0	8613	0.8	Very Low	0.3	0.2	0	0.5	0.3	Functionally Extirpated
4.0	13804	1.0	Very Low	0.3	0.2	0	0.5	0.5	Functionally Extirpated
4.0	7444	1.1	Low	0.3	0.2	0	0.5	0.6	Very Low

Under the Low Effects scenario, we would expect the viability of FPC and PNC to be characterized by a loss of resiliency, representation, and redundancy compared to current condition. We assume impacts from drought, high temperatures, small mammal herbivory; trampling by livestock, people, and OHVs; nonnative plant invasion; illegal collection; and other threats continue to occur on their current trajectory but also assume conservation measures reduce some threats to FPC and PNC. Under this scenario we project no current populations would have high resiliency in 30 years, and three FPC would have moderate resiliency, with all other populations having Low, Very Low, of Functionally Extirpated condition.

Under the High Effects scenario, we would expect the viability of FPC and PNC to be characterized by lower levels of resiliency, representation, and redundancy than under the Low Effects scenario. There would be no populations in High condition and three FPC in Moderate condition; all remaining populations would be in Low, Very Low, or Functionally Extirpated condition. We expect the majority of the FPC range outside of the three populations on the Navajo Nation in Moderate condition would be vulnerable to stochastic events that may result in widespread localized extirpations and greatly reduce the spatial extend of the FPC range. As these populations disappear, it would reduce redundancy for the FPC and PNC to persist in the face of increased drought, temperatures, and herbivory, and could reduce adaptive capacity of these cacti. Such a scenario is more likely towards the end of our future timeframes (i.e., 30 years from now) given the projected impacts of drought, high temperatures, and alterations in precipitation quantity, timing, and intensity.

LITERATURE CITED

Anable ME. 1990. Alien Plant Invasion in Relation to Site Characteristics and Disturbance: *Eragrostis lehmanniana*on the Santa Rita Experimental Range, Arizona, 1937-1989. Master's Thesis. University of Arizona, Tucson, AZ.

Archer SR, Predick KI. 2008. Climate Change and Ecosystems of the Southwestern United States. Rangelands **30**:23–28.

Arizona Game and Fish Department Heritage Data Management System. 2011, November 3. Plant Abstract for *Pediocactus peeblesianus* var. *fickeiseniae*.

Arizona Rare Plant Guide Committee. (n.d.). AZ Rare Plant Field Guide *Pediocactus peeblesianus* ssp. *peeblesianus*.

Aslan C. 2017. *Pediocactus peeblesianus* var. *fickeiseniae* Exhibits Exceptionally Low Pollination Rates. Page 35. Northern Arizona University.

Aslan C. 2024a, May 13. *Pediocactus peeblesianus* ssp. *fickeiseniae* Pollinators and Precipitation.

Aslan C. 2024b, July 19. Drought impacts pollinators of *Pediocactus peeblesianus* ssp. *fickeiseniae*.

Aslan C. 2024c, November 14. Invasion of *Salsola* near *Pediocactus peeblesianus fickeiseniae* populations.

Bailey V. 1923. Sources of Water Supply for Desert Animals. The Scientific Monthly **17**:66–86.

Baker M. 2014. Reassessment of Subspecific Taxa Within *Pediocactus peeblesianus* by Multivariate Analysis of Morphological Characters. Page 25.

Bardan R. 2025, January 10. NASA_2025_2024 Warmest Year on Record.pdf. Available from https://www.nasa.gov/news-release/temperatures-rising-nasa-confirms-2024-warmest-year-on-record/ (accessed February 10, 2025).

Beever EA et al. 2016. Improving Conservation Outcomes with a New Paradigm for Understanding Species' Fundamental and Realized Adaptive Capacity: A new paradigm for defining adaptive capacity. Conservation Letters **9**:131–137.

Benson L. 1962. A Revision and Amplification of *Pediocactus*. Cactus and Succulent Journal **6**:161–168.

Benson L. 1982. *Pediocactus* Britton & Rose. Page 1044 The Cacti of the United States. Stanford University Press.

Bureau of Land Management. 2007, May 9. Final Biological Assessment for the Proposed Resource Management Plan for the Arizona Strip Field Office (Arizona Strip FO), Vermilion Cliffs National Monument (Vermilion), and BLM Portion of Grand Canyon-Parashant National Monument (Parashant).

Bureau of Land Management. 2022. Safford Field Office Suspended Oil and Gas Leases Draft Environmental Assessment Navajo and Apache Counties, Arizona. Page 174. U.S. Department of the Interior Bureau of Land Management.

Bureau of Land Management. 2023. 2022 North Batch LHE: Amendments for Pipeline Allotment No. 06149. Page 13.

Butterwick M. 1987. Bureau of Land Management's Efforts to Conserve *Pediocactus peeblesianus* var. *peeblesianus* (Cactaceae). Page 14.

Chesshire PR, Holeski LM. 2025. Shifts in Northern Arizona Plant and Insect Pollinator Communities Between 2 Years with Substantially Different Precipitation Totals. Web Ecology **25**:5–27.

Clark DJ, Clark TO, Duniway MC, Flagg C. 2015. Effects of Ungulate Disturbance and Weather Variation on *Pediocactus winkleri* : Insights from Long-Term Monitoring. Western North American Naturalist **75**:88–101.
Clark RA. 2021. Stratigraphy, Lithology, and Depositional Environments of the Lower Permian Kaibab Formation, Northwestern Arizona. Contributed Report CR-21-E. Arizona Geological Survey, Tucson, Arizona, United States.
Climate Assessment for the Southwest. 2021, January 21. Southwest Climate Outlook January 2021.
Cockman J. 2014. Surveillance for Peeble's Navajo Cactus (*Pediocactus peeblesianus*), an Update on Species Populations, Conditions and Conservation Measures: Presented to Arizona Department of Agriculture.
Cockman J. 2019. DRAFT Business Plan to Promote the Conservation and Recovery of Two Rare Plant Species Peebles Navajo Cactus and Chihuahua Scurfpea. Page 60. Bureau of Land Management.
Crandall KA, Bininda-Emonds ORP, Mace GM, Wayne RK. 2000. Considering evolutionary processes in conservation biology. Trends in Ecology & Evolution **15**:290–295.
Dastrup R. 2025, February 11. Number of *Pediocactus peeblesianus* ssp. *fickeiseniae* counted during a complete census on Kaibab NF lands in 2015.
De Albuquerque FS, Macías-Rodríguez MÁ, Búrquez A, Cavalcante ADMB. 2025. Potential effects of climate change on cacti distribution and conservation in North American drylands. Journal of Arid Environments **226**:105282.
Duell EB, Londe DW, Hickman KR, Greer MJ, Wilson GWT. 2021. Superior performance of invasive grasses over native counterparts will remain problematic under warmer and drier conditions. Plant Ecology **222**:993–1006.
Garfin G, Jardine A, Merideth R, Black M, LeRoy S, editors. 2013. Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment. Island Press/Center for Resource Economics, Washington, DC. Available from http://link.springer.com/10.5822/978-1-61091-484-0 (accessed August 17, 2022).
Garrett TY, Huynh C, North GB. 2010. Root Contraction Helps Protect the "Living Rock" Cactus *Ariocarpus fissuratus* From Lethal High Temperatures When Growing in Rocky Soil. American Journal of Botany **97**:1951–1960.
Geiger EL, McPherson GR. 2005. Response of Semi-Desert Grasslands Invaded by Non-Native Grasses to Altered Disturbance Regimes: Disturbance Regimes in Semi-Desert Grasslands. Journal of Biogeography **32**:895–902.
Goodwin G. 2008. Report on Rare Plant Surveys Conducted on Cataract and Espee Ranches in 2008. Page 20.
Goodwin G. 2011. Vegetation Surveys Cataract and Espee Ranches 2006-2011. Page 27. Babbitt Ranches and The Nature Conservancy.
Hayes R, DeCelles P. 2022. Reconstructing paleosinuosity and sedimentary mass balance in the Upper Triassic Shinarump paleoriver in Utah and Arizona, U.S.A. Journal of Sedimentary Research **92**:1207–1232.
Hazelton A. 2015. 2015 Status Report for Fickeisen Plains Cactus (*Pediocactus peeblesianus* var. *fickeiseniae*). Page 32. Section 6. Navajo Natural Heritage Program.
Heil K, Armstrong B, Schleser D. 1981. A Review of the Genus Pediocactus. Cactus and Succulent Journal **53**:17–39.

Heil K, Porter JM. 2004. Cactaceae. Page Volume 4: Caryophyllidae (10 families including Chenopodiaceae, Cactaceae, and Nyctaginaceae). Available from http://floranorthamerica.org/Pediocactus (accessed September 11, 2024).
Howell A, Winkler D, Phillips M, McNellis B, Reed S. 2020. Experimental Warming Changes Phenology and Shortens Growing Season of the Dominant Invasive Plant *Bromus tectorum* (Cheatgrass). Frontiers in Plant Science **11**:1–15.
Hughes L. 1988. Annual Update 1988 *Pediocactus peeblesianus* ssp. *fickeiseniae* BLM Strip. Page 2. Bureau of Land Management.
Hughes L. 1989. Annual Update 1989 *Pediocactus peeblesianus* ssp. *fickeiseniae* BLM Strip. Page 2. Bureau of Land Management.
Hughes L. 1990. Annual Update 1990 *Pediocactus peeblesianus* var. *fickeiseniae*. Annual Report. Arizona Strip Field Office, Bureau of Land Management, St. George, Utah, United States.
Hughes L. 1992. Annual Update 1992 *Pediocactus peeblesianus* var. *fickeiseniae*. Annual Report. Arizona Strip Field Office, Bureau of Land Management, St. George, Utah, United States.
Hughes L. 2000. Arizona Strip Rare Plant Monitoring and Inventory 2000. Page 2. Bureau of Land Management.
Hughes L. 2002a. Updates Arizona Strip Rare Plant Monitoring and Inventory 2002. Page 3. Bureau of Land Management.
Hughes L. 2002b. Annual Update 2002 *Pediocactus peeblesianus* ssp. *fickeiseniae* BLM Strip. Page 3. Bureau of Land Management.
Intergovernmental Panel on Climate Change. 2021. Climate Change 2021 The Physical Science Basis Summary for Policymakers. Page 3,949.
Jamieson IG, Allendorf FW. 2012. How does the 50/500 rule apply to MVPs? Trends in Ecology & Evolution **27**:578–584.
Karlstrom K, Crossey L, Matthis A, Bowman C. 2021. Telling Time at Grand Canyon National Park: 2020 Update. National Park Service. Available from https://irma.nps.gov/DataStore/Reference/Profile/2285173 (accessed August 27, 2024).
Lambeth J. 2024, January 25. *Pediocactus peeblesianus* ssp. *fickeiseniae* Monitoring and Observations.
Lightfoot DC, Davidson AD, Parker DG, HernÁndez L, LaundrÉ JW. 2012. Bottom-up Regulation of Desert Grassland and Shrubland Rodent Communities: Implications of Species-specific Reproductive Potentials. Journal of Mammalogy **93**:1017–1028.
Mangel M, Tier C. 1993. A Simple Direct Method for Finding Persistence Times of Populations and Application to Conservation Problems. Proceedings of the National Academy of Sciences **90**:1083–1086.
Maschinski J, Albrecht MA. 2017. Center for Plant Conservation's Best Practice Guidelines for the reintroduction of rare plants. Plant Diversity **39**:390–395.
Meixner T et al. 2016. Implications of Projected Climate Change for Groundwater Recharge in the Western United States. Journal of Hydrology **534**:124–138.
Milne J. 1987. The ex-situ conservation of six rare species of *Pediocactus*. Page 42. Draft report under Conservation Grant IC-50235-85. Center for Plant Conservation, Boston, MA.
Moeller DA. 2004. Facilitative Interactions among Plants via Shared Pollinators. Ecology **85**:3289–3301.

National Park Service. 2015, June 13. The Chinle Formation. Available from https://home.nps.gov/zion/learn/nature/chinle.htm (accessed August 27, 2024).
NatureServe. 2020. Habitat-Based Plant Element Occurrence Delimitation Guidance. Version 1.0. NatureServe, Arlington, Virginia, United States.
Navajo Nation. 2012. Navajo Nation Fickeisen Plains Cactus Management Plan. Page 22.
Navajo Natural Heritage Program. 1994a. Survey for Fickeisen's Plains Cactus *Pediocactus peeblesianus* var. *fickeiseniae* on the Navajo Nation. Page 5.
Navajo Natural Heritage Program. 1994b. Survey for Fickeisen Plains Cactus (*Pediocactus peeblesianus* var. *fickeisenae*) on the Navajo Nation. Page 12.
Nicotra AB, Beever EA, Robertson AL, Hofmann GE, O'Leary J. 2015. Assessing the components of adaptive capacity to improve conservation and management efforts under global change: Assessing components of Adaptive Capacity. Conservation Biology **29**:1268–1278.
NS Energy. 2020, January 9. Cholla Power Plant, Arizona. Available from https://www.nsenergybusiness.com/projects/cholla-power-plant-arizona/ (accessed January 30, 2025).
O'Connor CD, Falk DA, Garfin GM. 2020. Projected Climate-Fire Interactions Drive Forest to Shrubland Transition on an Arizona Sky Island. Frontiers in Environmental Science **8**:137.
Payne K, White J, Ward RV. 2010. Potential Impacts of Uranium Mining on the Wildlife Resource of Grand Canyon National Park. Page 62. Natural Resource Program Center Natural Sounds Program. National Park Service, Grand Canyon National Park.
Phillips A, Phillips B. 2004. Population Dynamics of Peebles Navajo Cactus (*Pediocactus peeblesianus* var. *peeblesianus*): Summary of a Twenty-year Monitoring Program. Page 20.
Phillips AM, Phillips BG. 1997. Population Biology and Dynamics of Peebles Navajo Cactus (*Pediocactus peeblesianus* var. *peeblesianus*), an Endangered Cactus From Northern Arizona. Page 27.
Phillips AM, Phillips BG, Green LT, Mazzoni J, Brian N. 1982a. *Pediocactus peeblesianus* var. *fickeiseniae*. Status Report, Submitted to Office of Endangered Species, U.S. Fish and Wildlife Service. Museum of Northern Arizona, Flagstaff, Arizona, United States.
Phillips AM, Phillips BG, Green LT, Mazzoni J, Brian N. 1982b. Status Report *Pediocactus peeblesianus* var. *fickeiseniae*. Page 14.
Phillips AM, Phillips BG, Peterson EM. 1979. Status Report *Pediocactus peeblesianus* (Croizat) L. Benson var. *peeblesianus*. Page 16. Museum of Northern Arizona.
Phillips BB, Shaw RF, Holland MJ, Fry EL, Bardgett RD, Bullock JM, Osborne JL. 2018a. Drought Reduces Floral Resources for Pollinators. Global Change Biology **24**:3226–3235.
Phillips BG, Phillips AM, Avery CC. 1989. Population Biology and Monitoring Studies of Peebles Navajo Cactus (*Pediocactus peeblesianus* var. *peeblesianus*). Page 70. Contract with the U.S. Fish and Wildlife Service. Museum of Northern Arizona.
Phillips BG, Phillips AM, Butterwick M. 1983. Recovery Plan for the Navajo Plains Cactus *Pediocactus peeblesianus* (Croizat) L. Benson var. *peeblesianus* Technical Review Draft. Page 26.
Phillips K, Phillips DBG, Busco J, Alpert DGD, Pearson S. 2022. Furthering Our Knowledge of Ecology and Population Dynamics of Peebles Navajo Cactus, *Pediocactus peeblesianus*

subsp. *peeblesianus* (Croizat) L.D. Benson through Concurrent Range-wide Surveys, Updated Monitoring, and Pollination Studies. Page 57. Museum of Northern Arizona.
Phillips KO, Phillips BG, Hazelton A. 2018b. Population Dynamics of Peebles Navajo Cactus, *Pediocactus peeblesianus* subsp. *peeblesianus* (Croizat) L.D. Benson:45.
Porter DJM. 2010. Phylogenetic Analysis of Chloroplast trnL-F DNA Sequences in *Pediocactus* (Cactaceae), with Special Reference to *P. peeblesianus*. Rancho Santa Ana Botanic Garden.
Portilla-Alonso RM, Martorell C. 2011. Demographic Consequences of Chronic Anthropogenic Disturbance on Three Populations of the Endangered Globose Cactus *Coryphantha werdermannii*. Journal of Arid Environments **75**:509–515.
Redford KH et al. 2011. What Does It Mean to Successfully Conserve a (Vertebrate) Species? BioScience **61**:39–48.
Robinett D. 1992. Lehmann Lovegrass and Drought in Southern Arizona. Rangelands **14**:100–103.
Rogers K. 2015. Fickeisen Plains Cactus. Pages 1–21 The Quiet Extinction: Stories of North America's Rare and Threatened Plants. The University of Arizona Press, Tucson, Arizona, United States.
Schussman H, Enquist C, List M. 2006. Historic Fire Return Intervals for Arizona and New Mexico: A Regional Perspective for Southwestern Land Managers.
Sgrò CM, Lowe AJ, Hoffmann AA. 2011. Building evolutionary resilience for conserving biodiversity under climate change: Conserving biodiversity under climate change. Evolutionary Applications **4**:326–337.
Shaffer M, Stein B. 2000. Safeguarding Our Precious Heritage. Pages 301–321 Precious Heritage: The Status of Biodiversity in the United States. Oxford University Press.
Shryock DF, Esque TC, Lee Hughes. 2014. Population Viability of *Pediocactus bradyi* (Cactaceae) in a Changing Climate. American Journal of Botany **101**:1944–1953.
Smith DR, Allan NL, McGowan CP, Szymanski JA, Oetker SR, Bell HM. 2018. Development of a Species Status Assessment Process for Decisions Under the U.S. Endangered Species Act. Journal of Fish and Wildlife Management **9**:302–320.
Souther S, McGraw JB. 2014. Synergistic effects of climate change and harvest on extinction risk of American ginseng. Ecological Applications **24**:1463–1477.
Talkington N. 2019. USFWS Fickeisen Plains Cactus 5-year Status Review Request for Information. Page 10.
Tepedino VJ. 2000. The Reproductive Biology of Rare Rangeland Plants and Their Vulnerability to Insecticides. Page III.5-1-III.5-10 Grasshoppers: Their Biology, Identification and ManagementSpring 1996-Summer 2000. U.S. Department of Agriculture, Animal and Plant Health Inspection Service. Available from http://www.sidney.ars.usda.gov/grasshopper/Handbook/index.htm. Accessed on March 20, 2012.
The Nature Conservancy. 2004. Biotic Communities of the Southwest. Available from https://azconservation.org/publication/biotic_communities_of_the_southwest_gis_data/ (accessed January 15, 2025).
Travis JL. 1987. Pediocactus Soil Report. Final Report. North Kaibab Ranger District, U.S. Forest Service, Freonia, Arizona, United States.
U.S. Fish and Wildlife Service. 1979. Determination that *Pediocactus peeblesianus* var. *peeblesianus* is an Endangered Species **44**:61922–61924.

U.S. Fish and Wildlife Service. 2008. Peebles Navajo Cactus (*Pediocactus peeblesianus* var. *peeblesianus*) 5-Year Review: Summary and Evaluation:22.
U.S. Fish and Wildlife Service. 2013a. Endangered and Threatened Wildlife and Plants; Endangered Species Status for *Echinomastus erectocentrus* var. *acunensis* (Acuna Cactus) and *Pediocactus peeblesianus* var. *fickeiseniae* (Fickeisen Plains Cactus) Throughout Their Ranges Final Rule. Federal Register **78**:60607–606052.
U.S. Fish and Wildlife Service. 2013b. Endangered and Threatened Wildlife and Plants; Endangered Species Status for *Echinomastus erectocentrus* var. *acunensis* (Acuna Cactus) and *Pediocactus peeblesianus* var. *fickeiseniae* (Fickeisen Plains Cactus) Throughout Their Ranges. Federal Register **78**:60607–60652.
U.S. Fish and Wildlife Service. 2013c. Endangered and Threatened Wildlife and Plants; Endangered Species Status for Echinomastus erectocentrus var. acunensis (Acuña Cactus) and Pediocactus peeblesianus var. fickeiseniae (Fickeisen Plains Cactus) Throughout Their Ranges; Final Rule. Federal Register **78**:60646–60647.
U.S. Fish and Wildlife Service. 2021. Recovery Planning and Implementation User Guide Version 2.0.
U.S. Fish and Wildlife Service. 2022. Peebles Navajo Cactus (*Pediocactus peeblesianus* ssp. *peeblesianus*) 5-Year Review: Summary and Evaluation:43.
U.S. Geological Survey. 2010. Geology of the Circle Cliffs area, Garfield and Kane Counties, Utah. Available from https://www.nps.gov/parkhistory/online_books/geology/publications/bul/1229/sec1.htm (accessed August 27, 2024).
Ventrella N. 2024. Fickeisen Plains Cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae* Monitoring Report Hellhole Bend Monitoring Site The Navajo Nation 2012-2022 & Salt Trail Monitoring Site The Navajo Nation 2006-2022. Navajo Natural Heritage Program, Window Rock, Arizona, United States.
Waser NM, Price MV, Casco G, Diaz M, Morales AL, Solverson J. 2017. Effects of Road Dust on the Pollination and Reproduction of Wildflowers. International Journal of Plant Sciences **178**:85–93.
Wolf S, Hartl B, Carroll C, Neel MC, Greenwald DN. 2015. Why Recovery Under the Endangered Species Act Is More Than Population Viability **65**:200–207.

APPENDIX ONE

Fickeisen plains cactus (*Pediocactus peeblesianus* ssp. *fickeiseniae*) Representation Areas and Populations (HDMS 06-17-2024). As we have no location or population data for the few plants found in 2020 in southern Utah, we are not analyzing these plants here.

RA	EO_ ID	No. SFs	Feet Elev.	Site Name(s)	Land Management	Year First Seen	No. First Seen	Year High No.	No. High Seen	Year Last Seen	No. Seen
1	69	1	5040	Dutchman Draw / Main Street Valley	BLM	1980	rare	1992	219	2023	0
1	4443	1	4890	Beanhole Well	BLM / State	1979	3	2017	21	2017	21
1	6099	1	4250	Toquer Tank	BLM	1980	rare	1991	13	2013	1
1	9217	1	5000	Sunshine Ridge	BLM / State	1961	n/a	2023	50	2023	50
1	9267	1	3985	Upper Clayhole Valley	BLM	1980	2	2004	59	2023	50
1	15584	1	4600	Sunshine Draw	BLM / State	1986	17	1986	17	2013	1
1	15585	1	5200	Antelope Knoll / Tempe Trail 1	BLM	1981	rare	2001	7	2013	1
1	26683	1	5320	L Hurricane Valley, Tempe Tr. 1N	BLM	2004	n/a	2004	n/a	2004	n/a
1	26721	1	4250	Foot of Hurricane Cliffs	BLM	1980	n/a	1980	n/a	1980	n/a
2	18077	1	5560	Cataract Cyn Hill / Original Site	State	2006	2	2006	2	2007	7
2	18078	1	5497	Cataract Cyn; Shilo Tank 1	Pvt / State	2006	1	2006	1	2006	1
2	18079	1	5650	Cataract Cyn; Anita Road Site 4	State	2006	16	2007	16	2014	5
2	18080	1	5650	Cataract Cyn; Bull Pasture sw 18	Pvt	2008	2	2008	2	2008	2
2	18081	1	5620	Cataract Cyn, Box K Site 22	State	2008	5	2008	5	2008	5
2	18086	1	5550	Cataract Cyn; Little Harpo Site 12	Pvt	2007	7	2007	7	2007	7
2	18087	1	5650	Cataract Cyn; Linny / Water Tank	State	2007	4	2007	4	2007	4
2	18088	1	5600	Cataract Cyn; Islands Tank	Pvt / State	2007	35	2024	91	2024	91
2	18089	1	5575	Cataract Cyn, s Horse Tank 1	State	2007	2	2007	2	2007	2
2	20407	1	5600	Cataract Cyn, Espee 1 Site 21	State	2008	2	2008	2	2008	2
2	20408	1	5700	Cataract Cyn, SE Corner	Pvt	2008	26	2008	26	2009	23
2	20409	1	5680	Cataract Cyn, North End Site 35	Havasupai / State	2009	11	2024	61	2024	61
2	26680	1	4800	Cataract Cyn, North End Site 36	Havasupai / State	2009	8	2009	8	2009	8
2	26685	1	5625	Cataract Cyn, s Horse Tank 2	State	2007	1	2007	1	2007	1
2	26686	1	5660	Cataract Cyn, s. Box K Site 6	State	2007	8	2007	8	2007	8
2	26687	1	5600	Cataract Cyn, Bull Pasture/Drill Rd	Pvt / State	2007	42	2007	42	2007	42
2	26688	1	5560	Cataract Cyn, Bull Pasture, Tombstone 1-3, New Harpo	State	2008	33	2008	33	2008	33
2	26689	1	5590	Cataract Cyn, New Harpo N. Site17	State	2008	10	2008	10	2008	10
2	26690	1	5175	Cataract Cyn, Shilo Tank 2 Site 37	Pvt	2011	3	2011	3	2011	3
2	26691	1	5660	Cataract Cyn, Islands Tank Cabin 2	Pvt	2008	5	2008	5	2008	5
2	26692	1	5600	Cataract Cyn, Moore + Fuller Tanks	Pvt	2008	14	2008	14	2008	14
2	26693	1	5740	Cataract Cyn, Babbitt Tank SW site 25	Pvt	2008	13	2008	13	2024	0

RA	EO_ ID	No. SFs	Feet Elev.	Site Name(s)	Land Management	Year First Seen	No. First Seen	Year High No.	No. High Seen	Year Last Seen	No. Seen
3	14670	1	4500	House Rock Valley / N. Cyn. Wash	BLM / NPS	1970	n/a	1986	54	2022	13
3	26694	5	5280	CR South Cyn Point East	NPS / USFS	2013	26	2013	26	2013	26
3	26695	3	5200	CR South Cyn Point West	NPS / USFS	2014	50	2014	50	2014	50
3	26720	1	5560	Cataract Cyn; C.C. Ranch	State	2006	3	2017	34	2017	34
3	2843	2	4780	Mays Wash / Black Point	BLM / Pvt	1981	29	1981	29	2024	2

Navajo Nation Locations from NNHP 2015, 2019, & 2024, Not in HDMS; Those in **bold** font are in a conservation easement.

RA	EO_ ID	No. SFs	Avg. Feet Elev.	Site Name(s)	Land Management	Year First Seen	No. First Seen	Year High No.	No. High Seen	Year Last Seen	No. Seen
3	**1807**	60	5680	Salt Trail / Salt Trail Canyon	Navajo Nation	2005	55	2015	345	2015	345
3	228	13	5741	Little Colorado River Overlook	Navajo Nation	1956	n/a	1997	15	2015	24
3	1250	7	4805	s Cameron	Navajo Nation	1962	3	2015	18	2015	18
3	**70**	21	4475	w Cameron	Navajo Nation	1956	n/a	1990	8	2015	51
3	982	23	5941	Shinumo Altar	Navajo Nation	1993	42	1993	42	2015	48
3	771	36	5465	Tiger Wash 1 / Sheep Spring Wash	Navajo Nation	1991	13	1994	107	2015	57
3	1506	19	5630	Tiger Wash 2	Navajo Nation	1993	35	2015	40	2015	40
3	1042	2	5800	Shinumo Wash	Navajo Nation	1993	16	1993	16	2015	0
3	603	3	4920	Little Colorado River Gauging Station	Navajo Nation	1999	1	2015	1	2015	1
3	1540	4	5235	29 Mile Canyon	Navajo Nation	2000	2	2015	2	2015	2
3	1640	15	5600	Big Canyon	Navajo Nation	2002	15	2015	93	2015	93
3	**1647**	15	5300	w Hellhole Bend	Navajo Nation	2002	5	2015	58	2015	58
3	**1806**	9	5410	Blue Spring	Navajo Nation	2005	30	2005	30	2015	12
3	1902	3	5225	Small Ridge	Navajo Nation	2004	1	2004	1	2015	0
3	**3068**	163	5250	Hellhole Bend	Navajo Nation	2009	314	2013	358	2013	358
3	3866	47	5174	Black Rock	Navajo Nation	2012	4	2015	354	2015	354
3	3878	1	?	Sheep Bridge	Navajo Nation	2013	3	2013	3	2013	3
3	3879	16	5741	Tappan Wash	Navajo Nation	2014	33	2014	33	2014	33
3	3928	4	5578	s Pillow Mountain	Navajo Nation	2015	13	2015	13	2015	13
3	3951	2	4357	n Gauging Station	Navajo Nation	2015	2	2015	2	2015	2
3	4040	1	54427	Cedar Canyon Overlook	Navajo Nation	2015	1	2015	1	2015	1
3	4165	1	?	s Sheep Springs	Navajo Nation	2017	11	2017	11	2017	11

PNC

RA	EO_ ID	No. SF	Feet Elev.	Site Name(s)	Land Management	Year First Seen	No. First Seen	Year High No.	No. High Seen	Year Last Seen	No. Seen
4	8613	2	5053	Middle Little Colorado River	BLM, Private	1980	51	1994	387	2024	11
4	13804	5	5150	Middle Little Colorado River, Leroux Wash, Perkins Valley	BLM, Private, State	1940	?	1995	83	2024	61
4	7444	2	5140	Middle Little Colorado River Tanner Wash vicinity	BLM, Private	1992	4	2024	154	2024	154

APPENDIX TWO

Current and Future Scenarios – Calculations in a Single Table

RA	EO_ ID	Current Condition	Rank	Low Effects (-0.15) Climate	Low Effects (-0.10) Mines, etc.	Low Effects (-0.1) Small Pops	Total Deduction Low Effects	New Score Low Effects	Rank Low Effects	High Effects (-0.3) Climate	High Effects (-0.20) Mines, etc.	High Effects (-0.2) Small Pops	Total Deduction High Effects	New Score High Effects	Rank High Effects
1.0	69	1.1	Low	0.15	0.00	0.10	0.25	0.9	Very Low	0.3	0	0.2	0.5	0.6	Very Low
1.0	4443	1.1	Low	0.15	0.00	0.10	0.25	0.9	Very Low	0.3	0	0.2	0.5	0.6	Very Low
1.0	6099	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low	0.3	0	0.2	0.5	0.9	Very Low
1.0	9217	1.1	Low	0.15	0.10	0.10	0.35	0.8	Very Low	0.3	0.2	0.2	0.7	0.4	Functionally Extirpated
1.0	9267	1.1	Low	0.15	0.00	0.10	0.25	0.9	Very Low	0.3	0	0.2	0.5	0.6	Very Low
1.0	15584	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low	0.3	0	0.2	0.5	0.9	Very Low
1.0	15585	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low	0.3	0	0.2	0.5	0.9	Very Low
1.0	26683	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low	0.3	0	0.2	0.5	0.9	Very Low
1.0	26721	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low	0.3	0	0.2	0.5	0.9	Very Low
2.0	18077	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	18078	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	18079	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	18080	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	18081	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	18086	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	18087	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	18088	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	18089	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	20407	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	20408	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	20409	1.8	Low	0.15	0.00	0.00	0.15	1.6	Low	0.3	0	0	0.3	1.5	Low
2.0	26680	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	26685	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	26686	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	26687	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	26688	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	26689	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low

RA	EO_ ID	Current Condition	Rank	Low Effects (-0.15) Climate	Low Effects (-0.10) Mines, etc.	Low Effects (-0.1) Small Pops	Total Deduction Low Effects	New Score Low Effects	Rank Low Effects	High Effects (-0.3) Climate	High Effects (-0.20) Mines, etc.	High Effects (-0.2) Small Pops	Total Deduction High Effects	New Score High Effects	Rank High Effects
2.0	26690	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	26691	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	26692	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
2.0	26693	1.6	Low	0.15	0.00	0.00	0.15	1.5	Low	0.3	0	0	0.3	1.3	Low
3.0	14670	1.4	Low	0.15	0.10	0.10	0.35	1.0	Low	0.3	0.2	0.2	0.7	0.7	Very Low
3.0	26694	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	26695	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	26720	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	2843	1.6	Low	0.15	0.10	0.10	0.35	1.3	Low	0.3	0.2	0.2	0.7	0.9	Very Low
3.0	228	1.4	Low	0.15	0.10	0.10	0.35	1.0	Low	0.3	0.2	0.2	0.7	0.7	Very Low
3.0	1250	1.6	Low	0.15	0.10	0.10	0.35	1.3	Low	0.3	0.2	0.2	0.7	0.9	Very Low
3.0	70	1.8	Moderate	0.15	0.00	0.10	0.25	1.5	Low	0.3	0	0.2	0.5	1.3	Low
3.0	982	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	771	1.8	Moderate	0.15	0.00	0.10	0.25	1.5	Low	0.3	0	0.2	0.5	1.3	Low
3.0	1506	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	1042	1.4	Low	0.15	0.00	0.10	0.25	1.1	Low	0.3	0	0.2	0.5	0.9	Very Low
3.0	603	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	1540	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	1640	1.8	Moderate	0.15	0.00	0.10	0.25	1.5	Low	0.3	0	0.2	0.5	1.3	Low
3.0	1647	1.8	Moderate	0.15	0.00	0.10	0.25	1.5	Low	0.3	0	0.2	0.5	1.3	Low
3.0	1806	1.6	Moderate	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	1807	2.3	Moderate	0.15	0.00	0.10	0.25	2.0	Moderate	0.3	0	0.2	0.5	1.8	Moderate
3.0	1902	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	3068	2.3	Moderate	0.15	0.00	0.10	0.25	2.0	Moderate	0.3	0	0.2	0.5	1.8	Moderate
3.0	3866	2.3	Moderate	0.15	0.00	0.10	0.25	2.0	Moderate	0.3	0	0.2	0.5	1.8	Moderate
3.0	3878	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	3879	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	3928	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	3951	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	4040	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low
3.0	4165	1.6	Low	0.15	0.00	0.10	0.25	1.4	Low	0.3	0	0.2	0.5	1.1	Low

RA	EO_ ID	Current Condition	Rank	Low Effects (-0.15) Climate	Low Effects (-0.10) Mines, etc.	Low Effects (-0.1) Small Pops	Total Deduction Low Effects	New Score Low Effects	Rank Low Effects	High Effects (-0.3) Climate	High Effects (-0.20) Mines, etc.	High Effects (-0.2) Small Pops	Total Deduction High Effects	New Score High Effects	Rank High Effects
4.0	8613	0.8	Very Low	0.15	0.10	0.00	0.25	0.5	Functionally Extirpated	0.3	0.2	0	0.5	0.3	Functionally Extirpated
4.0	13804	1.0	Very Low	0.15	0.10	0.00	0.25	0.8	Very Low	0.3	0.2	0	0.5	0.5	Functionally Extirpated
4.0	7444	1.1	Low	0.15	0.10	0.00	0.25	0.9	Very Low	0.3	0.2	0	0.5	0.6	Very Low