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

Prepared by Nora Ventrella, Botanist

Navajo Natural Heritage Program

Department of Fish and Wildlife

P.O. Box 1480

Window Rock, AZ 86515

Photo by Daniela Roth

INTRODUCTION:

The genus *Pediocactus* is native to the Western United States. Benson (1982) recognizes seven species, six of which are highly restricted endemics on the Colorado Plateau. There are currently two widely recognized subspecies of *P. peeblesianus* (Heil and Porter 2001); although a recent morphological study did not find distinct differences between the two subspecies in correlation with geography, providing evidence that they should be treated as a single subspecies (Baker 2014). *Pediocactus p. ssp. peeblesianus* occurs just South of Navajo Nation in the Joseph City and Holbrook region on BLM and AZ State Trust Lands (USFWS 2008), and was listed as endangered under the Endangered Species Act in 1979 (44 FR 61922). *Pediocactus p. ssp. fickeiseniae (*Fickeisen plains cactus*)* does occur on Navajo lands and was listed as endangered under the Endangered Species Act in 2013 (78 FR 60607). This is species is also listed as Group 3, threatened, on the Navajo Endangered Species List (Talkington & Mikesic 2020).

Fickeisen plains cactus is a narrow endemic restricted to Kaibab Limestone-derived soils in Coconino and Mohave Counties in northern Arizona. It occurs along canyon rims and flat terraces along washes, typically with limestone chips scattered across the surface (Talkington & Mikesic 2020, Figure 1b). Populations are known to occur between 4000 and 6000 feet in elevation. The Fickeisen plains cactus occurs on lands managed by the Bureau of Land Management, Navajo Nation, Hualapai Nation, Arizona State Land Department, and the U.S. Forest Service (Roth 2008). It also occurs on private land (Goodwin 2008). On Navajo Nation, known populations occur along the east rim of the Little Colorado River Canyon and in the vicinity of the town of Gray Mountain, although potential habitat is more extensive (Figure 1a).

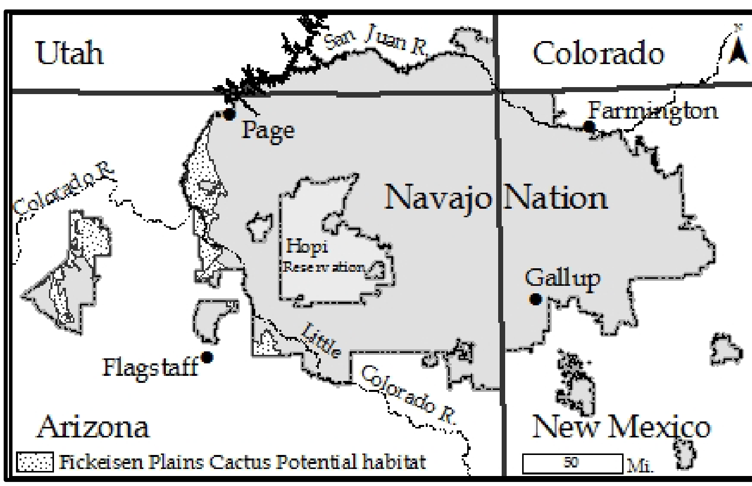

Figure 1. a. Potential habitat for Fickeisen plains cactus on the Navajo Nation. Figure from Hazelton 2011.

Figure 1. b. Typical Kaibab Limestone habitat for Fickeisen plains cactus along the rim of Marble Canyon.

Fickeisen plains cactus is a small (rarely larger than 5.5 cm in diameter), spherical cactus, usually with solitary stems (Roth 2008). It produces cream to yellow or greenish flowers from mid-March to late April. Fruit are smooth and reddish brown in maturity. This cactus has contractile roots and stems, and is known to retract into the ground in response to drought and/or heat or cold. This feature, coupled with the cactus's diminutive size (most are just slightly larger than a quarter), and spines that look very much like grass clumps, make this a very difficult species to see in the field when not in full flower.

Known threats contributing to Fickeisen plains cactus's listing in 2013 included off road vehicle use, livestock grazing, mining, recreational activities, road construction, commercial development, non-native invasive species, drought, and climate change (Endangered and Threatened Wildlife 2012). In her 2008 monitoring report for the salt trail monitoring site, D. Roth also listed invasive species encroachment as a significant threat to Navajo Nation populations. Possible pollination limitation was listed as a concern in the USFWS 5-year review of the species (USFWS 2020), after "extremely low" pollination rates were recorded by Dr. Clare Aslan in 2016 and 2017 within four populations of Fickeisen plains cactus occurring outside of the Navajo Nation (Aslan 2017).

Salt Trail Monitoring Site:

The Salt Trail monitoring site is located on the east rim of the Little Colorado River Gorge, near the Salt Trail Canyon, approximately 26 miles south of the northern-most population known on Navajo Nation and 36 miles north of the southern-most. Habitat consists of multiple eroding limestone terraces and bedrock drainages that lead into the canyon, with gravelly terraces surrounding low eroding knolls. The surface is covered with limestone gravel and other large scattered flags and boulders. Associated species include *Atriplex confertifolia, Gutierrezia sarothrae, Sporobolus, Lesquerella, Sphaeralcea grossulariifolia, Bromus rubens, Ephedra, Achnatherum hymenoides, Purshia stansburiana, Mirabilis multiflora, Bromus tectorum, Bouteloua gracilis, Erodium cicutarium, Artemisia bigelovii, Cylindropuntia,* and *Opuntia.*

Hellhole Bend Monitoring Site:

The Hellhole Bend monitoring site is located on the north rim of the Little Colorado River Gorge along the east side of Hellhole Bend, approximately 20 miles north of the southern-most range of this species on Navajo Nation. The landscape here is composed of gently sloping canyon rim habitat covered with Kaibab limestone chips and boulders. Associated species include *Ephedra torreyana, Agave utahensis var. kaibabensis, Hilaria jamesii, Bouteloua gracilis, Lesquerella arizonica, Cryptantha atwoodii, Gutierrezia sarothrae, Abronia nana, Echinocereus fendleri* and *Chrysothamnus greenei*. It is the largest population located on Navajo Nation known to date.

METHODS:

Salt Trail Monitoring Site:

In 2006, NNHP staff established four circular monitoring plots on the rim of Marble Canyon. In 2018, N. Ventrella and J. Mike established three additional plots at this site in an effort to capture more individuals and add statistical power. New plot locations were found by scouting the area near plots 1-4 and establishing plots where there was a high concentration of individuals within a four meter radius. The Fickeisen plains cactus in these plots have been monitored annually in mid-late April by NNHP since 2006. Exceptions include 2010 and 2016, when the program lacked a botanist, and in 2020, when travel restrictions were in-place due to the COVID19 pandemic.

Figure 2. Vigor assessment scale from Excellent (1)-Poor (4) used to classify stem health.

The center of each plot is marked with a large nail and the plots have a radius of 4 meters measured from this nail. Each cactus within this radius is individually tagged and the location recorded as distance from and azimuth relative to the center nail. Reproductive status, number and type of reproductive structures, stem diameter, and plant vigor are recorded annually. The vigor assessment consists of a four point system (Figure 2).

Any unusual or noteworthy characteristics of the cacti and habitat are recorded as well. Multi-stemmed cactus are uncommon in this species, but do occur. Without digging up the plant, it is difficult to tell whether cactus clusters represent a single multi-stemmed cactus or groups of individual (but likely related) cacti. Given the lack of mechanisms for seed dispersal observed for this species, it is hypothesized that seeds likely don't move very far from adult cacti (Endangered and Threatened Wildlife 2012). For this reason, clusters of cacti are given one tag and assigned a letter and cardinal position (for example 159a north and 159b south). Data is then collected for each stem (or cluster) individually and can be tracked over time. Any new untagged cacti found within plots are tagged and mapped. Cactus that had died are assigned a cause of death (or unknown) and tags are removed. Because this species has contractile roots and may be underground during monitoring, plants that are missing are recorded as "not found" during the monitoring period, but tags are left in place. If a cactus is recorded as "not found" for three consecutive monitoring years, then the cactus is considered "dead" and it's tag/pin is pulled.

Annual cactus growth rate was calculated for each interval between sampling visits as d_f-d_i where d_f= final stem diameter and d_i = initial stem diameter. Annual growth rate was only calculated for years where monitoring data was collected the following year. Only stems that were present and measured during both the initial and subsequent year of the growth interval were included in each calculation. Population reproductive effort was calculated for each sampling visit as the total number of reproductive structures (flowers and fruits, including any that aborted) produced divided by the total number of live stems.

The most recent Fickeisen plains cactus monitoring report prior to this one addressed the population status in 2011. This monitoring report will address the status of the Salt Trail Canyon population as recorded since 2011, as well as the longer-term trends captured by the full dataset beginning in 2006.

Hellhole Bend Monitoring Site:

The Hellhole Bend monitoring plots were established on May 16th, 2012 by Andrea Hazelton, a former NNHP Botanist. There are four plots total, spaced in clusters of two along the rim of the Little Colorado River gorge overlooking Hellhole Bend. Since 2012, these plots have been monitored in mid-May somewhat annually, though more sporadically than the Salt Trail plots; in 2013, 2017, 2018, 2019, 2021 and most recently in 2022. The cacti in these plots are monitored a month or so later than those in the Salt Trail plots in an effort to capture fruit development in this species. Other than monitoring timing, methods are identical to those described for the Salt Trail monitoring site. This is the first monitoring report for the Hellhole Bend monitoring site, which will address trends of this population from 2012-2022.

Climate Data:

Weather and climate data reported are projections based on gridded climactic datasets for the Salt Trail and Hellhole Bend monitoring locations using the PRISM (Parameter-elevation Relationships on Independent Slopes Model) dataset. This model aggregates surface station data to calculate climate for each digital elevation model grid cell based on a variety of factors such as location, elevation, coastal proximity, and topographic position (Daly et al. 2008). Data were accessed from the Western Regional Climate Center's SCENIC webpage (https://wrcc.dri.edu/csc/scenic/data/station_data/). Annual precipitation for the purposes of this study was calculated as the total precipitation for the 12 months preceding each monitoring visit. Winter precipitation was calculated as the total precipitation for the December through April immediately preceding the monitoring visit. Summer and spring maximum temperatures were averaged for the months of June-August and March-May. Winter minimum temperatures were averaged for the months of December-February. Long-term precipitation and temperature averages were calculated based on the period of record of 1981-2022 available for the PRISM dataset.

RESULTS

Population size:

Salt Trail

Throughout the study duration, 240 cactus individuals, clusters, or stems were assigned a tag number within the six plots. Of these, 21 were either multi-stemmed cacti or clusters of cacti (it's impossible to tell if stems represent one individual or clusters of related individuals without digging up plants). However, because this species is seldom multi-stemmed, it's likely that clusters of cacti are mostly solitary stems of related individuals. To reduce confusion and standardize monitoring results across years and between monitoring personnel, demography data are summarized on a per-stem basis throughout the rest of this report. With the exception of Table 1, data from plots 5 & 6, which were established in 2018, are omitted from this report for the sake of clarity. Since 2006, the number of live cacti in plots 1-4 has declined by 91 plants (Table 1). Declines were also observed in plots 5 & 6 over a period of 4 years (net decline of 11 cacti). For all but three monitoring years, the number of newly dead cacti has far outweighed the number of new stems observed.

Hellhole Bend:

From 2012 through 2022, 241 cactus individuals or clusters were assigned a tag number within the four plots. Of these, 32 were either multi-stemmed cacti or clusters of cacti. Since 2012, there has been a net increase of 20 live stems within the monitoring plots, with three monitoring years showing a net negative population growth and three years showing a net positive growth (Table 1). 2013 had the most new stems (67), however the majority of these were greater than 1 cm in diameter, indicating they were probably overlooked adults from the previous year and not new seedlings. 2021 and 2022 had the highest mortality (33 and 19 stems, respectively), and 2021 also had the lowest number of new stems found (5 greater than 1 cm).

Table 1. Total number live stems, number newly dead stems, number of stems not found (NF), and a tally of new stems, either new recruits, less than 1 cm in diameter, or overlooked adults, greater than 1 cm in diameter by monitoring year for ten permanent monitoring plots at the *Salt Trail* and *Hellhole Bend* monitoring sites. Net gains/losses for each monitoring year was calculated as the total number of new stems-total dead.

Monitoring Year	Total Live	Total Dead	Total NF	Number New Stems Likely New Recruits	Number New Stems Likely Overlooked Adults	Net Gains/Losses
Salt Trail: Plots 1-4						
2006	122	0	0	NA	NA	NA
2007	151	0	4	0	31	31
2008	145	9	11	0	13	4
2009	105	34	30	0	12	-22
2011	73	26	39	3	1	-22
2012	74	5	36	1	2	-2
2013	74	17	27	2	7	-8
2014	63	15	31	0	8	-7
2015	60	5	31	0	1	-4
2017	53	26	19	2	5	-19
2018	51	9	17	0	4	-5
2019	49	4	20	1	4	1
2021	35	12	23	0	1	-11
2022	31	9	19	0	1	-8
Salt Trail: Plots 5 & 6						
2018	16	0	0	NA	NA	NA
2019	19	0	0	0	4	4
2021	12	0	7	0	0	0
2022	5	7	7	0	0	-7
Hellhole Bend						
2012	101	0	0	NA	NA	NA
2013	161	4	1	5	62	63
2017	147	14	29	13	15	14
2018	131	10	45	0	9	-1

2019	144	5	47	1	20	16
2021	125	33	40	0	5	-28
2022	121	19	34	3	7	-9

Survival/Mortality:

Salt Trail:

Figure 3. Soil depressions and sheep scat are apparent signs of heavy domestic sheep use of the Salt Trail Fickeisen plains cactus monitoring site.

Just 10 stems survived throughout the entire 16 year monitoring period from 2006-2022, and half of these stems were not found in 2022, though not yet declared dead (stems may be alive but underground). The minimum stem size of the 5 long-survivors that were measurable in 2022 was 2.5 cm, and stems were an average of 2.8 cm. Of the 170 plants that died within the study interval, stems survived an average of 6.8 years (±0.31 SE). Impacts to plants from livestock use was significant throughout the survey interval, with heavy sheep use of the site noted yearly. Sheep have caused significant soil disturbance at the site by creating depressions for bedding down, which appears to be the main contributor to the high levels of Fickeisen cactus mortality observed within this population (Figure 3). The presence of exotic annuals *Bromus rubens, Bromus tectorum, and Erodium cicutarium*, which in wet years can make up to 70-80% of the ground cover, was recorded as the second-most common threat to Salt Trail cacti during monitoring visits. This population occasionally has signs of off-road use by ATV’s and vehicles, though not extensive use in recent years, due to the remote location of the site.

Hellhole Bend:

59 stems survived throughout the 10 year monitoring period from 2012-2022, though this includes 8 cacti which were not found in 2022, and were either underground or not yet declared dead. The average diameter of the long survivors was 2.4 cm (with a minimum of 0.9 cm and maximum of 3.7 cm). Of the 85 cacti that died within the study interval, stems survived an average of 6.8 years (±0.26 SE). For a majority of these stems, it was impossible to determine the cause of death (due to drought, predation, mechanical damage, erosion, etc.). Possible threats to the population on a site level noted by botanists has included; 1) disturbance from film crews shooting movies, commercials, and TV shows, permitted by Navajo Parks and Rec (2009), 2) disturbance from tourist groups (2009), and 3) evidence of cattle, abundant feral horse scat, sheep scat, and several dirt areas where sheep appeared to have bedded down (2012,2021). In recent years (2017-2022), the access road to the population appears to be seldom used, and there has been no evidence of film crew use or tourist group disturbance. Cattle, feral horse, and sheep sign is still apparent, however, and hoof prints have been found near missing cacti stems in plots, though this is not a frequent occurrence.

Size Class/Population Growth Rate:

Salt Trail:

In general, cactus stems at the Salt Trail site showed positive average diameter growth from one monitoring year to the next (Figure 4a). Exceptions were between 2012-2013 and 2017-2018, when stems shrunk by an average of -0.08 cm (± 0.05 cm SE) and -0.2 cm (± 0.06 cm SE), respectively. Stems grew the most (on average nearly 0.5 cm ±0.04 cm SE) between 2018 and 2019.

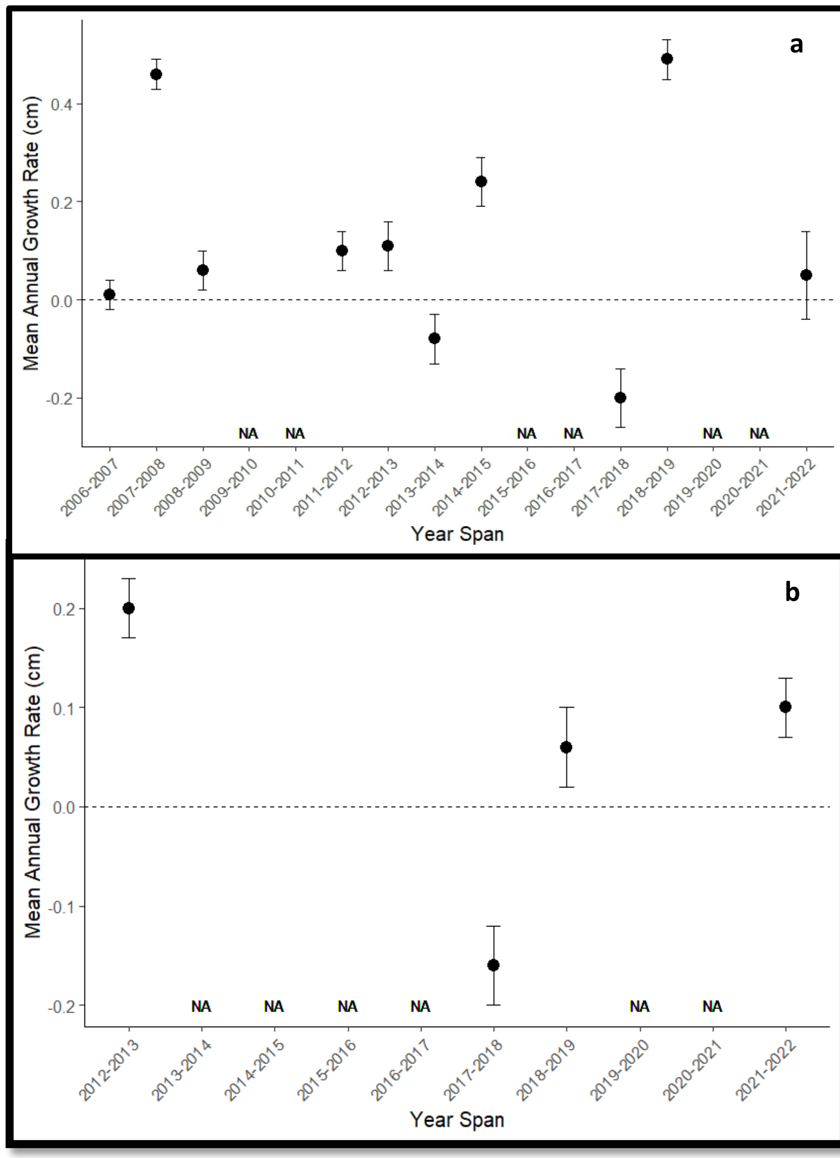

Figure 4. Mean annual growth rate ± 1 SE for Fickeisen cactus stems within a) four permanent monitoring plots at the *Salt Trail* site from 2006-2022, and b) four permanent monitoring plots at the *Hellhole Bend* monitoring site from 2012-2022.

Average stem diameter ranged from 2.17 cm (± 0.08 cm SE) in 2011 to 2.74 cm (±0.06 cm SE) in 2008, with most stems across all monitoring years falling into the medium (2-2.99 cm) size class (Figure 5a). Overall, there were very few stems in the seedling (0-0.99 cm) size class, with a maximum of 6 seedlings recorded in 2013, and zero seedlings recorded in 6 out of 14 monitoring years. In 2008, there were 60 stems in the large (3-3.99 cm) size class, which was 24 more stems than the next highest large stem year of 2009.

Hellhole Bend:

Though there were many monitoring intervals where a NNHP botanist did not collect data for two years in a row, average annual growth rates for stems were positive (showed growth) from 2012-2013, 2018-2019, and 2021-2022 (Figure 4b). Stems on average shrank from 2017-2018 (mean annual rate of -0.16 cm ± 0.04 cm SE).

Average diameter remained relatively consistent across the monitoring years (ranging from 2.19 cm ±0.05 cm SE to 2.26 cm ± 0.05 cm SE), with the exception of 2012, when the average diameter was slightly smaller (1.91 cm ± 0.06 cm SE). The majority of stems were classed in the medium (2-2.99 cm) size class across all monitoring years (Figure 5b). 2017 had the most large cactus stems (30 between 3-3.99 cm), as well as the most seedlings (16 between 0-0.99 cm). Zero seedlings were recorded in 2021.

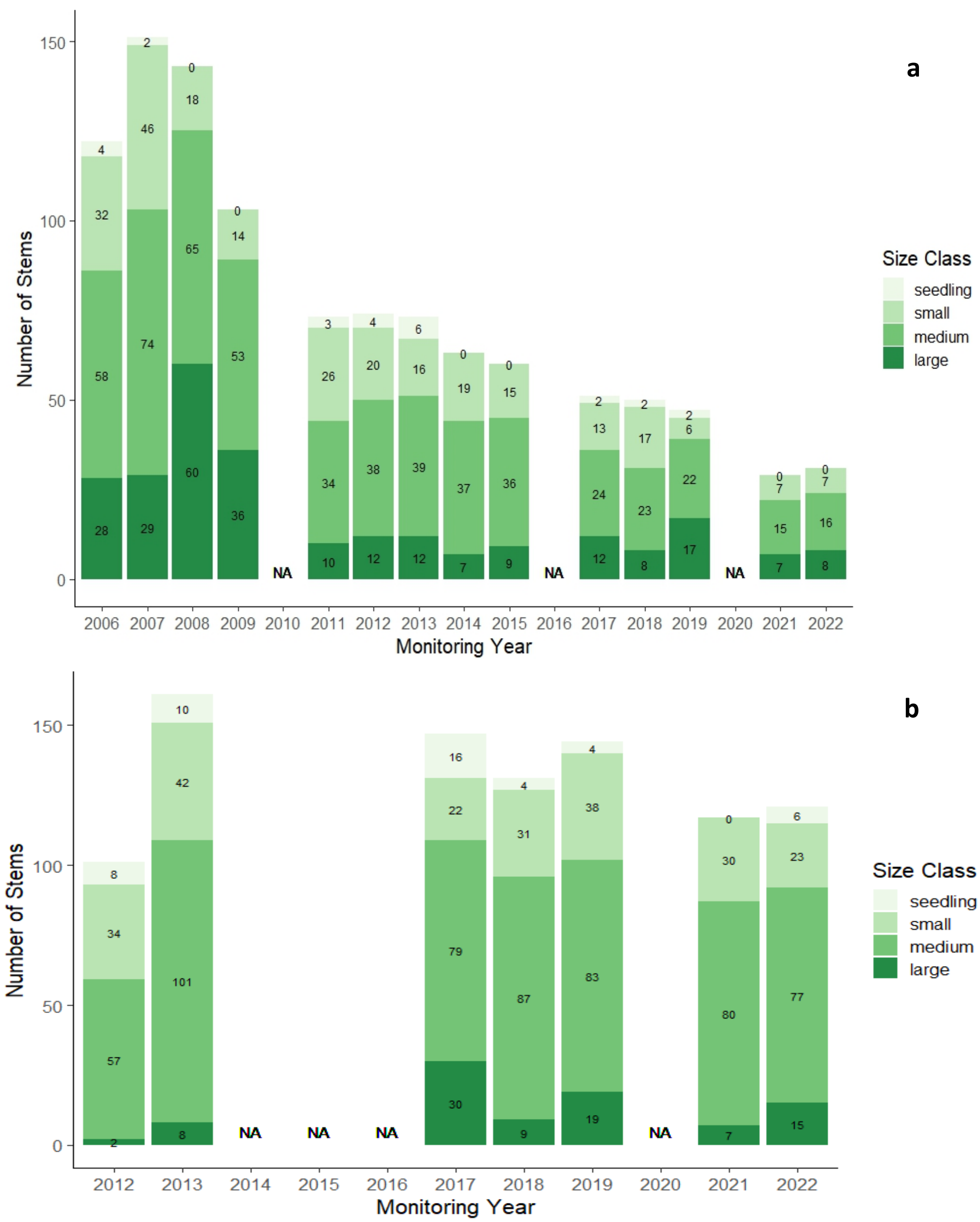

Figure 5. Number of stems by size class for Fickeisen cactus within, a) four permanent monitoring plots at *Salt Trail* monitoring site from 2006-2022, and b) four permanent monitoring plots at the *Hellhole Bend* monitoring site from 2012-2022.

Vigor:

Salt Trail:

Average vigor was high for the first three years of the study (Figure 6a), before declining in 2009, as over half the stems were classified as good-fair instead of excellent, and 14 stems were classified as poor (Figure 6b). From 2012 to 2022, average vigor remained relatively high (1.43-1.35), with a slight dip in 2017 (1.49), as 15 stems were classified as fair.

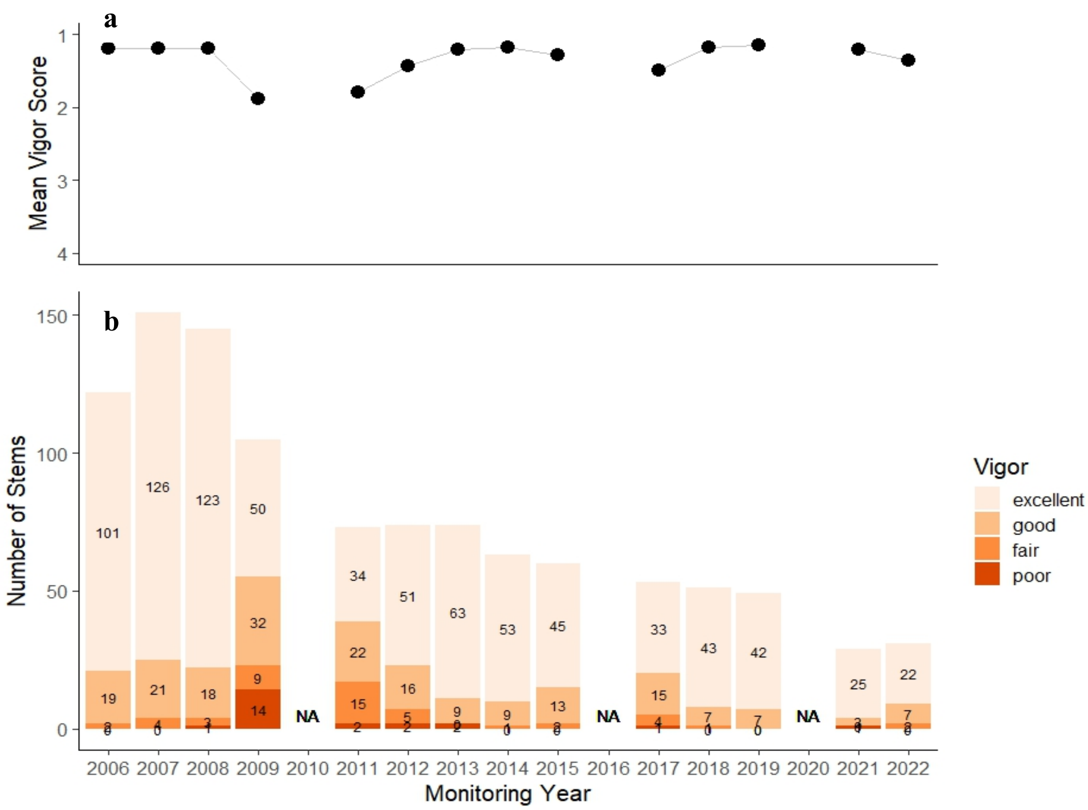

Figure 6. (a) Mean vigor scores for Fickeisen cactus stems and (b) total number of live stems by vigor score in 4 monitoring plots at the *Salt Trail* site from 2006-2022. See Figure 2 for a description of vigor assessments.

Hellhole Bend:

Fickeisen cactus stem vigor was high during the first two years of the study (2012,2013), with no stems rated as "fair" or "poor" in 2012 and 129 stems rated as "excellent" in 2013 (Figure 7b). From 2013 to 2017, there was an overall increase in average vigor from 1.3 to 1.8 (Figure 7a), with many more stems classified as "good", "fair" and "poor" than the previous monitoring year. Average vigor slowly decreased from 1.5 in 2018 to 1.3 in 2022, as there were less than 10 stems classified as "fair" or "poor" in 2021 and 2022, as compared to at least 14 or more from 2017-2019.

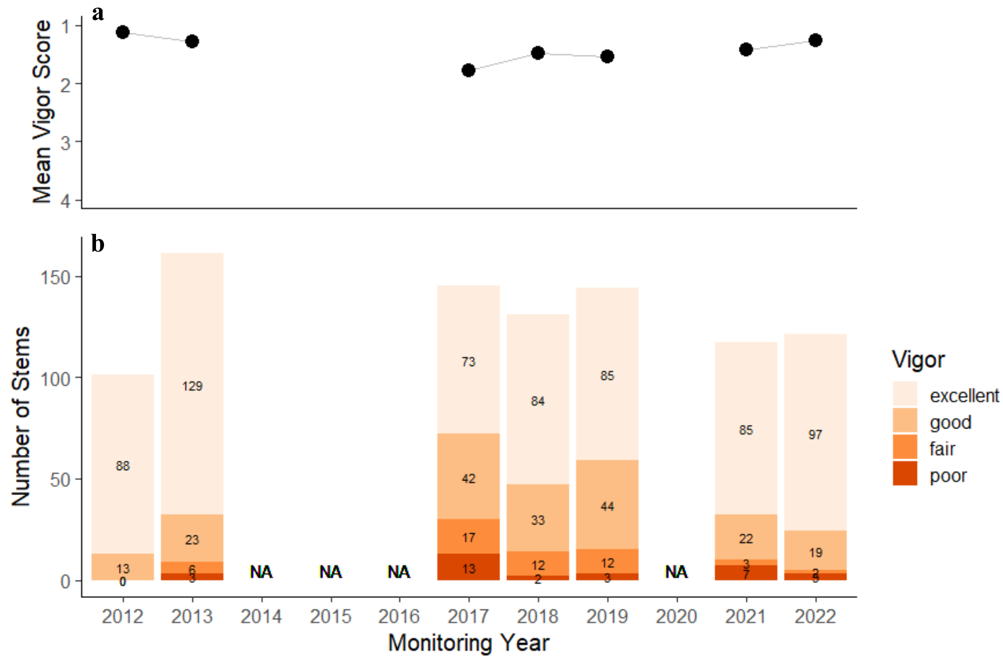

Figure 7. (a) Mean vigor scores for Fickeisen cactus stems and (b) total number of live stems by vigor score in 4 monitoring plots at the *Hellhole Bend* site from 2012-2022. See Figure 2 for a description of vigor assessments.

Reproduction:

Salt Trail:

On average, cacti within the four monitoring plots produced 41.2 (±13.8 SE) total reproductive structures per year, which translated to an average population reproductive effort of 0.48 (±0.10 SE) structures per stem. The maximum number of reproductive structures recorded on a single Fickeisen plains cactus at the Salt Trail plots was 5. By far the most productive year at the Salt Trail site was 2008, when 205 total reproductive structures (mostly buds and flowers) were recorded (Figure 7b), which translated to 1.4 structures per stem on average (Figure 7a). In contrast, the next most productive year of the study interval was 2013, when 67 total reproductive structures were recorded, for an average of 0.9 reproductive structures per stem. In 2007 and 2011, there were only 5 and 4 structures recorded on 151 and 73 live cacti, respectively. In 2021, zero structures were observed on the 35 live cacti remaining in the monitoring plots.

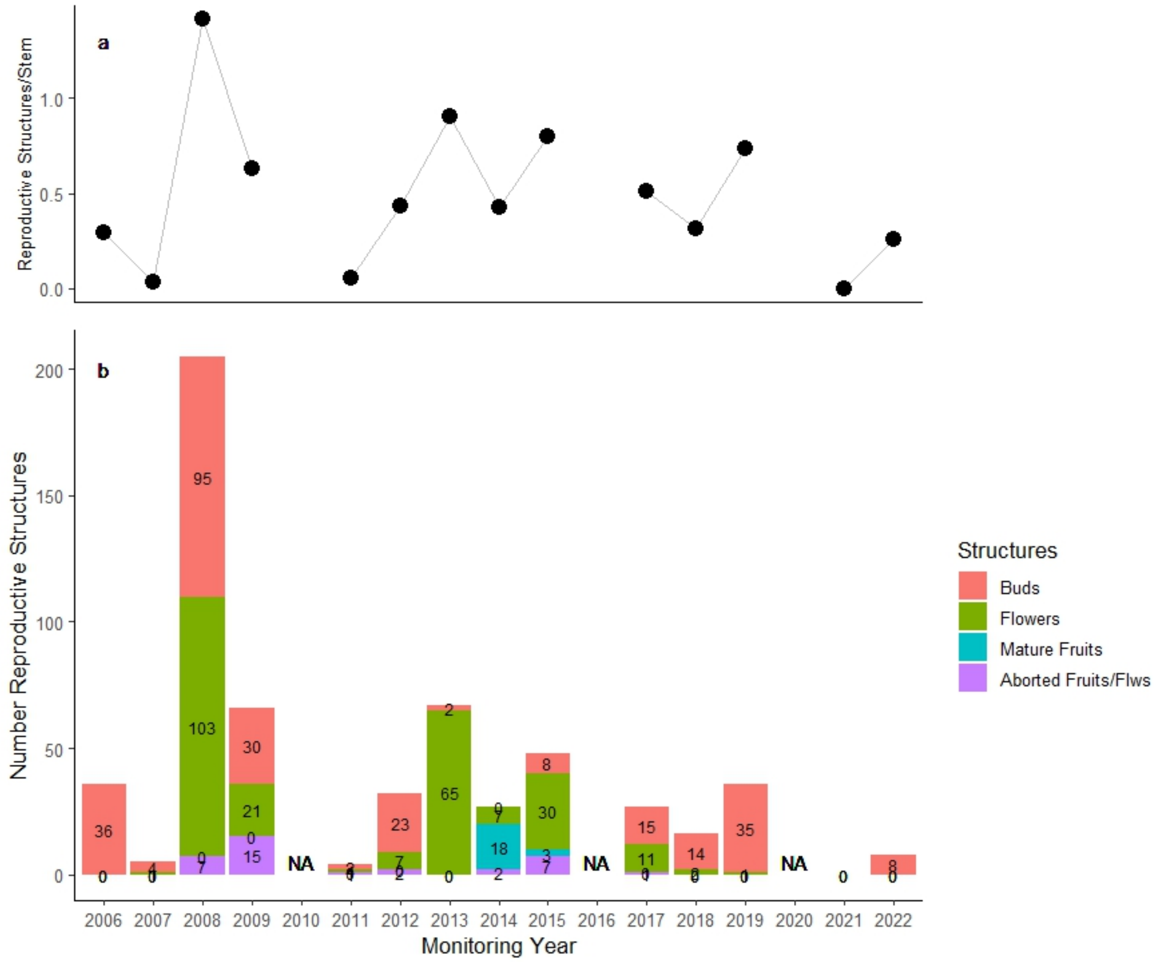

Figure 7. Reproductive output of Fickeisen plains cactus, reported as the average number of reproductive structures per stem (calculated as the total number of reproductive structures recorded/total number of live stems, a), and as the total number of reproductive structures by phenological phase b) in 4 monitoring plots at the *Salt Trail* site from 2006-2022.

Hellhole Bend:

On average, cactus within the four monitoring plots produced 52.4 (±17.7 SE) reproductive structures per year, which translated to an average population reproductive effort of 0.37 (±0.12 SE) structures per stem. The maximum number of reproductive structures recorded on a Fickeisen plains cactus within the Hellhole monitoring plots for all monitoring years was 4. The 2017 and 2019 monitoring years were the most productive during the study period, with 99 and 114 total reproductive structures observed (Figure 8b). However, slightly less than half of the structures produced in 2019 were aborted fruits or flowers, which indicates that although a high number of cacti flowered in 2019, this did not necessarily lead to a particularly good year for fruit and seed production. In 2021, very few cacti were reproductive, and the average population reproductive output was 0.09 (Figure 8a). The majority of structures observed in 2022 (36) were also aborted fruits and flowers, and just three viable fruits were recorded for that year.

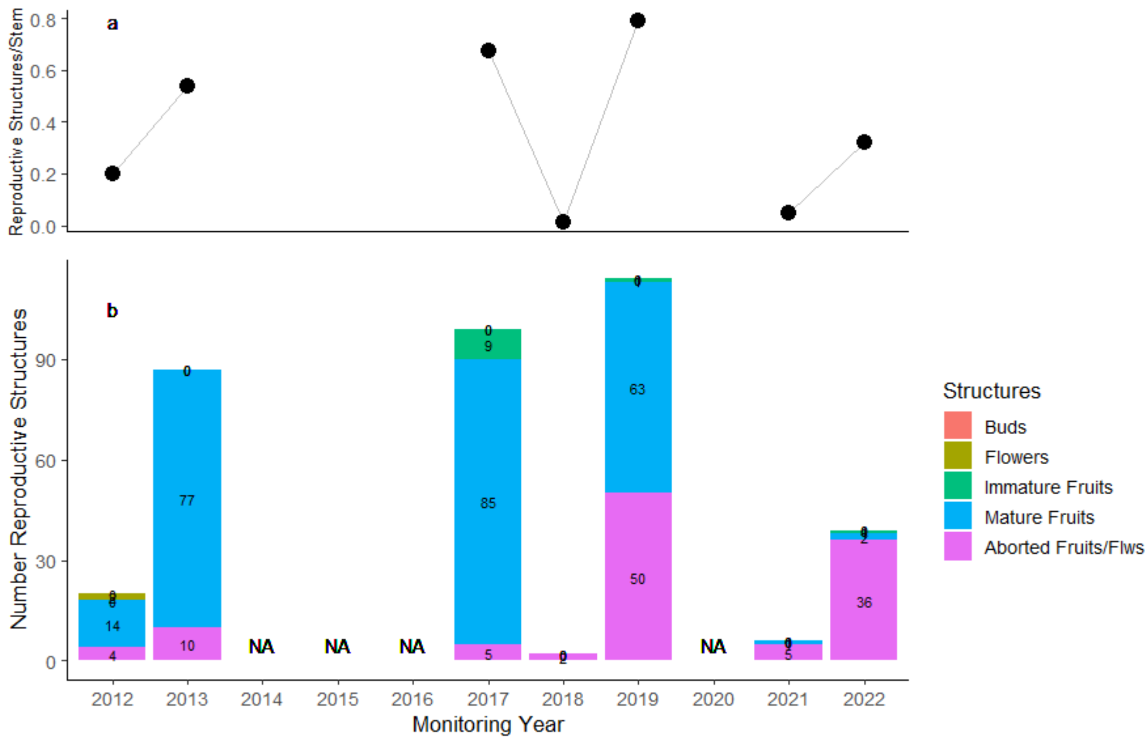

Figure 8. Reproductive output of Fickeisen plains cactus, reported as the average number of reproductive structures per stem (calculated as the total number of reproductive structures recorded/total number of live stems, a), and as the total number of reproductive structures by phenological phase (b) in 4 monitoring plots at the *Hellhole Bend* site from 2012-2022.

Precipitation:

Salt Trail:

Seven out 17 years of the study duration had higher than average total precipitation, with 2016 being the wettest in terms of total precipitation (10.55 inches) and 2019 being the driest (5.02 inches, Figure 9a). The proportion of total precipitation accumulating during the cool season and warm season varied greatly by year, with some years having low winter precipitation but an active spring and monsoon season (2012-2015), and some years having much more accumulation during winter months than spring and monsoonal months (2010, 2017, 2019, and 2020).

Hellhole Bend:

On average, Hellhole Bend gets more yearly precipitation than the Salt Trail site by 0.47 inches (Figure 9). Six out of 11 years of the study duration were higher than average years for total precipitation, with most of those years occurring between 2012 and 2017 (Figure 9b). Of the 5 years with lower than average precipitation, the majority occurred between 2018 and 2022. Water year 2018 was notably dry, with very little precipitation occurring during both the cool and warm season (5.04 in total). The cool season of water year 2019 (October-March) was unusually wet, with 8.8 in of precipitation occurring during these months alone. From 2018-2022, average warm season (April-September) precipitation was much lower (average of 3.1 in) than the period from 2012-2017, which had an average warm season precipitation of 6.8 inches.

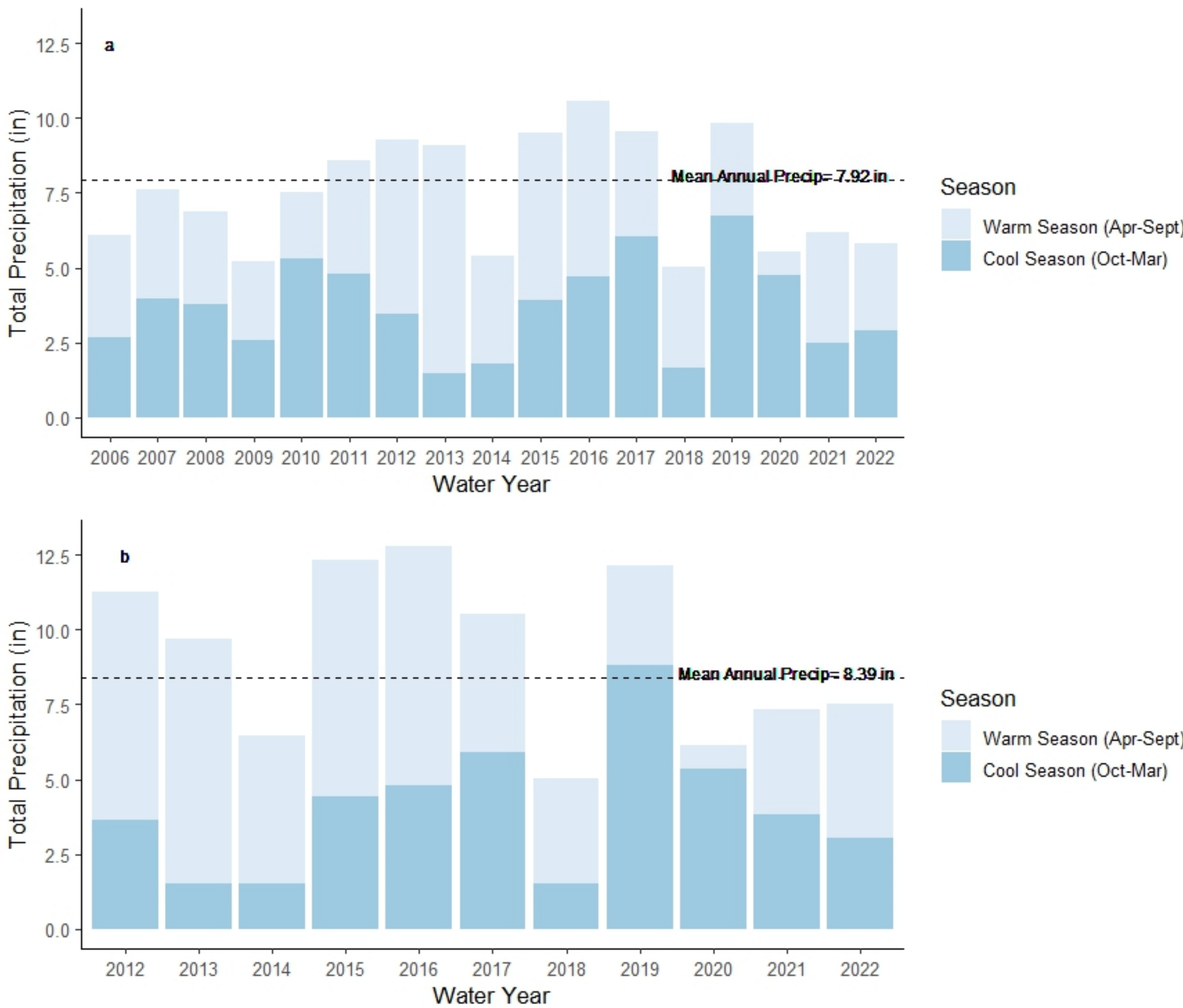

Figure 9. Yearly precipitation for the a) *Salt Trail* and b) *Hellhole Bend* monitoring sites based on gridded climactic predictions using the PRISM (Parameter-elevation Relationships on Independent Slopes Model) dataset; broken down by cool season (October through March) and warm season (April through September) for water years a) 2006-2022 and b) 2012-2022. Mean annual precipitation is a 30-year average, calculated from the years 1981-2022.

DISCUSSION

Cacti at the Salt Trail monitoring plot experienced die-offs in 2009-2011, when a large proportion of plants were lost, and then again in 2017. This does not appear to correlate with cool or warm season precipitation patterns, which suggests that other factors are contributing to cacti mortality at this site. Disturbance from heavy sheep use within rim habitat at these monitoring plots is consistently noted from year to year, and is a significant threat to this population, as cacti are disturbed when sheep dig depressions in the soil to use for "bedding down" areas. This population would likely benefit from livestock enclosure fencing along occupied rim habitat, if Tribal members permitted to run sheep in the region are open to it. During wet years, Fickeisen cactus at this site are also under heavy competition from exotic invasives such as *Bromus, Schismis, and Erodium cicutarium*, which can compose up to 80% of the vegetation cover. Its possible that exotic invasives are interfering with pollinator access to flowers and/or are limiting seedling establishment, though future studies are needed.

Hellhole Bend cacti are doing much better than Salt Trail cacti, and have experienced a net population growth of 20 cacti since plots were established in 2012. Unlike the Salt Trail site, this site is not heavily used by sheep, and although there are livestock (mainly cows) occupying this region, plots are not disturbed by depressions from "bedding down" areas. Though this site also has the same exotic invasives present as the Salt Trail site, they occupy less overall cover, even in wet years, and this site has more native plant cover and diversity. It also receives more rainfall on average than the Salt Trail site, which may explain why more plants were reproductive at this site on average. However, in some years (2019 and 2022, notably), a high proportion of flowers were aborted, which means that although the cactus flowered, no mature fruits or seeds were produced. If lack of adequate pollination is the reason for such a high proportion of aborted flowers, future studies are needed to explore possible pollination limitation in this species.

There are currently 35 populations (Element Occurrences) of Fickeisen plains cactus that are tracked by the Navajo Natural Heritage Program. A population for this species is defined according to Heritage Program methodology as separated by one km or less, when populations are connected by suitable habitat (NatureServe 2004). The last thorough census of Navajo Nation's known populations was conducted in the spring of 2015 by the NNHP botanist and two contract biologists through a USFWS Section 6 one-time grant (Hazelton 2015). Prior to 2015, many populations on the Navajo Nation had not been thoroughly surveyed in at least a decade. This inventory counted 1,046 total cacti, with the majority of plants occurring at the Black Rock (354 individuals), Salt Trail (345+ individuals), and Hellhole Bend (358 individuals). Together, these three populations make up 70% of the total known cacti found on the Navajo Nation. Therefore, population trends occurring at the Hellhole Bend and Salt Trail monitoring sites have significant implications for the status of Navajo Nation populations of Fickeisen plains cactus. Opposing trends from these two monitoring sites demonstrates that hyper-local threats can play a big role in determining population trajectories, and that adequate spatial representation of the species across it's range is critical for inferring population trajectories over time on a larger scale.

ACKNOWLEDGEMENTS

This report was adapted from previous reports from the Salt Trail monitoring site written by A. Hazelton and D. Roth, former botanists of the Navajo Natural Heritage Program, who originally implemented these study sites and collected all data prior to 2016. Thank you to D. Prall, J. Mike, L. Begay, K. Jensen, B. Powers, J. Josea, D. Valentine, J. Fort, J. Finch, and T. Fantano for field assistance from 2017-2022.

REFERENCES:

Applied Climate Information System. RCC-ACIS. NOAA Regional Climate Centers, [March 3, 2024].

Aslan, C. (2017). *Pediocactus peeblesianus var. fickeiseniae* exhibits exceptionally low pollination rates. Section 6, Segment 19-2015-2017-01. Final Report to U.S. Fish and Wildlife Service. Unpublished. 17 pp.

Baker, M., & Cloud-Hughes, M. A. (2022). Reassessment of subspecific taxa within *Pediocactus peeblesianus* (Cactaceae) by multivariate analysis of morphological characters. *Journal of the Botanical Research Institute of Texas*, *16*(1), 297-315.

Benson, L. (1982). The Cacti of the United States and Canada. Stanford University Press, Stanford, CA.

Daly, C., Halbleib, M., Smith, J. I., Gibson, W. P., Doggett, M. K., Taylor, G. H., Curtis, J., and Pasteris, P. P. (2008). Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. *International Journal of Climatology: a Journal of the Royal Meteorological Society*, *28*(15), 2031-2064.

Endangered and Threatened Wildlife and Plants; 12-Month Finding for the Lemmon Fleabane; Endangered Status for the Acuna Cactus and the Fickeisen Plains Cactus and Designation of Critical Habitat, 77 F.R. 60511 (proposed October, 2012) (to be codified at 50 C.F.R. pt. 17).

Goodwin, G. (2009). *Report on Rare Plant Surveys Conducted on Cataract and Espee Ranches in 2008*. Unpublished report- prepared for Babbitt Ranches, Flagstaff, Arizona and The Nature Conservancy, Northern Arizona Program, Flagstaff, Arizona.

Hazelton, A.F. 2011. Fickeisen Plains Cactus (*Pediocactus peeblesianus ssp. fickeiseniae*) Monitoring Report: Salt Trail Canyon Monitoring Site, 2006-2011. Unpublished report prepared for the Navajo Natural Heritage Program, Department of Fish and Wildlife, P.O. Box 1480, Window Rock, AZ 86515. Available online at < http://nnhp.nndfw.org/>.

Hazelton, Andrea. 2015. Status Report for Fickeisen Plains Cactus (*Pediocactus peeblesianus var. fickeiseniae*). Section 6 Final Report. Produced for US Fish and Wildlife Service and AZ Dept. of Agriculture.

Heil, K. D., & Porter, J. M. (2001). Cactaceae Cactus Family. Part Five: *Pediocactus* Britt. & JN Rose and *Sclerocactus* Britt. & JN Rose. *Journal of the Arizona-Nevada Academy of Science*, 9-18.

NatureServe. 2004. A Habitat-Based Strategy for Delimiting Plant Element Occurrences: Guidance from the 2004 Working Group. NatureServe, Arlington, Virginia. Accessed at *http://www.natureserve.org/library/deliminting_plant_eos_Oct_2004.pdf*

Talkington, N. & Mikesic, D. (2020) Navajo Nation Endangered Species List, Species Accounts, Version 4.20. Unpublished report prepared for the Navajo Natural Heritage Program, Department of Fish and Wildlife, P.O. Box 1480, Window Rock, AZ 86515. Available online at <http://nnhp.nndfw.org/.

Roth, D. 2008. Fickeisen Plains Cactus (*Pediocactus peeblesianus ssp. fickeiseniae*) monitoring report (Salt Trail Canyon monitoring site) 2006-2008. Unpublished Report Prepared for the Navajo Natural Heritage Program.

U.S. Fish and Wildlife Service. (2008). Peebles Navajo Cactus (*Pediocactus peeblesianus var. peeblesianus*) 5-Year Review, Summary and Evaluation. U.S. Fish and Wildlife Service, Arizona Ecological Services Field Office, Pheonix, Arixona.

U.S. Fish and Wildlife Service. (2020). Fickeisen plains cactus (*Pediocactus peeblesianus var. fickeiseniae*) 5-Year Review, Summary and Evaluation. U.S. Fish and Wildlife Service, Arizona Ecological Services Field Office, Pheonix, Arixona.