CONSERVATION STRATEGY

FOR

CLOVER'S CACTUS
(*Sclerocactus cloverae*)

AND

AZTEC GILIA
(*Aliciella formosa*)

August 30, 2020

Prepared by Institute for Applied Ecology
for
Bureau of Land Management New Mexico State Office
Agreement L15AC002

Executive Summary

This Conservation Strategy addresses Clover's cactus (*Sclerocactus cloverae*) and Aztec gilia (*Aliciella formosa*), two endemic plants restricted to the Nacimiento Formation in northwestern New Mexico. Most known populations are on BLM-managed lands, but populations are also present on Navajo Nation, State of New Mexico, and private lands.

Both species are threatened by rapid expansion of oil and gas development in the Nacimiento, confounded by their limited range size, climate change, insect attack and other human activities. Aztec gilia is listed as endangered in the State of New Mexico and Clover's cactus is proposed for state listing; both species are on the Bureau of Land Management (BLM) Sensitive Species List and are also listed endangered on the Navajo Nation. Current estimates of range size and total population numbers for both species suggest that both species are comparable to similar federally listed threatened cacti in Colorado and Utah, indicating that federal listing is probably required for these species in the absence of intervention. Proactive management is needed to reduce threats and prevent federal listing of Clover's cactus and Aztec gilia under the Endangered Species Act (ESA).

Commented [d1]: Listed State Endangered in 2020

Commented [d2]: Similar threats? Same threats? Fewer threats? Species are listed because of active documented threats, not because of a limited distribution

The goal of this Conservation Strategy is to reduce the likelihood and need for listing these species under the Endangered Species Act (ESA) due to impacts from oil & gas development. This strategy is strictly focused on lessening impacts from oil & gas development. In order to achieve this goal, the Strategy requires maintenance of sizable, stable populations occurring in suitable habitat that is protected for the long term, with acceptable levels of connectivity for genetic exchange through pollinator movement and seed dispersal. We have identified an approach and related management actions that are expected to result in better protection of these rare plants on lands leased for energy development. The approach is in alignment with the Council on Environmental Quality (CEQ) Mitigation hierarchy[1], and details (1) how to avoid impacts, (2) how to mitigate impacts when avoidance is not feasible, and (3) research that can improve future avoidance and mitigation. Voluntary, proactive conservation and mitigation and adherence to the Survey Standards in Appendix A and the Mitigation Measures in Appendix B are central to the achieving the goals of this strategy. Successful implementation will also require close coordination between project proponents and Bureau of Land Management representatives.

Commented [d3]: This strategy only provides recommendations for leased lands? Are all plants on leased lands?

Commented [MP4R3]: @John Kendall, please confirm

As new information about these species and suitable habitat becomes available, the Strategy will be amended and shared. After five years (2026) the status of Clover's cactus and Aztec gilia and recommendations in this strategy will be re-evaluated and revised as needed.

Commented [d5]: Based on what? Would be good to have a chapter at the end of this strategy that addresses this evaluation process. This would be very helpful in the potential forthcoming federal evaluation for listing.

[1] https://ceq.doe.gov/laws-regulations/regulations.html

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Introduction

The Nacimiento Formation (Figure 1) in the San Juan Basin of western New Mexico, the only place in the US where the Formation exists, is famous worldwide for its fossils and unusual landscapes. The first early Paleocene mammal fossils were discovered here, and the fossil mammal fauna remains among the most diverse for the early Paleocene in the world (Williamson 1996). The formation was deposited in floodplain, fluvial, and lacustrine settings mostly between ~65.7 and ~61 million years ago, during the early and middle Paleocene. The Nacimiento badlands are extensive, barren depositional shale, mudstone, and soft sandstone, with occasional selenite crystals and gypsum crusts found on the clayey sand soils. Gypseous substrates are more frequent north of the San Juan River and are classified as gypsum soils in the San Juan County soil survey (S. USDA, 1980).

[Insert map of Nacimiento here]

Figure 1. The Nacimiento Formation in western New Mexico

Clover's cactus (*Sclerocactus cloverae*) and Aztec gilia (*Aliciella formosa*) are rare species endemic to the Nacimiento formation, with total worldwide distributions limited to areas of 76 miles x 26 miles and 26 miles x 25 miles, respectively. Species with such limited distributions are inherently vulnerable to extinction because localized mortality events can impact large proportions of their worldwide numbers (Purvis et al. 2000). They may also be especially vulnerable to the effects of climate change because the fraction of their range that is displaced due to warming is larger (Schwartz et al. 2006). The overall range and total population size of Clover's cactus is comparable to those of several close relatives that are Federally listed as Endangered or Threatened (Table 1). The range size and number of Element Occurrences for Aztec gilia is also comparable to these listed species. While range size is not considered when evaluating a species' for listing under the ESA[2] (U.S. Fish and Wildlife Service 2016), it is useful to note that Clover's cactus and Aztec gilia are quite rare and compare range-wise to a number of listed species. This

[2] When evaluating a species for listing, the FWS considers five factors: 1) present or threatened destruction or modification of a species' habitat; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; 4) inadequacy of existing protection; and 5) other natural or manmade factors that impact its survival.

suggests without proactive management and threat reduction, these species could also soon be candidates for listing under the ESA.

Table 1. Comparison of range size, number of EOs (populations) and total estimated number of individuals for Aztec gilia, Clover's cactus, and several similar species that are federally listed under the ESA.

Common Name	Scientific Name	Range size (sq miles)	# EOs	Total individuals	Federal Status
Aztec gilia	*A. formosa*	650	42	No estimates available	
Clover's cactus	*S. cloverae*	1,976	56	16,347	
Colorado hookless cactus	*S. glaucus*	1,700	98	19,000	T
Mesa Verde cactus	*S. mesae-verdae*	2,250	8	5,000-10,000	T
Uinta Basin hookless cactus	*S. wetlandicus*	719	26*	109,000+*	T
Pariette cactus	*S. brevispinus*	112			T

* The two species hybridize and it is very difficult to be confident about which species a point actually represents when in the vicinity of the *S. brevispinus* species range. Utah BLM combined the two species together and used 1 km to create pseudo-EOs and a combined estimate of individuals.

In addition, the restriction of these species to the Nacimiento formation puts them at high risk because this region has experienced rapid expansion of oil and gas development. A total of 37,307 wells have been drilled within the Mancos-Gallup RMPA Planning Area of the Farmington Field Office. The Reasonable Foreseeable Development Scenario for Oil and Gas Activities projects 3,200 new oil and gas wells over the next 20 years (Crocker and Glover 2018). This will potentially increase the acreage of surface disturbance from 56,500 acres to 75,000 acres within the 4.2-million-acre planning area. Reclamation is predicted to reduce surface disturbance acreage to 43,000 acres by the end of the 20-year planning period, but plant populations will nevertheless be disturbed within the footprint of the maximum disturbance acreage. The small range sizes of these species make them further vulnerable to threats that are present throughout their range, including beetle and other animal damage, trampling, increased drought, off-road vehicle traffic, and invasive species.

Commented [MP6]: @John K – when to when?

Commented [d7]: Climate change!

Clover's cactus is one of several species in the *Sclerocactus* genus with restricted distributions and conservation concern. A former subspecies of clover's cactus, Brack's hardwall cactus (*S. cloverae subsp. brackii*), was until recently a BLM special status species and was listed as Endangered by the State of New Mexico (EMNRD 2019). Recent genetic work, however, demonstrated that subspecies *brackii* and *cloverae* are not genetically distinct, and the subspecies designation is not warranted (Porter and Clifford 2018). Despite this finding, the change in taxonomy will not substantively change management requirements as the species as a whole is now listed as Endangered by the state ~~(D. Roth, personal communication 2019; Z. Davidson, personal communication 2019).~~

Commented [d8]: In addition, the species has been petitioned for federal listing in 2020.

Aztec gilia is extremely rare, with only 42 known populations and evidence of long term declines since the 1990s (Roth and Sivinski 2018). It is a Bureau of Land Management special status species (Bureau of Land Management 2008a), and is listed as Endangered in the state of New Mexico (NMAC 19.21.2) and the Navajo Nation (No. RDCJA-01-20).

Biological Information

Clover's Cactus

Species Description and Taxonomy

Sclerocactus is a genus of "fishhook" or "little barrel" cacti with approximately 15 species that are found in high elevation deserts due to their tolerance of extreme drought and both high and low temperature (CITES Secretariat 2015a). Clover's cactus (*S. cloverae*) is elongate and cylindrical, with stems typically 10 cm wide by 12 cm tall, or larger. Stems are usually solitary and have 11-15 (usually 13) ribs formed of coalescent tubercles. There are approximately 11 spines per areole ranging from 1.5-4.6 cm long, with 4-9 in the central position. The lower spine is typically rounded and hooked, or absent, and the upper one is flattened on the outer face and often ribbon-like. Flower buds are rounded at the apex and open flowers are pink-purple and 2.3-4 cm long, 1.5 – 2.5 cm across. Fruits are green, tan or pink/magenta when mature, 7-15 mm long and 5-12 mm wide, opening along an irregular line of dehiscence just below the middle. The seeds are relatively large (1.3–3 mm long and 2-4 mm wide) and black, gray, or brown and kidney shaped with a lateral hilium (NatureServe 2019b; Muldavin et al. 2016b).

Figure 2. *Sclerocactus cloverae juvenile morphology in flower* (A) and adult morphology in flower (B). Photos by Robert Sivinksi.

Some Clover's cactus plants reach first flowering while still morphologically juvenile in appearance. This phenomena created taxonomic confusion for several years, and the designation of two subspecies (*S. cloverae ssp. brackii* and *S. cloverae ssp. cloverae*) which are no longer recognized as genetically distinct (Porter and Clifford 2018). Details of the systematics and comparison with look-alikes are summarized in Appendix C.

Range and Distribution

The genus *Sclerocactus* ranges from southwestern United States to northern Mexico, with the majority of taxa distributed in the United States (CITES Secretariat 2015a). Historical uncertainty around species delineation in *Sclerocactus* has led to conflicting information about the range and distribution of many species, including Clover's cactus. Appendix C has details of historic vs. current understanding of range and distribution. Although the edges of the range are not well defined, documented occurrences of Clover's cactus that have been confirmed both morphologically and genetically are restricted to the Nacimiento Formation or closely proximate to it (Figure 3) in New Mexico and the Navajo Nation in New Mexico, at 1500-2134 m (4921-7000 ft) elevation (Heil and Porter 2004b). These occurrences span a distance of 76 miles from north to south and about 26 miles across at the widest point (Figure 3). This yields an estimated total range of approximately 1,976 square miles, making Clover's cactus a highly endemic species at the global scale (Porter and Clifford 2018).

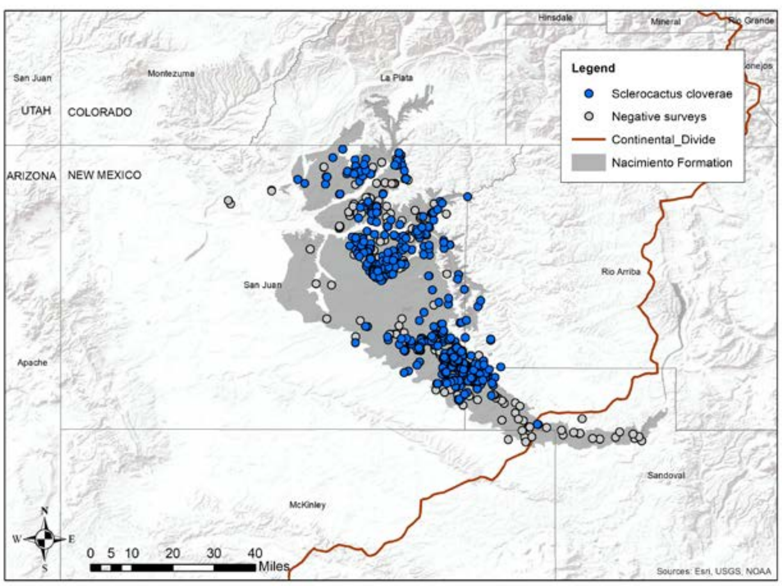

Figure 3. Distribution of known current and historic *Sclerocactus cloverae* occurrences. Blue dots are locations recognized by the New Mexico Natural Heritage Program as of 11/1/2019, with populations showing evidence of introgression with *S. parviflorus* removed (Appendix C). Grey dots are negative survey data (Muldavin et al. 2016).

Status and Trends

As of January 2020, the conservation status of Clover's cactus was in flux, with some regulatory agencies following the genetic analyses that combined former subspecies *cloverae* and *brackii* (Table 2). The species now receives increased protection on Navajo Nation lands, as it ~~is~~ was uplisted to Group 3 status (Endangered) on the Navajo Endangered Species List in 2020 (Navajo Nation, Division of Natural Resources, Department of Fish and Wildlife 2020). As of 2020, Clover's cactus is ~~currently being proposed for~~ listed~~ing~~ ~~as~~ State Endangered in New Mexico ~~(D. Roth, personal communication 2019)~~. See Appendix C for additional conservation status details.

Table 2. Conservation status changes with updated taxonomy of Clover's cactus (*Sclerocactus cloverae*).

Institution	Status of *former* subspecies designations		Status of *S. cloverae* (current taxonomy- no subspecies)
-	*S. cloverae ssp. brackii*	*S. cloverae ssp. cloverae*	*S. cloverae*
Federal	Not listed	Not listed	Not listed
NM State	Endangered[1]	Species of Concern[1]	~~Proposed~~ Endangered[2]
CITES	Appendix I – threatened with extinction[3]	Appendix I – threatened with extinction[3]	Appendix I – threatened with extinction[3]
NatureServe/ Natural Heritage New Mexico	G3T2 – Globally imperiled subspecies of a vulnerable species[4] N2 – Nationally imperiled S2 – Imperiled in New Mexico[8]	G3T3 – Globally vulnerable subspecies of a vulnerable species[5] N3 – Nationally vulnerable Not ranked at state level	G3 – Globally vulnerable[6] N3 – Nationally vulnerable Not ranked at state level
BLM	Sensitive[7]		Sensitive[7]
Navajo Nation	Endangered, Group 3[10]		Endangered, Group 3

[1] (EMNRD-Forestry Division 2017), [2] (D. Roth, personal communication 2019), [3] (Convention on International Trade in Endangered Species of Wild Fauna and Flora 2019), [4] (NatureServe 2019c), [5] (NatureServe 2019d), [6] (NatureServe 2019b), [7] (Bureau of Land Management 2019), [8] (New Mexico Rare Plant Technical Council 2019), [9] (Navajo Nation, Division of Natural Resources, Department of Fish and Wildlife 2020), [10]

Commented [d9]: For some unexplained reason the new name slipped through the listing process in 2020

Population trend data are not available for Clover's cactus, although the BLM initiated demographic monitoring plots across the range of the species in 2017 to remedy this (see Previous Monitoring section in Appendix C). Prior to 2018 and the genetic analysis that combined the subspecies, the New Mexico Natural Heritage program conducted extensive surveys and modeling to predict habitat and distribution of the former subspecies *brackii*, which was the only taxon with protected status at the time (Muldavin et al. 2016a). They revisited all known sites of both subspecies within the Nacimiento Formation, which contains the bulk of known occurrences, and searched new promising locations based on habitat indicators of geology, soils, and vegetation. They identified 155 positive locations of Clover's cactus in their range-wide survey and quantified a total of 4,139 live plants of both subspecies during two different survey events.

Commented [d10]: What about all the transplant monitoring since 2012?

Their surveys yielded a total population count of 16,347 live plants. Analyses based on these field-survey counts excluded *ssp. cloverae* data, but these were only ~5% of the data, so reanalysis including all data will not likely change results (E. Muldavin, personal communication 2019; R. Sivinski, personal communication 2019). Using standard NatureServe (2002) rules of separation by distance, they estimated that there are 56 Element Occurrences (EOs) (Figure 4), which are surrogates for populations when data on individual plant interactions, genetic isolation, and population dynamics are lacking. They determined the majority of EOs were likely to have poor viability because they were small populations represented by less than 50 individuals (Table 3). Details of their methodology and findings are summarized in the Previous Surveys section of Appendix C.

Commented [d11]: No from their field surveys. Their field surveys documented 4,139 plants.

Commented [MP12]: comment from mg: “Having info for just Bracks seems confusing to me. I recommend moving this section to an Appendix for “Former Brack’s cactus survey and modeling”. I would only state the main results of this work in one sentence. For example: NMNHP estimated a total of 16,347 Brack’s cactus plants, but researchers acknowledged that the habitat assessment transects utilized may have positively biased this estimate of population size.”

Commented [d13R12]: The 16,347 cacti are not an estimate but the total count through all surveys ever done, primarily through clearance surveys. Considering current and former management practices, the majority of these cacti are likely no longer in existence. Carrying this number forward is misleading.

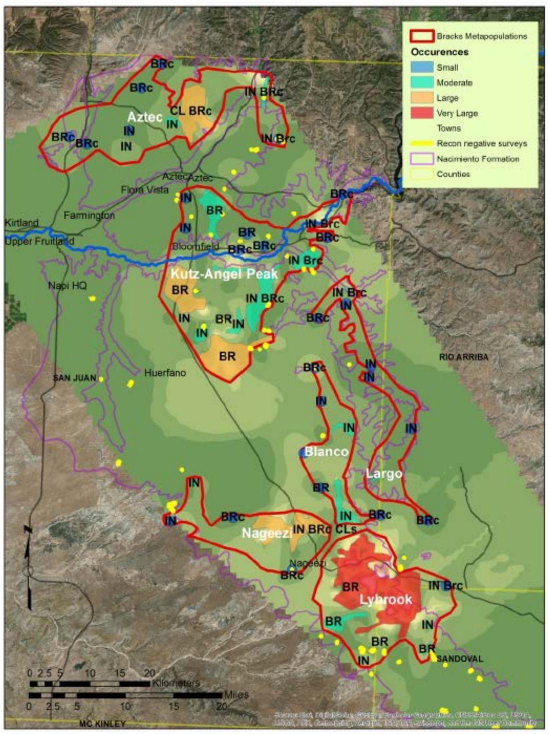

Figure 4. Element occurrences (EOs) and “metapopulations” overlain on an interpolated density surface based on field-survey counts of plants. EOs are separated by at least 3 km in contiguous potential habitat (most cases) or by 1 km where there are significant habitat barriers. (From Muldavin et al. 2016).

Table 3. Summary of Sclerocactus cloverae EOs with viability ranks from Muldavin et al. 2016

Rank	Viability	# of EOs	% of EOs	Sum of observations	Comments
A	Excellent	1	2%	13536	Lybrook Nageezi occurrence with acknowledged positive bias in plant counts from habitat assessment transects

Commented [MP14]: from MG - I know they did an adjustment to avoid overestimating, but I am still seeing a note here about the technique resulting in a positive bias. If this number does not seem well founded to you and Zoe, then maybe we should remove this table? Or it can be shared in an appendix.

Commented [d15]: Most of these counts came from clearance surveys. Heritage transects documented 2,572 individuals in the Lybrook/Nageezi focal zone. Sum of observations.

B	Good	8	14%	1904	
C	Fair	8	14%	547	
D	Poor	39	70%	360	

Habitat

Clover's cactus is not restricted to a particular substrate or soil, but a group of soils within the Nacimiento formation. It typically grows on gravelly or rocky ground, clay hills, mesas, and washes on the San Jose and Nacimiento formations and in Quaternary glacial outwash deposits (Porter and Prince 2011). The cactus occurs in equally varied plant communities in the Colorado Plateau Shrub Steppe biome, including salt desert, sparse grasslands dominated by blue grama (*Bouteloua gracilis*), galleta (*Pleuraphis jamesii*), Indian ricegrass (*Achnatherum hymenoides*), and needle and thread grass (*Hesperostipa comata*); on shallow sandy soils on or near sandstone outcrops in open pinyon juniper (*Pinus edulis*, *Juniperus osteosperma*) woodlands; in juniper savanna; in open to dense shrublands dominated by big sagebrush (*Artemisia tridentata*) and rabbitbrush (*Ericameria nauseosa*); and up in elevation to ponderosa pine (*Pinus ponderosa*) woodland (Heil and Porter 2004b; Porter and Prince 2011). It also occurs in sparsely vegetated, sandy shale badlands associated with species that indicate saline and clayey substrates such as shadscale (*Atriplex confertifolia*), stalked orach (*Atriplex saccaria*), bud sagebrush (*Picrothamnus desertorum*), oblongleaf basin daisy (*Platyschkuhria integifolia*), alkali sacaton (*Sporobolus airoides*), and greasewood (*Sarcobatus vermiculatus*).

Additional species that have been associated with Clover's cactus include Shockley's buckwheat (*Eriogonum shockleyi*), Aztec gilia (*Aliciella formosa*), tufted elkweed (*Frasera paniculata*), mock bitterweed (*Stenotus armerioides*), Ives bitterweed (*Hymenoxyx ivesiana*), prickly pear (*Opuntia erinacea*), narrowleaf yucca (*Yucca angustissima*) and Mormon tea (*Ephedra spp.*)(Heil and Porter 1994a; Porter and Prince 2011; Muldavin et al. 2016a). See Appendix C for additional habitat details.

Population Biology

Life history

Cacti in the genus *Sclerocactus* are slow growing, single stemmed, perennial succulents, which tend to be exceptionally cold and drought tolerant and long-lived. The longevity of Clover's cactus is not known (Porter and Prince 2011). Age at first flower is also unknown, but stems as small as 18 mm in diameter have been observed blooming. Observations during the NHNM study found that most mature cacti flowered from mid-April to mid-June (Muldavin et al. 2016b). Further formal descriptions of its life history are lacking, but anecdotal observations describe a brief period of biological activity in mid-March to early June, during which time cacti burst into growth and flower, followed by a state of dormancy as soon as it gets hot and in winter (S. Brack, personal communication 2019). Natural sources of mortality for the genus as a whole include desiccation, diseases, and predation from small mammals and insects.

Commented [d16]: Brief?

Commented [d17]: Followed by seed set? What does dormancy mean for a cactus? No growth?

Population Dynamics

The population dynamics of Clover's cactus have not been studied, but anecdotal reports of population crashes due to insects and other herbivores, and observations of dramatically age-structured populations with age classes separated by ~ five years, suggest it is likely to experience both episodic population crashes and episodic recruitment, as has been documented for *S. mesae-verdae* (Porter and Prince 2011). The plants can be very difficult, if not impossible, to detect due to the small stature of many individuals and their distribution in scattered clumps. This makes assessment of population fluctuations difficult without a systematic demographic study of marked individuals.

Commented [d18]: Anecdotal? See Muldavin et al 2016 and all the monitoring reports

Clover's cactus individuals tend to occur in scattered groups of cacti isolated from other such groups by more than 50 meters, even in areas where the highest plant counts were estimated (see Appendix C for details on Lybrook population center) (Muldavin 2019). The formation of scattered "family" clusters is likely a result of local habitat conditions and seed dispersal (Muldavin et al. 2016a).

Population Genetics

All populations sampled for the assessment of subspecies status in *S. cloverae* showed high levels of genetic diversity and low inbreeding rates (Porter and Clifford 2018). Despite this, there were substantial differences among populations and these differences showed a geographic pattern with strong evidence for two genetically distinct groups (Figure 5): one centering on southern populations of southeastern San Juan, Sandoval, and Rio Arriba counties (this overlaps the Lybrook/Nageezi population clusters in the NHNM report, Appendix C), and the other centering on northern populations (the Aztec and Kutz/Angel Peak clusters) mostly north of the San Juan River (Porter and Clifford 2018). These northern and southern clusters of populations are genetically differentiated groups which may require management as distinctive units (Porter and Clifford 2018). This means it will be important to limit movement of seeds or transplanted individuals between these areas because mixing of these two genetic groups could have negative fitness consequences. See Appendix C for additional details on population genetics and gene flow.

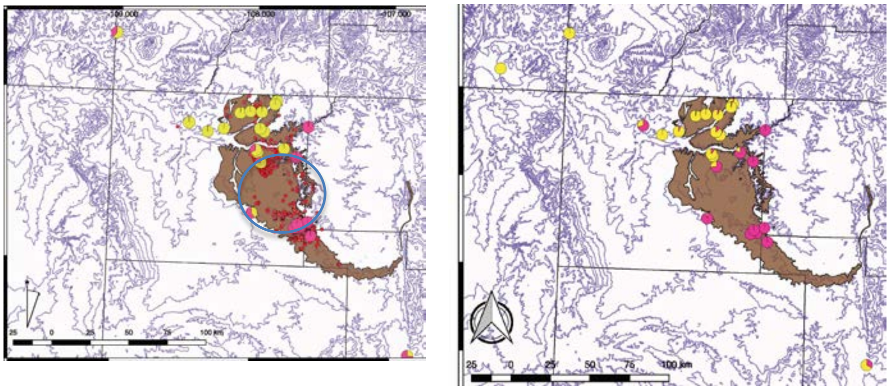

Figure 5. Patterns of genetic variation within and among populations reveal two distinct genetic groups of populations, but the boundary between them and the alignment of outlier populations differs with alternative methods of estimation. The 25 sampled populations are color-coded, yellow: northern genetic cluster; magenta: southern genetic cluster. Known sites of *S. cloverae* are shown as small, red dots and the Nacimiento Formation is shown in brown. From Porter and Clifford 2018.

Pollination and Breeding System

The breeding system of Clover's cactus is unknown, but species within the genus are typically self-incompatible and require cross pollination to set fruit (Porter and Prince 2011). Clover's cactus flowers from mid-April through mid-June (Muldavin et al. 2016b), with flowers opening diurnally and closing at night. Flowers last from 5-7 days. Fruits are found from mid-May through June (Porter and Prince 2011).

Observations during the NHNM survey that most mature cacti flowered and set fruit with few aborted flowers in a season with good spring precipitation suggest that the species is not pollinator-limited (Muldavin et al. 2016b), which is similar to the finding in a study of reproductive biology of the congeners *S. wetlandicus* and *S. brevispinus* in the Uintah Basin, UT (Tepedino, Griswold, and Bowlin 2010). No pollination studies have been conducted on the species, but bees observed on flowers during the NHNM survey were *Agapostemon sp.* and *Lasioglossum sp.,* in the subfamily *Halictinae*. These native bees are small ground-nesting species which visit a wide variety of flower species. Halictid bees in the Lasioglossum genus are the smallest observed floral visitors to *S. cloverae*, and they are predicted to fly between 64 -328 ft (50-100 m; Tepedino 2010 in (USFWS 2014)) when foraging. The other observed bee genus, *Agapostemon*, is slightly larger and predicted to fly between 1312 – 3281 feet (400 – 1000 m).

Seed Production and Germination

Descriptions of seed production and germination in Clover's cactus are limited to observations made by experienced botanists during field surveys or while propagating plants. Throughout the genus, the fleshy fruits dry and split open when mature (Hunt, Taylor, and Charles 2006; Hochstatter 2005), and germinate at the base of the parent plant unless they are dispersed by erosional processes (rainfall), wind, or harvester ants

(*Pogonomyrmex sp.)* (Sivinski 2011; Muldavin et al. 2016a). Collected seeds are ripe when the growing season is over in June, but usually will not sprout until they have overwintered (S. Brack, personal communication 2019).

Sclerocactus seeds have a hard outer coat which protects the viability of the seeds for a long time (Benson 1982). While little is known about seed longevity in the wild for the genus, there is some evidence that cactus species with seed dormancy may form a seed bank (Rojas-Arechiga and Vazquez-Yanes 2000; Bowers 2005). Collected and stored Clover's cactus seed has remained viable for up to 20 years (S. Brack, personal communication 2019), and for the genus in general it has been documented to remain viable for 10 years or longer (Hochstatter 2005).

No information exists on seed bank dynamics for Clover's cactus.

Aztec Gilia

Species Description and Taxonomy

Aztec gilia (*Aliciella formosa*) is a member of the *Loeselieae* group within the Phlox family (Polemoniaceae). Aztec gilia is a perennial herb with numerous branched stems, growing to 7-30 cm tall and becoming woody at the base. The plant usually has a sparse covering of short glandular hairs. Leaves are mostly basal, forming a dense rosette, but are also found along the stems, where they are reduced in size. Basal leaves are sharp-pointed, linear, entire, and 1-4.5 cm long by 1-1.5 mm wide. The inflorescence is few-flowered and open, with pinkish-purple, trumpet shaped flowers 15-27 mm long. Plants flower from late April through early June (Roth and Sivinski 2018). Details of the systematics and comparison with look-alikes are summarized in Appendix D.

Figure 6. Aztec gilia (*Aliciella formosa*). Photo: Daniela Roth

Range and Distribution

The total worldwide distribution of Aztec gilia is restricted to an area approximately 26 miles long x 25 miles wide (Figure 7) on the Nacimiento Formation in San Juan County near the towns of Aztec and Bloomfield, New Mexico (Porter 1998; Roth and Sivinski

2018). It is described from just west of the Animas River near the Colorado border, west to near La Plata, southeast to the Angel Peak badlands (upper Kutz Canyon), east to Largo Canyon and north to the vicinity of Cedar Hill on the Animas River (Roth and Sivinski 2018). Additional populations of Aztec gilia occurring on Navajo Nation lands occur in the checkerboard land ownership south of Bloomfield are not included in the Figure 6 map, but these populations still do not expand the range of the species (N. Talkington, personal communication 2019).

Commented [d19]: Seems irrelevant for this scale of map

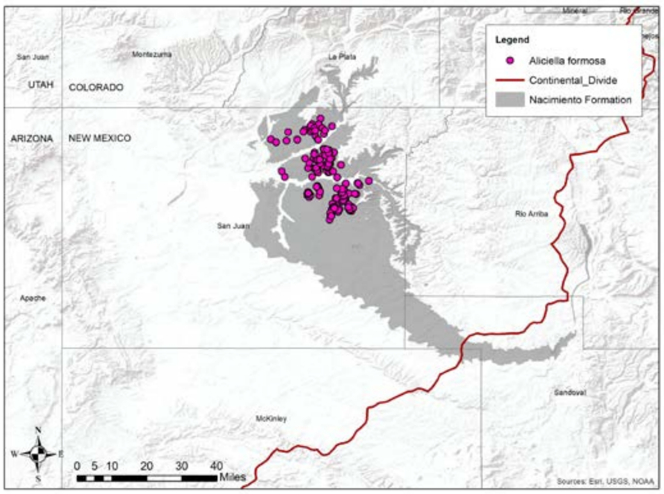

Figure 7. Worldwide distribution of *Aliciella formosa*, from mapped known occurrences in the Natural Heritage New Mexico NMBiotics database. The Nacimiento formation is highlighted in grey.

Status and Trends

The Aztec gilia is listed as Endangered by the State of New Mexico and the Navajo Nation (Table 4). See Appendix D for additional conservation status details.

Table 4. Conservation status of Aztec gilia (*Aliciella formosa*)

Institution	Status
Federal status	Not Listed
NM State status	Endangered[2]
NatureServe	G2 – Globally imperiled[3] N2 – Nationally imperiled
BLM	Sensitive[4]
Natural Heritage New Mexico	S2 – State imperiled[5]
Navajo Nation	Endangered, Group 3[6]

[1, 2] (EMNRD-Forestry Division 2017), [3] (NatureServe 2019a), [4] (Bureau of Land Management 2019), [5] (New Mexico Rare Plant Technical Council 2019), [6] (Navajo Nation, Division of Natural Resources, Department of Fish and Wildlife 2020)

After field botanists noted the disappearance or decline in plant numbers since 2000, a range-wide survey of Aztec gilia was conducted and long term monitoring was re-initiated in 2017 to determine the current status and degree of endangerment of the species (Roth and Sivinski 2018). The survey was conducted by revisiting 140 of the 173 known site locations in the Natural Heritage New Mexico NM Biotics database (all documented locations on BLM lands). Aztec gilia plants were relocated at 107 of the sampled sites, with a total of 13,674 plants detected (Figure 7). Thirty three of the 140 previous observations could not be relocated, and five previously undocumented locations were discovered. The majority of occurrences that were not re-located had inaccurate location coordinates or vague descriptions, as confirmed by the lack of suitable habitat in mapped locations. A couple of sites were inaccessible and seven were likely misidentifications of *A. haydenii* (Appendix D). General observations from the 107 locations that were successfully surveyed indicated a declining trend, with many having fewer than five plants remaining despite much larger numbers originally reported.

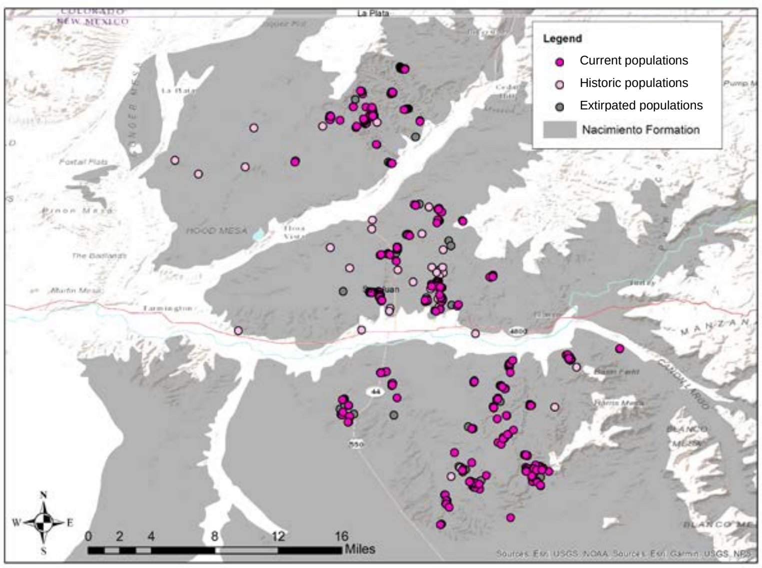

Figure 7. Historic and current distribution of *Aliciella formosa* from range-wide resurvey in 2017 (Roth and Sivinski 2018). Historic (light pink) points were not assessed either because they were not on BLM lands, access was limited, or location descriptions were too vague. Extirpated populations (negative surveys) were populations that were searched for in 2017 but no plants were relocated.

Habitat

Aztec gilia is found mostly on slopes, benches and summits of gently rolling hills in the northern badland regions of the Nacimiento Formation at elevations from 1,680 m to 1,940 m (5,500 – 6,360 ft) (Porter 1998; Roth and Sivinski 2018). It has been described as growing on dry saline clay or sandy clay soils, soft shaley sandstone strata, and the badlands it is associated with have selenite crystals and gypsum crusts (Roth and Sivinski 2018). It occurs in sagebrush-shadscale shrublands and pinyon-juniper woodlands, which are typically sparse in the badlands but can have diverse species composition (Roth and Sivinski 2018).

Associated species include widely scattered Utah juniper (*Juniperus osteosperma*), piñon pine (*Pinus edulis*), bitterbrush (*Purshia tridentata*), Utah serviceberry (*Amelanchier utahensis*), mountain mahogany (*Cercocarpus montanus*), rabbitbrush (*Ericameria nauseosa*), crispleaf buckwheat (*Eriogonum corymbosum*), Mormon tea (*Ephedra viridis*), Bailey's yucca *(Yucca baileyi*), brownspine pricklypear (*Opuntia phaeacantha*) and Clover's cactus (*Sclerocactus cloverae*). Common herbaceous species are needle and thread grass (*Hesperostipa comata*), galleta (*Pleuraphis jamesii*), Indian ricegrass (*Achnatherum hymenoides*), hoary Townsend aster (*Townsendia incana*), yellow catseye (*Oreocarya flava*), sleepdaisy (*Xanthisma grindelioides*), Ives' fournerved daisy (*Tetraneuris ivesiana*), fineleaf hymenopappus (*Hymenopappus filifolius*), sand verbena (*Abronia elliptica*), and Shockley's buckwheat (*Eriogonum shockleyi*).

Population Biology

Life history

Observations from four years of monitoring in the 1990s suggest that Aztec gilia plants produce a flexible, non-woody base and a "button" of true leaves up to 1.5-2 cm diameter in the first year, and can flower and set seed from a small, 2-3-flowered inflorescence in the second year (Floyd-Hanna 1994). Prolific reproduction does not begin until 3-4 years of age, after which reproductive effort correlates positively with size, and mature plants in undisturbed sites can reach up to 25-30 cm in diameter with over 40 inflorescences. Highly reproductive adults may live more than 10 years.

Plants tend to die as seedlings, due to abiotic, density-independent causes such as desiccation and heat, or at any life stage due to moth larval infestation (see Limiting Factors and Threats) or other predation.

Population Dynamics

Although this perennial species is reportedly long-lived, monitored populations have fluctuated widely from one year to the next (see Appendix D). Twenty (20) monitoring plots established by NHNM in the 1990s showed highly age-structured populations with the majority of plants being adults in all monitoring years (Roth and Sivinski 2018). From 2018 to 2019 the average ratios of seedlings and juveniles declined by more than 50%, suggesting there may be problems with successful recruitment due to high mortality of seedlings and juveniles even in years with high germination.

The distribution of Aztec gilia individuals is currently very patchy, with 100 m frequently separating patches, and plants often occurring as isolated individuals (Roth and Sivinski 2018). Plants occur in clusters of 1-375 plants, but most have fewer than 50 plants.

Population Genetics

There are no data on the population genetics of this species, and there is little concern about odd genetics for this species by the greater community.

Pollination and Breeding System

The Aztec gilia is self-incompatible, relying entirely on outcrossing for successful reproduction (Porter 1993). A study in the 1990s documented the hawkmoth *Hyles lineata* and the bee fly *Bombylius lancifer* as the most frequent visitors to Aztec gilia flowers in 6.25 hours of observations spread over 8 days (Porter 1993). The hawkmoth and bee fly contributed 76% and 15% of recorded visits, with other insect visitors being syrphid flies (8%) and Melyrid beetles (3%). Hawk moths and bee flies were also observed as the primary pollinators by other field biologists (Floyd-Hanna 1994; Roth and Sivinski 2018).

Plants flower from late April to early June (Roth and Sivinski 2018).

Seed Production and Germination

Plants germinate and establish between early April and early June depending on moisture availability (Floyd-Hanna 1994). Prolific germination resulting in dense coverage of seedlings has been observed following high winter precipitation. These observations occurred prior to 1995; there have been no observations or documentation of prolific germinations since.

Seed dispersal appears to be generally localized around maternal plants, but occasional longer distance dispersal by animal vectors or whirlwinds may take place (Roth and Sivinski 2018).

No information exists on seed bank dynamics for Aztec gilia.

Limiting Factors and Threats

Clover’s cactus and Aztec gilia face similar threats by virtue of their extremely limited global distribution and their shared endemism to the Nacimiento formation. Potential and ongoing Biological and Environmental threats and limiting factors (described below) include restricted range, climate, predation, hybridization. Anthropogenic threats include energy development, habitat fragmentation, dust, off-highway vehicles, livestock grazing, invasive weeds, and plant collections. Due to the restricted range of these species to the Nacimiento formation, intensive energy development in this region poses a significant threat.

Biological and Environmental

Restricted range

The small range sizes of Clover’s cactus (1,976 square miles) and Aztec gilia (650 square miles) inherently put these species at risk. Small range size is a strong predictor of extinction risk (Manne, Brooks, and Pimm 1999; Purvis et al. 2000; Gaston and Fuller 2009; Staude, Navarro, and Pereira 2020) because local adverse events can impact large portions of a species’ worldwide numbers. The small range sizes of Clover’s cactus and Aztec gilia exacerbate the impacts of the threats described below.

Climate

The Southwestern United States has experienced long periods of extreme drought (Western Regional Climate Center 2019). Climate models predict faster warming in the southwest than elsewhere in the country, with potential consequences including persistent or prolonged drought conditions, increased precipitation during normally dry seasons, changes in community assemblages, or changes in nonnative species abundance and vigor (Karl et al. 2009).

Climate change is acknowledged as a primary threat to rare and endangered plant species in New Mexico, both through its direct impact on species, as well as by its impact on their habitats and ecosystems (EMNRD-Forestry Division 2017). The confounding effects of climate change on rare plant species may be mitigated by managing for other threats and minimizing direct human impacts. Additional management actions could be ~~more~~ augmentation and increased monitoring during drought years.

Shifts in climate conditions are thought to have impacted seedling recruitment and adult survivorship of *Sclerocactus* taxa in the region (Porter and Prince 2011), including Clover’s cactus (K. Heil, personal communication cited in Porter and Prince 2011). These shifts are expected to affect the long term persistence of Clover’s cactus and other species in the genus (Porter and Prince 2011). In particular, anecdotal evidence from a controlled greenhouse study suggests that Clover’s cactus does not tolerate warmer nights and wetter summers (S. Brack, personal communication 2019). While not explicitly

Commented [d20]: This could be significantly stronger, given that climate change is the primary threat to all rare plants in NM, impacting plants throughout their range

Commented [d21]: Managing more intensively for other threats such as…..

Commented [d22]: Active management and habitat protection, more stringent mitigation measures, augmentation ratios, increased regulatory protections.

Commented [d23]: Not Aztec gilia?

Commented [d24]: Are we expecting wetter summers?

demonstrated, there is reason to expect that Clover's cactus will be impacted by the predicted climate changes.

The effects of shifting temperatures and precipitation patterns on Aztec gilia have not been specifically demonstrated, but impacts of prolonged drought and climate change have been suggested as possible contributors to the overall decline of the species (Roth and Sivinski 2018).

Predation

The native stem-boring insect, cactus longhorn beetle (*Moneilema sp*. in the *Cerambycid* family, Figure 8) has recently shifted from feeding exclusively on prickly pear and cholla to various species of *Sclerocactus* as an alternate host (Woodruff 2010). The beetle is recognized as a significant source of mortality for all *Sclerocactus* species in the Colorado Plateau, Intermountain Region, and Mojave Desert (Porter and Prince 2011). Effects on population dynamics and persistence of *Sclerocactus* species can be severe: beetle infestations can eliminate entire populations of adult cacti (Porter and Prince 2011). The beetles preferentially attack adult *Sclerocactus* cacti (Kass 2001; Coles, Decker, and Naumann 2012), probably to ensure sufficient resources for the developing larvae in the larger stems. This may cause a shift in population structure where larger cacti with higher reproductive rates are replaced by smaller cacti with lower reproductive rates, potentially lowering population viability if mortality outpaces recruitment.

Infestation by the cactus longhorn beetle was one of the leading natural causes of Clover's cactus mortality observed in the NHNM 2015 survey. Between 25-35% of sampled plots were affected, although mortality from drought could have been misinterpreted as beetle predation (Muldavin et al. 2016b).

Figure 8. Adult cactus borer beetle (*Moneilema sp*.) on *Opuntia sp*. and larva killing *Sclerocactus mesae-verdae*. Photos: Whitney Cranshaw, Colorado State University, Bugwood.org; Daniela Roth (Roth 2018)

Rabbits are another major natural cause of mortality to Clover's cactus (Roth 2019) and can decimate populations during outbreaks that may be related to lowered predator population levels (e.g., predator control may increase rabbit populations) or to precipitation patterns and associated vegetation growth (Lightfoot et al. 2011; Ranglack, Durham, and du Toit 2015). Rabbit predation contributed to mortality in 10-15% of sampled Clover's cactus plots in the NHNM 2015 survey, and was observed throughout the range of the survey and in various transplant locations (Muldavin et al. 2016a).

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A *microlepidopteran* moth larva (in the family *Gelechiidae*) has been observed to cause mortality of adult Aztec gilia plants and eliminate entire populations by boring into the lower woody caudex of the plant (Porter and Floyd 1993; Floyd-Hanna 1994). Larvae were observed to eliminate an entire population in a single season and significantly contribute to mortality of adults monitored for four years (Floyd-Hanna 1994 as cited in Roth and Sivinski 2018). It is possible this moth is causing a high level of mortality that is currently going mostly undocumented (Roth and Sivinski 2018).

See Appendix E for additional details on limiting factors and threats.

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Hybridization

Hybridization is a concern for the conservation of rare plants because of the possibility of genetic swamping, where the rare form is replaced by hybrids, or demographic swamping, where population growth rates are reduced as reproductive efforts are wasted on the production of maladaptive hybrids. Alternatively, hybridization may rescue the viability of small inbred populations (Todesco et al. 2016).

Sclerocactus parviflorus is the most widespread species in the genus and it appears to introgress with multiple species in different parts of its range (J. Mark Porter, personal communication 2019). Clover's cactus populations in the Hogback region just west of the Nacimiento Formation show evidence of mixed genetic lineage with *S. parviflorus* (see Appendix C), and genetics of the populations in the San Ysidro region are intermediate between the two species (Porter and Clifford 2018). These patterns of mixed genetic lineage can represent historic isolated hybridization events followed by many generations of back-crossing, or evidence of shared evolutionary history requiring further study to delineate geographic boundaries between species. While these areas do not appear to be active hybrid zones with high levels of genetic exchange that can result in genetic or demographic swamping, further research is needed to delineate the geographic boundaries between *S. cloverae* and *S. parviflorus*.

No concerns about hybridization in Aztec gilia were found in the literature.

Anthropogenic

Energy development

The entire ranges of both Clover's cactus and Aztec gilia are restricted to an area of intensive oil and natural gas exploration and development, and this is the most prevalent and destructive land use in the species' habitats (Muldavin et al. 2016a). Energy development causes an immediate and direct impact to Clover's cactus and Aztec gilia and their habitat, hence this Strategy is focused on minimizing impacts from energy development activities. The Nacimiento Formation is one of the primary natural gas fields in the San Juan Basin region. A total of 37,307 wells have been drilled within the Mancos-Gallup RMPA Planning Area of the Farmington Field Office, which encompasses the Nacimiento formation (Figure 9). The Reasonable Foreseeable Development Scenario for Oil and Gas Activities projects 3,200 new oil and gas wells over the 20 year period 2018-2037 (Crocker and Glover 2018). This will potentially increase the acreage of surface disturbance from 56,500 acres to 75,000 acres within the 4.2-million-acre planning area.

The area of highest potential for development identified in this Scenario occurs in the vicinity of Nageezi and Lybrook (Figure 9, right) and the eastern half of this area coincides with the Lybrook population center of Clover's cactus (Figure 4), which contains the highest estimated plant numbers in the range. The Bloomfield/Aztec region habitats for Clover's cactus and Aztec gilia are already densely developed by more traditional vertical wells (Engler 2014 cited in Muldavin et al. 2016). This area would continue to be impacted by approximately 2,000 additional wells that are anticipated to make natural gas available from the Mancos shale, mostly from the central part of the formation near the Colorado border.

The topography that is preferred for the construction of roads and pipelines correlates to the land form of the best and most densely occupied cactus habitats. Therefore, although surface disturbance is predicted to impact a small percentage of land area, the proportion of occupied Clover's cactus habitat impacted will be larger (Muldavin et al. 2016b). When permitting oil and gas activities, the BLM must also consider other resources or protected features such as archeological sites, which are subject to stronger laws and policies. In order to mitigate impacts to these other resources, sometimes there is no way to avoid Clover's cactus. Plants that are not directly in the path of ground disturbance may still experience indirect impacts when in close proximity to roads and pipelines, including the impacts of habitat fragmentation, dust (Duniway et al. 2019), chemicals, air pollution, invasive species, and impacts on pollinators (USFWS 2014).

Commented [d28]: That's true for Aztec gilia as well

On the other hand, Aztec gilia tends to prefer slopes and hillocks, making it easier to avoid since well pads, pipelines and roads tend not to be proposed in these areas. There is some evidence that Aztec gilia can tolerate and recover from some habitat disturbance but significant earth movement tends to eliminate the species (NatureServe 2019a; Roth and Sivinski 2018).

Several large solar farms are currently proposed for the FFO (S. Scott, personal communication 2019) and installation of utility-scale solar energy infrastructure requires extensive landscape modification including vegetation removal, land grading, soil compaction and construction of access roads (Hernandez et al. 2014). Direct and indirect impacts of solar farms are likely to be similar to those for oil and gas development.

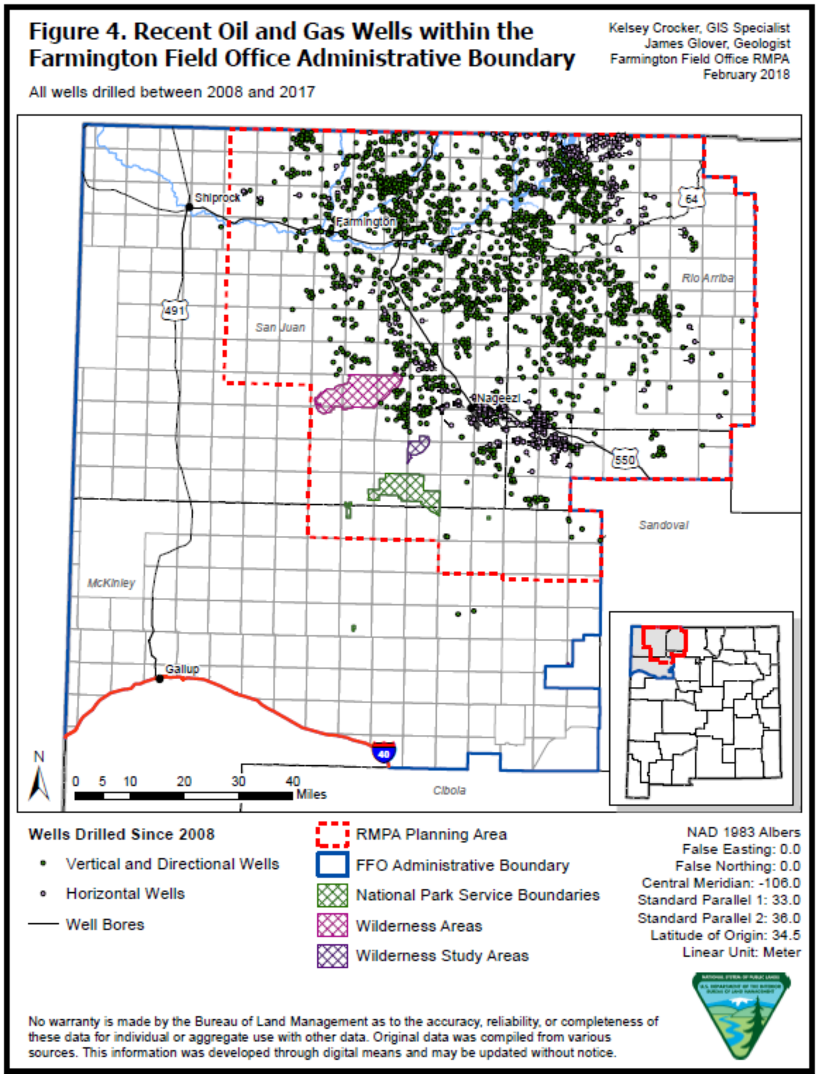


Figure 9. All wells drilled between 2008 and 2017 within the Farmington Field Office Administrative Boundary (Crocker and Glover 2018). The Lybrook S. cloverae population center is E-SE of Nageezi and overlays the eastern portion of the area of high potential for development

Commented [d29]: Would be a better map if distribution of Aztec gilia and Clover's cactus was added

Habitat fragmentation

Habitat fragmentation by roads and pipelines could negatively impact the genetic diversity and viability of both cactus and gilia populations by restricting pollinator movements and seed dispersal, introducing invasive species to enter sensitive habitats, or by creating more dust (see Dust section below). The primary sources of habitat fragmentation are the increased number of access roads, pipeline and other utility rights of way, anthropogenic topography and long-term surface disturbance from well pads and associated facilities.

Plants in the genus *Sclerocactus* are mostly self-incompatible and obligately outcrossing, relying on pollinators for successful reproduction. Clover's cactus depends on small native bees for pollen transfer. The barrier effect of roads on movement of bees appears to be especially pronounced for small species with poor dispersal ability (Andersson et al. 2017) such as the bees Clover's cactus rely on for gene flow. Thus, even relatively narrow dirt roads could represent a barrier to an unknown degree (see Appendix E). Similarly, Aztec gilia is self-incompatible and obligately outcrossing (Porter 1993), yet currently has a patchy distribution with distances between patches often exceeding 100 m and some patches containing only a few isolated individuals. Gene flow between patches may be entirely accomplished by pollinators, which appear to be mainly hawkmoths and bee flies.

Although seed dispersal is typically localized around maternal Clover's cactus plants, occasional longer distance dispersal by ants (Bregman 1988) or cyclonic wind events is likely (Muldavin et al. 2016a). If ants are important to long distance dispersal a 10-m wide road could inhibit recolonization of a habitat fragment that has lost its cacti (Muldavin et al. 2016a). Seed dispersal of Aztec gilia appears to be limited, with occasional long distance dispersal events possible (Roth and Sivinski 2018).

Further study is needed to determine the potential impact of habitat fragmentation on the population genetics and viability of both species, as well as any impacts of habitat fragmentation on rabbit predators that may potentially increase rabbit abundance.

Dust

Dust deposition from oil and gas development activities and OHV traffic can negatively affect many physiological processes in plants, including photosynthesis and drought tolerance (Sharifi, Gibson, and Rundel 1997). These effects may be more acute in cacti because stomatal clogging would interfere with the CAM photosynthetic pathway they rely on for water use efficiency. Dust can also reduce pollen loads and potentially interfere with pollination success (Waser et al. 2017). Fruit production and stomatal conductance both were found to decline with increasing dust deposition in the shrubby-reed mustard (*Schoenocrambe suffrutescens*) in the Uinta Basin (Lewis 2013). The chemical effects of road dust can also cause declines of cryptogamic soil up to 656 feet away, reducing their ability to aid germination and establishment and impacting soil stability and moisture retention (USFWS 2014).

Dust from ground disturbance and roads has been documented to lower photosynthetic rates, growth and reproduction of plants in multiple studies (Myers-Smith et al. 2006; Walker and Everett 1987; Veranth, Pardyjak, and Seshadri 2003; Etyemezian et al. 2004; Padgett et al. 2007; 2008; Forest Service 1983; McCrea 1984; Everett 1980; Lewis 2013; Elliott et al. 2009), with impacts on plants up to 1000 m (0.6 miles) away (Figure 10). The distance dust travels increases when disturbed soils have lighter particles such as small-particled clay (< 2 um, USDA 1987) and when surrounding vegetation is sparse and short-statured (multiple sources in USFWS 2014). Therefore, dust is likely to spread over relatively large distances in the Nacimiento Formation with its fine-textured soils and sparse vegetation.

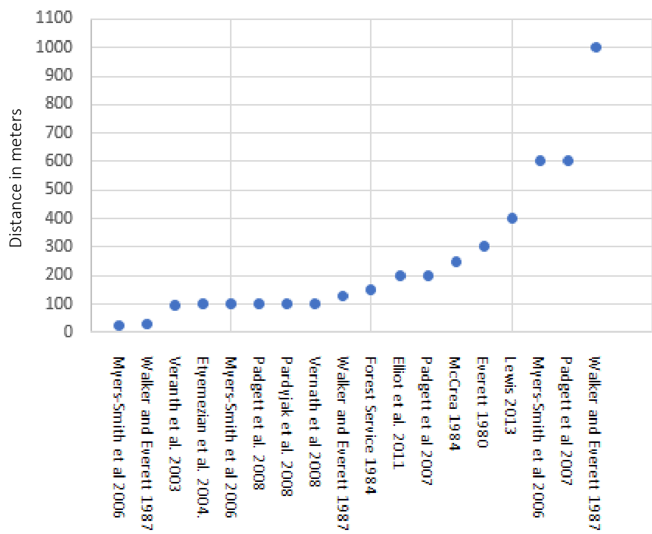


Figure 10. Distance of ecological effects of dust from ground disturbance and roads.

Recreation: Off-highway vehicles

Most lands in the BLM Farmington Resource area are open to year-round off-highway vehicle (OHV) access (Porter and Prince 2011), and significant amounts of soil disturbance from bicycle and motorized OHV traffic north of the San Juan River around Bloomfield, Aztec, and La Plata was evident during NHNM 2015 surveys, especially along ridges (Muldavin et al. 2016a).

OHVs may directly impact both species by physically crushing or uprooting plants, or by damaging the growing tip which can increase vulnerability to desiccation, herbivory or pathogens (Porter and Prince 2011; Roth and Sivinski 2018). OHV use may indirectly impact both species by destroying nearby individuals which may serve as nurse plants, destroying fragile soil crusts necessary for germination and establishment, damaging other vegetation leading to soil erosion, causing soil compaction, altering drainage patterns, forming and distributing dust and spreading weeds (Ouren et al. 2007). Additionally, destruction of fragile cyanobacterial-lichen soil crusts by OHVs can seriously alter nitrogen budgets in cold-desert ecosystems (Belnap 1996) and may open up germination sites for competitive non-native plants (DeFalco et al. 2001).

Livestock grazing

Land use in the area has historically been for livestock grazing, and all Aztec gilia sites on BLM-managed lands are within active grazing allotments (Roth and Sivinski 2018). Livestock use was evident in both intensive transect sampling and regional reconnaissance samples of the NHNM 2015 cactus survey. Most quadrats in the Lybrook Focal Zone transects (80%) showed signs of recent use by large grazing animals, with horse use detected at 62% of plots and cattle use at 30% of plots. Only 56% of the Regional Reconnaissance plots showed evidence of grazing, mostly to the south on Navajo Nation lands and BLM, but this incidence of grazing is similar to levels determined to be a significant impact for *S. wrightiae* in southern UT (Muldavin et al. 2016a). The majority of livestock impacts observed during the 2017 Aztec gilia status survey were south of the San Juan River, where grazing occurs year-round in some areas. It appears that Aztec gilia is not palatable to livestock but individuals can be trampled which can kill the plant or reduce its reproductive potential.

Impacts of livestock use can be similar to those for OHV use listed above, including direct trampling and effects on ecosystem structure and function (Fleischner 1994; Jones 2000). Indirect impacts of grazing can include dust deposition, increased erosion, soil compaction and the introduction of invasive species (Roth and Sivinski 2018)

Invasive Weeds

Non-native invasive plants can reduce available habitat through competition as well as alteration of ecological processes such as wildfire frequency and depletion of seasonal soil moisture (Brooks and Pike 2001; Parkinson et al. 2013 cited in Muldavin et al. 2016a). However, weeds were reportedly very infrequent in the 2015 NHNM cactus survey, occurring in only 19% of cactus plots, and contributing very little (no more than 25%) to vegetative cover in habitats sampled. Weeds commonly recorded in the survey included Russian thistle (*Salsola tragus*), cheatgrass (*Bromus tectorum*), halogeton (*Halogeton glomeratus*) and curveseed butterwort (*Ceratocephalus testiculatus*).

More recent field observations suggest an increase in halogeton, which is a concern as this invasive chokes out *S. mesae-verdae* plots and prevents recruitment (J. Kendall, personal communication 2019), possibly by depositing salt into the soils (D. Roth, personal communication 2020). Germinating halogeton seedlings may compete with the germination and establishment of cactus seedlings.

The Aztec gilia status survey also reports cheatgrass, Russian thistle (*Salsola kali*) and halogeton, especially in the vicinity of roads and well pads which had been disturbed.

Collecting – Commercial, scientific, and casual

Collection by plant enthusiasts does has not been documented for Aztec gilia, but cacti in the genus *Sclerocactus* are sought-after in the international horticultural market, and illegal harvest of plants and easily-transported seeds can adversely impact reproductive potential and possibly long term persistence of populations (CITES Secretariat 2016). An unknown amount of illegal Clover's cactus collections for the cactus hobbyist market is likely ongoing as suggested by websites with the species for sale (Porter and Prince 2011). The frequency and impact of collection has not been systematically assessed, and this would be challenging given the illegal nature of the activity, but collection is expected to remain a low-level threat for the foreseeable future.

Recent specimen collections for scientific purposes are infrequent, amounting to less than 25 Clover's cactus individuals since 2013 (Muldavin et al. 2016a; Porter and Clifford 2018), and essentially no Aztec gilia plants during this period.

Proposed Management Actions

Goals & Objectives

The ultimate goal of all management activities presented in this Conservation Strategy is to prevent a federal listing by maintaining sizable, stable populations occurring in suitable habitat that is protected for the long term, with acceptable levels of connectivity for genetic exchange through pollinator movement and seed dispersal. The Strategy focuses on minimizing impacts from oil & gas development by providing proactive management guidance to BLM land managers and Industry. The definitive measure of success of the Strategy would be removal of Clover's cactus and Aztec gilia from the BLM sensitive species list.

The best course of action to minimize the likelihood of listing is adaptive management that emphasizes avoidance through voluntary proactive conservation, and only then implementation of other mitigation strategies like minimization. The sections below outline a three-pronged approach with the goals of 1) protecting high likelihood habitat, 2) maintaining managed populations, and 3) addressing research needs.

The second goal of maintaining managed populations is in alignment with steps a – d of the CEQ Mitigation Hierarchy (Council on Environmental Quality 2000), while step e fits with goal one of protecting high likelihood habitat. The CEQ Hierarchy describes mitigation measures as:

a. Avoiding the impact altogether by not taking a certain action or parts of an action
b. Minimizing impacts by limiting the degree or magnitude of the action and its implementation
c. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment
d. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action
e. Compensating for the impact by replacing or providing substitute resources or environments

Impacts to Industry

The majority of land throughout the ranges of both Aztec gilia and Clover's cactus is already leased for development. This means that conservation of the species will be achieved primarily through voluntary actions of land users, and coordination between users with diverse interests will be required for activities to be impactful in protecting the species. Tools described in the sections below will improve the ability of both the BLM and project proponents to meet the standards proposed here by increasing the cost-efficiency of implementing surveys and mitigation actions.

Commented [d30]: Because leased lands offer no other means of protection?

Commented [d31]: May be

Implementation of this conservation strategy may increase permit approval timeframes and workload in the short-term at the field office and state office level as project proponents and BLM staff learn to implement the new survey and mitigation standards. However, as more populations are identified for conservation, low suitability areas may have streamlined survey protocols, for example. Implementation of block surveys and development of information sharing systems should also lower costs in the long run, as duplication of survey efforts is eliminated and avoidance of known plant locations occurs earlier in the planning process.

Goal 1: Protect High Likelihood Habitat

Commented [d32]: Seems like this is aiming to protect medium and high likelihood habitats

Strategic research, surveys, and monitoring are needed to understand population viability requirements throughout the species' range (i.e., population size, genetic diversity, gene flow, demography) and confidently recommend the ideal number of populations to conserve, their distribution, size, and connectivity. Until such data is available, there are several tools that can be used to identify high likelihood habitat and implement protection measures. Long term demographic monitoring and new survey data inform adaptive management, help to refine high likelihood habitat, and ultimately improve protection of these species.

Tools to Identify Suitable Habitat

a) Habitat Suitability Models

Habitat suitability models can inform conservation and management decisions about a species, including permitting of energy development (Reese et al. 2019). Habitat suitability models use known locations of a species and information on environmental conditions to predict habitat suitability for the species across an area of interest.

The USGS and BLM have cooperated to produce habitat suitability models (Figure 11) for Aztec gilia and Clover's cactus in New Mexico and southern Colorado. Occurrence data from multiple sources (e.g., the BLM, the State of New Mexico, and Natural Heritage New Mexico) were used to develop the models. The model algorithms relate the occurrence locations to predictor layers describing the environment (e.g., topography, soil, geology), and model results are ground-truthed through field surveys and continually refined. Model results will be available in a GIS layer for each species that displays areas with high, medium, and low habitat suitability to predict the presence of the target species. See Appendix F for more information on the development, uses, and limitations of habitat models.

The maps of habitat suitability for each species are classified into three levels based on suitability scores and the number of model algorithms predicting suitable habitat at that location on the landscape. Levels of suitability are as follows:

1. **High suitability areas:** predicted core locations where new ground disturbance should be avoided, protecting existing suitable habitat for each species to the greatest extent possible. These are priority habitat areas that should be surveyed for potential

conservation sites. Industry should attempt to plan around these areas as early as possible in the planning process.

2. **Medium suitability areas:** predicted areas that developers should avoid whenever feasible in light of other project restrictions (e.g., avoidance of archeological sensitive areas, raptor nests, or other resource concerns). These areas may be critical for long term persistence and connectivity of the species, especially as environmental conditions continue to change in the coming years.
3. **Low suitability areas:** occupied habitat might occur here and therefore individuals should be avoided when found. Plant surveys will still be required here to identify new populations and help broaden our understanding of the environmental conditions that may be suitable for each species.

Figure 11. SCCL (left) and ALFO (right) habitat suitability maps

b) Proactive Surveys

Completion of biological surveys before staking could increase cost-efficiency, and ideally an entire lease area would be surveyed or a habitat assessment completed before proposed well locations are staked in the field. Completion of Environmental Assessments (EAs) on entire leases allows for identification of areas to conserve with maximum habitat suitability and connectivity up front.

Project proponents can also utilize maps of suitable habitat to anticipate and plan for the need to conduct on-the-ground clearance surveys. This would allow for more efficient planning of well placement and help to avoid potential delays that can occur when a need for on-the-ground plant surveys is identified later in project planning. Plant surveys should occur whenever habitat models predict habitat within any suitability bin is predicted on or near the proposed project area, to ensure that individuals and occupied habitat are preserved to the greatest extent possible and that managers continue to gather data that can inform future conservation and management efforts for both species (Figure 12).

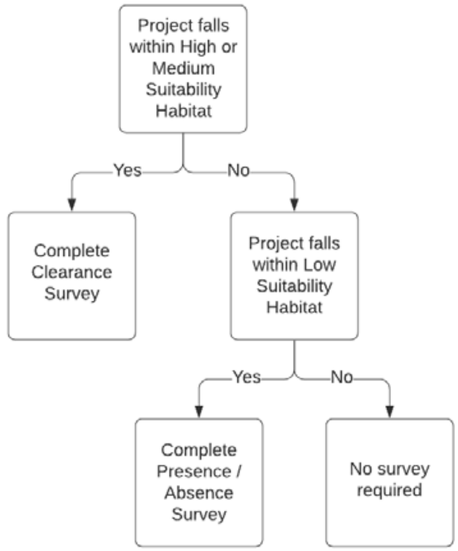


Figure 12. Decision tree for using a GIS layer of modeled high, medium, and low suitability habitat areas to guide proactive survey decisions.

Tools for Implementing Protection Measures

a) Online Sharing of Survey Data

During a meeting to discuss potential mitigation strategies in December 2019, project proponents from the Carlsbad and Farmington Field Offices suggested that cost efficiency could be improved with expansion of a pilot program from the Carlsbad Field Office, which provides an online interface for viewing previously completed survey buffers and known occurrences. Project proponents are exempted from surveying areas that were surveyed in the previous three years and can plan appropriately around known occurrences without investing in additional surveys. This approach would reduce the number of surveys that occur, which lowers operating costs and reduces impacts from intensive, tightly spaced survey transects on biological crusts and other sensitive features.

Data sharing agreements could be utilized to confidentially share known occupied sites to facilitate coordination among stakeholders and improve efficiency, or the known occupancy data could be hosted by the New Mexico Natural Heritage Program in an interface like their Environmental Review Tool (https://nmert.org/).

b) Habitat Conservation Areas

The development and use of voluntary Habitat Conservation Areas (HCAs) is a mechanism for protecting high likelihood habitat. HCAs are areas of special status species habitat where extensive development (i.e., roads or wellpads) or fragmentation has not occurred. Incorporation of HCAs as part of a Master Development Plan (MDP) allows lease or permit holders to voluntarily set aside important habitats to mitigate impacts to special status species in another area and minimize the possibility of listing these species under the Endangered Species Act. See Appendix G for additional details and recommendations from the FFO.

Commented [d33]: What is that? Is that something already in place for a leased area?

Project proponents can use habitat suitability models and results from surveys and monitoring to nominate Habitat Conservation Areas for Clover's cactus and Aztec gilia. Priority should be given to areas of high suitability habitat that are continuous with other HCAs and have known species occurrences. An HCA designation was created in 2016 for Clover's cactus, though implementation has been inconsistent and updates are needed based on new information and because previously undeveloped areas may now be developed.

Commented [d34]: Seems like this would also need to include a map of undeveloped areas with potential for HCA nominations.

Commented [d35]: Non-existent? After 4 years, an analysis of why these are not being considered might be prudent to ensure that HCA designations will be pursued in the future.

It is still recommended to minimize impacts to the species outside the HCAs; avoidance is always necessary for the continued existence of the species. Steps for avoidance include:

1. Plan disturbance outside high & medium modeled suitable habitat areas.
2. Survey disturbance area with 100 m buffer with all suitability types.
3. Avoid as many individuals as possible, especially family clusters.

Commented [d36]: This seems out of place here. Perhaps move to the end of this section?

Areas with no existing disturbance

Where oil and gas activities have not yet commenced:

Commented [d37]: Where would that be? Is there some kind of minimum size? Minimum occupancy?

1. An HCA will be a single parcel that does not include any historic development (i.e., roads or well pads).
2. Surveys are required if habitat suitability models indicate high, medium or low suitability for either species inside the lease area. Surveys will follow the Survey Standards in Appendix A and must be completed within two years of the start of construction.
3. An HCA(s) will be established to protect all high suitability habitat and any surveyed individuals or populations occurring outside of high suitability habitat. Surface-disturbing activities, including the construction of roads, may not occur within the HCA(s).
   - Where high suitability habitat encompasses more than 50% of the lease area, an HCA(s) will be established to protect a minimum of 80% of the high suitability habitat.
   - Areas with known occurrences, particularly family clusters of Clover's cactus, should be prioritized for HCA protection.

Commented [d38]: Shouldn't they be completed during the planning phase?

Commented [d39]: And all surveyed individuals? Allows for a lot of loop holes.

4. An HCA(s) will be established to protect, at a minimum, 80% of all medium or low suitability habitat.
    - Areas with known occurrences, particularly family clusters, should be prioritized for HCA protection.
5. The project developer should make every attempt to create a single HCA within the lease and connect the parcel to existing HCAs. Large, continuous protected areas minimize habitat fragmentation and facilitate gene flow.
    - Where multiple HCAs are required, they should be separated by no more than **[N meters]** to support connectivity and maintain gene flow. This Strategy considers populations to be genetically connected if they are within the maximum pollinator flight distance of another population.[3]

Commented [MG40]: Can BLM provide adjacent leaseholder information to developers?

Table X. Minimum habitat protection requirements for high, medium, and low suitability habitat types.

HABITAT SUITABILITY	% OF LEASE	AREA PROTECTED
HIGH	< 50	100 % of habitat
HIGH	> 50	80% of habitat
MEDIUM	n/a	80% of habitat
LOW	n/a	80% of habitat

Areas with existing disturbance

The guidelines above may be adapted for areas with existing disturbance, with the following amendment:

- All suitable habitat (high, medium, or low) that occurs within the lease area will be protected with an HCA.

c) Survey Standards

The US Fish and Wildlife Service has developed standards for Section 7 consultations under the Endangered Species Act for listed plant species in the State of Colorado, including species with similar range sizes and ecologies to Aztec gilia and Clover's cactus (U.S. Fish and Wildlife Service 2013). These standards specify areas where biological surveys are required, recommended survey buffer areas and transect spacing, analysis of impacts to target species, and considerations in designing conservation measures. In the development of the Farmington Field Office's *Survey Standards for Clover's Cactus and Aztec Gilia,* both *USFWS* Section 7 and the Carlsbad Field office survey standards were referenced as templates. The Carlsbad Field Office standards were developed in

[3] Estimated maximum flight distances of the genera of small native bees observed visiting Clover's cactus, *Lasioglossum* and *Agapostemon*, are between 50-100 m, and between 400-1000 m respectively (Tepedino 2010 in USFWS 2014), based on a documented relationship between flight distance and body size (Greenleaf et al. 2007).

consultation with BLM field offices in Colorado, Utah and Wyoming and were piloted in 2019.

The new FFO standards, which are summarized below and described in detail in Appendix A, are more demanding than those required under current policy. The recommended updates to the existing Survey standard include the need for larger surveys buffers, as a larger survey area will facilitate the avoidance of plants and other resource conflicts.

Commented [d41]: Where? Are those the ones in the RMPA? Or those that this strategy is proposing?

Commented [d42]: How does this coincide with the most recent draft RMPA? Are the existing Standards the new FFO standards? Am not following.

Other proposed updates to the existing Survey Standards include:

- Surveys are triggered if the proposed project occurs in modeled suitable habitat (high, medium or low) for either species (Figures 11).
- Survey extent and intensity vary depending on whether the proposed project falls in high, medium, or low suitability habitat for either species (Figure 11).
- Surveys must occur during bloom. This is especially important because mitigation is triggered if plants, not habitat, are located, and both species can be difficult to detect when it is not blooming. Blooming season surveys are standard across the botanical field, and early planning with habitat suitability models can accommodate blooming season surveys.

Commented [d43]: And the project cannot be moved into unsuitable habitat

Monitor Populations to Inform Management

Rigorous monitoring of plant populations with standardized protocols is essential to identify population declines, patterns of reproduction, and threats such as predation. Characterizing population trends and addressing causes of decline will promote successful conservation and mitigation measures.

The BLM New Mexico State Office initiated long term demographic monitoring plots for both Aztec gilia and Clover's cactus in 2017, with ten permanent Aztec gilia plots and 20 Clover's cactus plots set up throughout the major population centers of each species. Three years of inventory, vigor, reproductive status, and herbivory data have been collected. Expansion of these efforts to include a larger and more representative sample of occupied sites, including historically impacted, recently impacted, and pristine sites would improve our understanding of trends and the impacts of threats. Both species appear to experience episodic population crashes with little evidence of recovery. Long term demographic monitoring with repeated observations of marked individuals will shed light on this phenomenon and its causes.

Commented [d44]: The BLM is monitoring an additional 20 plots for Aztec gilia, established in the early 1990s.

Many extant populations are much too small to persist long term, so population augmentation will likely be required for long term species persistence. Augmentation can facilitate the recovery of a species by increasing the size of the population. As research provides the data needed to more confidently estimate the minimum number of populations, population sizes, and degree of connectivity required for persistence, monitoring plots and any augmented populations should continue to be monitored long term on an annual basis.

Commented [d45]: What research? Are you getting this info from 20 monitoring plots?

Tools that allow industry to more efficiently plan for impact avoidance, including habitat suitability models, an online interface for sharing survey boundaries and findings, and standards for larger survey areas and surveys during blooming season, will enable industry to identify alternative sites for well pad placement.

Goal 2: Maintain “Managed Populations”

Managed populations are those populations for which some mitigation activity had been implemented, be it impact avoidance or minimization, restoration of affected habitat, or reduction of the impact over time.

Commented [d46]: Does it include the thousands of transplanted cacti?

Plan for Impact Avoidance

Habitat suitability models could be helpful at the lease sale level because appropriate stipulations could be placed before leases are purchased so buyers are aware of potential conservation requirements imposed by the BLM in advance. Maps from the models can be used to identify when proposed projects are likely to overlap with areas of suitable habitat for these rare plant species. This will give all parties the ability to modify project locations and footprints early in the planning process to minimize overlap with likely suitable habitat for these rare plants whenever possible.

These predictions can allow project proponents to pre-plan to avoid the highest probability areas before investing in project design and biological surveys. Management decisions can be stream-lined on a project-level basis by delineating areas where project clearance surveys are required as well as the relative importance of impact avoidance for a given disturbance.

The importance of impact avoidance is highlighted in a recent report by the BLM New Mexico State Office summarizing all biological survey reports targeting *S. cloverae (ssp. brackii)* that were provided to the Farmington Field Office Wildlife Management Biologist (Beitner 2019). Clover’s cactus was found at 87 of the 234 proposed project sites evaluated from 2007 - 2018. Of the 10,777 total individuals identified, the majority are no longer alive; only 674 (6%) were avoided during project construction, 2,955 (27%) were transplanted, and 6,375 cacti (59%) were lost to construction. The status of 773 cacti (7%) was unknown due to lack of transplant reports or NEPA records (Figure 13). This Strategy and appendices build existing guidance to more effectively meet the goal of the BLM Sensitive Species Policy to prevent listing the cactus under the ESA.

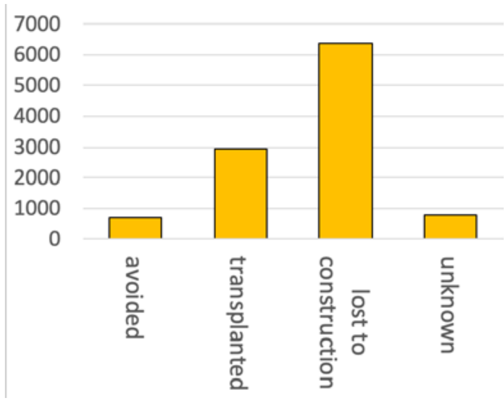


Figure 13. The fate of Clover's cactus individuals discovered during project clearance surveys in the Farmington Resource Area between 2007 and 2018.

Indirect impacts do not appear to be adequately prevented under the 2017 IM, because survey and avoidance buffers are only 30 m. Impacts of dust from ground disturbance and roads have been documented at much greater distances, with the majority of studies showing impacts in the 100-400 m range (Figure 10).

Adhere to Mitigation Standards

Until the requirements for persistence of Aztec gilia and Clover's cactus are better understood, mitigation for land use impacts that meet the highest available standards will provide the best chance to avoid listing under the Endangered Species Act. As with the Survey standards described above (see Survey Standards), a combination of standards from the USFWS CO guidance and the Carlsbad Field Office were used to develop best management practices and mitigation standards for the Farmington Field Office. Recommended updates to the policy are in Appendix B: Mitigation Measures for Clover's Cactus and Aztec Gilia during Energy Development.

Updates to the existing BMPs and Mitigation Standards include:

- If plants are detected during surveys, avoidance distances vary depending on the species found or the type of proposed disturbance. See Appendix B, Table B-1.
- If Aztec gilia is detected during surveys, it should always be avoided.
- If Clover's cactus is detected during surveys, it should be avoided. If avoidance of Clover's cactus is not possible, up to 10% of the population can be impacted, where transplanting the impacted individuals and augmentation at a ratio of 10:1 for every plant impacted is required.
    - Transplanting Clover's cactus is a salvage operation and requires a commitment to monitor populations for ten years following transplanting. Salvaged cacti need to be planted into existing populations occurring within 1 km of the site of origin.
    - Movement of Clover's cactus transplants must be limited to within 1 km of the site of origin whenever possible. Under no circumstances should

transplants be moved between the northern and southern genetic groups (Appendix B, Figure B-1).

- Suggestions for compensatory mitigation, which is voluntary and must be suggested by the project proponent, are given.

Employ Conservation Seed Banking

An immediate opportunity to contribute to long-term survival of the species is through conservation seed-banking. Seed banks can assist in augmentation and reintroduction efforts if these are determined to be feasible and successful and can serve as insurance against the possibility of extinction. Seeds should be collected from Aztec gilia and Clover's cactus to capture genetic diversity across the range of the species. Within a population, seed collections should be distributed evenly among as many individuals as possible to maximize the genetic representation of the source population and to ensure genetic diversity is available for future population augmentation. In addition, priority should be given to seed collection from sites that are most vulnerable to extirpation. Collect seed following guidelines in the Center for Plant Conservation's (CPC) Best Plant Conservation Practices (Center for Plant Conservation 2019), and store the seed in duplicate at a CPC member institution and the USDA-ARS National Laboratory for Genetic Resources.

It is important to be aware of the potential for natural introgression of Clover's cactus with *S. parviflorus* on the edge of its range (Porter and Clifford 2018) when seed banking and doing reintroduction projects. For example, seeds from hybrid zones or areas where the two species overlap should not be harvested. Education is also important to ensure that managers, conservationists, cactus propagators all know about this potential.

Create Off-site Plug and Seed Production

There are not enough populations of sufficient size for long term persistence of either species, so the potential for population augmentation should be investigated. Population augmentation provides the opportunity to not just mitigate to keep the status quo, but also to move towards recovery of the species. As there is there is no conclusive research that Clover's cacti will reproduce successfully or that Aztec gilia seed will germinate reliably, plug and seed production should be pursued in conjunction with habitat protection. Disturbance must be limited around any sites where populations are augmented.

In addition to conservation seed-banking, seed collections can be initiated for a nursery production program for Clover's cactus. If the species can be successfully propagated and out-planted as plugs, this would allow for reintroduction and population augmentation in areas lacking larger populations. Seed collection and plug production would also be an improved method of salvage mitigation over transplanting. At best, transplanting mitigates for individual cacti that would otherwise be destroyed by project disturbance, while seed collection and plug production can mitigate for losses in the seed bank and lost reproductive potential that occurs while transplanted cacti recover from translocation.

If propagation appears to have potential for success, a set of criteria should be developed to identify augmentation or reintroduction sites. An out-planting protocol must be then be developed and implemented to guide augmentation or reintroduce populations and monitoring of results. The out-planting protocol should include a guidance that Clover's cactus not be out-planted into pure stands of *S. parviflorus* and vice versa.

Consider Conservation Banking

Another potential conservation opportunity is through proponent-nominated, voluntary participation in a conservation or mitigation bank. Impacts to plants within suitable habitat should always be avoided, but if impacts are unavoidable, proponents could voluntarily pay into a compensatory mitigation bank in exchange for impacts. Close management of a mitigation bank account and the use of funds would be necessary to ensure conservation impact of this approach.

Potential compensatory mitigation actions that could be funded this way include funding:

- research to determine the effectiveness of mitigation actions and to increase cost-efficiency of conservation (see Research section).
- seed collection and nursery propagation
- out-planting needed to augment populations occurring in suitable habitat
- range-wide inventories

Steps to creating a Conservation Bank:

- Identify mitigation banker (city or county entity or private entity, including nonprofit organizations)
- Build an Interagency Review Team (IRT) or Mitigation Bank Review Team (MBRT) to approve plans, help maintain and monitor the bank, and approve the number of mitigation credits the bank may earn and sell with a particular project. Review teams may include representatives from various federal, state and/or local government agencies.
- Identify the "service area" (geographic area within which permitted impacts can be compensated).
- Develop a bank instrument, or formal agreement between the bank owners and regulators establishing liability, performance standards, and management.

The benefits of Conservation/Mitigation banks include improved species/environmental protection and species recovery funding. Industry benefits include expedited approvals and regulatory ease. It is easier for developers to buy credits from an approved bank than to get regulatory approvals that might otherwise take months to procure. The system of mitigation banking effectively transfers the liability of ecological loss from the developer/permittee to the mitigation banker. Once the permittee buys the required credits as per regulations, it becomes the responsibility of the mitigation banker to develop, maintain, and monitor the site on a long-term basis.

Monitor effectiveness of transplanting and impact avoidance

Preliminary data on Clover's cactus suggest the need for further monitoring before we can be confident that transplanting is a viable approach for mitigating impacts. Effects of transplanting should be monitored for a minimum of ten years, as reduced survival of transplants was not observed in Clover's cactus congeners until eight years after transplanting (Z. Davidson, personal communication 2019). Transplants should be watered on a weekly basis to improve likelihood of survival. Monitoring of transplanted and control cacti of similar age and size should compare reproduction, as well as survival and recruitment.

Commented [d47]: How about protect transplant sites from future impacts?

Commented [KW48]: Zoe do you have a reference? I had the species in an earlier version but don't remember them now.

Commented [ZMD49R48]: This was Sclerocactus in Utah, it is in a FWS report…we should quote that, not me. I'll have to find it again.

Historical applications for transplanting permits from the State and completion of monitoring requirements for Clover's cactus have both been inconsistent, with data standards varying among transplant sites and sometimes between years within a site. As referenced above, 10,777 *S. cloverae* individuals were found through project clearance surveys at 87 of the 234 project sites proposed between 2007-2018 (Beitner 2019). Transplanting was employed as a mitigation measure at 27 of these projects, but monitoring for at least one year was conducted for only 14 (52%). A compliance check and an improved and standardized monitoring protocol are required to improve reporting.

Clover's cactus and Aztec gilia plants that are avoided on developed sites should also be monitored at least twice in a five-year period to determine whether avoidance buffers and other mitigation actions outlined in Appendix B are sufficient. Buffers are intended to prevent mortality due to direct (i.e., destruction of plants and habitat by equipment or vehicles) and indirect (i.e., plant loss due to dust) disturbance. Monitoring should document when these impacts are observed. Avoided plants just outside of the buffers should be compared to controls that are not within the area impacted by the project. This would improve our understanding of the impact of threats and the effectiveness of mitigation methods. Results should be reviewed every five years and management practices should be adapted if necessary.

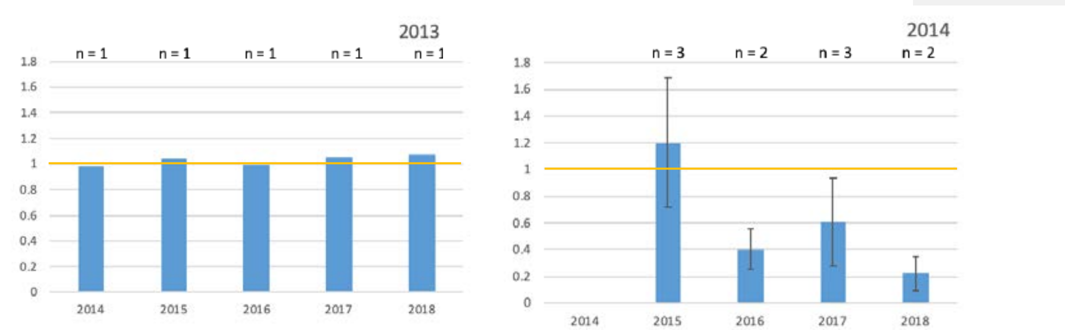
Previous Clover's cactus transplanting

Transplanting history

Between 2007 and 2018 a total of 2,955 Clover's cactus plants were transplanted, and 2,027 were monitored for at least their first year. In a summary of these data, Bei~~ie~~tner (2019) found that first year transplant survival ranged from 6% to 100%, with an average of 48%. By the fourth year after transplantation (with only a subset of plants monitored), survival ranged from 1% to 16%, averaging 9%. Therefore, transplants appear to decline in survival over time. By comparison, control plants that were not dug and moved but left undisturbed in their original location survived over the same period at a rate of 14%, suggesting that transplants have higher mortality than undisturbed plants.

Transplants vs controls

The data summary by Bei~~ie~~tner (2019) considered all plants in the transplant data set, but the data represent several transplant projects, some without controls (those prior to 2013) and some with. For this Strategy, we re-evaluated the data compiled by Bei~~ie~~tner to make direct comparisons of transplanted vs control plants. We found a subset of nine transplant sites with paired controls that were monitored for at least one year following transplanting, from 2013 forward. Three of these were monitored for four years. Data from a tenth site was removed from this summary because counts of total live + dead transplanted cacti in years 2 and 3 were 259 more than the original number of transplanted cacti. A total of 2,001 cacti were monitored from the nine paired sites, with 875 transplants and 1,126 controls. Relative survival of transplanted cacti vs. controls was calculated as the proportion of live transplanted cacti divided by the proportion of live control cacti at each site in each year. Values < 1 indicate that transplanted cacti had lower survival than controls. Only one site was monitored for 5 years, and sites in other cohorts were monitored inconsistently, yielding missing data in several years, so results should be interpreted with caution. With the exception of one site transplanted in 2013, transplanted plots had lower relative survival than controls after the first year of transplanting, with average transplant survival dropping as low as 22% of controls four years after planting (as measured with the 2014 transplant cohort, which had the most consistent monitoring) (Figure 14). Although it is clear that transplants generally survive at lower rates than undisturbed plants, the inconsistency in data collection over time across these transplanting projects makes precise estimates of the impact of transplanting difficult to measure.



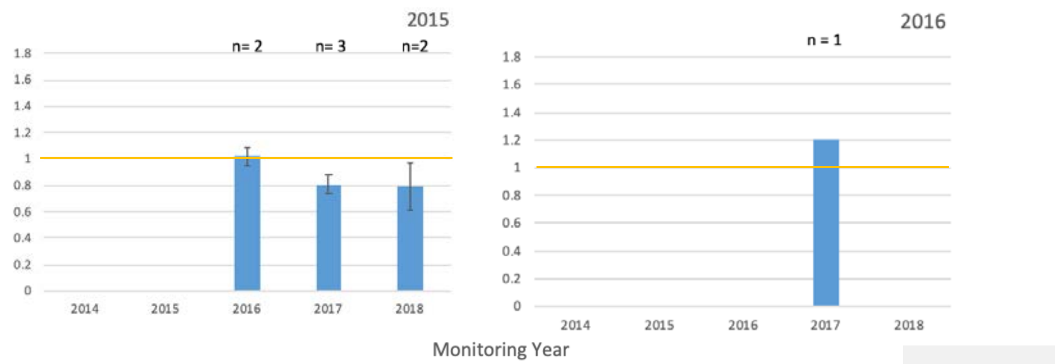


Figure 14. Average relative survival (+/- s.e.) of transplanted cacti compared to the paired controls at each site. Relative survival is calculated as the proportion of live transplanted cacti divided by proportion of live control cacti at each site in each year. Values < 1 indicate that transplanted cacti had lower survival than controls. Year transplanting occurred is in the top right corner of each graph. Number of sites that were monitored each year is listed above each bar, showing inconsistent monitoring of sites over time.

Planting ratio

The number of transplants needed to establish a population of a specific size can be estimated from the currently available data. Transplant survival to four years was estimated to average 9% by Bei~~ie~~tner (2019). Therefore, the number of transplants needs to exceed a target number of plants by a factor of at least 10:1. For example, if the goal is to establish 100 plants at a new location for mitigation purposes, and four years is identified as the minimum amount of time for plants to survive (which is reasonable given that plants take a few years to become reproductive and self-replacing), then at least 1,000 transplants would need to be established to achieve that goal.

Commented [d50]: So, would you need to plant those in an area with 1000 existing cacti for control purposes?

Goal 3: Address Research Needs

Commented [d51]: How about research on the impacts of climate change on these species? How about research on the impacts of the moth larvae causing significant declines in Aztec gilia? Seed viability? Soil chemistry analysis?

Genetic Diversity and Hybridization

Existing population genetic data for Clover's cactus suggests healthy levels of gene flow and genetic variation, but additional sampling is needed in the center of the range to delineate the boundaries between the northern and southern genetic groupings. Population genetics studies of populations on the edge of the range and work on the systematics of *S. parviflorus* as a whole will improve our understanding of the relationship between these two species and levels of introgression between *S. cloverae* and *S. parviflorus.* This research will be important to clarify range limits and understand whether hybridization is a risk.

Research on population genetics of Aztec gilia should be initiated, as currently no information exists on levels of genetic diversity, gene flow, or inbreeding for this species. The cause of the decline for Aztec gilia has not been established, and genetic research can help to fill knowledge gaps and support the development of management strategies.

Molecular Systematics

Genetic sampling of populations on the edge of the Clover's cactus range may be important because morphology appears to be uninformative in these areas (J. Mark Porter, personal communication 2019). While identifications of Clover's cactus are reliable in the center of the range on the northern half of the Nacimiento formation, populations on the edge may look morphologically indistinguishable from Clover's cactus but be very distinct genetically, as occurs in the San Ysidro area.

Research on the systematic of Aztec gilia is unlikely to enhance the efficacy of conservation measures.

Pollination Ecology and Pollinator Limitation

Research on the breeding system of Clover's cactus and on the pollination and seed dispersal ecology of both species would provide key information for determining the levels of connectivity needed for exchange of genetic material. Additional research is also needed to determine whether these species are sufficiently pollinated and produce viable seeds. Understanding population level rates of mortality and recruitment through seed production will be important to address threats and develop augmentation strategies.

There are no quantified studies documenting Clover's cactus pollinators, and the few observations of small halictid bees in the genera *Lasioglossum* and *Agapostemon* with predicted foraging ranges of 50-100 m and 400-1000 m respectively (Tepedino 2010 in USFWS 2014) suggest populations would need to be much closer together to remain connected if the species is self-incompatible like others in the genus. A forthcoming new study of southwest cacti pollinators may provide additional insight (see Appendix I). Research on the impacts of surface disturbance on pollinator population persistence and on their foraging patterns would also inform connectivity requirements and habitat restoration needs.

Preliminary data suggest Aztec gilia is primarily pollinated by hawkmoths and bee flies, suggesting populations could be connected even across long distances, but this information is based on just over 6 hours of observation, so additional pollinator studies would increase confidence in this decision. Research on the population ecology of Aztec gilia should be initiated to understand potential causes for decline that maybe related to pollinator limitation or impacts on pollination success.

Seed Dispersal and Seedbank Requirements

Research on seed dispersal for both species would also support decisions on connectivity, and data on seed bank longevity and germination requirements would inform our understanding of population connectivity and the potential for salvaged topsoil to serve as a means of population translocation or reintroduction.

Transplanting, Propagation and Out-planting Requirements

Augmentation of both species will likely be needed to ensure their persistence, and reintroduction of plants into previously occupied habitat or into new sites may be an appropriate form of mitigation or proactive conservation that goes beyond the benefits of salvaging transplants. A trained horticulturist should be employed in any transplanting or out-planting projects. Research into seed storage, germination, and horticultural requirements as well as out-planting techniques is needed. For example, studies that compare success of direct sowing verses plug planting, consider season of out-planting and age of the plant, and evaluate success in different microhabitats or in the presence of companion plants may reveal techniques that have optimal success in recovering the species.

Preliminary data on Clover's cactus suggest the need for formal transplantation and seeding experiments with consistent plant monitoring to document the effects of year, transplantation or seeding technique, soil conditions, and site context (disturbance history, etc.). Reproductive success should be evaluated in experimental transplantings and seedings because anecdotal information suggests that transplants may have reduced flowering for several years. For example, Mesa Verde (Sclerocactus mesae-verdae) cactus transplants in long term monitoring plots took 5 years to have similar reproductive effort as naturally occurring, undisturbed plants (D. Roth, personal communication 2020). In addition, development and use of cultivated vs. wild collected transplants should be evaluated as a method of establishing new populations.

Initial monitoring of transplanted populations of Clover's cactus suggests transplants may suffer higher mortality, and effects on reproductive success have not been assessed. Monitoring should continue for at least ten years, with 2-year intervals acceptable after the first five years, and should quantify reproductive output as well as survival. A standardized monitoring protocol should be used to ensure that transplant monitoring data is consistent. Cactus transplanting protocols vary widely, so systematic documentation of success rates of alternative methods will yield more reliable protocols. In the absence of population genetic data that informs appropriate seed transfer distances, seed of Clover's cactus should not be transferred between the northern and southern genetic groups identified in Porter and Clifford (2018).

Although the genus *Sclerocactus* is considered to be difficult to cultivate, with low germination rates and specific soil and environmental requirements (CITES Secretariat 2016), the experience of cactus horticulturists in the cactus trade suggest it should be possible to develop a production program as long as specific needs of the cactus are considered (S. Brack, personal communication 2019). Cacti should be grown at a facility with the technology to maintain optimal growing conditions; anecdotal evidence suggests that Clover's cactus does not tolerate warm nights or too much summer moisture.

Aztec gilia populations are in documented decline for unknown reasons. After determining and rectifying the cause(s) for the decline of the species, research should be conducted to better understand techniques for cultivation of Aztec gilia and augmentation of existing populations.

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Appendix A: Survey Standards for Clover's Cactus and Aztec Gilia during Energy Development

Appendix B: Mitigation Measures for Clover's Cactus and Aztec Gilia during Energy Development

Appendix C. Detailed Background on Clover's cactus

Additional details on Clover's cactus biology and conservation are included here as a reference for specialists.

Biological Information

Species Description and Taxonomy

The number and delineation of species in the genus *Sclerocactus* has been debated by botanists due to morphological similarities, overlapping distributions, and a poor understanding of genetic differences within species (Porter and Clifford 2018). This has led to a confusing array of species names and a shifting understanding of species' distribution, making conservation management extremely challenging. As suggested by the taxonomic controversies surrounding both delineation of the genus as a whole and of species within the genus, identification of *Sclerocactus* taxa in the field can be difficult for non-experts (Table C-1).

Table C-1. Differences between Clover's cactus (*Sclerocactus cloverae*) and lookalikes.

Trait	*Sclerocactus cloverae*	*Sclerocactus parviflorus*	*Sclerocactus whipplei*	Source
Flowers	2.2-3.2 cm long, 1.5-2 cm wide, turbinate, pericarpel with small papillae, smooth, purple	3.-5.7 cm long, 2.5-5.5 cm wide, funnelform, pericarpel with large papillae, granular surface	2.2-3.2 cm long, 1.5-2 cm wide, turbinate, pericarpel with small papillae, smooth, yellow	Heil et al. 2013
Central spines	Upper central spine flat and ribbon-like; 6-9 central spines	Upper central spine flat or angled. Often has 3 or more hooked central spines.	Upper central spine flat and ribbon-like, 4 central spines; flattened, somewhat daggerlike, adaxial central spine directed toward the stem apex	Heil et al. 2013; FNA account

S. cloverae was first circumscribed by combining two former varieties of *S. whipplei* (Heil and Porter 1994a). The species shares several features with *S. whipplei* (flattened upper central spine, small flowers with bracts that don't spread widely and flowers that lack granular papillae), and it has sometimes been listed as a synonym (Hunt, Taylor, and Charles 2006). It differs from *S. whipplei* based on stem length, the number of central spines, and flower color, which is yellow in *S. whipplei* (Porter and Prince 2011; Heil et al. 2013). Also, *S. whipplei* occurs only in NE Arizona and SE Utah, so it never co-occurs with *S. cloverae* (Heil and Porter 2004a).

S. cloverae floral developmental patterns and overall plant size are more similar to *S. parviflorus*, which also been listed as a synonym (CITES Secretariat 2015b; N. USDA 2019). In comparison to *S. parviflorus, S. cloverae* has smaller, narrower flowers without granular papillae, a more ribbon-like upper central spine, and blooms 2-3 weeks earlier (Ferguson 1998b in Muldavin et al. 2016b; Heil et al. 2013). *S. parviflorus* often has three or more hooked central spines, which is uncommon in *S. cloverae* (Porter and Prince 2011). *S. parviflorus* is very common just west and to the south of *S. cloverae's* range (Porter and Prince 2011). The two species meet only on the north side of the San Juan River at the eastern base of the Hogback monocline in San Juan County, NM, and here they can be confused.

While phylogenetic analyses based on chloroplast DNA and trnL–F DNA sequences suggest *S. cloverae, S. whipplei,* and *S. parviflorus* are closely related (Porter, Kinney, and Heil 2000; Porter and Prince 2011), recent genomic sequencing work on *S. cloverae* and close relatives has greatly clarified species delimitation (Porter and Clifford 2018). The study found strong support for the status of *S. cloverae* as a species which is genetically distinct from *S. whipplei* and from its closest relative, *S. parviflorus,* despite intermediate populations with evidence of mixed genetic lineage (introgression) on the edge of its range.

Two subspecies of Clover's cactus were previously recognized: *Sclerocactus cloverae ssp. brackii* and *S. cloverae ssp. cloverae*. The former subspecies were thought to differ in development timing and habitat preferences. The *brackii* morph reaches first flowering while still showing juvenile morphology and occurs primarily in badland habitats of the Nacimiento Formation, while the *cloverae* morph is slower to develop and is associated with pinyon-juniper woodlands (Porter and Clifford 2018). Despite these differences, the former subspecies were notoriously difficult to tell apart. In 2018, a genetic analysis showed cacti that were morphologically classified as either *S. cloverae ssp. cloverae* or *S. cloverae ssp. brackii* were not genetically distinct nor geographically separated from each other, and that separation of *S. cloverae ssp. brackii* from the rest of the species was not supported (Figures C-1 & C-2) (Porter and Clifford 2018).

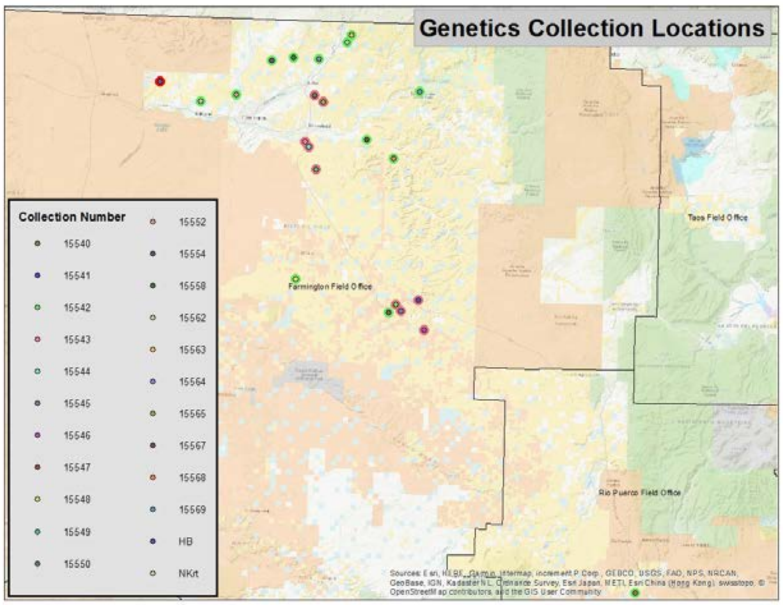

Figure C-1. Intermixed distribution of populations formerly classified as *Sclerocactus cloverae ssp. cloverae* and *Sclerocactus cloverae ssp. brackii.* Green outline is formerly known as *S. cloverae ssp. cloverae*, light red outline is formerly known as *S cloverae ssp. brackii* and the bright red in the northwest is *Sclerocactus parviflorus*. Note SE-most point (green) is actually *S. parviflorus* (Porter pers. comm).

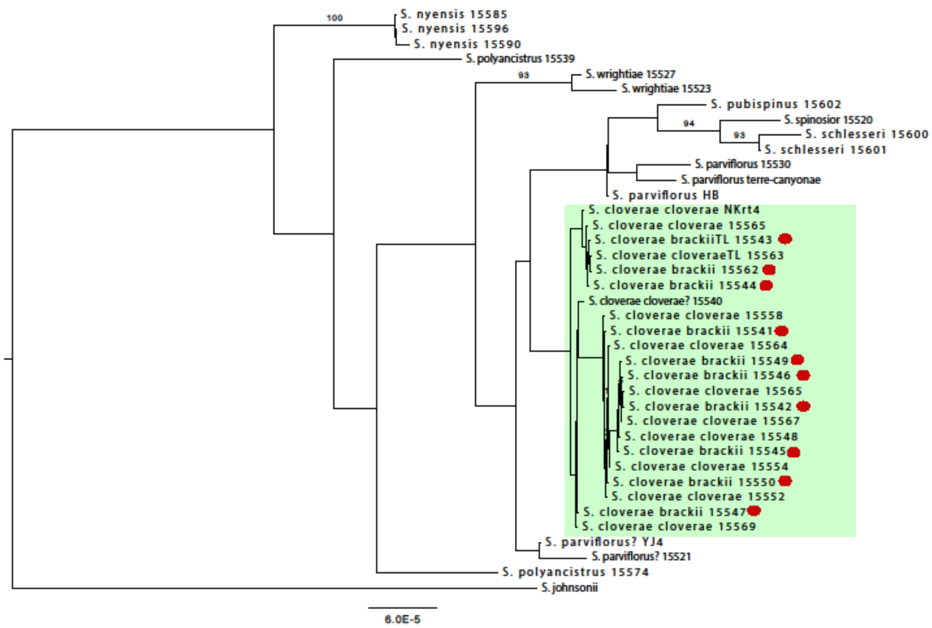

Figure C-2. Phylogenetic relationships among populations of *Sclerocactus cloverae* and eight other species of the genus, showing interrelatedness of populations with *ssp. brackii* morphology (red ovals) with those having “typical” morphology. The green box encloses those populations identified as the species *S. cloverae* (Porter and Clifford 2018).

Range and Distribution

Conflicting information exists in the literature regarding the distribution of *S. cloverae,* as a result of historical uncertainty around species delineation The original species description estimated the southern range limit was south of Albuquerque in northern Socorro County (Heil and Porter 1994b), and range estimates spanning from as far south as Sierra County NM to Archuleta and La Plata Counties CO have been cited in recent years (CITES Secretariat 2016). However, recent genetic information combined with increased field survey efforts related to energy development have clarified our understanding of the delineation and range of this species.

Morphology can be unreliable for species identifications on the edges of the range (Porter and Clifford 2018). Disjunct populations far south of the Nacimiento near San Ysidro are morphologically indistinguishable from *S. cloverae*, but genetically they are too different to be considered *S. cloverae*, instead being more similar to *S. parviflorus* (J. Mark Porter, personal communication 2019). Populations extending west of the

Nacimiento toward the Hogback show signs of mixed *S. cloverae* and *S. parviflorus* genetic lineage, but there are only three samples, so additional genetic surveys are needed to draw the boundary between species here.

The southern edge of the range within the Nacimiento is relatively well-defined, with negative NHNM surveys showing the species drops out near Counselor. This is likely due to the absence of Nacimiento shales south of Nageezi (E. Muldavin, personal communication 2019). Four occurrences 11.5 miles to the south in the Cuba region on the Continental Divide are outliers with unknown genetic profile. It appears the Continental Divide represents a southern barrier for the species (J. Mark Porter, personal communication 2019).

The extent of the range to the north, east, and west is not as well understood. The species is likely to occur in un-surveyed areas of the San Jose Formation to the east, particularly in the area surrounding Navajo Lake (K. Heil, personal communication 2019), as well as where the Nacimiento Formation extends into Colorado in La Plata and Archuleta counties. These areas in CO have not been surveyed before (Clifford, Heil, Porter personal communication 2019), possibly because they lie within Ute tribal lands, and the Colorado Natural Heritage Program does not track this species. The species has been documented from two locations on Navajo Nation, with a general range for former subspecies *brackii* stretching almost to the Four Corners region in San Juan County south of the San Juan River (Roth 2018; N. Talkington, personal communication 2019). However, identification of these plants was based on morphology, and given the introgression with S. parviflorus in the Hogback area just to the east, the genetic identity of these populations should be confirmed. Records for the Chaco River and upper Rio Grande drainages are all referable to S. parviflorus (NatureServe 2019b).

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Status and Trends

<u>EMNRD (NM State) status</u>: *Sclerocactus cloverae ssp. brackii* was listed as Endangered in New Mexico (EMNRD-Forestry Division 2017) but delisted in January 2019 (EMNRD 2019) when the subspecies were combined. Subspecies *cloverae* was a Species of Concern (EMNRD-Forestry Division 2017) before the taxonomy was updated, and currently the full species *cloverae* (including both former subspecies) is being proposed for Endangered status (D. Roth, personal communication 2019). State-endangered status only protects plants from unauthorized collection from their natural habitats. Other types of destruction and habitat disturbance are not regulated by the State.

<u>CITES status:</u> The Convention on International Trade in Endangered Species (CITES) is an international agreement of cooperation for the protection of endangered species of wild fauna and flora against over-exploitation through international trade. CITES transferred *Sclerocactus cloverae* from Appendix II to Appendix I in 2015 (CITES Secretariat 2015b). Trade in specimens of Appendix I species, which are "threatened with extinction", is permitted only in exceptional circumstances. Rationale for this greater level of protection was that "populations are restricted and are characterized by a high vulnerability to

intrinsic and extrinsic factors and an observed, inferred, or projected decrease in the number of subpopulations and the number of individuals”. The restricted distributions and small population sizes coupled with the persistent threats are the primary justification for transfer of the species to Appendix I.

NatureServe status: NatureServe ranks the species as globally vulnerable (G3) because, although it can be locally frequent, it is a regional endemic that has suffered from development projects and off road vehicle use (NatureServe 2019b). Species are ranked G3 if they are at moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.

Natural Heritage New Mexico status: NHNM revised the state conservation status rank for former ssp. *brackii* from S1 (critically imperiled) to S2 (imperiled) in 2016. This was primarily on the basis of the large number of plants estimated from the Lybrook population in their 2015 range-wide survey (Muldavin et al. 2016a). However, they note additional sampling is required to determine the actual extent and population size of each EO, and also that these occurrences were “at immediate risk because they were mostly located as part of clearance surveys for energy development” (p. 43). The species as a whole has not been reassessed since the 1990s (E. Muldavin, personal communication 2019) and remains at G3, which can still be vulnerable enough to be listed as Federally Endangered or Threatened (Muldavin et al. 2016b).

NM BLM status: The New Mexico BLM added *Sclerocactus cloverae* to the Sensitive Species list in 2019. Former subspecies *brackii* is being retained on the list until the updated nomenclature has been published (Bureau of Land Management 2019).

Federal Status: Clover’s cactus was recently petitioned to be federally listed by the Wild Earth Guardians (2020).

Navajo Nation status: The Navajo Nation Department of Fish and Wildlife recently updated its Endangered Species List, and *Sclerocactus cloverae* was uplisted from Group 4 (under consideration but lacking sufficient information to support listing) to Group 3 (prospects of survival or recruitment are likely to be in jeopardy in the foreseeable future) because of its limited geographic range and the threats of energy development, off-road vehicle traffic, livestock grazing, invasive species, rabbit and rodent predation, and cactus longhorn beetle infestation (D. Roth, personal communication 2020; N. Talkington, personal communication 2019). Any development that impacts Group 3 species requires mitigation. In general, management of Navajo Endangered Species can be challenging due to confusion about management responsibilities in regions with checkerboard surface management and different agencies managing surface and subsurface resources (N. Talkington, personal communication 2019).

Habitat

NHNM evaluated the relative importance of different habitat types with intensive sampling in a “focal zone” near Lybrook during their 2015 survey for former subspecies *brackii.* The focal zone for this habitat assessment was chosen because it is an area with both high cactus densities and intensive oil and gas development, so assessment of habitat suitability could inform effective management at the local site level to avoid or mitigate impacts on the subspecies. The researchers found the highest cactus densities in sparse grama-galleta grassland in yellow/tan hills, valleys, and eroding alluvial terraces along washes and channel edges (Muldavin et al. 2016b). Although habitat characteristics were typically used to distinguish between the former subspecies *cloverae* and *brackii*, the researchers did not see any habitat differences between them, and inclusion of subspecies *cloverae* habitat data would not likely change results (E. Muldavin, personal communication 2019; R. Sivinski, personal communication 2019).

Sparse grama-galleta grassland in yellow/tan hills, valleys, and eroding alluvial terraces along washes and channel edges that had the highest cactus densities contributed the lowest area of all habitat types to the focal zone, suggesting they are preferred habitats for the cactus. Habitat types that were important contributors of cactus numbers at the landscape scale because of the combination of cactus density and habitat availability were valley sites in open shrubland with some grass cover, red hills in barren/sparse grassland, and yellow/tan hills in scattered open woodlands. Cacti also occurred in low densities on gypsum outcrops and on gray-white hills in woodlands, open shrubland or barren/sparse grassland. Throughout all habitat types, cacti preferred erosional sites at the local scale.

The occupancy and density of cactus among habitat types was evaluated using a belt transect approach with opportunity-based quadrat sampling within transects. Each of the 131 survey transects were placed with a starting point at a known cactus location obtained from clearance surveys for roads or pipelines. This resulted in a high potential for cactus detection so that sufficient habitat data could be collected, as evaluation of suitable habitat was the primary goal. Bias for cactus detection was minimized by orienting the transects at right angles to the road/pipeline and extending transects outward into the adjacent landscape for as long as possible (90 m to 2,750 m). All living and dead cacti within 10 m x 20 m quadrats were counted and abundance of dominant vegetation assessed whenever a cactus was encountered.

Habitats were classified according to a combination of geology, landform, vegetation composition and cover (Table C-2). Using aerial imagery and quadrat data as ground-truthing, the authors mapped the entire length of transects by habitat and assigned each occupied quadrat to a type. The ratio of occupied area within a habitat type to the total habitat area along a transect is a measure of percentage occupancy stratified by type. This reflects the degree of clustering of individuals – greater occupancy leads to more continuous populations.

The availability of each habitat within the focal zone was determined by assigning habitats to 500 randomly-located points across the zone, based on aerial photo interpretation. The percentage of each habitat type among these 500 points was multiplied by the total zone area (20,793 ha) to estimate the relative area of each habitat type on the landscape.

Table C-2. Habitat classification system in Muldavin et al. (2016) based on geology and plant communities.	
Geologic classes	
Mesa Top	Summits of table lands interspersed among badlands, canyons and valleys.
Gray/White Hills	Badlands dominated by gray (blue) and white shales. Includes barren alluvial fans extending out from the hill slopes.
Red Hills	Hills and associated alluvial fans composed of red-colored baked sandstone and ancient unconsolidated river gravels.
Yellow Hills	Hills and associated alluvial fans composed of yellow to tan sandstones (sometimes orange) and some shale.
Valleys	Valleys, including dissected alluvial fan piedmonts and valley bottom fills. May also include remnant pediments of hills
Dry Wash	Ephemeral desert washes; includes adjacent alluvial terraces deposited by intermittent high flows

Plant community classes	
Woodlands	Open to moderately closed woodlands (10-60% canopy cover) dominated by pinyon pine and Utah juniper with grassy to sparse understories.
Dense shrubland	Dense canopied shrublands (>33% cover) dominated by big sage with rabbitbrush a common associate. Grass cover is generally low or absent.
Open shrubland	Open shrublands (10-33% canopy cover) dominated by big sage; inter-shrub spaces can be grassy or sparse but are often grassy.
Grassland	Grasslands with low to moderate cover dominated by blue grama with galleta and alkali sacaton as common associates.
Barren/sparse grassland	Sparsely vegetated or with scattered grasses (seldom greater than 5% cover).
Barren/channel	Open, active, sparsely vegetated desert washes.

In general, Clover's cactus occurs on gravelly, rocky, or sandy-clay soils, sometimes with cryptogamic (microbiotic) soil cover as high as 80% (NatureServe 2019b). The former subspecies *cloverae* and *brackii* were previously considered to be edaphically distinct, with *cloverae* occurring generally on soils with gravel or cobble alluvium or colluvium overlaying it, and *brackii* occurring on eroding sandy clay Gypiorthids-Badlands-Stumble complex soils, derived from shales and sandstones in badlands regions of the Nacimiento. Some of these badlands have high concentrations of selenium, and the cactus can also occur on gypseous soils north of the San Juan River but is not classified as a gypsophile (Porter and Prince 2011; Muldavin et al. 2016a). However, these differences were not observed during the NHNM survey (E. Muldavin, personal communication 2019; R. Sivinski, personal communication 2019). NHNM found a strong positive relationship between cactus density and the percentage of badland soils in all habitat types except for mesa tops (Figure C-3).

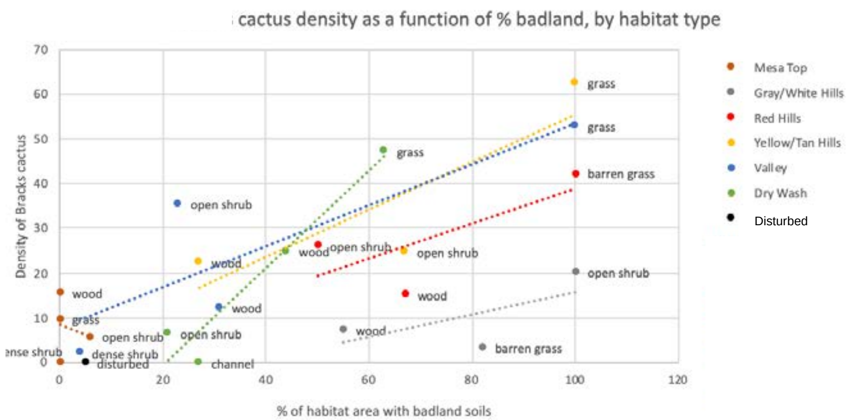

Figure C-3. Relationship between percent badlands soils and *S. cloverae* density.

Population Biology

Population Genetics

It appears that gene flow among populations of Clover's cactus is relatively low, with slightly higher rates of exchange among populations in the southern genetic group. Average estimated migration rates among populations varied widely depending on the estimation method used, ranging from a high estimate of 2 migrants per generation to a low of 1 migrant every 10 generations. However, one of the estimation methods (private alleles) was subject to bias because markers were frequently dropped during genetic sample processing, so the low estimated migration rate of 1 migrant every 10 generations based on F_{ST} is more reliable (J. Mark Porter, personal communication 2019).

Populations extending west of the Nacimiento from the Animas River to the Hogback incline, as well as populations in the San Ysidro area, show evidence of introgression with *S. parviflorus*. Rather than indicating active zones of hybridization where genetic swamping may be a threat to *S. cloverae*, introgression means there is a genetic signature of *S. parviflorus* within populations that remain genetically distinct and aligned with *S. cloverae* (in the Animas River-Hogback region), or vice versa (in the San Ysidro region).

Introgression usually results from past hybridization events followed by many generations of back-crossing. Broader sampling in *S. parviflorus* is needed to clarify the species boundaries in these parts of the *S. cloverae* range.

Pollination and Breeding System

While observations suggest the plant is not pollinator limited (Muldavin et al. 2016b), annual seed set can vary dramatically in plant species depending on numerous environmental and biological factors. To obtain an accurate assessment of reproductive capacity, monitoring should take place over several years.

Seed Production and Germination

Throughout the genus, seeds germinate in the fall and it is thought that seeds germinating near "nurse plants" receive protection against harsh winter weather and excessive sunlight during early stages of growth (Hochstatter 2005). Throughout the cactus family as a whole, seeds are metabolically inactive when mature in order to withstand extremes of drought and cold (Rojas-Arechiga and Vazquez-Yanes 2000). Dormancy ends when the temperature, precipitation or light limitation is removed.

New seedlings found during the NHNM survey were sometimes in close proximity to living and dead cacti (Muldavin et al. 2016a). This appears to be a common pattern, with most seeds germinating within the skirt of the mother plant between the body and the spines (S. Brack, personal communication 2019). Another potential agent of dispersal in the cactus family may be frugivores, as mainly rodents, but also birds, lizards and some mammals prey on fruits and seeds (Rojas-Arechiga and Vazquez-Yanes 2000). However in the congener *S. mesae-verdae* no long-range dispersal was observed by rodents or birds (Sivinski 2011). Seed dispersal distance and seed bank sampling in *S. mesae-verdae* found a total seed load around mature plants averaging 200 seeds within a 1 meter (3.3 ft) radius with 80 percent of the seeds 0 - 3 cm (0 - 1 in) deep in the soil (Cully et al. 1993) summarized in (Sivinski 2011).

Unlike many cacti from lower elevation deserts which readily germinate in warm, moist conditions, Cover's cactus seeds in horticultural settings require repeated freezing and thawing (vernalization), seed coat scarification, and the proper temperature and moisture for successful germination. This mirrors germination requirements documented for *S. mesae-verdae* (Sivinski 2011). Collected and stored seed from the same cohort may germinate sporadically over many years rather than simultaneously (S. Brack, personal communication 2019).

Previous Conservation Measures

Surveys

The NHNM 2015 survey of *Sclerocactus cloverae* (Muldavin et al. 2016b) is the only systematic assessment of the distribution and abundance of Clover's cactus to date. The intention of this survey was to delineate the range of former ssp. *brackii,* which was the taxon that was listed on the state and BLM sensitive lists at the time, but because it was difficult to distinguish between the two subspecies, the researchers visited all known sites of both types, and therefore likely captured the major population centers of the species as a whole, with the exception of outlying areas in the San Jose Formation and the Hogback area (R. Sivinski, personal communication 2019).

Previous Monitoring

In 2017, the BLM New Mexico State Office established permanent randomly selected plots throughout the range of Clover's cactus for long term demographic monitoring. Permanent belt transects or macroplots were set up in random locations stratified to hit the major population centers of Clover's cactus. Three years of data have been collected on numbers of living and dead individuals, plant vigor, reproductive status, and evidence of herbivory.

Research

Very little research has focused on Clover's cactus. Genetic diversity was analyzed and the taxonomy was revised as detailed above in the Description/Taxonomy and Population Genetics sections above (Porter and Clifford 2018). The species has been included in higher-level systematics studies looking at the relationship among species within *Sclerocactus* (J. M. Porter, Kinney, and Heil 2000).

Anecdotal evidence suggests that seed germination can be encouraged with sulfuric acid treatments or removal of part of the seed coat, and some success has been obtained with sowing outside in December into pots covered with a coarse screen to allow natural precipitation and exposure to repeated freeze-thaw cycles (vernalization), followed by irrigation once per week from March-May (S. Brack, personal communication 2019). The timing and volume of irrigation is critical because *Sclerocactus* are vulnerable to damping off which can eliminate the entire stock.

Appendix D. Detailed Background on Aztec gilia

Additional details on Aztec gilia's biology and conservation are included as a reference for specialists.

Biological Information

Species Description and Taxonomy

The genus *Aliciella* was formerly treated within the genus *Gilia*, but is currently placed within a different subclade of the Phlox family (*Polemoniaceae*), the *Loeselieae* group (Porter 1998; M. Porter and Johnson 2000; Johnson et al. 2008; Prather, Ferguson, and Jansen 2000). Within *Aliciella*, *A. formosa* is most closely related to *A. haydenii*, with others in the *Subnudae* subsections of the genus including *A. subnuda, A. cespitosa* and *A. tenuis* (Figure D-1).

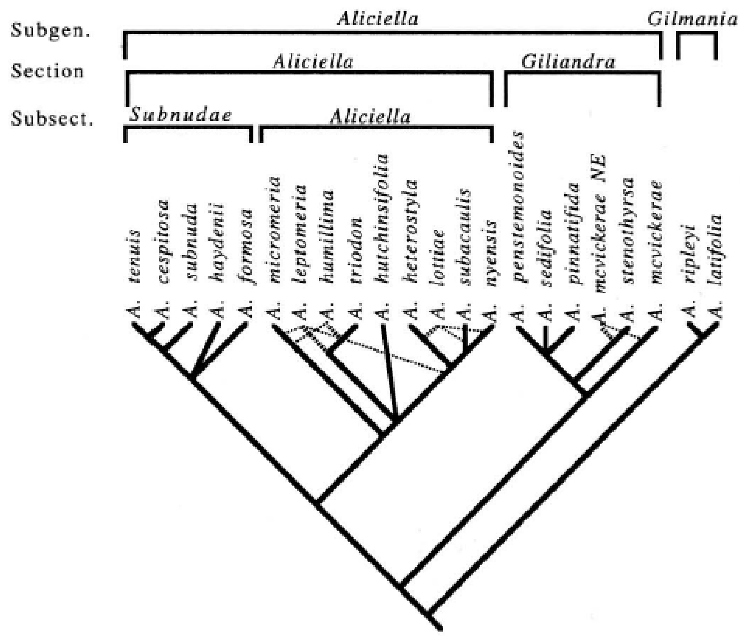

Figure D-1. Phylogenetic relationships among species within *Aliciella* (*Polemoniaceae*). Dashed lines represent proposed reticulate evolution (hybridization). From Porter 1998.

The closest relative of *A. formosa* is the look-alike *Aliciella haydenii*. *A. haydenii* ranges from northwestern Arizona to southwestern Colorado and southeastern Utah, then to northwest and northcentral New Mexico. It has a similar appearance to *A. formosa*, with similar size, branching pattern, glandular-hairiness, basal rosette and pink flowers. However, *A. haydenii* is an annual, biennial or short-lived perennial which doesn't become woody, and the basal leaves of the two species are very distinct. While *A. formosa* basal leaves are linear (1-1.5 mm wide) and entire, *A. haydenii* basal leaves are much wider (to 5.5 or 7 mm wide) and toothed or lobed (Figure D-2).

Figure D-2. Basal leaves in *Aliciella formosa* (left) and *A. haydenii* (right) make the species easy to distinguish. Photos: USDA Plants, American Southwest

Status

Federal status: The U.S. Fish and Wildlife Service (USFWS) recognized *A. formosa* as a Candidate for listing under Category 2 in 1985 (50 FR 39526). For candidate species in Category 2 included those taxa for which the USFWS possessed information indicating that a proposed listing rule was possibly appropriate, but for which sufficient data on biological vulnerability and threats were not available to support a proposed rule. The species was retained on the Category 2 Candidate list in subsequent reviews in 1990 and 1993, with a note that it was "declining" in 1993, but it was dropped in 1996 when the Service dropped all but Category 1 species from the Candidate list (FR 77 24908). The Service was petitioned to list *Aliciella formosa* as Endangered or Threatened in 2012, but the petition was found not to provide substantial enough information to warrant a listing (FR 77 24908). No demographic trend data were available at the time, and the only population estimates were derived from surveys in the 1990s or older. Aztec gilia was again petitioned to be federally listed by the Wild Earth Guardians (2020).

EMNRD (NM State) status: *Aliciella formosa* was listed as Endangered in New Mexico (Table 4) because it is a rare plant across its range within the state, and of such limited distribution and population size that unregulated taking could adversely impact it and jeopardize its survival in New Mexico (NMAC 19.21.2). The species is considered under-conserved in the New Mexico Rare Plant Conservation Strategy because of its limited range, current and potential threats, and lack of protection from these threats (EMNRD-Forestry Division 2017). State-endangered status only protects plants from unauthorized collection from their natural habitats. Other types of destruction and habitat disturbance are not regulated by the State.

NatureServe status: NatureServe ranks *Aliciella formosa* as globally and nationally imperiled (G2/N2) because although it can be locally abundant, it is a very narrow endemic, dependent on soil type, threatened by a high degree of development and disturbance (NatureServe 2019a). Species are ranked G2 if they are at high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.

NM BLM status: The New Mexico BLM added *Aliciella formosa* to the Sensitive Species list in 2008 according to listing criteria in BLM Manual 6840.

Natural Heritage New Mexico status: The Natural Heritage New Mexico program recognizes 42 known populations (Element Occurrences) of *Aliciella formosa*, made up of 173 known site locations, and ranks the species as S2, state-imperiled.

Navajo Nation status: The Navajo Nation Department of Fish and Wildlife recently updated its Endangered Species List, and *Aliciella formosa* was uplisted from Group 4 (under consideration but lacking sufficient information to support listing) to Group 3, endangered (prospects of survival or recruitment are likely to be in jeopardy in the foreseeable future). Any development that impacts Group 3 species requires mitigation. The increased protection is deemed necessary because the species is known from only 4 clustered populations on the Navajo Nation, ranging from 70 to several hundred plants in size, and 3 of which have not been surveyed in the last decade. Additional concerns are: 1) it is restricted in range to northern San Juan County, NM, and restricted edaphically to the Nacimiento Formation, an area of intense oil and gas exploration, and 2) transplanting and reseeding efforts have not been successful for this species, making habitat preservation especially important (N. Talkington, personal communication 2019). In general, management of Navajo Endangered Species can be challenging due to confusion about management responsibilities in regions with checkerboard surface management and different agencies managing surface and subsurface resources (N. Talkington, personal communication 2019).

Trends

Long term population trends of Aztec gilia were assessed by revisiting monitoring plots that were established in the 1990s by NHNM and the BLM (Roth and Sivinski 2018; DeBruin 1995; Floyd-Hanna 1994). Twenty of the original 30 plots established in the 1990s were relocated and extant plants were quantified. These 20 plots were revisited in 2018 and 2019 by biologists from the BLM Farmington Resource Area and these data are summarized here. Data from the first few years of monitoring in the 1990s suggest year-to-year variation in plant numbers, but when revisited in 2017 the number of living plants had dropped by 52-85%, and these numbers have continued to drop rapidly in 2018-

2019 (Figure D-3). Total live plants in all 20 plots went from 488 to 58 between 2017-2019, representing an 88% decline in the three-year period, and a 94% decline from early 1990s numbers.

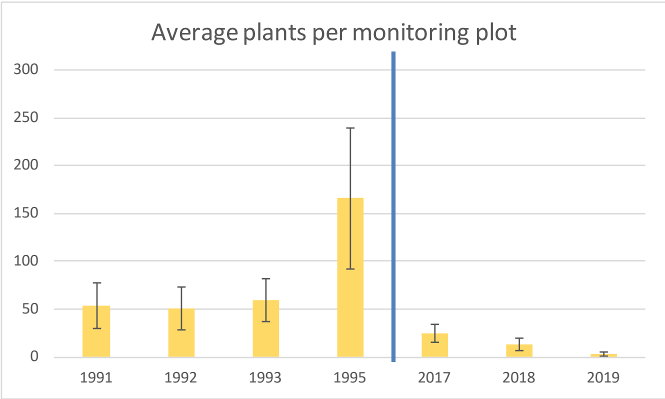

Figure D-3. Average number of living *Aliciella formosa* plants per plot (+/- 2*s.e.) in 20 plots surveyed from 1991-1995 and 2017-2019 (Roth and Sivinski 2018) (2018-2019 data provided by BLM FFO).

Population Dynamics

Demographic monitoring of four sites impacted by development of a right-of-way (ROW) and one undisturbed control from 1991-1994 revealed high population turnover, especially in disturbed sites (Floyd-Hanna 1994). High seedling recruitment can occur following wet winters, but survival to maturity can be very low, leading to population instability. Population structure at disturbed sites was skewed toward young, vulnerable size classes which produce fewer seeds per individual than older plants. In contrast, the control site was more stable due to its even size class distribution.

Previous Surveys, Monitoring, and Conservation Measures

Surveys

The distribution and abundance of Aztec gilia were assessed in 1986 by the New Mexico Department of Natural Resources (Knight and Culley 1986), in 1991 by the New Mexico Natural Heritage Program (DeBruin 1991) and in 2017 by the NM Energy, Minerals and Natural Resources Department-Forestry Division and RCS Southwest on behalf of the US Fish and Wildlife Service (Roth and Sivinski 2018).

Habitat Conservation

An Area of Critical Environmental Concern (ACEC) for Aztec gilia was established in 1988 just east and south of Aztec which also contained part of the Clover’s cactus population of that area. This ACEC was rescinded by the BLM in 2003 and converted to an OHV recreation site when Aztec gilia was located in some additional areas that seemed less threatened by energy development (Muldavin et al. 2016a; Roth and Sivinski 2018).

Monitoring

In addition to the 30 monitoring plots described in the Status and Trends section above, five plots were established in 1991 and monitored annually through 1994 as mitigation for a pipeline right-of-way (Floyd-Hanna 1994). Two of the ROW plots were relocated in 2017, and these have been monitored annually from 2017-2019. These plots are monitored for total numbers of seedlings, juveniles and adults, but individual plants are not tracked from year to year to determine stage transition rates.

In 2017, the BLM New Mexico State Office established ten permanent randomly selected plots throughout the range of Aztec gilia for long term demographic monitoring. Permanent belt transects or macroplots were set up in random locations stratified to hit the major population centers of Aztec gilia. Two years of data have been collected for on numbers of living and dead individuals, plant vigor, reproductive status, and evidence of herbivory; additional monitoring data are required to understand population trends.

Transplanting

Transplanting has been authorized and performed by the BLM in the past. However, transplant projects were unsuccessful and have not been permitted since.

Research

Very little research has focused specifically on Aztec gilia, aside from inclusion of this species in systematics research on the Phlox family (Porter 1993; Porter and Floyd 1993; Porter 1998; M. Porter and Johnson 2000; Johnson et al. 2008).

Appendix E. Limiting Factors and Threats Additional Details

Biological and Environmental

Predation

During a 2002-2003 period of severe drought, the cactus longhorn beetle reduced all monitored populations of the endangered *S. mesae-verdae* by 20-70% (Coles, Decker, and Naumann 2012), contributing to a pattern of episodic population crashes and reduction in overall population numbers since the 1990s (Porter and Prince 2011).

In addition to the beetle, *Sclerocactus* populations may be vulnerable to infestation by the army cutworm (*Euxoa sp*.), a migratory noctuid moth native to the Great Plains and Intermountain West. Army cutworms destroyed many *S. mesae-verdae* in the BLM Hogback ACEC study area and on Navajo Nation lands during the drought of 2002-2003 (Roth 2018), and it likely attacks Clover's cactus as well.

Insect attack may be a strong enough pressure on Clover's cactus populations to influence the evolution of the unique morphology and developmental timing in the former subspecies *brackii*. It has been speculated that the ability to flower while retaining juvenile morphology (paedomorphosis) may have evolved as an important means of ensuring reproduction in the face of periodic, devastating outbreaks of cactus longhorn beetles, which favor adult cacti, and army cutworms (Porter and Prince 2011).

Mortality as a consequence of rabbit and rodent browsing has also been documented in populations of other species of *Sclerocactus* (Porter and Prince 2011). Rodent predation was the likely cause of 89% mortality in *S. mesae-verdae* plots in 2018 (Roth 2018). A variety of small mammals, such as native ground squirrels, pack rats, rabbits, and mice, can severely damage or kill both mature and young cacti during times of drought when free water is unavailable (Kelly and Olsen 2011). Increased herbivory by rabbits may result from herbivore population booms in response to new growth during a high rainfall year, growth of weedy plants or sown reclamation mixes, or because of release from predator pressure (Ranglack, Durham, and du Toit 2015; Lightfoot et al. 2011) if density of owls, hawks, eagles, coyotes and bobcats decline with the noise, traffic and habitat fragmentation associated with energy development (Roth 2019).

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Anthropogenic

Energy Development

Direct impacts of oil and gas development result from ground disturbance associated with creating well pads and building networks of pipelines and roads to connect them. Drilling in habitats of the Angel Peak, Bloomfield and Aztec cactus and Aztec gilia population centers is typically vertical drilling for natural gas. This area has been developed since the 1950s (J. Tafoya, personal communication 2019) and current spacing of vertical wells is one well per 80-160 acres, but this could increase to a maximum of one well per 40 acres (16 wells per square mile). Each vertical well pad with a single well covers about 3.75 acres and an additional 0.6 acre is disturbed with installation of pipelines and access roads (J. Tafoya, personal communication 2019).

The horizontal wells currently being constructed in the Lybrook region are large but can accommodate more wells per pad. Per the 2018 RFD (supplemental Table C) and recent applications, proposed well pads are 6-7-acres with 2-6 horizontal wells each (J. Tafoya, personal communication 2019). Longer laterals averaging 2-2.5 miles with potential for up to 3 miles are also being proposed. Potentially, improvements in drilling technology could result in less surface disturbance over time.

Habitat Fragmentation

Although they are not impassable barriers, human structures like roads and railroads have been shown to constrain bumble bee movement during foraging bouts, possibly by contributing to spatial cues that determine bee site-specific foraging behavior (Bhattacharya, Primack, and Gerwein 2003). Bumble bees are capable of flying long distances (well beyond 1 km) when foraging (Goulson et al. 2002; Osborne et al. 2008), while much smaller bee genera observed on Clover's cactus flowers have correspondingly smaller predicted foraging ranges based on a documented relationship between body size and foraging distance (Greenleaf et al. 2007).

Recreation: Off-highway Vehicles

During NHNM 2015 surveys, OHV impacts were not as severe as the disturbance caused by roads and pipelines, but were quite noticeable. No off-road bicycle traffic was observed and there was very little evidence of motorized OHV use south of the San Juan River and through the southern part of the Nacimiento Formation.

However, the 2017 Aztec gilia surveys found that OHV and bicycle traffic created significant disturbance in habitat occupied by Aztec gilia, impacting the plants by directly by running them over, or impacting them indirectly by causing soil compact or erosion, increasing dust deposition, and altering drainage patterns (Roth and Sivinski 2018). Disturbance from OHV traffic and bicycles was most notable on BLM lands around Bloomfield, Aztec and La Plata.

Lowered water availability and ground cover resulting from OHV use can exacerbate the effects of climate change or grazing (Porter and Prince 2011). Effects on soil, vegetation, and hydrology can compound over time as additional routes are created, with increasing impacts to plants and their habitat. OHVs can also impact biocrusts, which may also retain moisture and provide an important source of water for plants (DeFalco et al. 2001).

Appendix F: Tools Used to Guide Avoidance Areas and Management Actions

Guidance Tools	What is it	Benefits	Current application for conservation of Clover's cactus & Aztec gilia
Habitat Suitability Model	Predict habitat suitability for the species across an area of interest (see details below)	Identification of suitable habitat can inform conservation and management decisions and permitting	In development
Habitat Conservation Area (HCA)	HCAs are areas of sensitive species habitat voluntarily set aside (by proponents) for no ground disturbance	Identification of these protected areas can expedite approval of proposed projects because the overall effects of the project are more likely to have no significant impact.	Under exploration for FFO (Appendix G)
Survey standards for Clover's cactus and Aztec Gilia during energy development	Standardization of survey protocols for use by FFO, project proponent(s), or anyone working on either party's behalf	Supports BLM environmental assessments and compliance with NEPA and expedited project permitting timelines for proponents	Current standards (Appendix A)

Habitat Suitability Models

Development

Habitat suitability models for Clover's cactus and Aztec gilia were produced following methods similar to those developed by Young et al. (2020) for model development and parameterization. The project is using an iterative modeling approach, meaning that results from initial models will be ground truthed through field surveys, and the resulting data will be used to further refine the models. Field surveys will always be a critical source of information for ensuring that occupied habitat is protected and for validating and refining habitat suitability models. Models should be reviewed and updated periodically to incorporate new findings from the field and changes in modeling best practice.

Uses
The habitat suitability maps are intended to inform future management actions on the landscape, including permitting of future oil and gas development and other ground disturbing activities in the region. The habitat suitability maps can be a valuable aid in planning such projects (Reese et al. 2019) at multiple levels. Habitat models are an important tool for informing conservation and management decisions about a species, but they should always be used with an understanding of their limitations. The modeling approach and results, and associated geospatial data, will be published and freely available to the public.

Limitations
Importantly, models of suitable habitat are just that: models. There is uncertainty in predicting suitable habitat for rare species for a whole host of reasons (e.g., Reese et al. 2019, Sofaer et al. 2019). Chief among these reasons are that available species occurrence data is usually limited in number, and may also have limited spatial accuracy, be dated, or have issues with species identification. Observation locations for rare species are also often spatially biased (e.g., areas near roads or trails are more likely to have been surveyed), and surveys may not have been conducted across the entire range of the species. Information on the biology and ecology of the species may be limited, along with our understanding of how environmental conditions drive the distribution of the species. Finally, it is important to remember that suitable habitat may not be occupied at any given time for a number of reasons, including fluctuations over time in population numbers or distribution because of changing weather or climate conditions, herbivory, competition with invasive species, or other factors (Reese et al. 2019).

Appendix G. HCA write-up from the Farmington Field Office, New Mexico

The following is a write-up produced by the Farmington Field Office (date) following (# of?) internal meetings to address conservation management concerns for Clover's cactus and Aztec gilia.

Background
In 2017 the Farmington District Office issued Instruction Memorandum No. NMF0120-2017-003 to provide guidance on habitat management of two special status plant species

(Brack's cactus and Aztec gilia) for ground disturbing projects on BLM managed lands. In the IM, the concept of HCAs was established to encourage lease and/or permit holders to voluntarily set aside important habitats to mitigate impacts to special status species.

Definition

On the ground, an HCA is an area of special status species habitat that contains specific components or constituents necessary for special status species persistence. HCA's have resource value, either for one resource or multiple, where habitat is present and extensive development or fragmentation has not occurred. The HCA concept is not exclusive to special status species and may be utilized to address any resource concern. In practice, HCAs are voluntary agreements between the FFO and lease holders to conserve habitat and mitigate impacts to habitat. HCAs function as proponent generated design features of a proposed action and are not a form of compensatory mitigation, land use allocations or lease stipulations and are not to be considered as such. An HCA would be incorporated into the appropriate NEPA analysis which would contemplate impacts to resources within the entire lease or project area.

Habitat Conservation Areas (HCAs)

The Bureau of Land Management Farmington Field Office (FFO) encourages the development and use of proponent nominated, voluntary Habitat Conservation Areas (HCAs) within fluid mineral leases or units as a proactive measure to mitigate habitat loss and maintain conservation of valuable habitat when evaluating projects with greater potential disturbance. These enhanced conservation efforts are intended to be a proactive approach to minimize listing of species as threatened or endangered under the Endangered Species Act, thereby allowing the BLM authorized officer to make more timely and cohesive decisions in regards to important, proponent-generated proposed actions (proponent generated NEPA).

The HCA would be submitted as a design feature of a Master Development Plan (MDP) for a proposed action for subsequent NEPA analysis. HCAs with clear benefits to the species will be more likely to receive a Finding of No Significant Impact. HCAs most likely to benefit target species are those which contain specific habitat components, are contiguous with or can adjoin an existing HCA, are of sufficient size and/or quality to mitigate direct and indirect impacts to habitat (1:1 ratio or better to demonstrate a net conservation benefit), have limited existing fragmentation, and have limited potential for future fragmentation.

Suggested guidance for the development of an HCA

HCAs should be developed by the project proponents. BLM will work with proponents to provide the best available data and input as requested. HCAs would be most effective when identified for leases, units or projects in geographic areas, and would be incorporated into larger scale planning documents (e.g., Plan of Development (POD) or MDP).

When contemplating the location of an HCA, areas containing the following features should carry a heavier importance:

- Contains specific habitat components/constituents (e.g. soil, aspect, slope)
- Habitat is contiguous or can adjoin an existing HCA
- Area is sufficient size and/or quality to mitigate direct and indirect impacts to habitat (1:1 ratio or better to demonstrate a net conservation benefit).
- Limited existing fragmentation, and limited potential for future fragmentation
- For species that occur in varied habitats, priority would be given to areas that are continuous, suitable habitat, preferably occupied by individuals or more importantly populations of special status species.

The FFO will provide the proponent all available BLM data and information (GIS data, potential issues, habitat maps, habitat characteristics, etc.) prior to their planning efforts. The FFO is not however, asserting that BLM data must be used in determining where and how an operator will decide what their HCA area will look like or consist of. HCAs remain voluntary, the agency will neither coerce or duress, nor withhold authorization for otherwise lawful activity, nor suggest that a favorable outcome is contingent upon adopting a certain HCA mitigation program.

HCA development will work best when specific areas of development are identified versus a hypothetical development scenario. The more information provided by the proponent of well placement, infrastructure, and other future development, the stronger the HCAs will be in meeting the goal of protecting important habitat areas and mitigating direct and indirect impacts.

<u>Implementation</u>

The HCA should be submitted as a design feature within the plan of development (pod) or equivalent document (such as a POD or MDP) for a proposed action for subsequent NEPA analysis. Once a decision is made, subsequent project proposals should be submitted outside of the HCA to preserve the use as a form of mitigation for a resource concern. This does not prevent a proponent from submitting project proposals within an established HCA, but may render the HCA ineffective, making the analysis used to justify the HCA inaccurate.

The establishment of an HCA does not preclude future development within the HCA. Depending on the nature, extent and intensity of the proposed project, additional NEPA documentation may be required. If future projects, regardless of the proponent, are proposed or developed within the HCA the BLM will review the existing analysis establishing the HCA to determine continued effectiveness.

HCAs are not intended to restrict lease development, but to provide the balance for development while providing meaningful design feature measures and protection to important habitat areas as mandated by FLPMA.

Participants at the FFO meeting identified several information needs that are barriers to adoption of HCAs; a working group should be convened to address barriers to adoption.

Barriers identified in the meeting include:

- Needing better parameters of what qualifies as an HCA (but see Appendix C)
- What size and degree of connectivity is big enough, connected enough?
- What specific protections do HCAs offer to the target species?
- How does participation limit project proponents and what benefits do they receive?

Appendix I: Southwest Cactus Pollinator Study

An ongoing study of *Echinocereus fendleri var. kuenzleri* (EFK) in south-central New Mexico looks to understand if the species is limited in any way by pollinators (O. Carril, personal communication 2020). A funded pollinator study of Clover's cactus would look to answer the same questions that are being asked of EFK.

Excerpt from EFK grant proposal:

> *To answer these questions, we will assess the pollinators associated with EFK, and their relative effectiveness in achieving seed set. Specifically, we will 1) measure seed set after single pollinator visits, with respect to each pollinator species, 2) quantify mean seed set per visit (effectiveness of each pollinating species), and 3) evaluate the effectiveness of pollinators with respect to their frequency of visitation. Simultaneously we will measure duration of visit, and positioning of pollinator when it visits the flower (i.e., does it come in contact with the stigma). Evidence exists that the presence of other insects inside flowers can deter pollinators from visiting (LeVan et al., 2014), so flowers will be evaluated for the number of ants or small beetles they contain, and compared to the number of pollinators they encounter in a day. Finally, to determine if there are sufficient pollinators in the area, surveys of pollinators across the populations, as well as on other co-blooming flowers in the area, especially other cactus species, will be conducted.*
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> *Plants will be randomly chosen within a population, so that bags are not clustered in one area. Plants will be covered with fine mesh bags before anthesis. On the day that plants flower, bags will be removed one at a time, and flowers will be observed until an insect visits. The identity of the insect visitor will be recorded, as well as the time of day, the duration of the visit, and whether it lands on the stigma when entering the flower. Once an insect visitor has left, the bag will be recovered to prevent further pollination events. Finally, small metal cages will be placed over plants to prevent herbivory of fruits. After fruits have matured, they will be collected, and the number of seeds found in each will be recorded. If possible, the number of unfertilized ovules will also be recorded. For comparison, natural levels of seed set (and fruit set) will be recorded for open-pollinated control plants to determine average reproductive output across each population. Finally, seed set for each bagged flower will be correlated with its pollinator to test whether species of insects differ from each other in terms of effectiveness in causing seed set (t-test).*
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> *Separately, a random set of open flowers will be observed for two-hour blocks for pollinator visits. For each of these flowers, the number of insects residing in the flower will be quantified. Pollinator visits will be compared to flower inhabitants to assess the relationship between the two (t-test).*

Finally, pollinators will be collected using aerial nets from across each entire population. The flowering plant on which the pollinator was collected, the date, and the location will be recorded. Collected specimens will be pinned, labelled, and identified by trained taxonomists, to compile a list of all EFK-visiting insects, compared to all flower-visiting insects in the area. Specimens will be deposited at the University of New Mexico in their insect collection at the conclusion of the study.