Winkler cactus (*Pediocactus winkleri*)
AND
San Rafael cactus (*Pediocactus despainii*)

Draft

RECOVERY PLAN

December 2015

U.S. Fish and Wildlife Service, Denver, Colorado

Winkler Cactus (Pediocactus winkleri)
AND
San Rafael Cactus (Pediocactus despainii)

DRAFT RECOVERY PLAN

Mountain-Prairie Region
U.S. Fish and Wildlife Service
Denver, Colorado

Approved:______________________________
Regional Director, Region 6

Date: 2.29.16

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EXECUTIVE SUMMARY

Current Species Status: Winkler cactus was listed as threatened in 1998 with a Recovery Priority Number of 11 (see Table 2) and San Rafael cactus was listed as endangered in 1987 with a Recovery Priority Number of 11C (see Table 2) under the Endangered Species Act (ESA). Winkler cactus (*Pediocactus winkleri*) and San Rafael cactus (*Pediocactus despainii*) occur in south-central Utah. The two species are closely related with a blending of morphological characteristics where their ranges meet. For management purposes those individuals found in Emery County are considered San Rafael cactus and those found in Wayne County or Sevier County are considered Winkler cactus.

Distribution and Range: Both species occur primarily on federal lands, including lands managed by the Price and Richfield Field Offices (FO) of the Bureau of Land Management (BLM), and on Capitol Reef National Park (CRNP). Both species have also been found on land owned by the State of Utah and managed by the School and Institutional Trust Lands Administration (SITLA).

Winkler cactus comprises four known populations (three in Wayne County and one in the southeast corner of Sevier County) and a total of 5,411 documented individuals (NatureServe 2004). San Rafael cactus comprises twenty-one known populations, all in Emery County and a total of 8,159 documented individuals. New populations of both species were identified as recently as 2013, suggesting that additional populations of both species may remain to be discovered. Many of the threats facing these species are the same, and actions required to manage the species and reduce threats are similar.

Habitat Requirements: Winkler cactus is endemic to specific, fine textured soils derived from the Dakota formation and Morrison formation in the lower Fremont River in Wayne County and southeast Sevier Counties of south-central Utah. It is generally found at elevations between 1,500 - 2,130 meters (m) (4,900 - 7,000 feet (ft)) on rocky, alkaline hill tops and benches, and gentle slopes on barren, open sites in salt desert shrub communities. These communities are associated with species such as Indian rice grass (*Achnatherum hymenoides*), blue grama (*Bouteloua gracilis*), curly grass (*Pleuraphis jamesii*), alkali sacaton *(Sporobolus airoides)*, sand hill muhly (*Muhlenbergia pungens*), prickly pear cactus *(Opuntia polyacantha)*, Mormon tea (*Ephedra torreyana*), little-leaf mountain mahogany *(Cercocarpus intricatu*s), shadscale *(Atriplex confertifolia),* four-wing salt bush (*Atriplex canescens* var. *canescens*), phlox (*Phlox* spp.), locoweed (*Astragalus* spp.), halogeton (*Halogeton glomeratus*), snakeweed *(Gutierrezia sarothrae),* and viscid rabbitbrush (*Chrysothamnus viscidiflorus*). It is also found among piñon-juniper (*Pinus edulis-Juniperus osteosperma*) woodland stands (Clark 2008; Welsh et al. 2003).

San Rafael cactus grows in a wide variety of soils, although it may favor fine textured mildly alkaline soils rich in calcium and derived from limestone substrates of the Carmel Formation and the Sinbad member of the Moenkopi formation. It has also been found on shale barrens of the Brushy Basin member of the Morrison, Carmel, Mancos and Dakota geologic formations and in areas of primarily alluvial and colluvium soils. The species most commonly occurs on benches, hill tops, and gentle slopes, and most abundantly on sites with a south exposure at elevations of 1450-2080 m (4760-6820 ft). San Rafael cactus populations are a component of the vegetative community occurring at the lower elevations of a piñon-juniper woodland plant community and the upper elevations of a galleta three awn shrub-steppe community of the Canyonlands section of the Colorado Plateau Floristic Division. The vegetative community is characterized by open woodlands of scattered Utah juniper and piñon pine with an understory of shrubs and grasses within the Colorado Plateau (Clark 2008; Welsh et al. 2003).

Factors Limiting Viability: We consider livestock grazing and climate change to be high-level threats to Winkler cactus. Moderate-level threats to Winkler cactus are off-highway vehicle (OHV)-related activities, illegal collection, and the inadequacy of existing regulatory mechanisms. Low-level threats are native ungulate disturbance, invasive species, predation, and energy and mineral development.

We consider off-highway vehicle (OHV)-related activities, livestock grazing, energy and mineral development, and climate change to be high-level threats to San Rafael cactus. Moderate-level threats to San Rafael cactus are illegal collection, and the inadequacy of existing regulatory mechanisms. Low-level threats are native ungulate and wild horse disturbance, invasive species, predation, and energy and mineral development.

Recovery Plan: This recovery plan includes Parts 1 through 5. Part 1 of this plan includes the biological and status information pertinent to recovering both cactus species. Part 2 presents a general strategy for achieving the species' long-term recovery in the wild. Part 3 outlines the recovery goals, objectives, and criteria specific to each cactus and describes the action program for achieving recovery objectives. Part 4 provides a schedule for implementing each action. Part 5 provides the references used in compiling this document. Recovery of these species is in an early stage; thus, it should be anticipated that the recovery program will change over time as informed by new information and the outcomes of implementing recovery actions. The recovery plan will be revised when needed to reflect changes in information, strategies, and/or actions.

Recovery Strategy: Recovery of Winkler cactus and San Rafael cactus will hinge on conserving extant populations, primarily by abating threats such as illegal collection, grazing impacts, OHV related disturbances and through demonstration of increasing trends within existing populations or additional populations to ensure long-term demographic and genetic viability.

Recovery of the Winkler and San Rafael cactus will include: (1) the sustained and stable presence of extant populations of each species and the possible discovery of additional stable populations, with the aim of ensuring representation and redundancy of each cacti; (2) long-term conservation of the ecosystems where these species are found (including the open land area needed for individual cactus and population growth, natural soil conditions, associated land formations and natural water hydrology, habitat for pollinators, and seedbanks), as a further means of ensuring redundancy; and (3) positive population trends and maintenance of natural population dynamics and genetic diversity, as a means of ensuring the resiliency of each species. All populations must be sustained with stable or increasing trends in order to reach recovery.

Successful achievement of recovery will require the active involvement of experts, land managers, and the public as well as a continuing recognition of the role each cacti species plays in the ecology of south central Utah. Because of the biological and historical uncertainties regarding the status and recovery potential of these species, the recovery strategy is necessarily contingent on a growing understanding of the species and their ecological requirements. Consequently, a dynamic and adaptive approach will be crucial to making effective progress toward recovery.

Recovery Goals and Criteria

The primary goal of this recovery plan is to achieve the long-term viability of Winkler cactus and San Rafael cactus in the wild, thus resulting in the removal of both from the Federal List of Endangered and Threatened Plants (50 CFR 17.12). Focal points of the recovery program include stabilizing the populations; addressing the main threats to the species from livestock grazing, climate change, OHV use and illegal collection; and long term protection of the cactus and their habitat from ongoing and future threats (Part 3). The recovery actions recommended in this Recovery Plan will achieve the goals and criteria set forth in the Plan.

Population-based and threats-based recovery criteria were developed to identify when San Rafael cactus can be considered for Winkler cactus and San Rafael cactus can be considered for delisting. Recovery is discussed in more depth in Part 3 of this document.

Population-Based Criteria

P-1. Based on analysis and modeling implemented under the recovery actions, trends for San Rafael cactus and Winkler cactus populations are shown to be stable or improving according to the following measures:

a) Species presence is maintained at all known San Rafael and Winkler cactus populations; **and**

b) Within at least three-quarters of the known populations that represent the majority of the total known individuals (and including the Wedge, Millsite/Clawson, and all of the McKay Flats populations) **and** represent the range of geographical, morphological, and genetic diversity of San Rafael cactus, plant density within occupied habitat is stable or improving over a 20-year period. These populations would be designated as Recovery Populations and this measurement would be based on a standardized, long term monitoring protocol developed by the Recovery Team and managing agencies. These criteria must be met for **all** known Winkler cactus populations due to the low number of known populations at this time. If additional Winkler cactus populations are discovered in the future, it may be determined that delisting is appropriate even if some populations are not stable or increasing; **and**

c) Predictive modeling using data from an additional 10-year period (30 years total), collected in accordance with a standardized monitoring protocol, provides an indication of long-term demographic stability as well as a projected survival probability of at least 95 percent over 100 years for each species.

P-2. Based on best available data, the available habitat base for each recovery population of each species is of sufficient quality and large enough to allow for natural population dynamics, population expansion where needed, and the continued presence of pollinators, with sufficient connectivity to allow for needed gene flow within and, where possible, among populations.

P-3. Population and habitat management is implemented for all populations of both species cactus in accordance with management plans developed under Recovery Action 1 (Section 3.4). Each species-specific management plan will include a course of action that addresses the following needs: habitat protection and management, threats abatement, biological and threats monitoring, and reporting and evaluation.

Threats-Based Criteria

FACTOR A. The present or threatened destruction, modification, or curtailment of habitat or range.

T-1. Federal land protection through long-term management agreements or plans is achieved for all known San Rafael and Winkler cactus populations. Protection considerations from grazing impacts, development, mining, oil and gas, and recreation must be included in the management agreements and the protected areas must meet the size and connectivity parameters determined through research to be adequate to sustain those populations. These may include but are not limited to resource management plans, conservation agreements, recreation management plans, and travel management plans.

FACTOR B. Overutilization for commercial, recreational, scientific, or educational purposes.

T-2. Management agreements or plans in place and being implemented for all Winkler and San Rafael cactus populations on all federal lands must include measures to address and curtail illegal collection activities. These plans should include criteria for appropriate law enforcement at correct times and places to prevent illegal collection and sales of plants or any plant parts.

FACTOR C. Disease or predation.

T-3. Adverse population-level effects from herbivory, disease, or predation, if any, are identified, monitored and abated to the extent that all known Winkler cactus and at least three quarters of known San Rafael cactus population trends are stable or increasing, as evidenced by demographic monitoring results from studies that have adhered to monitoring protocols developed under Recovery Action 2.4 (Section 3.4). Programs to control excessive herbivory or predation will be developed to adaptively manage each population per criterion P-3, and must take into consideration the degree which climate change may impact disease or herbivory levels in the future.

FACTOR D. The inadequacy of existing regulatory mechanisms.

T-4. Land protection covering the habitat of all populations for each species and/or statutory and regulatory protections for plants are such that the protections of the ESA are no longer needed to compensate for regulatory inadequacies.

FACTOR E. Other natural or manmade factors affecting the species' continued existence.

T-5. A long-term ex-situ conservation program is ongoing for all extant Winkler cactus and San Rafael cactus populations. This would include seed collection and storage, germination and viability trials, and development of a protocol for successful reproduction under greenhouse conditions. This would help avert the risk of extinction from stochastic events or environmental catastrophes.

T-6. In conjunction with recovery criterion P-2, the available habitat base for each of the populations designated under criterion P-1 is of sufficient quality and large enough to offset the threat of loss or restriction of the species' pollinators. Effective measurement criteria will be developed through research under Recovery Action 3.

Recovery Actions Needed

A detailed list of recovery actions designed to ensure both species meet the criteria required for delisting is found in Section 3.4 and are broadly summarized here:

1. Protect and conserve known extant Winkler cactus and San Rafael cactus populations and their habitat.

2. Survey for additional populations, and monitor all populations in order to apply conservation measures where and when needed.

3. Conduct in depth research into the biology, requirements, threat responses, and life histories of both species in order to develop and implement appropriate management practices for the purposes of achieving recovery.

4. Promote communication by encouraging and creating dialog regarding these species between managing agencies, land owners, developers, and the public in order to raise awareness and aid recovery.

5. Coordinate and work together with all stakeholders to achieve recovery.

Table 1. Estimated Recovery Cost

TOTAL ESTIMATED COST OF RECOVERY (IN $1,000'S)

Implementation Year	Recovery Action					Total
	1	2	3	4	5	
Y01	707	104	62	11	3	**887**
Y02	411	104	48	9	3	**575**
Y03	411	94	48	11	3	**567**
Y04	413	94	48	9	3	**567**
Y05	419	94	48	11	8	**580**
Y06-30	2586	900	1224	249	100	**5059**
Total	**4947**	**1390**	**1478**	**300**	**120**	**8235**

RECOVERY DATE

Estimated Date of Recovery: If the recovery actions needed to meet all recovery criteria are accomplished on schedule, recovery of both species is anticipated to be achieved in the year 2045. However, it should be recognized that recovery of these species is in an early stage and the recovery program may change over time; consequently, the estimated date for delisting may be revised.

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Key to Abbreviations used in this Document:

ac – acres (unit)

ACEC – Area of Critical Environmental Concern

AUM – Animal Unit Month. The amount of forage needed to sustain one cow and her calf, one horse, or five sheep or goats for a month. This is the unit of measurement the BLM uses to authorize the amount of grazing within an allotment.

BLM – Bureau of Land Management

CITES – Convention on International Trade in Endangered Species

cm – centimeters (unit)

CRNP – Capital Reef National Park

ESA – Endangered Species Act

FO – Field Office

ft – feet (unit)

ha – hectares (unit)

IA Team – Interagency Team

in – inches (unit)

m – meters (unit)

NPS – National Park Service

OHV – off-highway vehicle

SITLA – School and Institutional Trust Lands Administration (State of Utah)

UDOT – Utah Department of Transportation

USFWS – U.S. Fish and Wildlife Service

UTPR – Utah Department of Parks and Recreation

UTNHP – Utah Natural Heritage Program

WSA – Wilderness Study Area

PART 1. BACKGROUND

1.1 INTRODUCTION

The U.S. Fish and Wildlife Service is required under section 4(f)(1) of the Endangered Species Act (ESA) to prepare recovery plans for all listed species, unless we determine that such a plan will not promote the conservation of the species. Recovery plans serve as road maps for species recovery - they lay out where we need to go and how best to get there. Recovery plans are guidance documents; not regulatory documents. This means that no agency or entity is required by the ESA to implement the recovery strategy or specific actions recommended in a recovery plan. However, the ESA clearly envisions recovery plans as the central organizing tool for guiding each species' recovery process.

Winkler cactus (*Pediocactus winkleri*) and San Rafael cactus (*Pediocactus despainii*) are members of the cactus family (Cactaceae) and endemic to south central Utah. San Rafael cactus is found exclusively in Emery County, Utah and Winkler cactus is found primarily in Wayne County, Utah, with a single small population found in southeastern Sevier County. They were first included as Candidate 1 (C1) species for federal listing in a notice published in the Federal Register December 15, 1980 (45 FR 82480). Candidate 1 species were those species for which we had enough information to warrant proposing them for listing but were precluded from doing so by higher listing priorities. The two *Pediocactus* species remained as C1 species until a 1983 supplemental notice (48 FR 53640, November 28) in which we changed the status from C1 to Candidate 2 as a result of a careful review of status information. Candidate 2 species were those species for which we had some indication that listing as threatened or endangered might be warranted, but there were insufficient data available to justify a listing proposal. On September 27, 1985 (50 FR 39526), we published a revised notice of review in which both species were re-designated as C1 from the results of a status survey by Ken Heil (Heil 1984). The terms Candidate 1 and Candidate are no longer in use, as of 1996.

San Rafael cactus was proposed for listing as endangered in 1986 (51 FR 10560, March 27) and listed on September 16, 1987 (52 FR 34914). Winkler cactus was proposed for listing as endangered in 1993 (58 FR 52059, October 6), and was listed as threatened on August 20, 1998 (63 FR 44587). After listing, Winkler cactus was assigned a recovery priority number[1] of 11C and San Rafael cactus was assigned a recovery priority number of 11 (Table 1)

[1] Recovery priority numbers, which are determined in accordance with the criteria laid out in 48 FR 41985, are used to identify those species that should receive highest priority for recovery plan preparation and implementation. Recovery priority numbers range from a high of 1C to a low of 18, with "C" indicating an imminent conflict with development activity.

Table 2. Recovery Priority Numbers for San Rafael cactus and Winkler cactus.

<table>
<tr><th>Degree of Threat</th><th>Recovery Potential</th><th>Taxonomy</th><th>Priority</th><th>Conflict</th></tr>
<tr><td rowspan="6">High</td><td rowspan="3">High</td><td>Monotypic Genus</td><td>1</td><td>1C</td></tr>
<tr><td>Species</td><td>2</td><td>2C</td></tr>
<tr><td>Subspecies/DPS</td><td>3</td><td>3C</td></tr>
<tr><td rowspan="3">Low</td><td>Monotypic Genus</td><td>4</td><td>4C</td></tr>
<tr><td>Species</td><td>5</td><td>5C</td></tr>
<tr><td>Subspecies/DPS</td><td>6</td><td>6C</td></tr>
<tr><td rowspan="6">Moderate</td><td rowspan="3">High</td><td>Monotypic Genus</td><td>7</td><td>7C</td></tr>
<tr><td>Species</td><td>8</td><td>8C</td></tr>
<tr><td>Subspecies/DPS</td><td>9</td><td>9C</td></tr>
<tr><td rowspan="3">Low</td><td>Monotypic Genus</td><td>10</td><td>10C</td></tr>
<tr><td>Species</td><td>11
(San Rafael cactus)</td><td>11C
(Winkler cactus)</td></tr>
<tr><td>Subspecies/DPS</td><td>12</td><td>12C</td></tr>
<tr><td rowspan="6">Low</td><td rowspan="3">High</td><td>Monotypic Genus</td><td>13</td><td>13C</td></tr>
<tr><td>Species</td><td>14</td><td>14C</td></tr>
<tr><td>Subspecies/DPS</td><td>15</td><td>15C</td></tr>
<tr><td rowspan="3">Low</td><td>Monotypic Genus</td><td>16</td><td>16C</td></tr>
<tr><td>Species</td><td>17</td><td>17C</td></tr>
<tr><td>Subspecies/DPS</td><td>18</td><td>18C</td></tr>
</table>

The ranking for Winkler cactus of 11C is based on a moderate degree of threat to its habitat over its range, a low potential for recovery in terms of habitat conservation, and its taxonomic standing as a species. In addition, the modifier "C" is based on a local economic conflict with desires for recreational OHV use within its occupied habitat. The moderate degree of threat is linked to the risk of irreversible loss of individuals and habitat. The ranking for San Rafael cactus of 11 is based on a moderate degree of threat to its habitat over its range, a low potential for recovery in terms of habitat conservation, and its taxonomic standing as a species. The moderate degree of threat is linked to the risk of irreversible loss of individuals and habitat (USFWS 2006)

1.2 DESCRIPTION AND TAXONOMY

The plant genus *Pediocactus* contains nine species (eFloras 2014). Six of the nine species in the genus are rare endemics of the Colorado Plateau region of Utah, Colorado, New Mexico and Arizona. In addition to Winkler cactus and San Rafael cactus*; P. bradyi* (Brady pincushion cactus), *P. knowltonii* (Knowlton cactus), *P. peeblesianus* var. *peeblesianus* (Peebles Navajo cactus), *P. peeblesianus* var. *fickeiseniae* (Fickeisen's Navajo cactus) and *P. sileri* (Siler pincushion cactus) are listed as endangered or threatened under the ESA. These species may be relics of a once more widespread genus with a distribution that was fractured by prehistoric climatic change (Benson 1982). Due to the relatively recent discovery of Winkler cactus and San Rafael cactus, little information is available on the historic abundance of either species.

Winkler cactus and San Rafael cactus are described as separate species in all taxonomic treatments involving those species in regional floras (eFloras 2014; Neese 1981; Welsh et al. 1987; Welsh et. al. 2003) and in monographs of the genus (Heil et al. 1981). At one point, the two species were proposed as subspecies of *Pediocactus bradyi*, a federally listed species from northern Arizona (Arp 1972; Hochstätter 1995). However, it was later demonstrated through conclusive genetic analysis that Winkler cactus and San Rafael cactus are more closely related to *P. simpsonii*, but distinct from that species as well as from each other (Porter *et al.* 1999). Populations identified as Winkler cactus and populations identified as San Rafael cactus have distinct haplotypes (sets of DNA variations that tend to be inherited together) from each other, and thus can be genetically separated (Porter *et al.* 1999). Thus, we support the designation of Winkler cactus and San Rafael cactus as separate species. Demarcation of the range of each species is based largely on plant morphological characteristics and geographic location (Section 1.2.2).

1.2.1 Individual Species Descriptions

Winkler cactus

Winkler cactus was discovered by Agnes Winkler in the early 1960's (Heil 1979). At the time of its initial discovery, many thought that it was the same species as *Pediocactus bradyi* and it was thus forgotten (Heil 1984). The species was rediscovered in 1977 and described in scientific literature by Kenneth Heil from specimens collected in the vicinity of Notom, Utah (Heil 1979).

Winkler cactus is a small sub-globose cactus. The species stems are solitary or clumped, 3.9-6.8 centimeters (cm) (1.5-6.7 inches (in)) tall and 2.7-5.0 cm (1.0-2.0 in) in diameter. The top of the stem extends from ground level to 5 cm (2.0 in) above. Stems are ribbed with small projections 0.4-0.7 cm (0.2-0.3 in) long. Spine bearing areoles are borne at the top of these projections. The areoles are elliptic and densely wooly pubescent with spines obscuring or partially obscuring the stem. Central spines are lacking, radial spines commonly number 9-11. The spines, 1.5-4 millimeters (mm) (0.06-0.16 in) long, spread downward with tips tapering from bulbous bases. Flowers are borne on the upper end of the tubercles near the apex of the stem. Flowers are 1.7-2.2 cm (0.7-0.9 in) long with a peach to pink color. Stamens are yellow and stigmas are green. The fruit is 0.7-1.0 cm (0.3-0.4 in) long with a smooth surface, initially green, turning reddish-brown with age, and dehiscing (opening) with a vertical slit along the ovary wall. Seeds are shiny black with short, rounded bumps that coalesce into large irregular ridges (Heil 1979; Heil *et al*. 1981; Welsh *et al.* 2003). See Figure 1 Winkler cactus in flower and Figure 2 for Winkler cactus in bud.

Figure 1. Winkler Cactus in Bloom (Photo by Tom Clark/NPS)

Figure 2. Winkler Cactus With Flower Buds (Photo by Tova Spector/USFWS)

San Rafael cactus

San Rafael cactus was first discovered by Kim Despain in 1978 in the San Rafael Swell in Emery County, Utah (Welsh and Goodrich 1980). San Rafael cactus is a small sub-globose cactus. The species is usually solitary stemmed, 3.8-6.0 cm (1.5-2.4 in) tall and 3.0-9.5 cm (1.2-3.7 in) in diameter. The stem apex extends from the ground level to 5 cm (2 in) above. Stems are ribbed with tubercles 0.6-1.0 cm (0.2-0.4 in) long. Spine bearing areoles are borne at the apex of the tubercle. The areoles are elliptic with moderate spines partially obscuring the stem. Central spines are lacking. Radial spines commonly number 9-13, are white, and range from 2-6 millimeters long. Flowers are borne on the upper end of the tubercle near the apex of the stem. Flowers are 1.5-2.5 cm (0.9-1.0 in) long and colored yellow bronze, peach bronze, or pink with a purple mid-stripe. Stamens are yellow and stigmas are green. Fruit is 0.9-1.1 cm (0.3-0.4 in) long with a smooth surface, initially green, turning reddish-brown with age and dehiscing with a vertical slit along the ovary wall. Seeds are shiny black and kidney shaped with papillate mounds that coalesce into large irregular ridges (Heil *et al.* 1981; Welsh *et al.* 2003; Welsh and Goodrich 1980).

See Figure 3 for San Rafael cactus in flower, and Figures 4 and 5 for San Rafael Cactus in bud and fruit, respectively. Note the difference in portion of cacti above the soil surface. Degree of plant emergence from the soil can vary from site to site and from year to year.


Figure 3. San Rafael Cactus in Bloom (Daniela Roth/USFWS)


Figure 4. San Rafael Cactus with Flower Buds (Photo by Daniela Roth/USFWS)


Figure 5. San Rafael Cactus in Fruit (Photo by Daniela Roth/USFWS)

1.2.2 Distinction Between Species

Winkler cactus and San Rafael cactus are very closely related with a blending of morphological characteristics where their ranges meet (Porter *et al.* 1999). There is a large variation in morphological characteristics between individuals within each species, and similarities between many individuals of San Rafael and Winkler cactus, particularly those in the San Rafael Swell (Clark 1999). Identification of the species in the field is based on geographical location and morphology, but there is no completely reliable way to distinguish the two species from each other based on physical characteristics alone. Flower color and size, plant size, amount of plant above the substrate, timing of retraction into the ground, and whether retraction is complete or not are some of the traits that may be variable across the populations of both species (Truman 2014).

Recent genetic research has provided additional information on the extent of each species' range; however, areas of intermediate gradation exist and additional research is needed to conclusively determine each species full range. Early taxonomic research demonstrated that typical Winkler cactus from the Notom population (which is the type locality) was genetically different from typical San Rafael cactus from the San Rafael Swell (Porter *et al.* 1999). More recent genetic analysis (eFloras 2014) indicates that Winkler cactus and San Rafael cactus are very closely related to each other. However, the morphological variations and intermediate gradations between them present difficulties in precisely delineating the individual species ranges and where they overlap. A reduction of rank to subspecies is not recommended as a solution as it is believed that future genetic information for these plants will allow for grouping into more precise species ranges (Porter *et al.* 1999).

In general, the genetic relationships among Winkler cactus and San Rafael cactus populations correspond to geographic features in the region. Populations within the San Rafael Swell represent San Rafael cactus populations, and populations south of the San Rafael Swell represent Winkler cactus populations. However, within the San Rafael Swell some of the populations may include plants with Winkler cactus genetics, and a few are morphologically intermediate (eFloras 2014; Porter *et al* 1999).

These species are difficult to distinguish in the field, particularly on the borders of their respective ranges. Since 2000, the northern most boundary of CRNP has been used by all agencies involved in the management of the two species to address this difficulty (Figures 6 and 7). Those populations and individuals north of the boundary of CRNP are considered to be San Rafael cactus. Those found to the south of the northernmost boundary of CRNP are considered to be Winkler cactus (IA Team 2011, 2011a). The two species' ranges may overlap and they may also hybridize. Until further genetic testing is done, the artificial CRNP boundary line represents our best known information on the division between the species. Therefore, this boundary is used for management purposes and for discussion in this document.

This figure is intended to be printed in color and when viewed in black and white may be less illustrative.

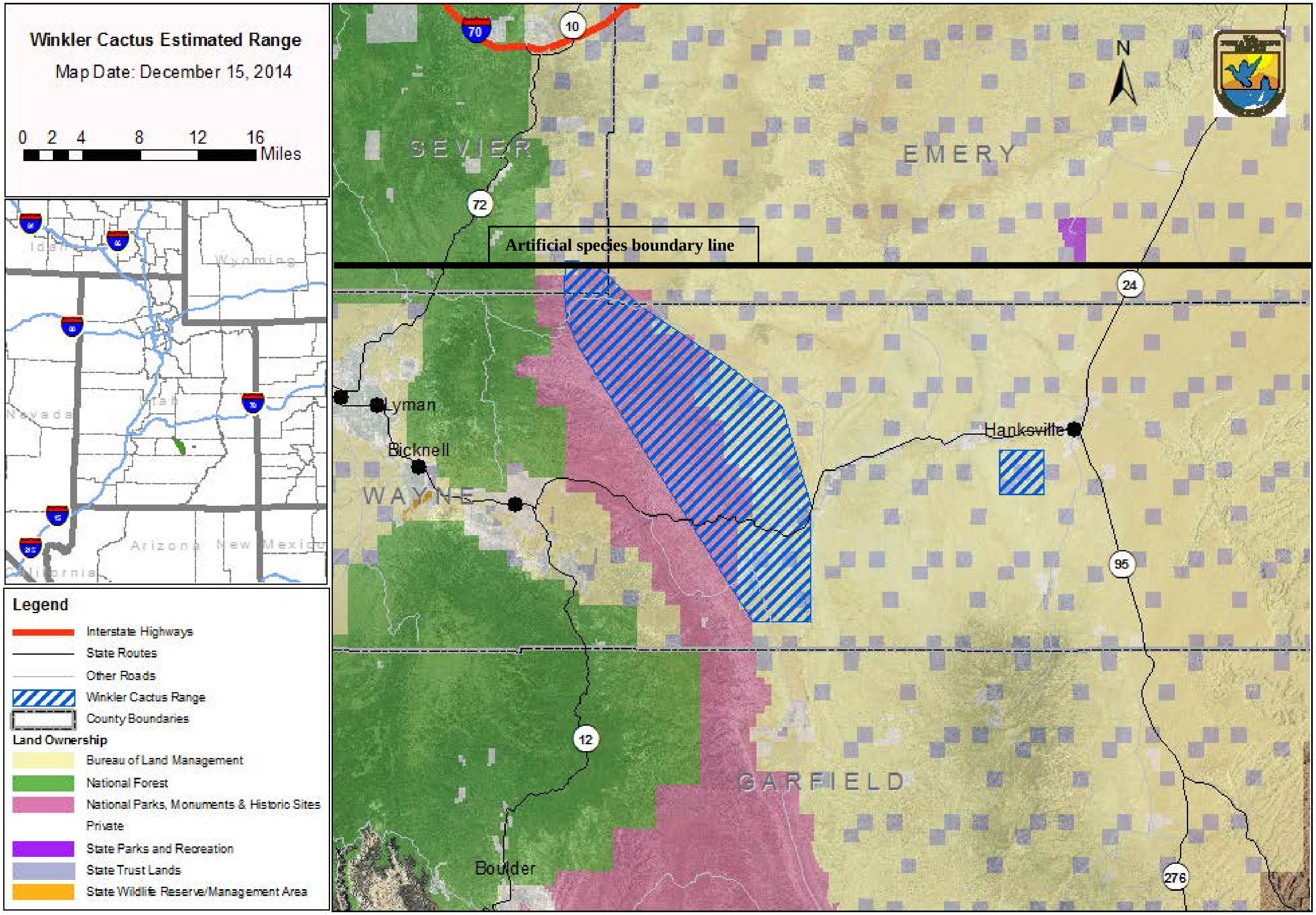

Figure 6. Estimated Range of Winkler Cactus

This figure is intended to be printed in color and when viewed in black and white may be less illustrative.

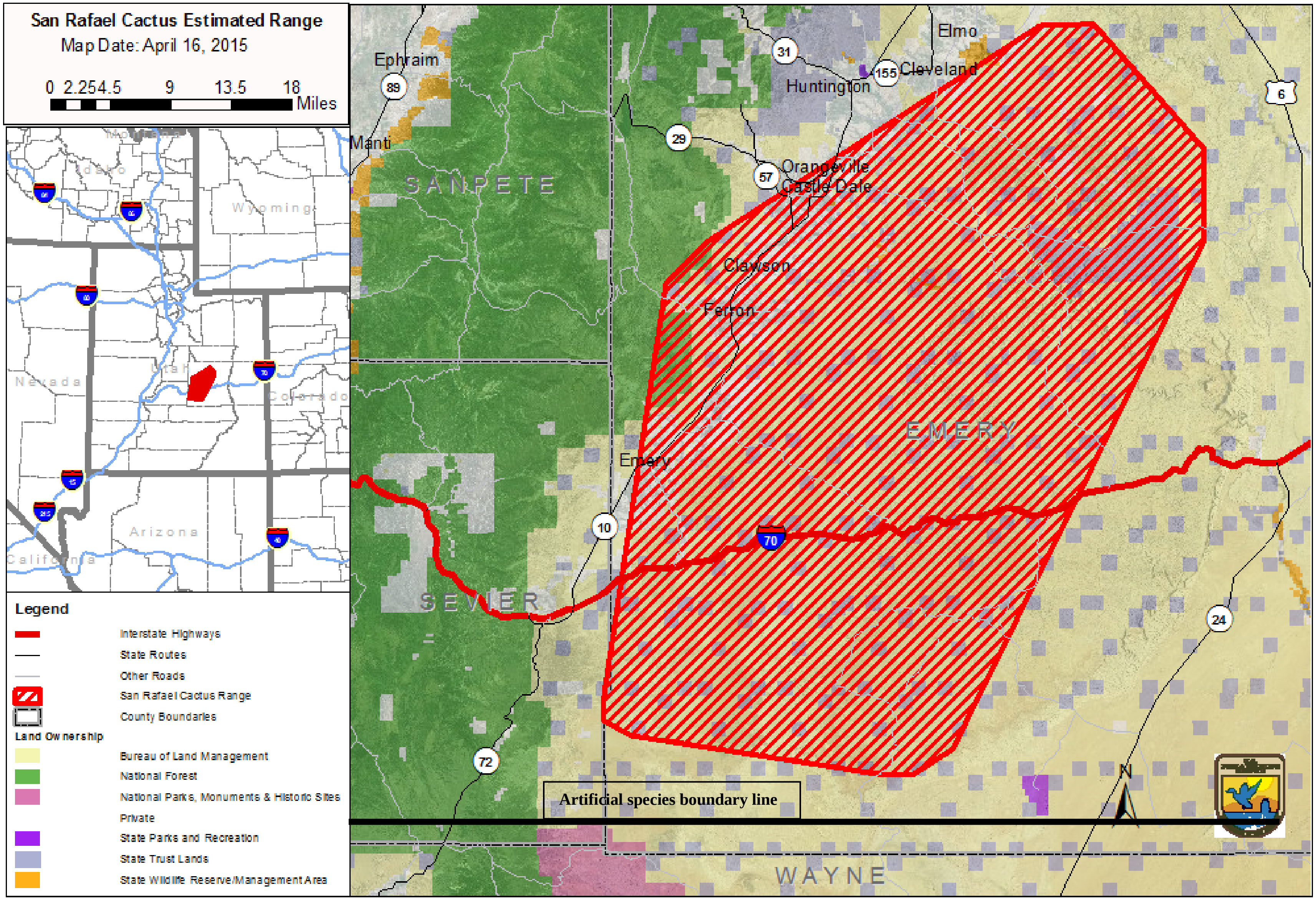

Figure 7. Estimated Range of San Rafael Cactus

1.3 HABITAT CHARACTERIZATION

Winkler cactus and San Rafael cactus are endemic to central Utah. Elevation, geologic formation/soil type, and plant community appear to be the primary defining habitat characteristics. Both species prefer sparsely vegetated areas. As with many rare plants, there are many areas of habitat that appears to be suitable for the species which are unoccupied. As more populations and sites are discovered, our understanding of the habitats in which they may occur expands. As of this writing, a habitat model is being developed by the U.S. Geological Survey (USGS), in partnership with USFWS, CRNP, and BLM. This model will help further delineate the potential range and the probability of occurrences within the modeled range.

Winkler cactus

Winkler cactus is generally found at elevations between 1,500-2,130 meters (4,900-7,000 ft) on rocky, alkaline hill tops and benches, and gentle slopes on barren, open sites in salt desert shrub communities (Figure 8). The species grows in alkaline silty loam or clay loam soils derived primarily from the following geologic formations: Dakota; Morrison; Summerville; Entrada; and Emery sandstone member of the Mancos formation (Clark 1998, 1999; Heil 1984; Neese 1987; 63 FR 33587, August 20, 1998). Winkler cactus populations are a component of the saltbush vegetative community of the Canyonlands section of the Colorado Plateau Floristic Division (Cronquist *et al.* 1972; Kuchler 1964). The vegetative community is characterized by drought tolerant shrubs and grasses with ephemeral forbs. Cacti, in general, are a conspicuous component of this vegetative type (Heil 1984). Winkler cactus is associated with species including Indian rice grass (*Achnatherum hymenoides*), blue grama (*Bouteloua gracilis*), curly grass (*Pleuraphis jamesii*), alkali sacaton *(Sporobolus airoides)*, sand hill muhly (*Muhlenbergia pungens*), prickly pear cactus *(Opuntia polyacantha)*, Mormon tea (*Ephedra torreyana*), shadscale *(Atriplex confertifolia)*, four-wing salt bush (*Atriplex canescens* var. *canescens*), phlox (*Phlox* spp.), locoweed (*Astragalus* spp.), halogeton (*Halogeton glomeratus*), snakeweed *(Gutierrezia sarothrae)*, and viscid rabbitbrush (*Chrysothamnus viscidiflorus*). It is also found among piñon-juniper (*Pinus edulis-Juniperus osteosperma*) woodland stands (NPS 2013).


Figure 8. Example of Winkler Cactus Habitat (Photo by Daniela Roth / USFWS)

San Rafael cactus

San Rafael cactus grows in fine textured, mildly alkaline soils rich in calcium derived from limestone substrates of the Carmel Formation and the Sinbad member of the Moenkopi formation (Heil 1984; Kass 1990) (Figures 9 and 10). The species also has been located growing on shale barrens of the Brushy Basin member of the Morrison, Carmel, Mancos and Dakota geologic formations (Clark 1999; Kass 1990) and in soils characterized as mainly alluvium and colluvium (Truman 2014). San Rafael cactus most commonly occurs on benches, hill tops and gentle slopes, most abundantly on sites with a south exposure and elevations of 1450-2080 m (4760-6830 ft). San Rafael cactus populations are a component of the vegetative community occurring at the lower elevations of a piñon-juniper woodland plant community and the upper elevations of a galleta-three awn shrub-steppe community of the Canyonlands section of the Colorado Plateau Floristic Division (Cronquist *et al.* 1972; Kuchler 1964). The vegetative community is characterized by open woodlands of scattered Utah juniper and piñon pine with an understory of shrubs and grasses (Heil 1984). San Rafael cactus appears to occur in a wider range of habitats than Winkler cactus.

Most of the associated vegetation is xerophytic and often only a small percent of the ground has vegetative cover (Heil 1984). There is no evidence of competition between these taxa and any other cactus or perennial plant for space, light or nutrients (Heil 1984).


Figure 9. Example of San Rafael Cactus Habitat 1 (Photo by Daniela Roth / USFWS)


Figure 10. Example of San Rafael Cactus Habitat 2 (Photo by Daniela Roth / USFWS)

1.4 DISTRIBUTION AND RANGE

Winkler cactus is known to occur almost exclusively in northern Wayne County, with one small population in the far southeast corner of Sevier County. San Rafael cactus occurs exclusively within Emery County, primarily in the central and southeastern portions. See above discussion (Section 1.4.1.1) for more details about management decisions on the geographic delineation between the two species.

Winkler cactus occurs primarily on National Park and BLM land, with some occurrences on SITLA land and private land. San Rafael cactus occurs primarily on BLM land, with some occurrences on SITLA land. It is difficult to know how many individuals or populations of these species occur on SITLA and private lands because no specific surveys have been conducted.

Researchers have used various terms in previous reports and datasets to define the occurrences of these species. These terms include "key areas" to define a geographic area where one or many clusters or aggregations of cactus occur along with potentially suitable habitat. The term, "key areas" was defined in a way that may or may not correspond with the population definitions in this document, and was applied differently by different researchers. These key areas have sometimes been grouped into meta-populations by the Interagency Team which collaborated on monitoring of these species until 2011. In addition, within identified key areas the term locality or site may be used to describe a distinct grouping of cactus. However these terms have not been applied uniformly by all researchers at all times. Therefore, for the purposes of this document, we have delineated "populations" based on the best available survey data and expert recommendations for each species and hereafter refer only to populations.

For this Recovery Plan, we delineated populations for Winkler and San Rafael cactus (Figure 11) using NatureServe criteria. These criteria dictate that individuals of a plant species occurring more than one kilometer (km) apart over unsuitable habitat or more than two km apart over suitable habitat are considered to belong to different populations (NatureServe 2014). In some instances exact point data were unavailable to determine whether there were connections between individual occurrences; however, field observations of the species between those occurrences met the NatureServe criteria for connecting the occurrences into a single population. If we could not verify that cacti were observed to connect two populations, these populations are treated as separate and additional surveys in the area are recommended. Our population analysis may split some populations which were previously grouped together, such as those in the McKay Flats and the Mussentuchit areas.

This document will also refer to survey sites, which are individual areas of occupation within a population which contain one or more cactus and were censused on a single visit by researchers. This term is used because it is representative of the way these populations have been surveyed and indicates the manner in which cacti are often clustered into somewhat discrete areas within populations. Survey site boundaries may merge together over time as more individuals are discovered in future surveys. In this document we have named the populations based on their location relative to existing grazing allotments. See Figures 11 and 12 for population distribution.

This figure is intended to be printed in color and when viewed in black and white may be less illustrative.

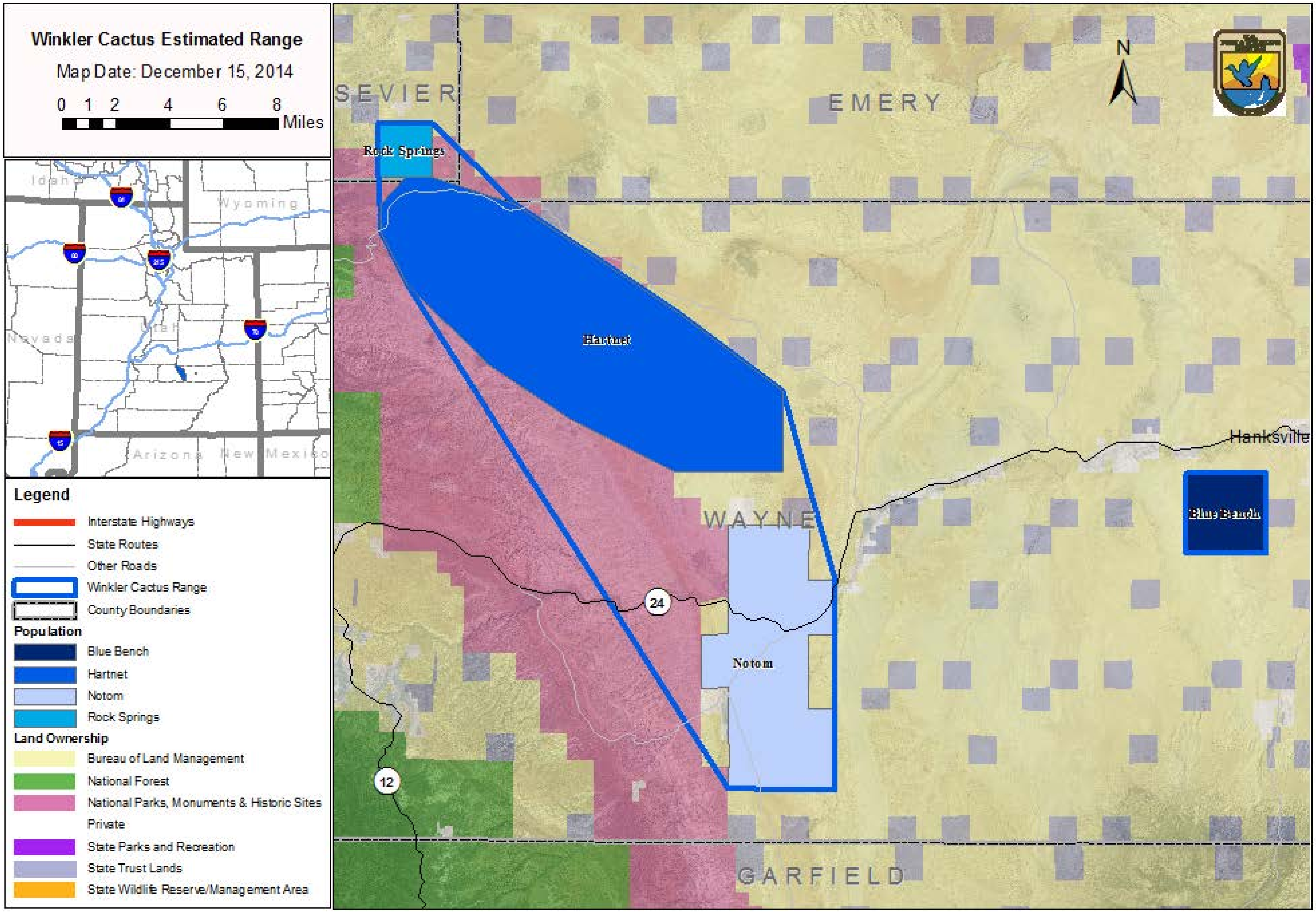

Figure 11. Populations of Winkler Cactus

This figure is intended to be printed in color and when viewed in black and white may be less illustrative.

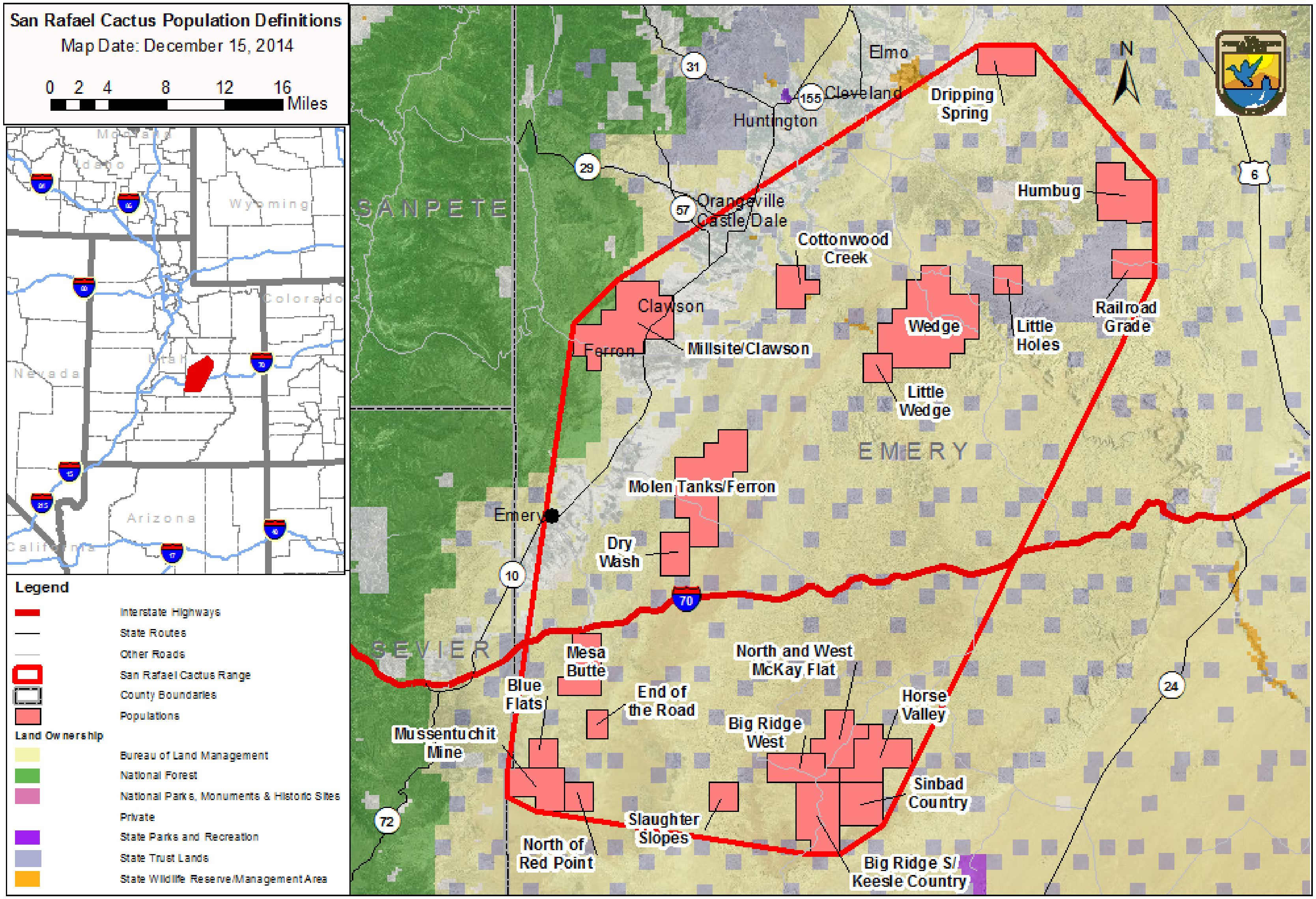

Figure 12. Populations of San Rafael Cactus

Winkler cactus:

The 1998 listing decision for Winkler cactus (August 20, 1998; 63 FR 44587) describes four populations of the species: Hartnet, Notom, Last Chance, and Ferron. The Last Chance and Ferron populations are in Emery County and are now considered to be San Rafael Cactus (BLM 2013a). Two additional Winkler cactus population were discovered in 2011 and 2013 – Rock Springs and Blue Bench (NPS 2011; BLM 2013). Therefore, there are now four known Winkler cactus populations: Hartnet, Notom, Rock Springs, and Blue Bench (Figure 11).

The discovery of the Rock Springs and Blue Bench populations significantly extended the known range of the species. The Rock Springs population is located in the far northwest corner of CRNP. The Blue Bench population is located west of Hanksville (BLM 2013; Rooks 2014), and extends the species' range approximately 29 km (18 miles) to the east from the Hartnet population (BLM 2013; Rooks 2014).

Overall, the known range of Winkler cactus extends from the southeast corner of Sevier County (near the northeast border of CRNP) to south central Wayne County. The overall distribution area is 31 miles north to south and 36 miles west to east. The estimated area that incorporates the known populations is approximately 76,486 ha (189,000 ac). For a more detailed breakdown of the individual populations, see Section 1.7.

San Rafael cactus:

The 1987 listing decision for San Rafael cactus (September 16, 1987; 52 FR 34914) describes just two populations of this species in Emery County: the Wedge and a portion of the Millsite/Clawson population. Since that time, many additional populations have been discovered and two previously identified Winkler cactus populations were reclassified as San Rafael cactus due to their geographic location.

There are 21 populations of San Rafael cactus throughout Emery County (Figure 11), the majority of which have been surveyed during re-inventory efforts within the past four years (BLM 2013a). The most recent population discovered (in 2013)—Dripping Spring—is also the northern-most population (Truman 2015).

Some of these populations are close to each other and are connected by suitable habitat, and it is possible that they are in fact parts of the same population. However, in the absence of any point data or field observations of occurrences that would definitively connect the populations under NatureServe Criteria, we have chosen to treat them as separate populations.

Overall, the known San Rafael cactus populations are found from Dripping Spring in the north, to Big Ridge South/Keesle Country to the south (approximately 122 km (78.5 mi) north to south), and from Mussentuchit Mine in the west, near the border of Sevier to the Humbug population in the east (approximately 88 km (48.5 mi) east-west) (Figure 9 and Figure 11). Based on the most recent survey data, the estimated area of the known populations is approximately 152,971 ha (378,000 ac) (USFWS 2014). For a more detailed breakdown of the individual populations, see Section 1.7.

1.5 LIFE HISTORY

Little research has been conducted on pollination mechanisms and pollinators, and no research has been conducted on seed germination success for San Rafael cactus or Winkler cactus. Both are considered long-lived species although there are no long term demography studies on San Rafael cactus, and only one small scale demographic study on Winkler cactus. Some monitored cacti lived at least 20 years after tagging, although the age of the cacti at the time of tagging was unknown (Clark *et al.* 2015). Winkler cactus individuals that were much larger than the largest and oldest tagged cacti in the demographic study (5 cm (2.0 in) in diameter as opposed to 3.7 cm (1.5 in) in diameter or less) have been recorded, suggesting that some individuals may live significantly longer than 20 years. Based on recorded growth rates, Winkler cactus individuals of 2 cm (0.8) in diameter are likely to be at least 15 years old, while those reaching 5 cm (2.0) in diameter may be closer to 40 years old (Clark *et al.* 2015).

Winkler cactus has very low overall fecundity, with 20 percent of monitored cacti in the demographic never flowering at all, and a very low flowering rate (10 percent) for small individuals. Size and age were positively correlated with reproductive effort, and the majority of flowers were produced by a few older and larger (over 2.1 cm (0.8 in) in diameter) individuals. Ten cacti in the study produced 31 percent of the total flowers (Clark *et al.* 2015). The most prolific large individuals were found to be sheltered under rocks or shrubs that provided protection from disturbance from cattle or other large ungulates and were not recorded to experience trampling events or damage during the study. This indicates that a lack of disturbance may be vital for the development of the large, reproductively active individuals necessary to maintain the population (Clark *et al.* 2015).

Recruitment of Winkler cactus was low and sporadic, and may be positively correlated with warmer temperatures in February and March; however, there may be a delay of several years between flowerings event and the first time seedlings are visible aboveground. This makes determining the factors that lead to successful recruitment difficult (Clark *et al.* 2015). While no detailed demographic study has been conducted on San Rafael cactus, it is likely that the species behaves similarly in terms of growth and reproduction.

Both species reproduce sexually, are self-incompatible and cross pollination is needed to produce viable seeds (Tepedino 2000). Pollinators visiting San Rafael cactus include many species of bees, from multiple families, while Winkler cactus is visited by bees from the large family Halictidae (Tepedino 2000). Pollinator visitation to plants is positively affected by plant population size (Goverde *et al.* 2002). Therefore, small population size may limit pollinator visits and reproductive success.

Flowering of both cactus species occurs from March to May with fruiting from May to June (Heil 1984). The specific timing of flowering and fruiting varies from year to year apparently due to temperature and moisture conditions of late winter and early spring (Clark *et al.* 2015; Truman 2014). The lower elevation occurrences usually flower at least 5 to 15 days earlier than the upper elevations (Heil 1984).

Much of the year cacti from both species shrink underground or back to ground surface, to defend against an annual cycle of extreme heat, drought and cold (Clark 1999). The time of year when the cacti retract underground and whether they retract fully under the surface of the soil or remain partially visible appears to vary by individual population and weather conditions for that year. However, retraction generally occurs during the summer and winter with stems resurfacing in spring and fall. Resurfacing in the spring appears to be dependent on winter and spring moisture (Clark *et al.* 2015). Some populations of San Rafael cactus do not fully retract underground at any time of year while others remain above the surface for only a brief period each year (Truman 2014).

Although, Winkler cactus can survive underground for up to two years during drought conditions, drought still plays a large role in the population dynamics of the species (Clark and Clark 2008). During the drought from 1999-2003 high rates of adult mortality were recorded for Winkler's cactus. In addition, adult mortality was coupled with low rates of recruitment resulting in a declining population during years of drought (Clark 2008; Clark *et al.* 2015).

Our understanding of the life history of Winkler cactus and San Rafael cactus is limited. Additional information regarding pollination and reproduction, lifespan, demographics and recruitment, drought resistance and vulnerability, and response and vulnerability to insect and rodent predation is needed to effectively manage the species. In addition, surveying of additional suitable habitat for as yet undiscovered populations of both species is vital to help understand the actual range, distribution, and abundance of Winkler cactus and San Rafael cactus. A habitat suitability model for these species, which will help define the potential range for the cacti as well as provide guidance to locate potentially undiscovered populations, has been commissioned but not completed.

1.6 POPULATION ABUNDANCE AND TRENDS

1.6.1 Challenges in Surveying and Trend Establishment

Lack of scientific knowledge and monitoring information affects our ability to effectively manage and recover the species. The nature of Winkler cactus and San Rafael cactus makes it difficult to return accurate counts of the species from year to year even when the same protocol is followed. Survey timing and weather conditions (both recent and seasonal) can affect the number of visible cacti—i.e., degree of plant emergence from the soil varied between sites and years (Section 1.2). Even when fully emerged from the soil, individuals may remain very low to the ground and can be difficult to spot, particularly when not in flower. Some younger individuals may be smaller than 1 cm (0.4 in) and almost impossible to distinguish from the surrounding soil (Figure 13). Cacti are more visible after periods of high rainfall, when they swell and brighten in color after taking in moisture; however, individuals may not surface every year. Thus the number of individuals counted in a survey may vary greatly from year to year, depending on the surveyor skill, the timing of the survey, and the weather conditions (both recent and for the year). In addition, mortality is difficult to document because dead individuals may remain under the soil without any visible evidence of their demise on the surface (Clark *et al.* 2015).

The large range and inaccessibility of some populations also contributes to the challenges of monitoring. These monitoring difficulties mean we are unable to speak with any certainty about population trends for the species. We recommend monitoring plans for the species consist of a combination of paired census plots and detailed demographic monitoring plots. This would allow for tracking of individuals over time to easily establish year to year trends. This would also provide more detailed information about changes in population structure, reproduction, and threat impacts in order to make projections about the future of population for the purposes of recovery.

Figure 13. Size Example of Young San Rafael Cactus (Photo by Tova Spector/USFWS)

Due to the danger of illegal collection, flagging individuals from year to year is not prudent in most cases. This makes it impossible to establish definitive trends based on current data, as an increase in the number of individuals surveyed may not indicate an increase in actual population numbers, because not all cactus may be present aboveground or equally visible to surveyors at a given time. To determine population trends, consistent long term monitoring methods specific to the unique needs of these species should be developed.

However, some information on changes to surveyed occurrences can be broadly gleaned from site revisits. An Interagency Team comprised of representatives of CRNP and the BLM Richfield and Price offices visited 93 Winkler cactus and San Rafael cactus sites between 1998 and 2008. Seventeen sites that were reported to contain large numbers of Winkler cactus in 1998 were revisited in 2008, thus providing some documentation of changes over time. In 2008, an increase in number of plants was found at three sites (18 percent), one site remained unchanged (6 percent), and a decrease in number of plants was found at 13 sites (76 percent) (Clark 2008a). Two sites had no live plants remaining. In addition to losing all plants at two sites, the other significant change was that one site had a decrease in cactus numbers from 730 in 1999 to 261 in 2008. In general fewer plants and fewer occupied sites were found in 2008 compared to 1998. Most revisited sites had 40 or fewer plants located in 2008 (Clark 2008, 2008b; IA Team 2011). This may be indicative of a downward trend, although timing of surveys, weather conditions, survey methods, and individual surveyor differences can also influence the number of cacti located at different survey times.

1.6.2 Method of Determining Abundance

Unless otherwise noted, we used data from surveys performed between 2010 and 2015 to determine current abundance. If a population was surveyed multiple times over these years, the totals were added together unless the same sites within the population were surveyed multiple times in that period. In those cases, to avoid double counting individuals, numbers from the most recent survey were used. If a population had not been surveyed in the past 5 years, the most recent available numbers for the population were used.

1.6.3 History of Inventory/Monitoring Efforts and Current Status

Between 1998 and 2011, monitoring and inventory of both species was done through an interagency cooperative team that included representatives from the National Park Service (NPS) at CRNP, the Richfield BLM Field Office, the Price BLM Field office and the USFWS. Typically, presence/absence survey methods were used, with some revisits to known sites and efforts to locate new sites. General information on the sites was collected, including slope, aspect, geological formation, and any disturbances or impacts. The primary survey efforts occurred in 1998, 1999, 2002, and 2008 (which focused on revisiting known sites) (Clark 1998, 1999, 2002, 2008).

In 1999, paired plots for both species were established (two sets for each) in an effort to gather some long term monitoring data and quantify the effects of livestock grazing. One plot at each high livestock usage site was fenced off from cattle while the other was left open. However, the fenced plots for San Rafael cactus were never completed, and the fenced plots for Winkler cactus experienced theft of individuals because the fencing made the plants easier to locate (Clark 2008a). Despite the shortcomings of the study, some valid information was collected and sampling results from the Winkler cactus study are discussed below, along with long term demographic monitoring efforts within CRNP.

In 2009 and 2010 presence/absence data was collected on San Rafael cactus at the Millsite/Clawson population, but no other surveys were conducted. In 2011, the interagency team created a re-inventory and monitoring plan. The plan aimed to standardize survey methods through a set of universal search and counting protocols. These protocols consisted of quantification of damage and disturbance to the plants by cattle, human, native ungulate, insects, and rodents. Phenological and size data was also collected on individuals (BLM 2011; IA Team 2011). The interagency team was disbanded before the re-inventory and monitoring plan could be implemented. However, the NPS and BLM assumed the responsibility to re-inventory and monitor cacti on their own lands. The re-inventories used methods that generally followed what was outlined in the original interagency plan, and this work occurred between 2011-2013 for Winkler cactus on both CRNP and BLM land. Re-inventories also occurred for San Rafael cactus over the same time period and are continuing (BLM 2012, 2013a). Long term monitoring plots, as outlined in the interagency plan (IA 2011), have been established at CRNP for Winkler cactus. One set of monitoring plots for Winkler cactus was established on BLM land in 1999. However, it was abandoned and not regularly monitored again until 2013 and it is not certain the exact location of the unfenced plot from 1999 was relocated. Comparisons between the unfenced and fenced plots from 2013-2015 show a decline in abundance in both plots and fewer individuals in the unfenced plot, but more years of data are needed to establish a trend (Rooks 2014). No paired monitoring plots were successfully established for San Rafael cactus on BLM land.

Winkler cactus

As described above (Section 1.4), we know of four populations of Winkler cactus: Rock Springs, a disjunct population in the northwest corner of CRNP; Hartnet, a population occurring in both CRNP and adjacent BLM land; Notom, a population primarily occurring on BLM land to east of CRNP; and Blue Bench, a recently discovered population occurring near Hanksville, UT. NatureServe criteria were used to delineate populations.

The recorded number of Winker cactus individuals surveyed from the species' description in 1979 to the 1998 listing (19 years) was 5,800. Based on surveys over the past six years (2011-2015) and, despite the discovery of new sites and a new population, the known population of Winkler cactus remains similar (5,400 individuals). The majority of cacti are split between the Hartnet and Notom populations. The Blue Bench and Rock Springs populations are much smaller and more isolated (BLM 2011b, 2013; NPS 2013; Rooks 2014).

The interagency team established a long-term demographic monitoring plot for Winkler cactus in 1995 and this plot was monitored annually through 2015 (Clark *et al.* 2015). Forty-four cacti were tagged in 1995 and followed annually through 2014 (20 years) or until they died (this was confirmed by checking for a carcass underground if the tagged plant did not emerge for several years). Any additional cacti appearing in the plot over successive years were also tagged and monitored in the same way. The number of cacti in the plot peaked in 1999 with 67 cacti and then declined to 31 live individuals by the end of the study. Drought, livestock disturbance, and trampling were identified as the primary causes of mortality. Of all 107 individuals that were tagged over the course of the study, 74 were disturbed by large ungulates (primarily cattle) during their lifespan (Clark *et al.* 2015). Many individuals were disturbed multiple times and a cumulative effect on mortality was found. A cactus that had been disturbed three times during a three year period was six times as likely to die as a cactus that had not experienced disturbance (Clark *et al* 2015). In addition, between 1995 and 2008 it was found that that 58 cacti had experienced a direct trampling event by a large ungulate (primarily cattle) and that 60 percent of those cacti experiencing a trampling event died within four years (Clark and Clark 2008).

The highest annual percent mortalities were from 1999 through 2003 and can be directly correlated to the worst of the recent drought years in south-central Utah. There is also some evidence that recruitment is correlated with moisture regime (Clark 2008; Clark and Clark 2008). Due to differences in survey methods over time, the addition of new occurrences, and variable survey results from year to year, it is not possible to determine an accurate population trend for this entire species with the available data. However, this study corresponds well with re-inventorying and survey results that suggest a general population decline in many places. This trend can be attributed to drought conditions, rodent and beetle predation, and trampling by livestock (Clark 2011; NPS 2013). See Table 2 for summary of populations range-wide.

Table 3. Winkler Cactus Population Summary

Population Name	Alternative Population Names	Grazing Allotment(s)	Land Ownership	Year(s) of Most Recent Survey	Number of Individuals counted	Notes on Population
Rock Springs	Rock Springs	Rock Springs	CRNP	2011	99	Previously surveyed last in 2001 and 114 individuals were found.
Hartnet	Hartnet Draw Jailhouse Rock	Hartnet	CRNP, BLM	2011-2013	2,723	2,380 individuals were counted in CRNP and 343 on adjacent BLM land.
Notom	Notom	Hartnet Sandy #1	BLM, SITLA	2011-2013	2,360	Not all historic occurrences were surveyed in the repeat inventory. This was due to the difficulty in relocating some sites and the close distance between coordinates. Error between sets of survey coordinates was also noted due to precision difference in GPS Equipment used during different surveys. New occurrences were located and inventoried in this population.
Blue Bench	South Pinto Hanksville	Blue Bench	BLM, SITLA	2014	229	The population was discovered in 2013 and first surveyed in 2014.
Total					**5,411**	

San Rafael cactus

At the time of listing, the species was known only from two populations, approximately 25 miles apart (Section 1.4). These two populations were estimated to contain 2,000-3,000 individuals each (52 FR 34914, September 16, 1087). In 1995, an additional population was discovered and the total population of the species was estimated to comprise 20,000 individuals (USFWS 1995). Since that time, many additional occurrences of San Rafael cactus have been documented. Based on historic records, re-inventory efforts over the past five years, and recent discoveries of additional populations and occurrences, we now know of 20 populations of San Rafael cactus consisting of a total of approximately 8,200 documented individuals (BLM 2012, 2012a, 2013a; Truman 2014, 2015). As described above (Section 1.4), NatureServe criteria were used to delineate populations.

Not all survey sites were revisited within the past six years (2011-2015), and only the available survey data was used to determine current population levels. Populations range in size from as few as 4 recorded individuals at the Little Wedge population to approximately 3,700 at the Wedge population (Robinson 2011; Truman 2014, 2015). More than half of the populations are under 100 recorded individuals and only two populations (the Wedge and Millsite/Clawson) are over 1,000 individuals. Although recorded population size is partially correlated with the amount of effort and number of surveys performed, many of the known populations appear to be small in size. Future survey efforts should target populations that are recorded as small or have not been surveyed recently. This would allow for a more accurate estimate of current population size and would determine whether any of these smaller populations are connected. Connected populations should be considered part of a single, larger population. Monitoring should also continue to evaluate the larger populations to ensure their continued long-term viability.

Due to differences in survey methods over time, the addition of new occurrences, and variable survey results from year to year, it is not possible to determine an accurate population trend for this species with the available data. Additionally, no long term monitoring plots were established for this species. See Table 3 for population summary.

Table 4. San Rafael Cactus Population Summary

Population Name	Alternative Population Names	Grazing Allotment(s)	Land Ownership	Year(s) of Most Recent Survey	Number of Individuals Found	Notes on Population
North and West McKay Flat	N of McKay West McKay	McKay Flat, Red Canyon	BLM	2011, 2014	111	77 individuals were found in re-inventory surveys in 2011 and an additional 34 were found in 2014 surveys. One historic site in this population (North of McKay Flat) has not been surveyed since 1999). This population may be connected to other McKay Flat allotment populations. More surveys are needed.
Sinbad Country	Sinbad country	McKay Flat	BLM	2015	107	This population may be connected to other McKay Flat allotment populations. More surveys are needed.
Big Ridge South/Keesle Country	Big Ridge South Keesle Country	McKay Flat	BLM	2014	57	Three historic sites in this population have not been surveyed since 1990. This population may be connected to other McKay Flat allotment populations. More surveys are needed.
Big Ridge West	Big Ridge West Big Ridge	McKay Flat	BLM	2011	112	Three historic sites in this population (Big Ridge West key area) have not been surveyed since 1990. This population may be connected to other McKay Flat allotment populations. More surveys are needed.
Horse Valley	Horse Valley	McKay Flat	BLM	2011, 2015	278	This population may be connected to other McKay Flat allotment populations. More surveys are needed.
Slaughter Slopes	Slaughter Slopes	Mussentuchit	BLM, SITLA	2001	2	Two individuals were found here in 2001, possibly on SITLA land. No resurvey has been performed since, but as this is 12 km (7.5 mi) from the nearest other occurrence it would constitute a separate population. More surveys are needed.

Population Name	Alternative Population Names	Grazing Allotment(s)	Land Ownership	Year(s) of Most Recent Survey	Number of Individuals Found	Notes on Population
Mussentuchit Mine	Bentonite Mine Wests Reservoir Last Chance	Mussentuchit	BLM, SITLA	2014	84	All historic sites appear to have been resurveyed. Some occurrences are more than 2 km (1.2 mi) apart over suitable habitat; however researchers have observed occurrences between recorded sites and believe they are a single population (Truman 2014). More surveys are needed.
Blue Flats	Blue Flats	Mussentuchit	BLM, SITLA	1998	38	This population has not been re-inventoried and consists of a single historic site. More surveys are needed.
North of Red Point	N of Red Point	Mussentuchit	BLM	2005	17	This population has not been re-inventoried. Three historic sites exist but two list an unknown number of individuals. More surveys are needed.
End of the Road	Road End	Mussentuchit	BLM	2013	59	All historic sites were resurveyed.
Mesa Butte	Blue Flats Reservoir	Lone Tree	BLM, SITLA	2011	105	All historic sites appear to have been resurveyed. Some occurrences are more than 2 km (1.2 mi) apart over suitable habitat; however researchers have observed occurrences between recorded sites and believe they are a single population (Truman 2014). More surveys are needed.
Millsite/Clawson	Diversion Hollow Millsite Reservoir Eli Hollow Indian Bench West Clawson Reservoir Ferron	Ferron Mills NW Ferron Clawson Dairy	BLM	2010-2015	2,090	All historic sites were re-inventoried and new site have been discovered.
Railroad Grade	Railroad Grade	Chimney Rock Flat	BLM	2011	49	All historic sites were re-inventoried.
Humbug	Chimney Rock	Chimney Rock Flat Humbug	BLM	2011-2014	579	All historic sites were re-inventoried.

Population Name	Alternative Population Names	Grazing Allotment(s)	Land Ownership	Year(s) of Most Recent Survey	Number of Individuals Found	Notes on Population
Cottonwood Creek	Cottonwood Creek Hambrick Bottoms	Hambrick Bottoms	BLM	2011	20	All historic sites were re-inventoried.
Molen Tanks/Ferron	North of Red Hole Draw Red Hole Draw East of Reef Dry Wash South Ferron	Molen Tanks North Ferron South Ferron Dry Wash	BLM	2011-2013, 2015	610	Some occurrences are more than 2 km (1.2 mi) apart over suitable habitat; however researchers have observed occurrences between recorded sites and believe they are a single population.
Little Wedge	None	Fuller Bottom	BLM	2012	4	Only 4 plants were located in the 2012 survey, but there were likely more present (Truman 2014). More surveys are needed.
Wedge	Wedge Overlook Buckthorn	Buckhorn	BLM, SITLA	2011, 2014	3,735	Surveys were conducted in 2011, 2014 and 2015.
Little Holes	Furniture Draw	Little Holes	BLM, SITLA	2015	79	Survey conducted in 2015
Dripping Spring	None	Dripping Spring	BLM, SITLA	2014	23	This is a new population. Many more individuals were observed than were documented during the survey (Truman 2014)
Total					**8,159**	

1.7 LISTING FACTORS AND CONTINUING THREATS DISCUSSION AND ASSESSMENT

Threats facing Winkler cactus and San Rafael cactus at the time of listing (52 FR 32914, September 16, 1987 for San Rafael cactus and 63 FR 44587, August 20, 1998 for Winkler cactus) included collection for horticultural purposes, OHV-related activities, livestock trampling, and mineral exploration (including uranium, gypsum, and clay mining). The discussion under each listing factor, below, addresses the threats identified at the time of listing and newly identified and/or predicted threats that are likely to occur in the foreseeable future.

Recovery of Winkler cactus and San Rafael cactus depends on the reduction of risks to the point where the protections of the Act are no longer necessary (i.e., the species is no longer in danger of extinction or likely to become so within the forseeable future in all or a significant portion of its range). This requires an understanding of the relative level of endangerment or extinction risk posed by individual and combined threats to the species' continued survival, which is derived from a structured threats assessment. The following assessment considers: (1) the extent to which the cacti are exposed to each threat described in the preceding section; and (2) the level of risk posed by each identified threat.

A note about disturbance: Monitoring plans established by the BLM, NPS, and USFWS outlined disturbance thresholds for San Rafael and Winkler cactus as 5 percent at each survey site (IA Team 2011, 2011a). Five percent was chosen because it is the level below which disturbance will not likely have a significant negative impact on a population (IA Team 2011, 2011a). These thresholds were determined by the USFWS in coordination with BLM and CRNP as the level of disturbance that would trigger implementation of additional conservation measures to protect the species. Distance from cacti to livestock disturbance was measured during inventories in 2011 and 2012 and cacti were considered disturbed by livestock if a hoof print was found within 15 cm (5.9 in) of a cacti. This distance was used because an average cattle hoof print is 10 cm (3.9 in) in diameter and 15 cm (5.9 in) is approximately the length of the shallow horizontal roots of a medium sized Uinta Basin hookless cactus (*Sclerocactus wetlandicus*), which is a related species with similar habitat requirements and life history (Spector 2013). This disturbance threshold is used by the BLM, USFWS, and CRNP as a useful measurement tool to determine whether the level of livestock disturbance at a site is within acceptable limits. The 5 percent disturbance threshold within 15 cm (5.9 in) has also been applied to other sources of disturbance including OHV/human disturbance, invasive species, and wild horse/native ungulate disturbance.

1.7.1 FACTOR A. The present or threatened destruction, modification, or curtailment of habitat or range.

The small populations, specialized habitat requirements, and slow growth habit of Winkler cactus and San Rafael cactus make these species highly vulnerable to human-caused habitat disturbances. OHV-related activities, mineral development, road and utility corridor development, and livestock trampling have all adversely affected these species (Clark and Clark 2008; Clark 2008b; Heil 1984, 1987, 1994; Neese 1987; NPS 2013; BLM 2013, 2013a; USFWS 1995, 2009, 2010; 52 FR 32914, September 16, 1987; 63 FR 44587, August 20, 1998).

These species are especially vulnerable during the spring flowering period when they are at or above ground and seasonally moist soils make them susceptible to damage and mortality from surface disturbance of their habitat (Section 1.6). OHV-related activities and livestock grazing are most intense during the mild spring season when these species are most vulnerable to habitat disturbance and can be easily dislodged from the ground. The species also forms flower buds in the autumn that persist over winter (Heil *et al.* 1981). These flowering buds are at the ground surface level and vulnerable to surface disturbance. We do not know impacts to or response of individuals that remain entire below ground during disturbance events

1.7.1.1 Off-highway Vehicle (OHV) Use and Other Recreational Activities, and Impacts Associated with Roads

For this document, OHV refers to any motorized vehicle (including motorcycles, all-terrain vehicles, 4x4 trucks or jeeps, etc.) that travel cross-country, or off designated roads or highways. OHV and recreational trail use (e.g., mountain bikes and motorized bikes), including associated camping and road maintenance activities, may result in habitat fragmentation and loss through soil compaction, increased erosion, rutting, invasion of nonnative invasive species, reduced pollination, and damage or mortality of individual plants (Eckert *et al.* 1979; Lienert 2004; Lovich and Bainbridge 1999; Ouren *et al.* 2007; Wilson *et al.* 2009).

Road traffic and OHV use mobilizes and spreads dust and particulates, thereby contributing to the fragmentation of habitat (Craig *et al.* 2010; Farmer 1993; Trombulak and Frissell 2000). Dust comprised of finer particulates causes improper functioning of the stomata of plants (Eller and Brunner 1975; Eveling and Bataille 1984; Fliickiger *et al.* 1979; Rawson and Clarke 1988; Ricks and Williams 1974), resulting in increased water loss. Dust can also decrease the ability of plants to photosynthesize (Sharifi *et al*. 1997). Dust affects photosynthesis, respiration, transpiration, water use efficiency, leaf conductance, growth rate, plant vigor, gas exchange, and allows the penetration of phytotoxic gaseous pollutants (Eller 1977; Farmer 1993; Hobbs 2001; Sharifi *et al.* 1997; Thompson *et al.* 1984; Trombulak and Frissell 2000). These impacts result in reduced plant fitness and reduced seed-set.

Dust impacts vegetation composition at least out to 400 m (1312 ft) from the edge of a road; impacts are greater nearer roads than further away (Everett 1980; Hobbs 2001; Myers-Smith *et al.* 2006). For every vehicle traveling one mile of unpaved roadway once a day, every day for a year, approximately 2 ½ tons of dust are deposited along the 1524 m (500 ft) to either side of the road center line along that mile (McGarigal *et al.* 2001). The relationship between vehicle speed and dust emissions is linear (Hobbs 2001: Sanders and Addo 1993). For instance, reducing vehicle speeds from 30 miles per hour to 15 miles per hour reduced dust emissions by 50 percent (Hobbs 2001).

The deposition of dust from OHV use affects plant-animal relations as well, including those between pollinator and plant (Aizen *et al.* 2002; Debinski and Holt 2000; Gathmann and Tscharntke 2002; Kolb 2008; Lennartsson 2002; Moody-Weis and Heywood 2001). Fragmented plant populations are less attractive to insect pollinators, which spend more time in larger, unfragmented plant habitats (Aizen *et al.* 2002; Kolb 2008; Lennartsson 2002). As previously described (see section 1.6,), pollinator visitation to plants is positively affected by plant population size (Goverde *et al.* 2002; Kolb 2008). Diversity and pollination effectiveness of insect pollinators tends to be higher and inbreeding is lower in larger, denser populations (Goverde *et al.* 2002; Kolb 2008; Lennartsson 2002; Mustajarvi *et al.* 2001; Steffan-Dewenter and Tscharntke 1999). Lower pollinator visitation rates are also associated with lower seed-sets in fragmented sites compared to intact sites (Jennersten 1988). Thus, habitat fragmentation negatively impacts plant reproductive success (Aizen *et al.* 2002).

Bee populations occur in naturally patchy landscapes. Habitat fragmentation caused by anthropogenic processes, including the proliferation of roads and OHV use, changes native bee habitats and populations (local extinction, persistence, or proliferation)(Cane 2001). This study also indicated that species composition can also be affected due to alterations in nesting substrate. Ground nesting bee species sometimes have specific nest site requirements including soil substrate, texture, moisture, salinity and aspect (Cane 2001). Some solitary bee species tend to use the same nesting places for decades (Gathmann and Tscharntke 2002). In fact, nest sites are more often a limiting factor than pollen or nectar (Gathmann and Tscharntke 2002). Anthropogenic alteration of nests sites and fragmentation of the landscape negatively affects pollinators that are necessary for the persistence of cactus species.

OHV and other recreational use and road maintenance activities may cause direct mortality of cactus via the crushing of plants by tires, damage to individual plants, decreased vigor from dust deposition, and impacts to pollinators and their habitat (Clark 2008, 2010, 2011a; BLM 2013a; Truman 2014). Injured or damaged plants may persist for several years with reduced reproductive potential before recovering or succumbing to their injuries (Clark *et al*. 2015). Hard-tired OHVs such as motorcycles and four wheel drive trucks are most damaging to both species' habitat. These vehicles can cause damage and mortality even when plants are dormant. Increased erosion as a consequence of OHV-related activity damages the natural cryptobiotic crust potentially increasing loss of individual plants (Spector 2015). In addition, OHV trails and open areas provide increased access for collectors, thereby facilitating illegal collection of cacti (Factor B and Factor D).

Natural resource utilization for outdoor recreation, particularly OHV-related activities and biking, severely affects some Winkler cactus and San Rafael cactus populations, and if not properly managed, OHV related activities in the direct vicinity of plants, could cause long-term, irreparable harm. In addition, the demand for recreational and general access is likely to grow as the regional human populations increase, exerting more pressure on these species.

BLM has restricted OHV use to existing trails and routes in all Winkler and San Rafael cactus habitat since 2008 and is currently addressing some of these impacts through implementation of their RMP and the development of a travel management plan (BLM 2008, 2008a). Although known locations of San Rafael cactus, and Winkler cactus may rebound and persist with effective management controls, compliance by OHV riders to these rules must be high in order to provide adequate protection for the species and law enforcement may be required in areas where voluntary compliance to signs and regulations is poor.

Winkler cactus

Approximately 45 percent of recorded Winkler cactus plants occur within CRNP (the entire Rock Springs population and 78 percent of the Hartnet population, Figure 13). Off-highway vehicle use is not allowed within CRNP and thus OHVs are not a threat to the portions of the population within the park. However approximately 20 percent of known occurrences within CRNP occur within 400 m (1,312 ft) of unpaved roads (USFWS 2014), the range at which dust is known to impact the plant community (Spector 2013a). The remaining recorded plants occur on BLM land (52 percent) or SITLA land (3 percent) adjacent to CRNP. All BLM and SITLA Land with known populations of Winkler cactus allows OHV use, but vehicles are restricted to designated routes only. No vehicular cross-country travel is permitted where Winkler cactus is known to occur (BLM 2008a).

The Richfield BLM Field Office restricted OHVs to designated routes in 2008 (BLM 2008a) which may be helping to reduce OHV impacts to the species. There is little available data regarding level of compliance to designated route travel requirements for OHVs over the range of the species but surveys include presence of OHV tracks near cacti (BLM 2013).

The 2011-2013 inventory of Winkler cactus by the BLM recorded only two individuals out of 2,703 surveyed as being impacted by OHV use (i.e., within 15 cm (5.9 in) of an OHV track) and none damaged by OHV use (BLM 2013). This report did not note the presence or absence of OHV tracks further than 15 cm (5.9) from a recorded individual, or whether a surveyed site showed any other OHV use in violation of BLM designated routes. However, BLM and NPS botanists have stated they believe compliance for OHV use near Winkler cactus sites is generally good (Clark 2011a; Rooks 2014). We do not know the compliance of OHV use on SITLA lands. However, approximately 37 percent of recorded individuals of Winkler cactus on BLM or SITLA land are within 400 m (1,312 ft) of a road or designated OHV route (BLM 2008a; USFWS 2014), and thus the species may still be vulnerable to the effects of OHV use even though OHV impacts prior to 2008 were likely significantly greater.

In summary, and based on available information regarding OHV use in Winkler cactus habitat, OHV use has a documented detrimental effect on cactus and cactus habitat. Although direct impacts from OHV appears to be low, the little amount of compliance data for OHV use on BLM and SITLA land over the entire range where Winkler cactus occurs and the proximity of significant percentages of the population to unpaved roads and OHV routes is cause for concern. Therefore, we designate the threat level from OHV use and impacts associated with roads for Winkler cactus as **moderate**. This level may be reassessed if more detailed OHV use and compliance data near Winkler cactus occurrences is collected showing high rates of compliance.

San Rafael cactus

The majority of the known San Rafael cactus individuals occur near established unpaved roads and are subject to dust effects. Pressures from recreation, including OHV use and biking are extremely high at the two largest known San Rafael cactus populations.

All recorded individuals of San Rafael cactus occur on BLM (85 percent) or SITLA (15 percent) land that is open to OHV use on designated routes only. Two heavily used, unofficial OHV recreational areas are located adjacent to or within occupied habitat areas and are impacting individual plants and their habitat. One of these areas is at the type locality (the location from which the species was first described and named) for the species (BLM 2013a).

OHV-related impacts to individuals and habitat of three populations of San Rafael cactus are well documented and tend to occur where they are near populated areas and compliance with travel restrictions is low. The two largest documented populations of San Rafael cactus are both subject to heavy OHV impacts including the creation of new, unauthorized routes within the populations (BLM 2012a). These two populations, Wedge and Millsite/Clawson, contain the majority of the recorded individuals of the species. In addition, the Molen Tanks/Ferron population had OHV disturbance documented in 2012 (BLM 2012).

In 2011 3,488 individual San Rafael cacti were identified with data points and an additional 634 individuals were observed at the Wedge population. In total, 99 sites were surveyed containing from 0 to 159 cacti each. At 70 percent of these sites evidence was found of unauthorized OHV use and 100 percent of the sites were in areas frequently used for OHV recreation (Robinson 2011). To address this issue, the BLM is partnering with Emery County to install barriers to prevent OHV use off of designated trails in this area (Truman 2014). We do not know the compliance level of OHV use in SITLA lands within the Wedge population.

Within the Millsite/Clawson population, both sites surveyed in 2011 and 2012 exceeded 5 percent disturbance by OHVs. Additionally, evidence of unauthorized OHV use was observed in multiple locations throughout the population (BLM 2012, BLM 2012a) including immediately adjacent to individuals (Truman 2014). The BLM is partnering with local OHV recreational groups to attempt eliminate cross country travel through improved signage and restoration of effected areas (Truman 2014).

Two of the three sites surveyed in 2012 in the Molen Tanks/Ferron population documented OHV disturbance as a concern – one site documented 2 percent disturbance from OHV use and the other had 10 percent disturbance (BLM 2012). The remainder of the populations does not have significant OHV impacts and receive lower recreational use with higher rates of compliance (BLM 2012a). Price Field Office restricted OHVs to designated routes in 2003 (BLM 2008). Prior to 2003, OHV impacts were likely significantly higher.

In addition to OHV use, other forms of recreation, including camping and bike riding, exert pressure on some San Rafael cactus populations, particularly the Wedge and Millsite populations. The Wedge area is known as the Little Grand Canyon and is an extremely popular recreation site. A 24-kilometer (15-mile), unauthorized bike trail around the rim of the Wedge known as the Good Water Rim Trail has existed for many years and runs through known occupied San Rafael cactus habitat (BLM 2015). In addition to regular use, which includes many side trails and user created detours near documented cactus occurrences, an annual bike festival has been held at the Wedge for the past nine years, which involves large numbers of people camping in the area and utilizing the trail at one time (MECCA 2015). The BLM proposes to designate this as an official bike trail and believes, based on past compliance in other locations, that this designation would allow for better enforcement in the area and help eliminate off trail activity and creation of side trails.

Overall, the majority of documented plants and three populations (including the two largest populations), comprising approximately 10,500 ha (25,946 ac) of occupied habitat, occur in areas known to have high recreation levels, high OHV use, and unauthorized off-trail uses (particularly in the absence of clearly signed and designated trails). The BLM has taken measures to reduce OHV impacts at these populations but the effectiveness of these measures has not yet been documented. The negative impacts of OHV use, including physical injury and mortality, and negative impacts to reproduction from dust, soil erosion and compaction, within plant populations is well documented, as described above.

In summary, the negative effects of OHV on cactus and cactus habitat are well documented. There is extremely high recreation pressure on the two largest San Rafael cactus populations and there is a high concentration of OHV use and poor adherence to designated routes in and around these populations. These factors are combined with the presence of additional recreation pressures, which are increasing throughout the region.

Therefore, we designate the threat level from recreation (including OHV use, camping and biking) and existing roads as **high**. This level may be reassessed pending continued action by the BLM and local partners to reduce recreation impacts to San Rafael cactus populations and/or quantifiable results showing a decrease in OHV-related and other recreation disturbance in and around those populations.

1.7.1.2 Livestock grazing

The deleterious effects of livestock on western arid ecosystems and the cactus species are well-documented (Clark *et al.* 2015; Jones 2000). Trampling by livestock can disturb the soil cryptobiotic crust layer (Belnap and Gilette 1997) which can result in increased erosion and reductions in soil fertility and soil moisture (Belnap *et al.* 2001; Belnap *et al.* 2009; Kuske *et al.* 2012; Rosentreter *et al.* 2007; Schwinning *et al.* 2008). Cryptobiotic crusts are beneficial for plant establishment and growth (Belnap *et al.* 2001), and may take hundreds of years to recover from disturbance (Belnap 2003). Cryptobiotic crust occurs at many sites for both species, and contains important nitrogen-fixing bacteria at several Winkler cactus sites (Spector 2015). Soil compaction by livestock trampling can affect water infiltration, soil porosity, and root development, making cacti less able to take up water and more vulnerable during drought conditions (Castellano and Valone 2007; Sharrow 2007).

Cattle trampling can result in severe damage to individual cacti, particularly in heavily travelled areas such as watering areas, fences, and along trails (Clark *et al.* 2015) (Figure 14). A long term study of 106 Winkler cactus from 1995 through 2015 in an area of CRNP heavily used by livestock showed that 60 percent of cactus directly impacted (stepped on) by cattle died within 4 years of the impact. In addition, 65 percent of directly impacted cacti were observed to bloom after they had been impacted, compared with a bloom rate of 78 percent for those that were not impacted (Clark *et al.* 2015). Although a similar study was not conducted on San Rafael cactus it is reasonable to assume mortality rates would be similar, based on similarity in morphology, known life history, and close genetic relatedness. These cacti species also form flower buds in the autumn that persist over winter (Heil *et al*. 1981). The flowering buds occur at the ground surface level and are vulnerable to surface disturbance during winter grazing activities.

As livestock use an area, they can cause changes to soil structure from trampling the ground and help introduce invasive species which changes the structure of the plant community. This, in turns, can alter the insect community. Some of these changes include damage to ground-nesting pollinators and their nests, changes in water infiltration due to soil compaction, subsequent nonnative invasive plant invasions, and changes in the timing and availability of pollinator food plants (Jones 2000).

A literature review of the research on the effects of livestock grazing on listed Colorado Plateau cacti species concluded that the activity comprises a novel ecological disturbance process to which these cacti species are poorly adapted (Spector 2013). Cacti evolutionary and life history traits and their desert habitats generally result in naturally low vital rates. Livestock grazing likely results in suppression of already low population growth rates, through lowered recruitment rates (Clark 2008a; Clark *et al.* 2015; Clark and Clark 2008). Growth rates for these cactus species are difficult to determine, but may be as little as 1-2 cm (0.4-0.8 in) total over 14 years for non-impacted individuals (Clark 2008a). This slow rate of growth makes it difficult for these species to recover from impacts resulting from livestock grazing, as it takes many years for these species to reach a large size. Because reproductive effort is positively correlated with size, impacts from livestock grazing that negatively affect size would be expected to negatively affect reproduction and species survival (Clark 2008c; Spector 2013).

In summary, livestock grazing affects to the listed cacti species include the following (Spector 2013):

- Trampling cacti causing direct mortality.
- Trampling cacti causing injury or stress resulting in reduced fitness and reduced defenses to predators.
- Trampling suitable habitat causing soil disturbance thus preventing seedling germination and recruitment.
- Trampling of soils causing soil compaction resulting in increased water stress and reduced resiliency during drought.
- Altering vegetation community through selective grazing and widespread trampling resulting in increased herbivory from rodents and lagomorphs.
- Altering vegetation community with the introduction and spread of competing invasive plant species.
- Disruption of soil biological crusts resulting in sedimentation, erosion, reduced soil-water retention and fewer suitable recruitment sites.
- Fragmentation of populations, thus reducing or preventing pollination leading to reduced fitness.

- Continual disturbance with no rest period exhausting stored resources and preventing cacti from returning to good condition.
- Degradation of community processes and function reducing plant health, recruitment rates, and potential for recovery.

Figure 14. Damage/Disturbance from Livestock on Winkler cactus (Photo by Tova Spector/USFWS)

Winkler cactus

Trampling by livestock has been recognized as a threat to Winkler cactus since at least 1981 (Spector 2013). Cattle grazing is currently allowed in most Winkler cactus populations. The Rock Springs grazing allotment was retired in 1998 (Table 4) (NPS 2013), but this allotment contains only 2 percent of known Winkler cactus individuals.

Table 5. Grazing in Winkler cactus range

Allotment Name		Federal Land Acreage	Federal Active AUMs	Percent of Winkler individuals in allotment	Population(s) of Winkler cactus occurring in allotment
1	Hartnet (CRNP)	72,816	1,141	36%	Hartnet
	Hartnet (BLM)	22,990	1,802	21%	Hartnet, Notom
2	Sandy #1	30,608	1,180	37%	Notom
3	Rock Springs	103,875	0	2%	Rock Springs
4	Blue Bench	111,361	4,601	4%	Blue Bench

The Hartnet gazing allotment within CRNP is authorized for 1,141 AUMs of cattle between October 15 and May 31, and the BLM portion of the Hartnet grazing allotment is authorized for 1,802 AUMs of cattle between October 15 and May 31. The Sandy #1 allotment is authorized for 1,180 AUMs between October 15 and May 31. Of the recorded individuals of Winkler cactus, 94 percent of them occur on the Hartnet and Sandy #1 grazing allotments. The remaining 4 percent of recorded individuals occur on the Blue Bench grazing allotment (BLM 2008; IA Team 2011).

In the two primary populations of Winkler cactus, which make up 94 percent of the total recorded population (i.e, Hartnet and Sandy #1), approximately 50 percent of sites surveyed had livestock disturbance over the 5 percent threshold and in some cases over 50 percent. No grazing takes place in the Rock Springs population (NPS 2013).

Since 1983, livestock use in Winkler cactus habitat has decreased 39 percent for the Hartnet grazing allotment, 17 percent for the Sandy #1 allotment, and 31 percent for the Blue Bench allotment (Jackson 2009). The AUMs within CRNP were reduced by half in 1988, and a reduction of AUMs in corresponding monitoring plots resulted in an increase in the number of cacti in all size classes over a 20 year period. This increase was observed in monitoring for fenced and unfenced plots. After the reduction of AUMs, cactus number and size classes increased at a higher rate in fenced plots than in unfenced ones (Clark 2008a).

A 1999-2005 Winkler cactus study to determine response to livestock pressure was initiated in CRNP. This study used two replicates of fenced and unfenced plots but was ultimately inconclusive due to illegal harvesting of study cacti during two sampling periods (Clark and

Clark 2008). Despite confounding results, this study provides some basic information on the effects of livestock grazing on cactus mortality. In one of the unfenced plots, cattle trampling killed 6 percent of the tagged cacti over the study period. In the other unfenced plot 37 percent (14 of 38) of the cacti were killed as a result of livestock trampling during the 6 year study period (Clark and Clark 2008).

In 2008, 17 sites within CRNP that were surveyed in 1998 were revisited to determine presence of Winkler cactus. Heavy livestock trampling was attributed to the loss of cacti at two sites and a decrease of cacti by half at a third site. The decline at all three sites corresponded with heavy livestock trampling from cattle and wild horses (Clark 2008b). Cacti within CRNP are consistently found damaged or disturbed by cattle at high rates (above 5 percent and at some sites up to 100 percent) even after a reduction of AUMs in the park (Clark 2008, 2011, 2012; NPS 2011, 2012, 2013).

A twenty year study on the impact of livestock trampling on Winkler cactus followed tagged individuals within a monitoring plot located at CRNP, in an area subject to high levels of livestock usage. It found that disturbance of an individual by cattle increased the likelihood of mortality of that individual over the next two years. Multiple disturbance events of the same increased the likelihood of mortality exponentially with each event. Additionally, after a disturbance event an individual's likelihood of flowering was decreased by 53percent compared to a non-disturbed individual (Clark *et al.* 2015).

On BLM land from 2011 to 2013, 39 Winkler cactus sites in the Hartnet and Notom populations were surveyed and one third of these sites showed livestock disturbance over the 5 percent threshold, at levels from 22 percent to 83 percent. Approximately 2 percent of cacti surveyed during that time were directly damaged by cattle. An additional 5 percent were damaged by rodents, whose number can increase as an indirect result of livestock grazing (Spector 2013). No disturbance surveys were performed at the recently discovered Blue Bench population, but the area was described as "lightly grazed" during the 2014 survey (Rooks 2014).

In summary, the negative effects to Winkler cacti from livestock grazing increase with increasing livestock use. Very few to no cacti were recorded as trampled during low to moderate livestock activity. As livestock activity increases, so does disturbance levels near cacti (Clark 2008b). There is extremely high grazing pressure throughout the majority of the species' range. The negative impacts of livestock grazing on the species and the habitat are well documented. Additionally, livestock grazing exacerbates other threat factors (including response to drought potentially caused by climate change and predation).

Therefore, we designate a **high** threat level to Winkler cactus from livestock grazing and trampling. This threat level may be reassessed if changes in land use and grazing pressure on Winkler cactus populations occur.

San Rafael cactus

Trampling by livestock has been recognized as a threat to San Rafael cactus since at least 1981, with impacts to cacti documented regularly since that time (Heil et al. 1981; Spector 2013).

Grazing is permitted throughout the known range of San Rafael cactus and evidence of livestock has been recorded in every population, although grazing pressure is not equal at every population or every surveyed site within a population. San Rafael cactus occurs on 19 grazing allotments managed by the BLM Price Field office (Table 6).

Table 6. Grazing in San Rafael cactus range

Allotment Name		Federal Land Acreage	Federal Active AUMs	Percent of San Rafael individuals in allotment	Population(s) of San Rafael cactus occurring in allotment
1	Buckhorn	49,640	3,626	49%	Wedge
2	Chimney Rock Flat	24,221	1,200	8%	Railroad Grade, Humbug
3	Clawson Dairy	1,830	65	3%	Millsite/Clawson
4	Dry Wash	8,290	560	3%	Molen Tanks/Ferron
5	Ferron Mills	3,050	150	21%	Millsite/Clawson
6	Fuller Bottom	11,560	629	<1%	Little Wedge
7	Hambrick Bottoms	16,410	2,005	<1%	Cottonwood Creek
8	Little Holes	2,790	80	<1%	Little Holes
9	Lone Tree	107,234	5,271	1%	Mesa Butte
10	McKay Flat	47,350	1,274	6%	North and West McKay Flat, Sinbad Country, Big Ridge South/Keesle Country, Big Ridge West, Horse Valley
11	Molen Tanks	4,970	490	2%	Molen Tanks/Ferron
12	Mussentuchit	52,360	1,998	3%	Slaughter Slopes, Mussentuchit Mine, Blue Flats, North of Red Point, End of the Road
13	North Ferron	7,370	882	<1%	Molen Tanks/Ferron
14	Humbug	37.957	3,020	1%	Humbug
15	Northwest Ferron	1,980	118	1%	Millsite/Clawson
16	Red Canyon	36,830	2,249	Unknown; historic occurrence	North and West McKay Flat
17	South Ferron	4,130	245	<1%	Molen Tanks/Ferron. Dry Wash
18	Dripping Spring	19,313	1,069	2%	Dripping Spring
19	Mounds	22,353	759	1%	Dripping Spring

Due to the larger range and number of populations of San Rafael cactus, and the difficulty in accessing some of the sites, livestock disturbance and impact records are not as detailed as those for Winkler cactus. However there is still ample documentation of negative livestock impact in multiple San Rafael cactus populations, particularly the Wedge, Millsite/Clawson, and Mesa Butte populations. Typically, the sites with the highest pressure from livestock are those containing a water source or cattle trailing areas (Truman 2014).

Livestock trampling was documented to impact 1 percent, 12 percent, and 12.5 percent of the cacti sampled in three monitoring plots at the Wedge population in 2010 (Clark 2010). One monitoring plot in the same population containing 50 cacti experienced 12 percent mortality from cattle trampling over four years (Clark 2010). In 2011, 30 percent of the San Rafael cactus survey sites visited by the BLM had livestock tracks within 15 cm (5.9 in) of individual cacti at rates above the 5 percent disturbance threshold (i.e., the rate of disturbance identified by the interagency rare plant team, above which conservations actions should be taken to reduce disturbance) (BLM 2011: IA Team 2011). In 2012, 43 percent of survey sites visited by the BLM had disturbance rates greater than 5% (BLM 2012).

As of 2012 the populations with documented disturbance from grazing were: the Millsite/Clawson population (primarily the portion near Clawson Reservoir and Eli Hollow); the Wedge population (in areas less used for recreation that have watering sites for cattle); and the Mesa Butte population (which receives heavy trailing from livestock at sites near the road and is located near reservoirs) (BLM 2013a; Spector 2013; Truman 2014).

Two of the populations (Millsite/Clawson and the Wedge) with high levels of documented disturbance contain the majority of the recorded individuals and both face high pressures from recreation and native ungulates. A livestock disturbance rate of 24% was documented where the Millsite/Clawson populations occur around the West Clawson Reservoir. Mesa Butte is currently documented to be a small population; most of the known individuals occur along the road side where cattle trail and may be endanger of extirpation from cattle impact. Livestock disturbance was documented at 35% of the individuals in that population (BLM 2012, Truman 2014). In the detailed survey of the Wedge population in 2011, grazing disturbance was noted at 44% of sites surveyed (Robinson 2011).

Other populations that have been partially or entirely surveyed over the past five years and are open to grazing are Molen Tanks/Ferron, Little Wedge, Railroad Grade, North and West McKay Flat, Horse Valley, Big Ridge West, and Blue Flats. No disturbance from livestock was recorded within 15 cm (5.9 in) of any individual cactus for these populations. However, evidence of grazing was observed (BLM 2012a, Truman 2014). Disturbance levels from grazing at the remaining populations (Dripping Spring, Dry Wash, Little Holes, Slaughter Slopes, Mussentuchit Mine, Cottonwood Creek, North of Red Point, and End of the Road) are not known.

In summary, less long term monitoring data exists for San Rafael cactus than for Winkler cactus, but the effects of livestock disturbance and impact on the species are likely comparable due to similarity in morphology, known life history, and close genetic relatedness. There is grazing pressure throughout the species' range and high pressure on several survey sites which include the majority of recorded individuals. The negative impacts of livestock grazing on the cacti and its habitat are well documented. Additionally, livestock grazing exacerbates other threat factors (including response to drought potentially caused by climate change and predation).

Therefore, we designate a **high** threat level to San Rafael cactus from grazing. This threat level may be reassessed if changes in land use and grazing pressure on affected populations occur.

1.7.1.3 Native Ungulate Disturbance

Native ungulates (elk and deer) in large numbers can impact cacti in similar ways to livestock grazing. Traditionally, native ungulates do not congregate in large herds the way that livestock do, and thus likely do not cause high levels of disturbance to soils and plants in most places. However, high levels of ungulate use in localized areas (which may be affected by human developments and livestock presence) has been shown to impact Winkler and San Rafael cactus in portions of some populations (BLM 2013, 2013a; NPS 2011, 2013).

Current information on native ungulate use around clusters of Winkler cactus and San Rafael cactus demonstrates the presence of mule deer and elk using these areas at low intensity levels or intermittently at higher levels, as compared to livestock use in the same areas which is more widespread and continuous.

Winkler cactus

Monitoring shows that elk and deer prints near listed cacti at Capitol Reef National Park are not as severe or regularly occurring as that from livestock. Elk prints within 15 cm (5.9 in) of Winkler cacti ranged from 2-10 percent of cacti surveyed in 2011-2012. Deer prints were found within 15 cm (5.9 in) of only 1-1.7 percent of Winkler cactus (NPS 2013).

Between 2011 and 2013, five survey sites in the Hartnet population within CRNP had greater than 5 percent disturbance rates by native ungulates (22-31 percent), which correlated with the survey sites that had lower amounts of disturbance by livestock. Of the 2,380 plants surveyed in CRNP between 2011 and 2013, 15 were recorded as being trampled by elk (NPS 2013). In the Hartnet population outside of CRNP and in the Notom population, native ungulate disturbance was found at only 1 percent of surveyed cacti and no damage was recorded. This discrepancy may be due to the higher elevations of some of the survey sites at CRNP. Surveys for native ungulate disturbance have not been performed at the Blue Bench population.

Due to the localized nature of native ungulate impacts, we designate a **low** threat level for native ungulate disturbance at this time. This level may be reassessed if native ungulate patterns change or additional populations in areas of high use by native ungulates are discovered.

San Rafael cactus

Deer prints have been documented within 15 cm (5.9 in) of San Rafael cactus at several sites and can locally be more abundant than livestock tracks but are not as widespread (Spector 2013). For example, in the Millsite/Clawson population, deer disturbance within 15 cm (5.9 in) was found in places at rates over 20 percent, including one survey site with a rate of 95% (BLM 2012); the survey sites are located near an area called Diversion Hollow (BLM 2012; Truman 2014). Deer winter in the area and spring use is high in some parts of the Millsite/Clawson population area. Deer were not noted as a major factor of disturbance at any of the other survey sites or populations for San Rafael cactus during the 2011-2012 surveys (BLM 2012a).

Although the Millsite/Clawson population makes up approximately 40 percent of the recorded individuals of San Rafael cactus, heavy deer use only impacts a portion of this population.

Due to the localized nature of native ungulate impacts, we designate a threat level of **low** for native ungulate disturbance. Steps should be taken in the areas of the Millsite/Clawson population to reduce deer impact in the most heavily affected areas. This threat level may be reassessed if native ungulate patterns change or additional populations in areas of high use by native ungulates are discovered. Actions should still be taken to protect portions of populations receiving high levels of disturbance.

1.7.1.4 Wild Horse Disturbance

Impacts and disturbance to plants and habitat from wild horses and burros can be very similar to those of cattle and other livestock grazing. Wild horses and burros occur within a portion of San Rafael cactus range in the BLM Price Field Office planning area (BLM 2008a). Wild horses and burros are not known to occur within the range of Winkler cactus.

The BLM Price RMP designates 283,000 acres for wild horses in the Muddy Creek Herd Management Area (HMA), 55,000 acres for horses in the Range Creek HMA, and 99,210 acres for burros in the Sinbad HMA. Herds are managed under the Federal Land Policy and Management Act of 1976. The BLM monitors the herd size at a minimum of every three years and adjusts the herd size based upon available forage to comply with their Standards for Rangeland Health (BLM 2013). Aircraft and motorized vehicles are used in round-up activities.

Populations of San Rafael cactus that overlap with wild horse or burro herds or management areas are North and West McKay Flat, Sinbad Country, Big Ridge South/Keesle Country, Big Ridge West, Horse Valley, Mussentuchit Mine, Blue Flats, North of Red Point, End of the Road, Molen Tanks, and Dry Wash. Of these populations, impacts or disturbance from wild horses were reported at North and West McKay Flat, Sinbad Country, Big Ridge South/Keesle Country, Big Ridge West, and Horse Valley, all of which fall close together in the McKay Flats grazing allotment (and may be connected). In 1999, 85 percent of 20 sites surveyed by the BLM in the McKay Flats allotment had recorded impacts by wild horses (Clark 1999). In 2011, 15 percent of cacti in the Horse Valley population (where there is a known horse dust bath area) were disturbed by horse tracks within 15 cm (5.9 in), while 1 percent in the Big Ridge West population was likewise disturbed. Four of the plants recorded in the allotment (1 percent) were trampled by wild horses. No other disturbance by horses was recorded, although horse tracks and sign were recorded at the other populations in the McKay Flats allotment (BLM 2011a). A horse trail was also observed at a survey site in the Molen Tanks population in 2012, but no disturbance was recorded (BLM 2012a).

The five populations in the McKay Flats allotment (Table 6) that have the highest pressure from wild horses make up approximately 8 percent of the recorded individuals of San Rafael cactus, and may be connected into a single population.

Due to the localized nature of the wild horse disturbance and the relatively small number of individuals impacted (<3 percent of the population), we designate a **low** threat level from wild horses and burros to San Rafael cactus. However, given that the San Rafael cactus in the McKay Flat allotment has a unique haplotype from other studied San Rafael cactus populations (Porter *et* *al.* 1999), preservation of these populations to ensure genetic diversity should be a priority and management steps to protect San Rafael cactus within the most heavily impacted areas should be considered. This threat level may be reassessed if wild horse and burros pressures on the McKay flats population increase or if land use patterns by wild horse and burros begin impacting the other populations within the Horse Management Areas.

1.7.1.5 Energy and Mineral Exploration and Development

The habitat of San Rafael cactus is underlain by potential oil and gas reserves and gypsum deposits. The habitat of Winkler cactus is underlain by bentonite clay and uranium ore deposits (52 FR 32914, September 16, 1987; 63 FR 44587, August 20, 1998). Surveying and development of these deposits has the potential for adversely impacting these species and their habitat. Mining activities, including oil and gas exploration and development, can impact cactus by destroying habitat, increasing erosion potential and dust deposition, fragmenting habitat through access road construction, degrading suitable habitat, and increasing invasive plant species (Brock and Green 2003). Impacts to individual cacti include crushing and removing plants, reducing plant vigor, and reducing reproductive potential in damaged plants and through increased dust deposits. This reduces seedbank quantity and quality, and decreased pollinator availability and habitat (Brock and Green 2003).

Winkler cactus

Energy/mineral exploration and development is not a threat to the Rock Springs population or the portion of the Hartnet population within CRNP, as mining and energy development is not allowed within national parks. For the portion of the Hartnet population outside of CRNP and the Notom population, approximately 50 percent of the recorded individuals are on BLM land that is not open to leasing or disposal for salable and non-energy solid leasable minerals or for fluid mineral (oil and gas) leasing. Additionally, 30 percent are on BLM land open to leasing subject to minor constraints such as seasonal restrictions. The remaining 20 percent are on BLM land open to leasing subject to no additional constraints (BLM 2008a).

The Blue Bench population is located on BLM land designated open to leasing or disposal for salable and non-energy solid leasable minerals and for fluid mineral (oil and gas) leasing subject to no additional constraints (BLM 2008a). There are currently no active leases or leases put forward for sale near any Winkler cactus populations and approximately 75 percent of Winkler cactus recorded individuals are protected from future energy development.

There are no known coal resources near any Winkler cactus populations. Several survey sites are located close to active mining claims for other locatable minerals. Two recorded points exist just inside the borders of active mining claims; however, those points are from 1986 and 1998, and prior to the use of GPS in the field and have not been relocated since, so it is unknown if their locations are accurate and whether mining poses a risk to them. Recent resurveys did not find any individuals within the bounds of active mining claims, although several of them are in Winkler cactus habitat and it is extremely possible cacti could be found there (BLM 2013). None of these claims were permitted for surface disturbance activities and cactus surveys should be required before any such action would be taken. No current or historic oil and gas wells or oil and gas lease parcels exist near Winkler cactus populations (BLM 2013).

In summary, the detrimental effects of energy and mineral exploration and development are well documented, but there is a general lack of current and historic mining activity and oil and gas development within the range of the species and low potential in the foreseeable future.

Therefore, we designate a **low** threat level for energy and mineral exploration and development on Winkler cactus at this time. Surface disturbance permitting on active mining claims or the sale of leases for fluid or non-energy solid minerals within the range in the future could cause the threat level to increase, as could discovery of additional populations in areas with more active mineral development.

San Rafael cactus

Approximately 86 percent of the total population San Rafael cactus occurs on BLM land that is open to oil and gas leasing either with no additional constraints or subject to minor constraints, including the entirety of the two largest populations (The Wedge and Millsite/Clawson). Twenty percent of the Millsite/Clawson population and 80 percent of the Humbug population occur on active oil and gas leasing parcels (USFWS 2014). No current impacts to either population are known. However, previous energy development activity in the Millsite area has destroyed individual plants and occupied habitat (BLM 2008a; Clark 2011). In 2012 and 2013, there was a request for lease sales that would have overlapped 80 percent of known occupied habitat for the species (Truman 2014). However the requests for these parcels were deferred due to time constraints for proper analysis and concerns about impacts to rare plants, including San Rafael cactus. There continues to be a high amount of interest in oil and gas leasing in known San Rafael cactus habitat, some parcels with known occupied habitat were nominated in 2015 (Truman 2015).

Bentonite clay mining impacted the Mussentuchit Mine population by destroying individual plants and occupied habitat in the mid-1990s, and the population occurs entirely on land with registered mining claims, although no surface disturbance activities have been recently permitted there (Clark 2011). A portion of the Mesa Butte and Wedge populations also occur on land with active mining claims, and there is an active gypsum mine in close proximity to the population, permitted for 63 ha (155 ac) of surface disturbance. A 2007 survey found no individuals of San Rafael cactus within the area proposed for disturbance (USFWS 2009).

In summary, there is a high level of interest in development throughout the range and the majority of the species' occupied habitat is open to leasing. The negative impacts on cactus habitat from oil, gas, and mining development, are well documented.

Therefore, we designate a threat level for energy and mineral exploration and development for San Rafael cactus as **high**. This level may be reassessed if occupied areas are closed to leasing in the future (or made subject to more rigorous restrictions) or if leases are sold in occupied or suitable habitat.

1.7.1.6 Road and Utility Corridor Development or Other Construction

Unauthorized utility and road development within the Notom population of Winkler cactus caused individual plant mortality and habitat degradation in 1995 (63 FR 44587, August 20, 1998). Currently, no plans for road or utility corridor development intersect with known San Rafael or Winkler cactus populations. One construction project exists that will impact San Rafael cactus. The Natural Resources Conservation Service is proposing to raise the level of the Millsite Reservoir Dam and this will affect several individual San Rafael cacti by flooding and increased recreational impacts; however, impacts from this project to the range-wide population of San Rafael cactus will be minimal (NRCS 2015).

There are many existing roads within both species' habitat, primarily unpaved. Several populations or portions of populations of both species are located directly along dirt roads. Maintenance of these roads may impact individuals and care should be taken by local authorities to avoid cactus populations when performing this maintenance.

Because there is no currently pending construction, road, or utility corridor development projects within known occupied habitat of Winkler cactus and only one pending project in known occupied habitat of San Rafael cactus, we designate a **low** threat level for road and utility corridor development or other construction for Winkler cactus and San Rafael cactus at this time. This level may be reassessed if new projects are put forward that would impact known cacti populations, or if new populations are discovered that would be impacted by road and utility corridor development projects.

1.7.1.7 Paleontological Exploration and Excavation

Although not mentioned in the listing decision, San Rafael cactus may be subject to some impacts from paleontological exploration and excavation. Emery County is the location of a number of paleontological sites, including the Cleveland-Lloyd Dinosaur Quarry near Price. Paleontological interest in the area has been increasing with recent finds on BLM land (Truman 2014). Disturbance to plants from paleontological activities can include direct injury or mortality of plants situated at an excavation site, effects from dust due to surface disturbance at excavation sites, and impacts from associated activities such as camping near and hiking into sites by paleontological field crews.

In 2013 and 2014 BLM informally consulted (section 7, ESA) with us on two dinosaur excavation projects near the Mussentuchit Mine population. Crews working on the dig were trained to identify San Rafael cactus and to walk in washes where cacti do not occur when hiking to and from the dig location. No cacti were directly disturbed by the dig (Truman 2014). The Dripping Spring population is located near the Cleveland Lloyd Dinosaur Quarry and may be subject to surface disturbance from fossil prospecting, and from excavation disturbance in the future if additional sites are found. Both areas may experience impact from workers going to and from their excavations, and from camping, although in all cases so far the workers have been warned about the cactus and ways to minimize their impact (Truman 2014).

In summary, potential impacts to San Rafael cactus from paleontological exploration and excavation are trampling by workers walking to and from sites, trampling around camping areas, and damage to plants growing directly on dig sites being excavated. These impacts can be largely abated through training of paleontological crews, and currently no cacti have been identified within dig sites.

We therefore designate a **low** threat level from paleontological exploration and excavation to San Rafael cactus at this time. This threat level may be reassessed if additional paleontological sites are found in San Rafael cactus habitat.

1.7.1.8 Invasive Species

Invasive species were considered as a threat in the listing decision for San Rafael cactus but not for Winkler cactus. Nevertheless, non-native invasive species are known throughout the ranges of Winkler cactus and San Rafael cactus, the most common of which are cheatgrass (*Bromus tectorum*), halogeton (*Halogeton glomeratus*), and Russian thistle (*Salsola tragus*). Cheatgrass and halogeton are considered some of the most ubiquitous invasive species in the Intermountain West due to their ability to rapidly invade native dryland ecosystems and out-compete native species (Duda *et al.* 2003; Harper *et al.* 1996; Masters and Sheley 2001; Stoddart *et al.* 1951). Halogeton and Russian thistle are also linked to increasing soil pathogens that may attack and kill germinating seeds and seedlings of native perennial plants (Harper *et al.* 1996).

Invasive annual species can alter ecological relationships in desert ecosystems by altering soil chemistry and outcompeting native species (Duda *et al.* 2003; Harper *et al.* 1996; Stoddart *et al.* 1951). Although halogeton is a poor competitor in healthy perennial communities, it rapidly invades and dominates disturbed areas (Duda *et al.* 2003; Stoddart *et al.* 1951). Invasive species may inhibit the germination and reestablishment of new recruits into a population resulting in a gradual decline and eventual expiration of a site that has been invaded. Disturbance from livestock grazing facilitates the spread and introduction of invasive species, and presence of invasive species is correlated with grazing pressure (Spector 2013).

Winkler and San Rafael cactus inhabits sparsely vegetated areas that are not prone to fire, but the presence of invasive plants can alter local fire regimes (Stoddart *et al.* 1951; Harper *et al.* 1996; Brooks and Pyke 2001; Brooks *et al.* 2003; Duda *et al.* 2003). Cacti are not adapted to frequent fires in their habitats and are therefore not expected to persist through more frequent and intense fire cycles. In addition, fires may produce intense heat that can kill seeds, thereby reducing seedbank viability (Brooks and Pyke 2001).

No studies have been performed on the impact of invasive species on Winkler cactus and San Rafael cactus specifically. Some recent surveys have assessed the presence of invasive species at cactus sites, whether invasive species occur within 15 cm (5.9 in) of an individual cactus, and the level of invasion, but invasive species have not been confirmed as a significant threat at any one population (BLM 2013, 2013a; Clark 2011; NPS 2013). More research is needed to determine the impact of invasive species in Winkler cactus and San Rafael cactus habitat, and whether any particular populations are at risk.

In summary, there is a low incidence of invasive species in cacti habitat. There is also and the lack of high risk level at this time to any particular population or portion of a population, although there is legitimate concern that predation from insects or rodents on cacti may increase in the future.

Therefore, we designate a **low** threat level from invasive species to Winkler cactus and San Rafael cactus at this time. This level may be reassessed pending more data on invasive species within cacti populations.

1.7.2 FACTOR B. Overutilization for commercial, recreational, scientific, or educational purposes.

Illegal Commercial and Hobby Collecting

At the time of listing of Winkler cactus and San Rafael cactus, pervasive field collection of these species for commercial and hobby purposes was a significant threat. The listing rules stated that collectors could quickly reduce known populations if protective measures were not instituted (52 FR 32914, September 16, 1987 and 63 FR 44587, August 20, 1998). This concern was so significant that we determined that it was not prudent to designate critical habitat. Specifically, we determined publication of critical habitat maps detailing population locations would make the species even more vulnerable to illegal taking.

Illegal collecting of both species continues to occur. Winkler cactus and San Rafael cactus are attractive small cacti, especially when they are in flower. Although difficult to cultivate in most horticultural settings, these rare plants are highly desired in cactus collections and gardens and are sought by hobby and commercial cactus collectors (Hochstatter 1990; Heil 1984). The fact that these species are difficult to maintain in garden settings stimulates a continual demand for replacement plants as cultivated garden and greenhouse plants die. Cactus collectors are active in the Colorado Plateau, going from the habitat of one species of *Pediocactus* to the next to collect a complete set of the genus (Heil 1994; 52 FR 32914, September 16, 1987; 63 FR 44587, August 20, 1998).

A large portion of the Notom population of Winkler cactus has been severely reduced primarily from losses to collectors (Heil 1984; 63 FR 44587, August 20, 1998). Winkler cacti are also routinely taken from the Hartnet population. San Rafael cactus are taken from the Wedge and Millsite/Clawson populations because they are easy of access and cactus collectors are aware of their locations (Heil 1984). Cairns have been found marking Winkler cactus locations in the Hartnet population within CRNP, and were likely placed by collectors to return to in the future (Clark and Clark 2008). A long-term paired monitoring study within the Hartnet population was disrupted and was abandoned after significant, repeated theft from the plots (Clark and Clark 2008). It is unknown how many plants have been collected from these sites, but it is clear that illegal collecting is an on-going issue.

Several cactus locations are close to back roads and are known to collectors. However, most of these areas are off main thoroughfares and are not popular with visitors. They are also largely unchecked by federal law enforcement. Therefore, we do not know the level of illegal collection that occurs. Collectors can quickly reduce known populations, especially those that are small, if protective measures are not instituted.

The widespread, dispersed distribution pattern of the species may be to their advantage. Commercial scale collecting may be more time consuming and probably less profitable for these species than for a more densely grouped species like *Sclerocactus glaucus*. However, substantial law enforcement efforts are required throughout the backcountry where these cacti occur to address this threat.

Because of the wide range of both species and the difficulty in monitoring populations for illegal collection, it is difficult to determine what rate of illegal collection occurs and to what degree it impacts the populations. Portions of populations that are well known (such as both type localities) or those close to an accessible road are under a higher threat of illegal collection than sites located far from roads or populations that were recently discovered. Illegal collection has occurred in the two largest populations of Winkler cactus and the two largest populations of San Rafael cactus, comprising 94% and 74% of known individuals, respectively (Clark 2008).

In summary, there is a known historic impact on these species from illegal collect. The current scale of illegal collection is unknown, although many populations have locations well known to cactus collectors. However, new sites and populations have been discovered recently which are less accessible and not well known to collectors.

Therefore, we designate a **moderate** threat level from illegal commercial and hobby collecting for Winkler cactus and San Rafael cactus. This threat level may be reassessed if hard data on collecting activities is obtained or new methods of protection for cactus at vulnerable sites are implemented (Factor D).

1.7.3 FACTOR C. Disease or predation.

Insect and Rodent Predation

Disease and predation were not considered factors affecting the Winkler cactus or San Rafael cactus listing decisions (52 FR 32914, September 16, 1987; 63 FR 44587, August 20, 1998). We now know of cactus mortality occurring from insects and rodents, but it is unclear if these types of predation are having unnatural population-level effects to these cacti species. For example, the re-inventory study of Winkler cactus from CRNP found 2 percent of cacti damaged by rodents or insects from 2011-2013 (NPS 2013).

Rodents, including Ord's kangaroo rat (*Dipodomys ordii*), white-tailed antelope ground squirrels (*Ammospermophilus leucurus*), and *Peromyscus* mice are known to eat Winkler cactus fruits (BLM 2013a; Clark and Clark 2008; Clark 2008a; Kass 2001). The 2011-2013 re-inventory of Winkler cactus by the Richfield BLM Field office found 5 percent of plants damaged by mice, usually occurring to the fruits which were either damaged or removed entirely (BLM 2013a) (Figure 17). Impacts of rodent predation may be greatest during times of drought (Clark 2002). Despite the potential for rodents to affect individual cacti we have found no information that indicates that it has a population-level effect to Winkler cactus or San Rafael cactus.

Both species are susceptible to infestations and mortality of insect larvae, including the flightless cactus borer beetle (*Moneilema semipunctatum*) (Figure 15). The cactus borer beetle larvae enter the plant by eating tunnels, usually at ground level in the stem of the plant and ultimately ingest most of the plant stems' succulent cortex. Cactus-borer beetle predation can result in 25 to 30 percent mortality in cacti populations, and episodic die offs of significant portions of these species populations due to cactus borer beetles were observed within the past 25 years (Kass 1990; Neese 1987; USFWS 1995; 52 FR 32914, September 16, 1987; 63 FR 44587, August 20, 1998). It is unknown whether this is a new threat to the species, as the cactus borer beetle was only previously observed to use prickly pear cactus (*Opuntia* spp.) as hosts, or if it is a natural part of the cacti's lifecycle that had been previously unobserved. Cactus borer beetle has been expanding its range northward, possibly as a result of climate change (Kass 2001). Cactus borer beetles caused the death of five individuals in the Millsite/Clawson population of San Rafael cactus and damage to several more, but no other damage from insects or rodents was noted in available reports (BLM 2012, BLM 2012a).

Cacti infested by the cactus-borer beetle exhibit chew marks; shrinkage between growth segments; and a spongy and yellow appearance (Kass 2001). Beetle infestations cause lower vigor, decreased fecundity, and death of individual plants (Kass 2001). The beetles appear to select for larger, reproductively mature cacti, which likely results in a decline of reproductive rates (Kass 2001).

San Rafael cactus is also predated by weevils (Figure 16). At the Wedge population, 3 percent were found to be infested with weevils which consume the flower buds thereby preventing reproduction. An additional 5 percent were noted to have damage from an unidentified rodent or insect, and several were observed to be infested with the cactus borer beetle (Robinson 2011).

In summary, despite the potential for the cactus borer beetle to impact the cacti, we have found no conclusive information to indicate that it is having an unprecedented, population level effect on Winkler cactus or San Rafael cactus. The recently documented die-offs from beetle borer may be part of the species' natural life cycle. The recent levels of recorded damage or mortality to San Rafael cactus and Winkler cactus from insects and rodents during recent surveys are relatively low. Also, the predators thus far recorded have been species native to the ecosystem.

Therefore, we designate a **low** threat level for insect and rodent predation on Winkler cactus and San Rafael cactus at this time. This threat level will be reassessed if data shows pressure from predation to be increasing due to climate change or other factors, or that predation poses a substantial threat to particular populations.

Figure 15. San Rafael Cactus Mortality from the Cactus-Borer Beetle (Photo by Dana Truman/BLM)

Figure 16. Weevil damage to San Rafael cactus (Photo by Daniela Roth/USFWS)

Figure 17. Winkler Cactus With Fruits Removed by Rodent (Photo by Dustin Rooks/BLM)

1.7.4 FACTOR D. The inadequacy of existing regulatory mechanisms.

When Winkler cactus and San Rafael cactus were listed under the ESA the inadequacy of existing regulatory mechanisms was considered a threat due to illegal collections and the lack of state laws protecting endangered plants. Despite being protected by ESA and listed as Appendix I species under the Convention on International Trade in Endangered Species (CITES 2011; see section 1.7.4.1, below), these cacti species are still being illegally collected from the wild on federal and state lands and likely exported out of the country. Without adequate law enforcement protection of wild populations, these species remain insufficiently protected. In addition, there are currently no laws in the State of Utah that afford protection specifically to these species on State or private lands.

1.7.4.1 Federal Laws and Regulations

As discussed in section 1.7.2, collection for hobby and commercial purposes was considered a threat contributing to the listing of the species. Because much of the habitat is unpatrolled and due to the overall lack of law enforcement resources, the current degree of illegal collection is unknown, but theft has been recorded multiple times at the two largest populations of both species.

The CITES Appendix I includes species that may be threatened with extinction and which are or may be affected by international trade, including Winkler and San Rafael cactus. International trade in wild specimens of these species is subject to strict regulation and is normally only permitted in exceptional circumstances. Trade in artificially propagated or captive-bred specimens is allowed, subject to license. In the absence of ESA protection, these cactus would still be protected by CITES, although they may be moved to Appendix II, which provides less stringent protection for whole groups of organisms of trade value, including all member of the cactus family not listed in Appendix I (CITES 2011). Species listed under Appendix II may be granted an export permit as long as certain conditions are met, such as that the trade will not be detrimental to the survival of the species in the wild. Without ESA listing, CITES is not sufficient to protect these cactus due to continued illegal collection and lack of adequate law enforcement resources.

Land ownership within the ranges of Winkler cactus and San Rafael cactus is predominantly Federal (Table 2; Figures 6 and 7). The National Environmental Policy Act (NEPA) (42 U.S.C. 4371 *et seq.)* provides some protections for listed species that may be affected by activities undertaken, authorized, or funded by Federal agencies. Prior to implementation of projects with a Federal nexus, NEPA requires an agency to analyze the project for potential impacts to the human environment, including natural resources. In cases where the analysis reveals significant environmental effects, the Federal agency must consider mitigation to offset those effects (40 CFR 1502.16). However, NEPA does not require that adverse impacts be mitigated, only that impacts be assessed and the analysis disclosed to the public. In the absence of the ESA's protections, it is unclear if Federal agencies would provide sufficient protection for the species through the NEPA process.

The Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701 *et seq.)* is the primary Federal law governing most land uses on BLM lands and would be the primary law affording Winkler and San Rafael cactus protection on BLM lands absent the ESA. Section 102(a)(8) of the Federal Land Policy and Management Act states public lands will be managed, in part, to provide protection to ecological and environmental resources. The Special Status Species Management Policy Manual #6840 directs BLM to manage habitat for sensitive species in a manner that will ensure that all actions authorized, funded, or carried out by the BLM do not contribute to the need for the species to become listed (BLM 2008c). Both Winkler and San Rafael cactus are on the BLM sensitive species list for Utah. Typically, this means the impacts to these species are considered during project planning stages and conservation measures may be included, but are not mandated, at the discretion of agency biologists.

The BLM resource management plans (RMPs) provide some general habitat protection mechanisms. However, they have few species-specific protections for threatened or endangered plants such as Winker and San Rafael cactus. Existing RMPs incorporate protective mechanisms such as oil and gas leasing stipulations and lease notices, OHV trail designations, and land designations including Wilderness Study Areas (WSA), Areas of Critical Environmental Concern (ACEC), and wilderness designations. However, they do not fully address this species' needs, such as minimizing grazing impacts and habitat fragmentation (BLM 2008; BLM 2008a). In addition, many of these protective measures were developed because the species is listed under the ESA. Absent ESA protection, it is unclear how many of these measures would remain in place to ensure protection of these cacti.

As discussed above (Section 1.7.1.1), recently (2008)) the BLM Price and Richfield FOs revised their RMPs to designate OHV routes and play areas and close other areas including those where listed species are found. The closures and annual monitoring measures have resulted in better protection for the plants and their habitat, and resulting management actions and increased law enforcement have decreased impacts to plants and their habitat (BLM 2011a).

Winkler cactus has not been found within any BLM WSAs or ACECs, and no special area status has been designated for the species. The largest known population of San Rafael cactus, the Wedge population, occurs primarily within the San Rafael Canyon ACEC (6,151 ha/15,200 ac). Although these ACECs do not contain specific stipulations for the protection of the cactus, OHV use is restricted to designated roads and trails, rights-of-way are not granted, and oil and gas leasing is subject to major constraints including no surface occupancy. However, these ACECs are open to mineral development, grazing, and range improvement projects (BLM 2008a). As discussed above, these types of activities have been shown to cause a threat or potential threat to the species. Despite these protections, however, much of the San Rafael cactus Wedge population still faces threats from grazing or recreational use (Section 1.7.1), and approximately 25 percent of recorded individuals in this population occur on SITLA land which is not subject to the constraints of the ACEC. Because the ACECs were not strictly set aside for the protection of San Rafael cactus, it is unlikely that management prescriptions for populations within these ACECs would protect the species in the absence of ESA protection.

The small population of San Rafael cactus known as the Little Wedge population (most recent survey found only four individuals) is located within the Sids Mountain WSA (32,767 ha/80,970 ac) (BLM 2011a). The WSAs contain undeveloped United States federal land retaining its primitive character and influence, without permanent improvements or human habitation. They are managed to preserve their natural conditions and protect their value until a determination can be made whether to designate them as official Wilderness areas. Land falling within a WSA is protected from mining and energy development. However they allow some activities which would not be permitted in an official Wilderness area, including OHV use on designated trails (BLM 2008a). Because the WSA was not strictly set aside for the protection of San Rafael cactus, it is unlikely that management prescriptions for this WSA would protect the species in the absence of ESA protection. Without ESA protection, management activities within the WSA would not be required to address impacts to the species.

The NPS Organic Act of 1916 (39 Stat. 535, 16 U.S.C. 1, as amended), states that the NPS "shall promote and regulate the use of the federal areas known as national parks, monuments, and reservations … to conserve the scenery and the national and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." This law applies regardless of the species' listing status. The National Park Service (NPS) biological resource management policy is "to maintain as parts of the natural ecosystems of parks all plants and animals native to park ecosystems" (NPS 2006). Associated management principles direct conservation measures for listed and non-listed species within park boundaries. This includes Winkler cactus in CRNP.

The 1976 Mining in the Parks Act (16 U.S.C. 1901 *et seq.*), the Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701 *et seq.*), and the Clean Air Act of 1977, as amended, (42 U.S.C. 7401 *et seq.*) provided tools for parks to remove and prevent mining and drilling ventures (NPS 2002). All mining claims within CRNP were either declared invalid or were nullified by 1986 (NPS 2006). By the end of the 1980s, oil and gas leases also were either eliminated or suspended (NPS 2006). All national parks are now closed to new Federal mineral leasing (NPS 2006).

Winkler cactus is protected from some impacts within the boundaries of CRNP, including energy and mineral development and OHV use (Sections 1.7.1.1 and 1.7.1.5). However, plants occur in the immediate vicinity of existing roads and are susceptible to impacts from road traffic, maintenance and improvements, unauthorized access, and illegal collection. In addition, livestock grazing and trailing are allowed within the species' habitat on CRNP. Because of these impacts, despite regulatory mechanisms, the populations within the park are not fully protected. Therefore, regulatory mechanisms are inadequate to protect the species from the threats present on CRNP lands.

Although some regulatory mechanisms protect Winkler cactus and San Rafael cactus across their range, enforcement is difficult for threats posed by collection, unauthorized access, and road maintenance activities. Therefore, in the absence of the protection of federal rules and regulations, there would be inadequate mechanisms to protect the species from the majority of human-caused threats, and impacts to Winkler cactus and San Rafael cactus would be significantly higher.

The ESA is the primary Federal law that provides protection for Winkler cactus and San Rafael cactus. Section 7(a)(1) states that Federal agencies, in consultation with the USFWS, shall carry out programs for the conservation of endangered species. Section 7(a)(2) requires Federal agencies to consult with the USFWS to ensure any project they fund, authorize, or carry out does not jeopardize the continued existence of a listed species or modify their critical habitat. Jeopardy includes engaging in any action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR §402.02). Section 9(a)(2) of the ESA prohibits the following activities: 1) the removal and reduction to possession (i.e., collection) of endangered plants from lands under Federal jurisdiction, and 2) the malicious damage or destruction on lands under Federal jurisdiction, and 3) the removal, cutting, digging, damaging, or destruction of endangered plants on any other area in knowing violation of a State law or regulation, or in the course of any violation of a state criminal trespass law. Section 9 also makes illegal the international and interstate transport, import, export and sale or offer for sale of endangered plants and animals.

Existing regulatory mechanisms are aided by the protections afforded under the ESA. Many section 7 consultations with federal agencies have occurred since the listing of these species. For example, conservation measures specifically addressing the protection of Winkler and San Rafael cactus were included in section 7 consultations for the BLM Price and Richfield field offices' RMPs (BLM 2008a and b) and recent grazing permit renewals (USFWS 2009; USFWS 2010). The BLM committed to conducting intensive surveys and monitoring activities for applicable listed species over the term of the renewed grazing permits (USFWS 2009; USFWS 2010a). In the absence of the ESA it is unlikely that even basic protection measures such as surveys, monitoring, and impact minimization measures would be in place.

1.7.4.2 State Laws and Regulations

No laws in the State of Utah afford protection to plant species. Listed plants receive limited protection on state or private lands under the ESA (a federal nexus must be present) and through the Utah Mined Land Reclamation Act of 1975, which includes mineral mining (Utah Code Title 40, Chapter 8). The Utah Mined Land Reclamation Act mandates the preparation of State environmental impact assessments for large mining operations, which are defined as mining operations which create more than 2 ha (5 ac) of surface disturbance on State and private lands, including lands with patented mining claims. State environmental impact assessments must address, at a minimum, the potential effects on federally listed plant species, avoiding or minimizing impacts to plant species is not mandatory. Therefore, in the absence of protection from the ESA, protection of these cacti would not be guaranteed and is at the discretion of the management agency.

Utah protects native vegetation from harvest or transport without proof of ownership or landowner permission (Utah Code 78B-8-602). This law does not sufficiently protect Winkler cactus and San Rafael cactus because it is not well known or enforced. It also does not apply specifically to either cactus species.

No state laws protect the species from grazing on SITLA or private lands. At least 3 percent of Winkler cactus and 15 percent of San Rafael cactus individuals of both species occur on SITLA or private lands (BLM 2012; Spector 2013). However, all recent surveys have targeted Federal lands only and recorded individuals on SITLA or private land incidentally. Targeted surveys of suitable habitat on non-Federal land near known populations would likely yield additional individuals. In the absence of the protection of the ESA, there would be no mechanism to protect the species from grazing related impacts on these lands.

In summary, existing regulatory mechanisms, secured through the ESA, have reduced some threats on Federal lands. In the absence of the ESA's protective regulatory mechanisms, we believe the threats to the species would be amplified and cause further declines to both species. There are no state laws specifically protecting the species in Utah. Without the protection of the ESA, impacts to the species from OHV use, livestock grazing, and recreational activities would likely increase. These activities can kill or damage cacti, and degrade cactus habitat. In addition, the lack of monitoring data makes it difficult to determine the species' needs and provide long-term protection. Reducing pressure on the species from collection and unauthorized access is difficult because of limited law enforcement resources and the remoteness of the habitat. Continued efforts are needed through law enforcement and habitat protection to ensure the species is protected over the long-term and the ESA provides the legal protection to the species to enforce unauthorized harvest.

We therefore determine the inadequacy of regulatory mechanisms is a **moderate** threat to Winkler cactus and San Rafael cactus. This threat level may be reassessed if management policies that specifically address the protection of Winkler cactus and San Rafael cactus independent of the ESA are enacted throughout significant portions of their range.

1.7.5 FACTOR E. Other natural or manmade factors affecting the species' continued existence.

1.7.5.1 Small populations

The original listing decisions cited the restricted known localities and low population numbers as factors affecting Winkler cactus and San Rafael cactus. Small populations and species with limited distributions are vulnerable to relatively minor environmental disturbances (Given 1994). While small population size is not considered a threat in and of itself, small populations are also are at an increased risk of extinction due to the potential for inbreeding depression, loss of genetic diversity, and lower sexual reproduction rates (Ellstrand and Elam 1993; Wilcock and Neiland 2002).

Lower genetic diversity may, in turn, lead to even smaller populations by decreasing the species' ability to adapt, thereby increasing the probability of population extinction (Barrett and Kohn 1991; Newman and Pilson 1997). Species with limited ranges and restricted habitat requirements are also more vulnerable to the effects of global climate change (Section 1.7.5.2)(IPCC2002; Jump and Penuelas 2005). Additionally, pollinator visitation to plants is positively affected by plant density and pollination is limited by foraging distance of ground nesting bees (Section 1.7.1.1) (Goverde *et al.* 2002; Greenleaf 2005; Greenleaf *et al.* 2007; Kolb 2008;).

Since these cacti are almost completely self-incompatible (flowers unable to fertilize successfully with pollen from the same individual) (Tepedino 2000), having a high number of flowering individuals in an area reachable by pollinators is vital for outcrossing and reproductive success (Steffan-Dewenter and Tscharntke 1999).

The minimum viable population size for these cacti species is unknown. Viable population size of a closely related species, *Pediocactus bradyi*, is heavily influenced by changes in climate, particularly increased drought. Under historically normal climate conditions at least 500 individuals of *P. bradyi* were needed for a population to have a greater than 80 percent probability of avoiding quasi-extinction (fewer than 10 individuals in a population) within 75 years (Shryock *et al*. 2014). We can therefore consider that any population of Winkler cactus or San Rafael cactus smaller than 500 individuals to constitute a small population. Future species-specific population viable analyses may result in adjustments to this estimate.

The Rock Springs population of Winkler cactus is very small in size (99 individuals) (NPS 2013). The Blue Bench population consists of only 229 recorded individuals (Rooks 2014).In addition, extirpation of sites within the two large populations (Hartnet and Notom) has been documented (BLM 2013; NPS 2013). Continued extirpation of sites may result in those large populations becoming fragmented into small ones. Currently, the loss of one small population for this species would constitute a 25 percent reduction in the number of populations.

Of the known populations of San Rafael cactus, more than half consist of less than 100 recorded individuals and all but three consist of less than 500 individuals (even if the five populations in the McKay flats allotment were shown to be connected, that population would still consist of less than 500 individuals based on current data). This means a majority of populations of this species are moderately to extremely vulnerable to extirpation from known threats and stochastic events. Very little data on genetic diversity within this species exists, and none at all for many of these populations. The difference in morphological characters over the range of both species suggests that there may be genetic diversity in the species. The loss of any one population could constitute a major loss of genetic diversity for the species.

Additional genetic work on both these species and additional surveys focused on censusing small populations and determining connectivity between currently separated populations would increase our understanding of the threat small populations pose to Winkler cactus and San Rafael cactus. Population viability and demographic studies would help better define what constitutes a small or at-risk population for each species. Although we do not have a clear understanding of the viability of small populations, the small and decreasing number of individuals within some occupied sites combined with the other threats the species faces make them highly vulnerable to localized extirpations which may cumulatively result in the loss of entire sites or populations across significant portions of the species' range. The level of threat posed by small population size is only marginally influenced by the protection afforded under the ESA (i.e. increased law enforcement). However, the protection of the ESA increases the opportunities for studying and managing the effects of small population size on the species.

In summary, the negative effects of small populations are well documented and include decreased genetic diversity and increased risk of extirpation from existing threats and stochastic events. Approximately 50 percent of the known populations of Winkler cactus are small populations (and the large populations are in danger of being fragmented into small populations) and 86 percent of the known San Rafael populations are small populations. Small populations are more vulnerable to every type of threat than larger populations.

Therefore, we consider small population size to be a **factor**, present and acting on Winkler cactus and San Rafael cactus, which increases overall risk from other existing threats. This may be subject to reassessment if additional populations are discovered, existing populations are found to contain many more individuals than previously believed, and/or existing small populations are found to be connected.

1.7.5.2 Climate Change

Climate change was not identified as a threat to Winkler or San Rafael cactus at the time of listing, but we analyze it in this document based on the most recent information.
The term ‘‘climate change’’ thus refers to a change in the mean or the variability of relevant properties, which persists for an extended period, typically decades or longer, due to natural conditions (e.g. solar cycles) or human-caused changes in the composition of atmosphere or in land use (IPCC 2013a). Scientific measurements spanning several decades demonstrate that changes in climate are occurring. In particular, warming of the climate system is unequivocal, and many of the observed changes in the last 60 years are unprecedented over decades to millennia (IPCC 2013a). The current rate of climate change may be as fast as any extended warming period over the past 65 million years and is projected to accelerate in the next 30 to 80 years (National Research Council 2013).

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of greenhouse gas (GHG) emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions. Model results yield very similar projections of average global warming until about 2030, and thereafter the magnitude and rate of warming vary through the end of the century depending on the assumptions about population levels, emissions of GHGs, and other factors that influence climate change. Thus, absent extremely rapid stabilization of GHGs at a global level, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by human actions regarding GHG emissions (IPCC 2013b). Global climate projections are informative, and, in some cases, the only or the best scientific information available for us to use. However, projected changes in climate and related impacts can vary substantially across and within different regions of the world (IPCC 2013c) and within the United States (Melillo *et al.* 2014). Therefore, we use ‘‘downscaled’’ projections when they are available and have been developed through appropriate scientific procedures, because such projections provide higher resolution information that is more relevant to spatial scales used for analyses of a given species (Glick *et al.* 2011).

Various types of changes in climate can have direct or indirect effects on species. These effects may be positive, neutral, or negative and they may change over time, depending on the species and other relevant considerations, such as the effects of interactions of climate with other variables (e.g., habitat fragmentation) (Chen *et al.* 2011; Galbraith *et al*. 2010). In addition to considering individual species, scientists are evaluating potential climate change-related impacts to, and responses of, ecological systems, habitat conditions, and groups of species (Beaumont *et al.* 2011; Berg *et al.* 2010; Deutsch *et al.* 2008; Euskirchen *et al.* 2009; McKechnie and Wolf 2010; McKelvey *et al.* 2011; Rogers and Schindler 2011; Sinervo *et al.* 2010).

The Intergovernmental Panel on Climate Change and the U.S. Global Climate Change Program conclude that changes to climatic conditions, such as temperature and precipitation regimes, are occurring and are expected to continue in western North America over the next 100 years (Smith *et al*. 2000; Solomon *et al*. 2007; Trenberth *et al.* 2007). By the end of this century, temperatures are expected to warm a total of 2 to 5 °C (4 to 10 °F) in the Southwest (Karl *et al.* 2009). Annual mean precipitation levels are expected to decrease in western North America and especially the southwestern States by mid-century (IPCC 2007; Seager *et al*. 2007). These changes are likely to increase drought in the area where these species occur. An increase in the intensity and frequency of drought conditions may lead to a decline in abundance or range adjustments for the species. Some estimate that approximately 20 to 30 percent of plant and animal species are at increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5 °C (2.7 to 4.5 °F) (IPCC 2007). Drought conditions led to a noticeable decline in survival, vigor and reproductive output of rare plants in the Southwest during the drought years of 2001 through 2004 (Clark & Clark 2007; Hughes 2005; Roth 2008, 2008a; Van Buren & Harper 2003, 2004).

Increased competition from invasive species, pest outbreaks, and changes in fire regimes will put additional stressors on rare plants already suffering from the effects of elevated temperatures and drought. Impacts from livestock grazing can cause individuals and populations to have decreased drought resistance as well, through soil compaction and the inhibition of water infiltration into the soil. The effects of invasive annual species and livestock grazing, small population size, and insect predation, are discussed in detail under Factors A and C, respectively. These factors are acting together to negatively impact cactus resiliency and population stability (Section 1.8.5.4).

Drought years also resulted in a measurable increase in mortality and decrease in recruitment of Winkler cactus in CRNP (Clark 2008a; Clark *et al.* 2015). Overall, the smallest change in environmental factors, especially precipitation, plays a decisive role in plant survival in arid regions (Herbel *et al.* 1972). In addition, populations of many pest species are limited by low temperatures during parts of their life cycle and warmer temperatures are expected to lead to more pest outbreaks in some areas (IPCC 2007).

No studies specifically on the impact of drought on San Rafael cactus have been performed, but given the data available for other related species of cactus with similar ranges (Clark 2008a; Clark and Clark 2008). Increased drought conditions are likely to negatively impact the long-term persistence of the species. This is particularly true when drought impact is assessed cumulatively with small population size and other human-caused and natural threats. Drought plays a large role in the population dynamics of Winkler cactus, and likely impacts San Rafael cactus in a similar way. During the drought from 1999-2003, Winkler cactus experienced the largest rates of adult mortality over a 13 year period (Clark and Clark 2008). Adult mortality attributed to drought and increased infestation of cactus borer beetle was coupled with low rates of recruitment resulting in a declining population during years of drought.

The level of threat posed by global climate change is only marginally influenced by the protection afforded under the ESA (i.e. increases the potential of management activities for other threats). The protection of the ESA increases the opportunities for studying and managing the effects of climate on the species.

In summary, climate change and its impacts to the region are well documented and projected to continue and increase. There was a documented decline of Winkler cactus during the 1999-2003 drought, and the similarity of San Rafael to Winkler cactus suggests a comparable response. (Clark and Clark 2008). Additionally, rare plants have a negative response to drought (Roth 2003, 2004; Van Buren and Harper 2003, 2004), and drought severity and frequency is set to increase due to climate change (IPCC 2007; Karl *et al*. 2009).

Therefore, we designate a **high** threat level from global climate change on Winkler cactus and San Rafael cactus. There are uncertainties in our threat evaluation since downscaled climate projections are not available for our specific location, and a vulnerability assessment has not been performed for these species. We will re-assess the degree of threat climate change poses when more specific information becomes available.

1.7.6 Cumulative Effects from All Factors

Many of the threats to Winkler and San Rafael cactus are interconnected. Livestock grazing causes direct injury to plants, soil compaction, increased erosion of soil in the species' habitat, potential loss of pollinators, increases rodent populations, and improves the favorability of the habitat to invasive weeds (which in turn increases fire frequency). Livestock impacts to the soil also decrease its ability to retain moisture, which exacerbates the impact of drought (Spector 2013). OHV use and human recreation have similar impacts (Clark 2008; Ouren *et al.* 2007; Wilson *et al.* 2009). Both grazing and OHV use contribute to increased dust which damages plants directly and negatively impacts pollinators (Hobbs 2001; Sharifi *et al.* 1997; Trombulak and Frissell 2000). These and other surface disturbing activities also increase habitat fragmentation. This in turn increases the number of small populations and the risk that those populations may be extirpated due to lack of enough individuals for population viability or through stochastic events (Lennartsson 2002; Shryock *et al.* 2014). Habitat fragmentation decreases connectivity between populations and negatively impacts reproductive success, which limits gene flow (Aizen *et al.* 2002).

Climate change causes increased frequency of drought, which impact the species directly through lack of available water which reduces reproductive success and increases mortality (Clark 2008). Drought also exacerbates the impact of surface disturbing activities, including grazing, OHV use, construction, and energy development and mining, as low moisture in the soil makes it more vulnerable to erosion and increases dust levels. This negatively impacts both pollinators and plants (Damschen *et al.* 2010; Spector 2013). Increased CO_2 levels in the atmosphere are more favorable for the growth of invasive weeds, particularly grasses, which compete with native species, alter the structure of plant communities (including competing with non-listed species which provide floral resources for pollinators), and increase the frequency of fire (Smith *et al.* 2000, Ziska *et al*. 2005). Climate change may also be responsible for the recent northward expansion of cactus longhorn beetle, which have been increasingly found to damage Winkler cactus and San Rafael cactus. Cactus longhorn beetle has caused severe negative impacts to several closely related cactus species whose ranges overlap or are adjacent to these species (Coles *et al.* 2012; Kass 2001; Smith and Farrell 2005).

Our lack of scientific knowledge and large-scale demographic monitoring make it difficult to determine the most effective ways to abate many of these threats or to recover highly threatened populations, and the effects of climate change are largely out of management control (although measures can be taken to reduce the secondary impacts of climate change). In addition, threats from cactus collectors, as well as native ungulates and wild horses, add to pressure on these species and in some cases particularly impact populations (or portions of them) which face fewer impacts from the threats listed above.

Due the wide range of threats facing Winkler cactus and San Rafael cactus, the interconnectedness of the majority of them, and the inevitability of continued climate change, we designated the cumulative threat level for these species as **high**. This level may be reassessed if the individual threats designated as high decrease and additional scientific research and monitoring on the species results in a reassessment of the status of Winkler cactus and San Rafael cactus.

1.8 THREATS ASSESSMENT SUMMARY AND MATRICES

For this Recovery Plan we systematically examined what we know about the life histories of Winkler cactus and San Rafael cactus in the context of the same five factors we considered when we listed the species. In order to better understand how a given threat affects the species, each identified threat was partitioned into **stressors**, which are processes or events that negatively impact the species. Through this threats assessment process, we evaluated each stressor for its **scope**, **immediacy**, and **intensity**, as a way to identify the true magnitude of the potential threat. We then characterized the **exposure** of Winkler cactus and San Rafael cactus to the stressors and the **response** we would expect from the species if exposed to the stressor. Using this approach, we are able to integrate the scope, immediacy, intensity, exposure, response at the species level, and our professional interpretation, into an overall threat level (Table 7). The threats presented in the table are ranked according to our "Draft Guidance for Conducting Threats Assessment under the Act" (USFWS 2006).

Table 7. Key To Overall Threat Level Ranking Components

Scope (geographic extent of the stressor)	Localized- extent sums to 10 percent of the population or less.
	Moderate – extent sums to more than 10 percent population.
	Rangewide – stressor is present throughout the range
Immediacy (timeframe of the stressor)	Imminent – is the stressor present and acting on the target now
	Future – anticipated in the future
	Historic – the impact already occurred
Intensity (the strength of the stressor itself)	Low
	Moderate
	High
Exposure (the extent to which a target resource & stressor actually overlap in space and/or time given the scope)	Small (<10 percent of total population exposed)
	Moderate (11-50 percent of total population exposed)
	High (>51 percent of total population exposed)
Response (level of physiological/behavioral response due to a specific stress considering growth, fecundity, and mortality rates)	Basic need inhibited–basic plant needs for growth & development
	Basic need supported-basic plant needs for growth & development
	Injury – direct physical injury
	Mortality – identifiable reduction in growth rate or survival
Overall Threat Level (integration of the scope, immediacy, intensity, exposure, and response at the species level)	Beneficial (no action is needed)
	Potential (at this point in time, we lack scientific information regarding this factor to determine the overall threat level)
	Low (at this point in time, no action is needed)
	Moderate (action is needed)
	High (immediate action necessary)
Recovery/Management Potential (how possible it will be to reverse and abate the threat, based on technical expertise and management capabilities)	Low (no known management techniques, no way to predict success at this point)
	Moderate (management techniques are known but success is less predictable))
	High (management techniques are well-known and success is highly likely)

The threats matrices for each species are found below (Tables 8 and 9). As the matrices show, although all populations of each species are exposed to some threats; some activities threaten populations throughout the range, and some affect only a minority of sites. Pervasive threats to these species include OHV-related impacts, domestic livestock disturbance, commercial and hobby collecting, reproductive limitations due to small number of cacti per site, predation by insects and rodents, and the prospect of prolonged drought caused by climate change. Invasive non-native plants have the potential to increase in some occupied sites.

Table 8. Winkler Cactus Threats Matrix

Listing Factor	Threat	Scope	Immediacy	Intensity	Exposure	Response	Threat Level	Recovery/ Management Potential
Factor A. The present or threatened destruction, modification, or curtailment of the species' habitat or range.	Off-highway Vehicle (OHV) Use and Other Recreational Activities, and Impacts Associated with Roads	Moderate	Historic/ Imminent/Future	Moderate	Moderate	Basic need inhibited/Injury/ Mortality	**Moderate**	**Moderate**
	Livestock Grazing	Rangewide	Historic/ Imminent/Future	High	Moderate	Basic need inhibited/Injury/ Mortality	**High**	**Moderate**
	Native Ungulate Disturbance	Moderate	Historic/ Imminent/Future	Moderate	Small	Basic need inhibited/Injury/ Mortality	**Low**	**Low**
	Energy and Mineral Exploration and Development	Moderate	Future	Low	Moderate	Basic need inhibited/ Mortality	**Low**	**High**
	Road and Utility Corridor Development or Other Construction	Localized	Historic/Future	Low	Small	Basic need inhibited/ Mortality	**Low**	**High**
	Invasive Species	Rangewide	Historic/ t/Future	Moderate	Moderate	Basic need inhibited	**Low**	**Low**
Factor B. Overutilization for commercial, recreational, scientific, or educational purposes.	Commercial and hobby collecting	Moderate	Historic/ Imminent/Future	Moderate	High	Mortality	**Moderate**	**Low**
Factor C. Disease or predation	Small mammal and insect predation	Rangewide	Historic/ Imminent/Future	Low	Moderate	Basic need inhibited/Injury/ Mortality	**Low**	**Low**

Listing Factor	Threat	Scope	Immediacy	Intensity	Exposure	Response	Threat Level	Recovery/ Management Potential
Factor D. The inadequacy of existing regulatory mechanisms.	Inadequacy of Federal, State, and local laws and regulations	Rangewide	Historic/ Imminent/Future	Moderate	Moderate	Basic need inhibited/Injury/ Mortality	**Moderate**	**High**
Factor E. Other natural or man-made factors affecting the species' continued existence.	Climate Change	Rangewide	Imminent/Future	Moderate	High	Basic need inhibited/ Mortality	**High**	**Low**

Table 9. San Rafael Cactus Threats Matrix

Listing Factor	Threat	Scope	Immediacy	Intensity	Exposure	Response	Threat Level	Recovery/ Management Potential
Factor A. The present or threatened destruction, modification, or curtailment of the species' habitat or range.	Off-highway Vehicle (OHV) Use and Other Recreational Activities, and Impacts Associated with Roads	Rangewide	Historic/ Imminent/Future	High	High	Basic need inhibited/Injury/ Mortality	**High**	**Moderate**
	Livestock Grazing	Rangewide	Historic/ Imminent/Future	High	Moderate	Basic need inhibited/Injury/ Mortality	**High**	**Moderate**
	Native Ungulate Disturbance	Moderate	Historic/ Imminent/Future	Moderate	Small	Basic need inhibited/Injury/ Mortality	**Low**	**Low**
	Wild Horse Disturbance	Moderate	Historic/ Imminent/Future	Moderate	Small	Basic need inhibited/Injury/ Mortality	**Low**	**Moderate**
	Energy and Mineral Exploration and Development	Rangewide	Future	Low	High	Basic need inhibited/ Mortality	**High**	**High**
	Road and Utility Corridor Development or Other Construction	Localized	Historic/Imminent /Future	Low	Small	Basic need inhibited/ Mortality	**Low**	**High**
	Paleontological Exploration and Excavation	Localized	Imminent/Future	Low	Small	Basic need inhibited/Injury/ Mortality	**Low**	**High**
	Invasive Species	Rangewide	Historic/ Imminent/Future	Moderate	Moderate	Basic need inhibited	**Low**	**Low**
Factor B. Overutilization for commercial, recreational, scientific, or educational purposes.	Commercial and hobby collecting	Moderate	Historic/ Imminent/Future	Moderate	High	Mortality	**Moderate**	**Low**
Factor C. Disease or predation	Small mammal and insect predation	Rangewide	Historic/ Imminent/Future	Low	Moderate	Basic need inhibited/Injury/ Mortality	**Low**	**Low**

Listing Factor	Threat	Scope	Immediacy	Intensity	Exposure	Response	Threat Level	Recovery/ Management Potential
Factor D. The inadequacy of existing regulatory mechanisms.	Inadequacy of Federal, State, and local laws and regulations	Rangewide	Historic/ Imminent/Future	Moderate	Moderate	Basic need inhibited/Injury/ Mortality	**Moderate**	**High**
Factor E. Other natural or man-made factors affecting the species' continued existence.	Climate Change	Rangewide	Imminent/Future	Moderate	High	Basic need inhibited/ Mortality	**High**	**Low**

1.9 CONSERVATION MEASURES AND ASSESSMENT

Efforts to conserve these cacti and their habitat have been underway since the time of listing. The ESA requires us to sufficiently reduce the risk factors so that the risk of extinction is no longer imminent now or within the foreseeable future. The aim of recovery is for conservation to outpace threats until the ability of these species to persist within their natural ecosystems becomes likely. This section thus identifies ongoing conservation measures and informally assesses their contribution to recovery relative to the level of threat that still faces the species.

1.9.1 Surveys and Monitoring

Survey and repeat inventory efforts were completed throughout the range of both species beginning in 1987. These were a responsibility of the Interagency team from 1998 through 2008, which then transferred to individual managing agencies from 2011-2013. Because of these efforts we now have a better understanding of the status and distribution of the species as well as habitat requirements. Although we now know of many more occupied sites and populations than we did when we listed the species, not all suitable habitat has been surveyed. Some long term monitoring and demographic research has been conducted on Winkler cactus within CRNP, but rangewide monitoring that would determine population trends for both species was never initiated due to the lack of funding and staff resources. There is currently no comprehensive, funded plan from any of the managing agencies for continued inventory and monitoring of these species.

A habitat modelling project for both species has been initiated by the USGS, with funding from USFWS and the support of the BLM and CRNP, which will use existing inventory and site data to help determine potential suitable habitat and delineate the range of Winkler cactus and San Rafael cactus. The model will identify the most influential environmental factors of presence/absence for the species. This will be useful in locating additional sites and populations, as well as helping determine the need for cactus surveys prior to proposed projects that impact potential habitat.

1.9.2 Seed Storage and Propagation

Seeds of Winkler cactus and San Rafael cactus have been collected for conservation purposes, most recently in 2013. Seeds are currently stored and maintained at the National Center for Genetic Resource Preservation in Ft. Collins, CO and at Red Butte Garden in Utah. No plants are currently being propagated.

1.10 BIOLOGICAL CONSTRAINTS AND NEEDS

The purpose of this section, which synthesizes information presented in previous sections of the plan, is to identify limiting factors that must be considered when designing a management program for Winkler cactus and San Rafael cactus and when evaluating project effects on this species. Biological constraints for these cacti include predation, small population size and genetics (genetic drift, inbreeding depression), seedbank viability and low recruitment, effective habitat size and connectivity, and interdependence with pollinators for reproductive success. Abiotic environmental factors impacting populations include moisture regimes, temperatures, and soil restrictions. An understanding of biological limiting factors will inform not only recovery recommendations, but also section 7 consultations and other ESA activities that could benefit Winkler and San Rafael cactus.

1.10.1 Biotic habitat constraints and needs

Winkler and San Rafael cactus require intact habitats relatively free of invasive species. Both cactus prefers areas of low vegetation and may not be adapted to high interspecies competition (section 1.8.1.8.) Invasive plants not only increase competition, but also increase the frequency of fire in habitat (Harper *et al.* 1996). Cacti are not adapted to frequent fires in their habitats and are therefore not expected to persist through more frequent and intense fire cycles. In addition, fires may produce intense heat that can kill seeds, thereby reducing seedbank viability.

These species also require the presence of native plants which support their pollinators in order to successfully reproduction. Reproduction can be constrained not only by a lack of pollinators, but by predation from insects and rodents causing mortality or loss of fruit.

1.10.2 Adequate population size and gene flow

Winkler cactus and San Rafael cactus require populations that are large and well connected to thrive. It is likely that population sizes of at least 500 individuals per population are necessary to avoid extirpation. Half of the known Winkler cactus populations are small (less than 500 individuals known) and the other half may be at risk of being fragmented into small populations. For San Rafael cactus, 86 percent of the known populations are small (Section 1.8.5.1).

Small populations and species with limited distributions are vulnerable to stochastic extinction events and the effects of climate change. They are also at an increased risk of extinction due to the potential for inbreeding depression, loss of genetic diversity, and lower sexual reproduction rates (Ellstrand and Elam 1993; Given 1994; IPCC 2002; Jump and Penuelas 2005; Wilcock and Neiland 2002).

Composition of the populations is also important. Old, large size class Winkler cacti have the highest reproductive effort (Clark and Clark 2008). Therefore, site locations with a greater percentage of the larger size classes are those with the highest reproductive potential. If a population loses plants in these larger size classes due to drought, livestock activity, or other mortality factors, it is less able to sustain a high reproductive potential over the long-term, reducing already small populations.

1.10.3 Pollinators

Winkler and San Rafael cacti do not reproduce through vegetative methods, and their sexual reproduction is contingent on pollen reaching receptive stigmas for seed production. This biological process can be constrained by factors pertaining to pollen quality, quantity, pollinator success, and origin of pollen received. These cacti are likely unable to self-pollinate (Tepedino 2000). Therefore, a reduction or loss in pollinators over time could decrease the genetic viability and variability of these species and decrease the number of seeds within the seedbank (Spence 1993; Tepedino 2000). Even with a sufficient pool of pollinators, in years when plant numbers are low, fruit and seed production may be reduced either by poor pollination if pollinators are attracted to other co-flowering species, or by a reduction in plant mating types (Spence 1993).

Presence of pollinators depends on meeting their habitat and foraging requirements. Fragmented plant populations appear to be less attractive to insect pollinators which spend more time in larger, unfragmented plant habitats (Jennersten 1988). Pollinator visitation to plants is positively affected by plant population size and pollination is limited by foraging distance of bees. Reduced availability of pollinators could severely reduce population viabilities; thus, impacts on the plants and their pollinators must be considered together (Jennersten 1988). Therefore, conservation of pollinators and their habitats is fundamental to recovery of Winkler and San Rafael cactus. As habitats get more fragmented and wind pollinated nonnative invasive grasses increase, floral resources may become scarcer across the landscape, thereby limiting access to pollinators. Reproductive processes such as seed output also diminished as plants become more thinly dispersed across the landscape (Harper *et al.* 1996).

1.10.4 Seedbank and recruitment

We do not have a good understanding of the population dynamics for Winkler and San Rafael cactus, including the viability of the species, their seedbanks and the longevity of the seeds. Seedbanks are created by the persistence of seeds in the soil despite unfavorable germination conditions. This survivorship mechanism represents a biological constraint because an unknown percentage of genetic heritage remains dormant within the soil during times of prolonged drought or other unfavorable conditions. We do not have good data on how long the seedbank may remain viable, although we know that a range of factors, particularly livestock trampling and drought, negatively impact blooming rates of these species. Long term stresses could deplete the seedbank, making these populations more vulnerable to stochastic events.

If unfavorable conditions result in the reduction or loss of the species' habitat and seedbanks, this loss may reduce the overall resiliency of the species (Section 2.2). In general, these cacti have a very limited seed dispersal zone and the majority of the seeds are deposited near the parent plant (BLM 2011). However, water, natural soil erosion, wind, birds, and small ground animals may play a role in seed movement, as indicated by the distances between sites within populations. Given this, the protection of natural habitat processes and connectivity within the landscape is needed to allow natural dispersal over time.

Winkler cactus and San Rafael cactus are cacti that grow under an irregular moisture regime. The persistence of seeds in the soil through unfavorable germination conditions, i.e., the seedbank, as well as adult plant dormancy are survivorship mechanisms that represent biological constraints. In addition to the seedbank, an unknown percentage of genetic heritage remains dormant within the soil during times of prolonged drought. For example, Winkler cacti can remain underground for up to two years during times of drought (Clark and Clark 2008).

1.10.5 Abiotic needs and constraints

Winkler cactus and San Rafael cactus are associated with a variety of geologic formations (particularly the Dakota and Morrison formations for Winkler cactus and the Carmel and Moenkopi formations for San Rafael cactus) within a certain geographic area. The species are associated with certain physical features of the soil. These species are constrained by soil type and geologic formation. Although they are desert species, they are also constrained by water availability; drought has been shown to correlate with a decline in reproductive effort and an increase in mortality (Section 1.7.5.2.)

PART 2. RECOVERY STRATEGY

Strategic considerations for implementing an effective Winkler and San Rafael cactus recovery program include the species' current status relative to recovery needs and opportunities, the need for a general vision that will provide direction for the recovery process, and the need for broad solutions to problems that are affecting the species' ability to persist in the wild. These considerations are discussed in the following sections.

2.1 CURRENT RECOVERY STATUS

A species' recovery status is based on the balance between continuing threats and the amount of conservation that has been achieved, i.e., the degree to which threats have been abated and population viability has been ensured. As indicated previously (section 1.8), threats to the long-term persistence of the cacti in the wild continue to outpace conservation efforts. In particular, recreational land uses, illegal collection, energy and mineral development, and the effects of domestic livestock trampling have the potential to cause loss of individual populations and significant overall population declines. The rarity of the cacti increases their vulnerability to these and other threats; it also increases their susceptibility to loss of fitness due to deleterious small-population effects such as genetic drift and inbreeding depression. Both species are in the earliest phase of the recovery process, so it should not be surprising that threats outweigh recovery achieved to date. Likewise, the recovery program for these species is characterized to a large extent by biological uncertainties and information gaps. The recovery status of the cacti can thus be measured by their intrinsic vulnerability, the array of threats facing each species, and the relatively rapid pace at which these threats could lead to extinction.

2.2 GUIDING BIOLOGICAL PRINCIPLES

Conservation programs, including recovery programs for listed species, are strengthened by adherence to three primary principles of conservation biology--representation, resiliency, and redundancy (Shaffer and Stein 2000). Each concept focuses on a different aspect of ensuring a species' long-term survival. Representation involves conserving the breadth of the genetic makeup and natural variation across a species' range in order to conserve adaptive capabilities. Resiliency entails ensuring that each population is viable and sufficiently large to withstand stochastic events. Redundancy involves protecting an adequate number of populations to provide a margin of safety for the species to withstand catastrophic events (Shaffer and Stein 2000). The recovery program will take these principles into account when looking at population conservation needs for each species.

2.3 JOINT SPECIES RECOVERY STRATEGY

Recovery under the ESA is the process by which listed species and their ecosystems are restored and their future is safeguarded to the point that protections under the ESA are no longer needed. As implied, this means that population trends are favorable for long-term persistence in the wild, that evolutionary and ecological processes are intact and will remain so, and that specific threats, including but not limited to all those that led to listing the species in the first place, no longer pose a significant or likely risk of extinction. Using this definition and the principles outlined above as a conceptual framework for envisioning recovery of the species, it is clear that the status of these species must be greatly improved before they can be considered fully recovered. In addition, the recovery vision is based on two assumptions: first, that historic population numbers exceeded current numbers; and second, that continuing population declines are likely if conservation actions are not implemented.

Recovery of Winkler cactus and San Rafael cactus will hinge on conserving extant populations, primarily by abating threats such as illegal collection, grazing impacts, OHV related disturbances and through demonstration of increasing trends within existing populations or additional populations to ensure long-term demographic and genetic viability.

This will require the active involvement of experts and the public. It also will require a continuing recognition of the role each cacti plays in the ecology of central and southern Utah. Because of the biological and historic uncertainties regarding the status and recovery potential of these species, the recovery strategy is necessarily contingent on a growing understanding of the species and their ecological requirements. Consequently, a dynamic and adaptive approach will be essential to making effective progress toward recovery.

Recovery will include: (1) the sustained and stable presence of extant populations of each species and the possible discovery of additional stable populations, with the aim of ensuring representation and redundancy of each cacti; (2) long-term conservation of the ecosystems where these species are found (including the open land area needed for individual cactus and population growth, natural soil conditions, associated land formations and natural water hydrology, habitat for pollinators, and seedbanks), as a further means of ensuring redundancy; and (3) positive population trends and maintenance of natural population dynamics and genetic diversity, as a means of ensuring the resiliency of each species. The majority of populations, making up a representative sample of the species physical range and genetic variation must be sustained with stable or increasing trends in order to reach recovery. This includes extant and, any new populations found for each species. San Rafael cactus is currently comprised of twenty-one extant populations (see Table 3) with approximately 8,000 known plants on 58,000 acres (23,470 hectares). Winkler cactus is currently comprised of four populations (see Table 2) with approximately 5,400 known plants on 39,000 acres (15,780 hectares).

2.4 RECOVERY SOLUTIONS

Recovery solutions for Winkler cactus and San Rafael center on the removal of obstacles to their long-term viability, including the species' vulnerability to a variety of anthropogenic threats, information gaps, and a lack of legal safeguards coupled with the need for stronger public support. Recovery will be based on resolving these problems through a variety of possible solutions. The key recovery solution for both species is protection of occupied and suitable habitat through land management plans, conservation easements, and, where possible, acquisition of SITLA lands that provide occupied or suitable habitat for these species. In conjunction with habitat protection measures, habitat fragmentation can be remedied (that is, a needed level of connectivity among protected populations can be ensured) by protecting and maintaining existing lands between occupied locations. Land protection initiatives need to alleviate two of the threats of highest concern to these cacti species, i.e., domestic livestock trampling and OHV impacts. Illegal collection activity is another significant threat to the species that needs to be addressed through education and increased law enforcement participation.

Controlling OHV and livestock trampling impacts without exacerbating conflicts among competing interests will require creative solutions and partnerships that go beyond simply establishing land use restrictions. Long-term solutions will ultimately be based on: (1) finding opportunities to meet recreational and ranching demands without impinging on the plants' survival needs; (2) enlisting ranchers and OHV users to campaign for responsible use of areas in proximity to fragile land formations and habitats; and (3) crafting and enforcing adequate regulatory controls for livestock grazing and recreational use of valued natural resources.

The other major concerns for the species including the potential for prolonged drought caused by climate change and the cumulative effects of small population size, livestock grazing, climate change, insect and mammal predation, and OHV use may be more difficult to resolve. However, during prolonged periods of drought, more aggressive management may become necessary, including steps to ameliorate range-wide population losses through solutions such as seed storage and propagation, and establishment of new populations in areas that may be more hydrologically conducive to survival of the plants and seedbanks through dry periods.

Our lack of scientific knowledge and long term monitoring are serious concerns that must be addressed to effectively manage these species. All recovery actions will require a more robust information base for Winkler and San Rafael cactus. The size and amount of habitat connectivity necessary to support stable and healthy populations of these species are unknown and should be determined in the process of effectively implementing recovery actions. Therefore, inventories in potential habitat and research that addresses questions affecting these species, e.g., pollinator requirements, will be promoted as recovery priorities, particularly during the early phases of the recovery process. Research will be directed toward answering those questions that have the greatest bearing on the recovery needs of these species. Significant areas of uncertainty remain, with crucial implications for recovery. Uncertainties about the viability of individual populations under different threats and management scenarios, genetic variability, breeding and dispersal systems, and how to address various threats pose likely impediments to long-term recovery if left unresolved. Thus, research will be given equal priority to active management at this stage of recovery. Specific research priorities will be identified, beginning with effective population monitoring to ensure that any evidence of a declining trend is detected so that the cause(s) can be immediately identified and if possible, addressed.

Building public support for recovery along with implementation of regulatory protections will be undertaken in an effort to create a strong and lasting constituency for conservation. Along with the general public and interest groups, cooperative efforts will be pursued with Federal and State agencies. Eventually, a clearer understanding of the biological requirements of the species will lead to more predictability about their recovery prognosis. This in turn is likely to lead to refinement of recovery criteria and actions for the species, and the recovery plan will be revised accordingly.

Initial recovery solutions will center on taking the necessary measures to ensure that the species' current status does not further deteriorate, which hinges on the overriding need to address all three imminent threats; illegal collection, OHV related impacts, and impacts from domestic livestock trampling. Thus, top priority will be given to, first, maintaining the current number of populations at a size and distribution indicative of each species' population dynamics and known range, and, second, conserving the habitat for these populations and their pollinators. This will require appropriate resolution of threats involving habitat degradation, as well as actions to fully compensate for unavoidable impacts to extant populations. Protection of known sites on federally managed lands may need to be boosted through special designations, management commitments, or other administrative tools. Active management will be needed to restore habitats currently in degraded condition and prevent further habitat degradation, including moving OHV activities away from areas occupied by the species, reducing domestic livestock disturbances, and increasing law enforcement presence to address illegal collection activities.

There is not only a need for retaining, but also for finding additional populations and possibly expanding distribution. It is possible that Winkler cactus and San Rafael cactus occurred in more locations historically than they now do. Degradation of occupied habitat and illegal collection may have reduced the historical ranges of these species to what we now know. Given past survey results, it is very likely that additional natural populations will be found.

Recovery criteria based on trends and other population parameters will drive recovery actions such as research and monitoring, population management, and habitat management for Winkler cactus and San Rafael cactus. Threats-based criteria for recovery stem from the threats assessment for these species, which, along with illegal collection, identified motorized recreational activities and associated road and trail development, prolonged drought cycles, and domestic livestock trampling of soils and plants as significant concerns. The most imminent threats to these species will be addressed on a site-specific basis. Recovery will be promoted by conducting problem-solving discussions centering on habitat protection, by tracking and alleviating threats, and by building a shared understanding of projected threats and recovery needs.

PART 3. RECOVERY PROGRAM

3.1 RECOVERY GOALS

The goal of this recovery program is to achieve the long-term viability of Winkler cactus and San Rafael cactus in the wild, resulting in their removal from the Federal List of Endangered and Threatened Plants (50 CFR 17.12).

3.2 RECOVERY OBJECTIVES

The shared recovery objectives are to:

• Maintain representative distributions of Winkler cactus and San Rafael cactus throughout their current ranges;

• Effectively manage the species' habitat to support the species, taking into account environmental changes and new insights, i.e. adaptive management techniques;

• Maintain stable or increasing population trends through appropriate management and monitoring of population trends, addressing emerging threats to the species, and the implementation and performance of protection strategies;

• Ensure that needed offsite measures are in place to minimize extinction risk from catastrophic events; and,

• Engage partners in a long-term and active commitment to recovery and post-delisting conservation of these cacti.

3.3 RECOVERY CRITERIA

Each of these species will be considered to be biologically secure when: (a) a species' survival probability of at least 95 percent over 100 years can be projected; (b) long-term retention of current levels of genetic diversity in and across populations is ensured; and (c) sufficient habitat with naturally reproducing populations of the species is protected and managed to allow for continuation of natural selection.

Achievement of the recovery objectives for these species will be measured by a dual set of recovery criteria: a) population-based criteria; and b) threats-based criteria. Meeting the criteria will lead to delisting proposals. Although the criteria apply to both Winkler cactus and San

Rafael cactus, they must be met independently for each species, and each species can be independently delisted.

It is important to remember that these criteria may change, if and when new information or accomplishment of recovery actions indicates the need for adjustments in the recovery process. If, in the future, additional data for San Rafael cactus becomes available to allow us to thoroughly reassess its status and downlist it from endangered to threatened, then a downlisting proposal should be considered. However, given the current lack of data on the species, the level of effort required to achieve downlisting, and the minimal benefit to land managers from downlisting versus delisting, we have chosen to focus on delisting as a goal for both species. Therefore we have presented criteria for delisting only. Should downlisting become a desirable interim goal or additional data allows us to better generate clear, achievable downlisting criteria, then this should be considered.

Population-Based Criteria

<u>Delisting</u> of **Winkler cactus and San Rafael cactus** will be considered when:

P-1. Based on analysis and modeling implemented under the recovery actions trends for San Rafael cactus and Winkler cactus populations are shown to be stable or improving according to the following measures:

Species presence is maintained at all known San Rafael and Winkler cactus populations; **and**

b) Within at least three-quarters of the known populations that represent the majority of the total known individuals (and including the Wedge, Millsite/Clawson, and all of the McKay Flats populations) **and** represent the range of geographical, morphological, and genetic diversity of San Rafael cactus, plant density within occupied habitat is stable or improving over a 20-year period. These populations would be designated as Recovery Populations and this measurement would be based on a standardized, long term monitoring protocol developed by the Recovery Team and managing agencies. These criteria must be met for **all** known Winkler cactus populations due to the low number of known populations at this time. If additional Winkler cactus populations are discovered in the future, it may be determined that delisting is appropriate even if some populations are not stable or increasing; **and**

c) Predictive modeling using data from an additional 10-year period (30 years total), collected in accordance with a standardized monitoring protocol, provides an indication of long-term demographic stability as well as a projected survival probability of at least 95 percent over 100 years for each species.

P-2. Based on best available data, the available habitat base for each recovery population of each species is of sufficient quality and large enough to allow for natural population dynamics, population expansion where needed, and the continued presence of pollinators, with sufficient connectivity to allow for needed gene flow within and, where possible, among populations.

P-3. Population and habitat management is implemented for all populations of San Rafael cactus in accordance with management plans developed under Recovery Action 1 (Section 3.4). Each species-specific management plan will include a course of action that addresses the following needs: habitat protection and management, threats abatement, biological and threats monitoring, and reporting and evaluation.

Threats-Based Criteria

The following recovery criteria address threats to the cacti, arranged according to the five listing factors.

Delisting of **Winkler cactus and San Rafael cactus** will be considered when threats to the species are further abated as follows:

FACTOR A. The present or threatened destruction, modification, or curtailment of habitat or range.

T-1. Federal land protection through long-term management agreements or plans is achieved for all known San Rafael and Winkler cactus populations. Protection considerations from grazing impacts, development, mining, oil and gas, and recreation must be included in the management agreements and the protected areas must meet the size and connectivity parameters determined through research to be adequate to sustain those populations. These may include but are not limited to resource management plans, conservation agreements, recreation management plans, and travel management plans.

FACTOR B. Overutilization for commercial, recreational, scientific, or educational purposes.

T-2. Management agreements or plans in place and being implemented for all Winkler and San Rafael cactus populations on all federal lands must include measures to address and curtail illegal collection activities. These plans should include criteria for appropriate law enforcement at correct times and places to prevent illegal collection and sales of plants or any plant parts.

FACTOR C. Disease or predation.

T-3. Adverse population-level effects from herbivory, disease, or predation, if any, are identified, monitored and abated to the extent that all known Winkler cactus and at least three quarters of known San Rafael cactus population trends are stable or increasing, as evidenced by demographic monitoring results from studies that have adhered to monitoring protocols developed under recovery action 2.4. Programs to control excessive herbivory or predation will be developed to adaptively manage each population per criterion P-3, and must take into consideration the degree which climate change may impact disease or herbivory levels in the future.

FACTOR D. The inadequacy of existing regulatory mechanisms.

T-4. Land protection covering the habitat of all populations for each species and/or statutory and regulatory protections for plants are such that the protections of the ESA are no longer needed to compensate for regulatory inadequacies.

FACTOR E. Other natural or manmade factors affecting the species' continued existence.

T-5. A long-term ex-situ conservation program is ongoing for all extant Winkler cactus and San Rafael cactus populations. This would include seed collection and storage, germination and viability trials, and development of a protocol for successful reproduction under greenhouse conditions. This would help avert the risk of extinction from stochastic events or environmental catastrophes.

T-6. In conjunction with recovery criterion P-2, the available habitat base for each of the populations designated under criterion P-1 is of sufficient quality and large enough to offset the threat of loss or restriction of the species' pollinators and impacts from climate change, if feasible. Effective measurement criteria will be developed through research under Recovery Action 3.

If the recovery actions needed to meet all recovery criteria are accomplished on schedule, recovery of both species is anticipated to be achieved in the year 2045.

3.4 RECOVERY ACTIONS

Note--The recovery program for Winkler cactus and San Rafael cactus is divided into five major areas of action: (1) protection and conservation; (2) surveying and monitoring; (3) research; (4) communication; and (5) coordination. Overall, these sets of actions are tied directly to achievement of the recovery criteria for each species, and they are arranged in hierarchical order, with more specific actions stepping down from the broad actions that link to the criteria. An outline of the primary recovery actions is provided for ease of reference, followed a narrative description of each action, including a few more detailed actions not included in the broad outline.

1. **Protect and conserve known extant Winkler cactus and San Rafael cactus populations and their habitat**

   1.1 **Protect plant populations on Federal lands through formal agreements and/or land designations to a degree comparable with Critical Habitat designations but that would not require publication of population locations.** Critical Habitat designation is not recommended due concerns of theft should populations become public. Other forms of designation and agreements can provide equal or greater protection for the species without public disclosure of specific localities. Long-term management agreements, conservation agreements, management plans, land designations (such as Areas of Critical Environment Concern), and other potential methods (such as designation of Core Conservation Areas) should be used to ensure protection for areas of sufficient size and connectivity for recovery of each species. Designation should provide specific protections for the species including avoidance measures, developing adequate buffers, surface disturbance activities, compensatory mitigation and protecting habitat connectivity for activities that may impact the species. These administrative protections will be undertaken in cooperation with the BLM and NPS. On-the-ground management activities are covered under other recovery actions.

1.2 Incorporate plant protection into Federal agency planning documents. Best management practices should be developed and periodically evaluated for all activities that may occur regularly or repeatedly across the landscape. Examples include but are not limited to recreational activities, invasive nonnative weeds, livestock grazing, and route/trail development. Protections such as avoidance measures, no surface occupancy (NSO), buffers, surface disturbance caps, protection of pollinator habitat, population connectivity should be incorporated into planning documents when and where needed to protect the species.

1.3 Work with the Utah State Parks and SITLA to protect cactus populations on their land. Maintain a dialogue with the State of Utah to develop and implement a long-term management plan for the conservation of San Rafael cactus on two State Parks, as well as, for Winkler and San Rafael cactus on SITLA land. Management strategies and regulations on State lands should be as consistent as possible and include similar protections as discussed above with those on adjacent Federal lands in order to better protect populations. If necessary, acquire or gain conservation easements on inholdings of State lands for consistency in land management practices, species conservation, and regulatory mechanisms**.**

1.4 To the extent possible, protect plant populations on non-Federal lands. There are a few known sites on private lands. However, land protection tools such as land exchanges, easements or acquisition, cooperative or voluntary agreements could still be used to establish plant conservation as a primary land use objective for the site. Accomplishment of this action will rely on the cooperative efforts of SITLA, municipalities, non-governmental landholders such as The Nature Conservancy, and other willing landowners.

1.5 To the extent possible, avoid loss of occupied habitat and plant damage due to land development/disturbance activities including construction projects, oil and gas development, and mining. Long-term conservation of occupied and potentially occupied habitat requires maintaining land in a natural state that will support the ecological requirements of each species over the long term.

1.5.1 Evaluate oil, gas, and mineral leases in occupied or suitable habitat that are nominated for sale prior to them being put forward to determine potential impact on cactus populations or sites, and include those considerations in the lease sale decision. Lease sales should take into consideration the potential impact to these species and in areas of occupied or potential habitat, the Service should be consulted before the sale moves forward. If leases are sold in suitable or occupied habitat, appropriate restrictions to protect the species should be included in leasing conditions and stipulations.

1.5.1.1 Adequate conservation measures should be incorporated into future leases (e.g., NSO, deferring of lease parcels, including adequate lease notices or stipulations) in all areas where the species occurs over 75 percent of the habitat or more.

1.5.1.2 BLM should implement at minimum 400 m (1,312 ft) avoidance buffers, surface disturbance limits, and compensatory mitigation in areas where NSO is not possible.

1.5.1.3 Implement dust abatement measures on all roads associated with development and all construction projects in occupied habitat.

1.5.1.4 Avoid or adequately minimize fragmentation of sites within populations.

1.5.1.5 BLM should develop species-specific reclamation and restoration guidelines and require these activities as part of the permitting process in suitable habitat for the species and its pollinators.

1.5.2 Minimize the effects of road and/or highway projects near occupied habitat. A consistent protocol should be developed with the Utah Department of Transportation and Wayne, Emery, and Sevier County Road Maintenance Divisions to minimize the impacts of maintenance of existing roads and highways. This protocol should apply to the creation of new roads, highway rights of way, pullouts, etc. in the future. Speed limits to decrease dust effects should be considered for all unpaved roads adjacent to occupied habitat.

1.5.2.1 This protocol should include evaluating whether work is planned in occupied or suitable habitat and what the potential impacts to both individual plants and habitat are. Impacts directly to individuals should be avoided, but considerations of damage to occupied or suitable habitat that could negatively impact species recovery should also be considered.

1.5.2.2 If a conflict exists, develop and implement conservation measures. Conservation measures for minimizing the effects of road work include but are not limited to surveys, delineating population boundaries near work areas, fencing off work areas, dust/silt abatement, and training crews in the identification of the species and measures to minimize impacts in work area.

1.6 Minimize human recreational disturbance, particularly OHV-related disturbance, of known populations and their habitat on BLM, NPS, and State land in order to meet recovery objectives. Human recreational activities such as hiking, mountain biking, horseback riding, and OHV related activities can lead to degradation of the landscape by increasing erosion, changing hydrology and vegetation patterns, compacting soils, and/or inadvertently trampling plants. Managing agencies should work together to implement the below Recovery actions in a consistent manner where habitat and populations cross land ownership boundaries.

1.6.1 Locate trails and campsites away from occupied sites. Human activities and travel across the landscape can be guided by the establishment of designated routes and trails. In federally managed areas, established routes and trails, designated or otherwise, should be controlled or eliminated in areas of occupied habitat. Placement of new trails should be based on an evaluation of the need for and use of a proposed route in relation to the recovery of the species. To the extent possible, any new routes or trails should be established to redirect human activities outside of occupied habitat. Routes and trails should reduce direct human interface with individual plants and be sensitive to areas of existing potential habitat.

1.6.1.1 BLM, SITLA, and NPS should identify and evaluate impacts from recreational use areas that overlap or are within 400 m (1,312 ft) of plant occurrences.

1.6.1.2 BLM, SITLA, and NPS should develop and implement a plan to, when possible, relocate recreational use areas and facilities that are within 400 m (1,312 ft) of occupied habitat.

1.6.1.3 When possible, all new recreation trails and facilities should be located at least 400 m (1,312 ft) from occupied habitat.

1.6.1.4 Planned development in suitable habitat should be minimized and unavoidable impacts fully mitigated.

1.6.2 Identify sites and populations most heavily impacted by recreation, particularly OHV use, and those at which compliance to existing OHV restrictions is poor. Some populations or portions of populations receive greater pressure from OHV use and other recreational activities than others, particularly those located near populated areas or adjacent to well-known play areas. Populations identified in this document that may be at risk include but are not limited to portions of the Hartnet and Notom populations of Winkler cactus, and the Millsite/Clawson and Wedge populations of San Rafael cactus.

1.6.2.1 Implement effective OHV control measures, including improved signage and enforcement of existing OHV restrictions in areas where compliance is poor. Control of OHV related activities should continue to include designating play areas, trails, and access corridors outside of occupied or suitable habitat, preparing designated trail and corridor maps, and installing signs to indicate where trail use is acceptable. Educational efforts and law enforcement presence should be increased in newly designated areas to educate user groups and ensure that occupied cacti habitat remains undisturbed. In areas of unauthorized use BLM, SITLA, and NPS should install barriers, enhance enforcement and enlist compliance from user groups, restore affected habitat, and provide alternative areas to ride in unsuitable habitat.

1.6.2.2 Evaluate high impact sites to determine if additional restrictions on OHV use, trail rerouting, or closures are necessary to protect populations or sites and implement those changes. Sites and populations receiving high OHV pressure should be carefully monitored and impacts to cacti recorded. This data should be evaluated carefully to determine what changes to the current OHV use patterns might be necessary or desirable to preserve and improve the state of the populations or sites. If impacts to plants are occurring from recreational use, BLM, SITLA, and NPS should implement measures to reduce these impacts such as education kiosks, designated trails, barriers, and good signage.

1.6.3 Develop and implement a comprehensive strategy to reduce human recreational impacts on the species, with specific measures to address OHV impacts on populations and sites. This strategy should be responsive to changes in recreational use over time and include, but is not limited to, the following measures:

1.6.3.1 Protect specific sites from OHV use with fencing or other physical barriers and maintain these protections. Where adverse effects from OHV related activities cannot be effectively abated by designating play areas, or relocating roads and trails, fencing or other physical barriers (such as large rocks preventing access) is recommended to reduce immediate impacts. Maintaining fences in good repair is a challenge in Wayne, Emery, and Sevier Counties (e.g., fences are frequently vandalized by individuals or groups seeking unrestrained access), and repair costs should thus be taken into account and obligated as an integral component of the fencing project.

1.6.3.2 Evaluate non-OHV recreational impacts such as hiking, biking, camping, and horseback riding on cactus populations and sites to determine if changes to existing land use regulations are necessary. Although OHV use is the greatest recreational threat to these species currently, other forms of recreational land use should be considered when developing a management strategy. The current regulations should be evaluated to determine if they are effective in protecting the species and if changes can be made to provide better protections. If impacts are documented to be occurring, land management agencies should immediately develop and implement a plan to reduce these impacts.

1.6.4 Provide appropriate levels of law enforcement at the correct times and places to protect the species from recreational impacts. Law enforcement should be deployed to protect the species in the way that is judged by the managing agency to be most effective in preventing harm to plants and habitat. Factors taken into account should include type of use, known authorized and unauthorized use levels, and time (such as holiday weekends or recreation based festivals).

1.6.5 Enforce existing regulations preventing unauthorized land uses. In the past, adverse land uses include illegal dumping, dispersed camping, OHV use, and target practice occurred, and these activities are continuing to occur at several sites despite no longer being authorized. Protection of cacti habitat will require a heightened awareness on the part of law enforcement regarding the recovery needs of these species and the necessity of maintaining a vigilant presence in these areas.

1.6.5.1 Ensure law enforcement and biologist coordination occurs when unauthorized activities that result in harm to plants or habitat are documented.

1.6.5.2 Develop education and compliance program with user groups.

1.7 Minimize livestock grazing disturbance to known populations and their habitat on BLM, NPS, and State land in order to meet Recovery Objectives. Nearly all populations of these species are on federal lands within areas of active grazing allotments; therefore, occupied habitat within these allotments should be surveyed and the relationship of cactus distribution to livestock use patterns determined. Effective grazing management may include fence construction, water trough placement, rest-rotation grazing, and revisions of allotment plans, grazing schedules, and stocking levels to maintain cacti habitat. Monitoring of grazing-trampling impacts should be developed and implemented rangewide in occupied sites within grazing allotments. Monitoring should be conducted on a regular basis with appropriate disturbance level triggers that would initiate a change in grazing management practices to protect the species. Conservation easements with private landowners can also be considered.

1.7.1 In so far as is possible, locate livestock trails and watering areas away from populations and sites to avoid trampling. Heavy damage and disturbance to plants occurs when livestock are trailed through a population or site, or when proximity to a water source results in constant use of livestock in an occupied area. Encouraging the use of water sources away from occupied sites and routing trails around occupied sites can result in a lower impact to the species without other changes to grazing on the allotment. Designated trails should be routed to avoid trampling of individuals, at a distance that is determined to be site-appropriate. Where possible, move or establish supplements and water sources 400 m (1,312 ft) away from occupied habitat.

1.7.2 Continually identify sites and populations impacted by livestock grazing and rank and prioritize them by impact. Some populations or sites receive greater pressure from grazing than others. Populations identified in this document that may be at high risk include but are not limited to portions of the Hartnet and Notom populations of Winkler cactus, and the Millsite/Clawson, Mesa Butte, and Wedge populations of San Rafael cactus. These ranked sites will serve to focus efforts where impacts are highest.

1.7.3 Develop and implement a comprehensive strategy to reduce grazing impact on the species, with specific measures to address grazing impacts at populations and sites which experience high grazing/ trampling impacts. This strategy should consider the best available data regarding site-specific population-level impacts from livestock grazing, be responsive to changes in grazing use over time and include, but is not limited to, the following measures:

1.7.3.1 Implement restrictions on grazing use as necessary to reduce impacts, such as fewer AUMs authorized on the allotment, rest periods, shorter authorized grazing periods, and seasonal changes to grazing authorization, pasture rotation or closures of grazing allotments as necessary to protect populations or sites. Sites and populations impacted by livestock grazing and trampling should be carefully monitored and impacts to cacti recorded in order to implement livestock grazing regime changes. This data should be evaluated carefully to determine what changes to the current grazing use patterns might be necessary or desirable to preserve and improve the state of the populations or sites. Finally, changes to livestock grazing regime should occur to reduce impacts to the species when they are determined to be detrimental to the population as a whole and other abatement measures are not successful or suitable.

1.7.3.2 Protect specific sites from livestock grazing with fencing or other physical barriers and maintain these protections. Where adverse effects from livestock grazing related activities cannot be effectively abated by changes in grazing authorizations for the allotment, physical barriers to protect individuals and sites should be used, either to prevent entry of livestock into occupied areas or to encourage livestock to deviate from habitual routes that would increase the likelihood of trampling or disturbing individuals.

1.8 Identify sites or populations which receive high levels of disturbance or impact from other large ungulates, evaluate the potential for reducing these impacts, and create and implement a management plan to effectively protect the species. Large ungulates including deer, elk, and wild horses are known to impact sites and populations of both these species in ways that can be similar to livestock grazing. Sites with impacts to the species should be identified and appropriate management actions to protect at-risk areas developed, such as population reduction of wild ungulates, or fencing of occupied sites as needed.

1.9 Implement measures to identify and reduce the impact of climate change on these species, including via increased predation and herbivory. Climate change can cause increased temperatures, changes in seasonal timing, increased temperature fluctuations, and drought. These changes can impact plant species both directly (changes in phenology, reproductive success, winter or drought survival, etc.) or indirectly (introduction of new predators, changes in herbivory levels of known predators, pollinator behavior alteration, availability of pollinators while flowering, etc.). Efforts should be made to determine what impact climate change is having on these species, which populations and sites are most at risk, and what may be done to mitigate the impacts of climate change on the species.

1.9.1 Investigate changes in herbivory threats to the species, particularly from cactus borer beetle, and develop management actions to mitigate those impacts. Climate change may be altering the feeding habits of cactus predators such as cactus borer beetle, which can cause plant injury, mortality, and decrease in reproductive success. Some research indicates that predations from cactus borer beetle and other herbivores on these species are increasing (Daerr 2001; Kass 2001). Grazing can also impact the abundance and structure of rodent populations. The scale of this threat should be determined and actions identified and taking to mitigate increased herbivory due to climate change or grazing.

1.9.1.1 Fund and implement a study to determine whether and how herbivory from insects, particularly cactus borer beetle, is increasing. Such a study should include how herbivory impacts mortality and reproduction, to what degree any increase is tied to climate change, and project how those impacts might continue to increase in the future.

1.9.1.2 Develop and implement strategies that reduce or mitigate for impacts. Using data from the herbivory study, create a plan for management of the threat herbivory poses, both currently and as projected in the future.

1.9.1.3 Develop and implement strategies to improve habitat conditions that would allow the species to better withstand drought. Improvement of ecosystem health and soil integrity improves drought tolerance. Measures such as decreasing disturbance and encouraging the growth of cryptobiotic crust that retains moisture could be part of this strategy.

1.9.2 Determine the potential for cacti to migrate into currently unoccupied habitat as a response to climate change and preserve such habitats for the future. Many species respond to changes in climate by moving into previously unoccupied habitats adjacent to their former habitats when those habitats become less suitable for their needs and new habitats become more suitable. This may include colonizing areas of higher altitude or different aspects in order to obtain better conditions. The potential for these species to move into adjacent habitat in response to climate change should be assessed (perhaps using a habitat suitability model), and if it is found that migration is a possible strategy for these species to cope with climate change, potentially suitable areas adjacent to occupied areas should be protected.

1.10 Protect populations from theft through effective law enforcement and by maintaining site locations as confidential information when feasible. Illegal collection is an ongoing concern at several well-known populations of both species, and could easily become a concern at more remote or unknown populations if their locations are made public.

1.10.1 Determine which populations experience the highest levels of illegal collection and increase the presence of law enforcement in those areas. The populations at highest risk are likely to be well documented in literature and easily accessible by roads, although they are often in areas that are rarely visited otherwise. These populations should be identified and receive an appropriate law enforcement presence.

1.10.2 Determine ways in which managing agencies can share population and location information as needed without risking that information becoming public. Shared data is essential for effective monitoring and management of the species, but steps should be taken to ensure that location data is not widely released, as this would increase the risk of theft to populations that thus far have remained unexposed.

1.11 Protect vegetation communities/ecosystems and pollinators associated with each species. Habitat protection includes the greater natural ecosystem, particularly in terms of pollinators, seed dispersal, germination requirements, and maintenance of natural regimes. Protection needs of the vegetation communities and ecosystems within which these species are found should be evaluated and prioritized. Evaluation of needs should include, but not be limited to, impacts related to landscape fragmentation and loss of occupied lands to development; nonnative weeds; areas where overuse has created land-scars; and the deleterious effects by domestic animals. This evaluation should occur for all extant populations and be extended to any additional discovered populations.

1.11.1 Identify supporting species and communities which are important to the continued health of the cactus. Pollinators of the cactus, plant species that support those pollinators and other vegetation known to associate positively with this species should be identified for both species and all populations to determine what the supportive needs of the cactus are.

1.11.2 Include supporting species considerations when developing protected areas. These species and communities identified as important to cactus welfare should be included when planning and implement protections to cactus populations to ensure the long term health and survival of the cactus.

1.11.3 Incorporate protective measures such as buffers and surface disturbance limits in maintaining undisturbed areas. Ensure the protected areas are not negatively impacted by adjacent disturbances or high levels of fragmentation which would decrease their effectiveness in protecting the cactus.

1.11.4 Avoid or reduce anthropogenic disturbance in and around known occupied areas. In all populations, decrease the pressure from recreation and livestock grazing through management actions to move such activities away from the known populations.

1.11.5 Identify and protect suitable non-occupied habitat adjacent to existing populations. Suitable habitat preservation is vital if the species is to recover. The availability of unoccupied habitat provides the cactus with room to expand their range and increase their population, and an alternative if currently occupied areas become unsuitable. These areas, particularly those adjacent to the existing populations, should be identified and protected (e.g., federal land management mechanisms, conservation easements, acquisitions) for the future.

1.12 Protect the seedbanks of each species. The existence of a robust seedbank for rare plant species provides much needed protection against the loss of the species through declines of adults or stochastic events.

1.12.1 Protect the in situ (onsite) seedbank of each species. These and other closely related cacti species with similar sized seeds tend to have very limited seed dispersal zones (USFWS 1985, 1990, 2003). It is estimated that the majority of seeds are dispersed within a few meters of the parent plant. Seeds represent future offspring while preserving genetic diversity of past generations. Actions to reduce seed loss require protection from ground disturbance, e.g., soil compaction, erosion, and loss of natural soil biotic conditions. Habitat protection actions will reduce or abate loss and damage to seeds contained in the soil. Onsite seed conservation also will require the establishment of best management practices to ensure the protection of natural soil conditions and seeds.

1.12.2 Protect seeds ex situ (offsite). Seed-storage, although by no means meant to replace conservation of wild populations in their natural habitat, can increase the survival prospects of imperiled plant species by preventing unique genotypes from disappearing altogether. Seed-storage can effectively preserve and maintain viable seeds in long-term storage, thereby reducing the possibility of extinction and contributing to recovery.

1.12.3 Develop seed collection and permitting guidelines. A protocol for seed collection that will minimize effects to Winkler cactus and San Rafael cactus is needed. The number of seeds collected and the collection interval should be determined in conjunction with the most current standards and models used by such entities as the national Center for Plant Conservation. Standards should be determined in advanced of collection activities, and seed collection permits should be assessed for need and duplication. At a minimum, permit holders should provide documentation of activities, with specific information on the number of plants at collection site, number of plants collected from, and number of seeds removed per plant.

1.12.4 Collect and store seeds representing the genetic variability of each species. The rarity of Winkler cactus and San Rafael cactus make these species highly vulnerable to random environmental and human-caused events. As a protection against significant loss of genetic material, seed representing the geographical, morphological, and genetic diversity of each taxon should be regularly collected and stored for long term conservation in at least one Center for Plant Conservation approved facility. The stored seed could be used for efforts to establish new populations and periodic testing will be necessary to estimate the rate of viability loss during seed storage. This estimate will help establish the correct interval, adequacy, and quantity of seed collection and storage.

2. **Survey for additional populations, and monitor all populations in order to apply conservation measures where and when needed.** Find previously unknown populations of both species to better understand the true abundance and range. Monitor all populations to determine trends, threats, and progress towards recovery.

   2.1 **Locate and conserve additional extant populations.** Suitable habitat has not been fully surveyed for either species, and the recent discovery of additional populations indicates that undiscovered populations may exist within or even beyond the known range.

   2.2 **Implement new searches in potential habitat areas, focusing on creating or proving connectivity between known populations.** Information gained in survey efforts may have a significant bearing on the recovery strategy for these species (i.e., in relation to cactus abundance and distribution necessary and available for recovery). The importance of surveying as a component of the recovery program underscores the benefit of continued and increased cooperation between all partners. Surveys should be guided by the best available data and the most recent habitat model.

      2.2.1 **Develop a suitable habitat model.** Using all existing data both on individual plants and the surrounding environmental and ecological conditions to develop a dynamic habitat model for both species which would allow researchers to search for new populations more efficiently. The model should also strive to determine which factors are most important to the survival and wellbeing of the species. This model is in progress should be continually refined as more data is gathered.

      2.2.2 **Delineate appropriate potential habitat areas and conduct surveys on Federal lands.** Habitat elements required by all three species can be evaluated through existing information such as soil type and geological formation maps and aerial photos. Existing data about habitat requirements should be used to refine habitat delineation and create maps of potential habitat within the species' ranges. Determination of survey requirements should be based on identifying data gaps for areas of suitable habitat currently thought to be unoccupied. Additionally, survey efforts could include soil sampling of appropriate habitats and other research that will develop and refine a habitat suitability model.

      2.2.3 **Obtain permission from State and private landowners to conduct surveys on non-federal lands.** Although there are few known sites on private lands, surveys are still necessary to ensure thorough knowledge of these species ranges'. Surveys on non-Federal lands should follow procedures consistent with surveys on Federal lands, with priority given to areas where activities may affect habitat or where habitat may be acquired or managed for conservation.

2.2.4 Maintain a database for survey efforts, including negative results. In order to assess status of inventory needs and efforts for these species, a database should be maintained for compiling new survey data and analyzing compiled survey results between agencies.

2.3 Apply the protection and conservation measures detailed in recovery action 1 to each additional population found. Land exchanges, acquisition, trades, and disposal actions could negatively affect the species' ranges, distribution, and rates of recovery. Measures should be implemented to conserve occupied and suitable habitats across both species' ranges.

2.4 Monitor Winkler cactus and San Rafael cactus sites for threats and trends and address threats as needed. Regular, standardized monitoring is vital in order to determine whether the species is declining or in recovery, what threats are of most concern to individual populations, and to what impact those threats are having.

2.4.1 Scientifically determine appropriate disturbance thresholds for each individual threat and use them to determine if abatement action needs to be taken. In the past, a 5 percent disturbance threshold for all threats triggered conservation actions, because it was reasonable to assume any disturbance impacting less than 5 percent of the population was not having a detrimental effect on the population as a whole. However, each species may have a different tolerance for disturbance from different threats. The managing agencies should conduct studies to determine at what actual disturbance level the threat becomes detrimental to the population and set disturbance thresholds accordingly. Threats above these thresholds will still be managed with a "top-down" approach.

2.4.2 Address threats to each population with a "top-down" approach, treating the threat causing the highest amounts of documented disturbance as the immediate priority for abatement measures. Disturbance thresholds should be established and used as a measure of whether action needs to be taken to abate the threat. Priority of action will be determined from the highest disturbance level and working down to the threat with the lowest disturbance level still above the determined disturbance threshold.

2.5 Develop and follow standardized range-wide survey and monitoring procedures for each species. Land managers and Recovery Team should work together on standardizing surveying and monitoring procedures across agencies and districts, so that long term trends in populations can be determined. The previous Interagency program conducted surveys for these species from 1998-2011 and published a standardized field survey technique and form for gathering data in the field in 2011. These techniques are a useful starting point for developing a standardized protocol moving forward. A total population estimate may be developed based on reliable monitoring data and used for the purposed of management but this is not a requirement for Recovery.

2.5.1 Implement standardized monitoring on Federal lands. A joint effort on the part of Federal agencies and interested parties is needed to refine monitoring needs and applications. There is a fundamental need for range-wide assessment of population trends of all three species in order to evaluate threats abatement measures, population health and stability, and effectiveness of recovery implementation. A standardized monitoring program should be developed to provide an assessment of population numbers and demographics as a means to determine each species' biological status, e.g., stable, improving, or declining.

2.5.2 Create a database for long-term collection and evaluation of monitoring data. Participating federal agencies should develop a single repository and common data base for all monitoring data. This need may be met through the Utah Natural Heritage Program.

3. Conduct in depth research into the biology, requirements, threat responses, and life histories of both species in order to develop and implement appropriate management practices for the purposes of achieving recovery.

3.1 Establish a set of need-based research priorities aimed at abating or minimizing threats and increasing population health and numbers. Although some aspects of the biological requirements of these species are known, if recovery and conservation is to be achieved, more must be learned. Research for recovery purposes will be aimed specifically at the protection and conservation of Winkler cactus and San Rafael cactus. Studies also may reveal new techniques or actions for recovery, which will be incorporated into an updated plan as appropriate (see recovery action 9).

3.2 Analyze available data and identify data needed to evaluate population trends. Limited data have been collected for these species. However, analysis of these data will provide an important baseline for future trend analyses as recovery proceeds. The data also may indicate further data collection needs and provide a platform for refining and standardizing data collection methods. During the course of analyzing available data, experts should identify the data inputs needed for an appropriate quantitative predictive model, such as a population viability analysis. Data on climate changes and weather patterns that may affect the species should also be evaluated. These activities should be coordinated with recovery action 3.1.

3.3 Develop standard procedures for setting annual research priorities and evaluating proposals. To provide recovery in the most expedient and cost-effective fashion, research activities should be consistently prioritized in terms of benefit, need, and cost-value. Criteria such as urgency, scale, benefits to one or more species, significance of data gap, possible negative effects, transference of study results, and ancillary benefits (e.g., to other species or the broader ecosystem) should be standardized and conveyed to interested researchers. A process for using these criteria to direct annual research priorities as well as to evaluate any research proposal that may benefit or affect Winkler cactus and San Rafael cactus should be established. The selection/evaluation criteria should then be disseminated to all prospective investigators.

3.4 Establish protocols for protecting cacti populations during the course of field studies. Although the studies identified below will benefit the species, it is well-acknowledged that research can negatively affect both the landscape and target populations. Prior to initiating recovery-oriented research, a set of fundamental protective protocols should be established by a group of experts as a means of minimizing potential impacts on the cacti and their habitat. These protocols should include, but not necessarily be limited to, measures for controlling human foot traffic and minimizing its effect on living soils and seedbanks (e.g., through soil compaction and erosion), procedures for limiting the spread of nonnative plants via human transport, and effects of research actions on pollinators and potential seed dispersal vectors.

3.5 Conduct needed investigations into the biology and life history of the species. Identify and implement recovery applications of research results. The information base for each of these cacti should be as complete as possible to ensure the effectiveness of recovery efforts, such as determining population status and habitat needs and identifying sites of unknown but potential occupancy.

3.5.1 Pollinator research. Conservation of pollinators and their habitats is fundamental to recovery of the species Research is thus needed regarding essential pollinators and their role in the reproductive biology (see recovery action 4.4.1) of the species. Preliminary work has identified some insect pollinators and their role, and further research could investigate the adequacy of pollinator visitation, identify nesting substrate of known pollinators, and determine which other flowers these pollinators visit (native and nonnative) and the effects of these other floral resources on pollination for these cacti. Knowledge of pollinator presence, density, preference of floral resources, and nesting substrate may be essential to the viability of the current populations, establishing habitat protection, and the suitability of potential introduction sites.

3.5.2 Habitat substrates and soil conditions research. Soil profiling and documenting other natural land conditions at known locations of the species may provide insight into current life-supporting conditions for these species, and aid the level of health, fitness, and adaptability of a population vis-à-vis natural and human-caused stresses. Information on reproductive biology should include information on seed set and viability in order to build a predictive model to determine population trends.

3.5.3 Genetic variation and reproductive biology research. The amount of variation within the gene pool of cactus sites is unknown. Genetic information should be obtained and evaluated with regard to resiliency, genetic drift, and inbreeding depression. Genetic diversity research may indicate that problematic gaps remain in our knowledge about each species' reproductive biology, biological constraints, microhabitat requirements, genetics, effective habitat size and connectivity, as well as clarify the effects of various activities relative to population viability.

3.5.4 Seedbank viability and longevity research. To better understand long-term survival strategy of a species, an understanding of the soil seedbank must be taken into consideration. Seedbank research should be aimed toward quantifying existing seedbanks, investigating seed dispersal mechanisms, and determining the range and viability of seedbanks for these cacti species. In particular, these studies should be conducted in order to better understand the long-term strategies these species employ for survival. Overall, seedbank research will add to the information needed to effectively advocate for the protection of habitat resources and will assist with understanding the life cycle and survival mechanisms of these cacti species.

3.5.5 Parasitism, herbivory, and disease research. Damage to stems and flowers from herbivory has been identified for both cacti species. Additional effort should be given to documenting these events and collecting predators. Notes should be taken in the field to describe the patterns of effects from beetle and small mammal predation/herbivory. If investigation is needed to determine the source or amount of damage, protocols should be established for a data record-keeping system for these phenomena. Quantifying natural seed predation may be needed for predictive modeling.

3.5.6 Nonnative weeds research. Research involving nonnative weeds should: (a) evaluate factors pertaining to interaction, such as competition between nonnative weeds and the species for soil and/or pollinator resources; (b) determine the need for nonnative plant control; and (c) study management measures in a controlled setting that may contain similar but unoccupied habitat.

3.5.7 Modeling. Modeling provides a means of using data on demographic processes and environmental variability to estimate probability of extinction by a specific time, assess recovery success, and determine management needs (Morris et. al 2002). Additional models should be developed to evaluate alternative management strategies, and updated to track recovery progress of these species for both population trends and for size of needed habitat. The quality of the models will improve over time commensurate to the availability of information on, for instance, viable seed longevity and seedling survivorship rates, etc. Modeling on these species should include factors such as precipitation cycles and response, level of threat impacts and response, pollinator success, and genetic data.

3.5.8 Restoration and propagation research. In order to recover the species, it is vital to know what restoration methods are effective and how the species may potentially be propagated and reintroduced if it becomes necessary or beneficial to do so. A knowledge of which techniques are suitable for the species provides a line of defense should existing populations continues to decline.

3.5.9 Response to livestock management changes. Monitoring to identify cactus responses to changes in livestock management within populations should occur. These changes can include increase or reduction of AUMs, relocation of water sources, fencing areas to exclude cattle, or change in timing of grazing season. Cactus should be monitored for changes in reproductive effort, recruitment, size classes, and survivorship.

4. **Promote communication by encouraging and creating dialog regarding these species between managing agencies, land owners, developers, and the public in order to raise awareness and aid recovery.**

4.1 Promote effective communications with partners and stakeholders regarding the species recovery needs and progress. Recovery success requires the engagement of key parties through personal contacts, effective working relationships, and ongoing dialogues with recovery partners and stakeholders. Communications should focus on the role that various governmental and non-governmental groups play in implementing recovery actions and facilitating recovery progress. We also should exhibit a willingness to enter into open discussions about the potential effects of various recovery actions on stakeholders in order to develop implementation strategies that are realistic and can gain the public's support.

4.2 Maintain an active dialogue with Federal, State, and municipal agencies and private interests about recovery issues. It is imperative that all planning and management agencies which influence land use decisions and management actions for areas occupied by these species be kept apprised of recovery needs and opportunities. In addition to equipping decision-makers with good information, recovery partners should become involved with agency and community initiatives involving recreation, economic planning and development, and use of environmental resources. The aim of this action should be to foster development plans, regulatory mechanisms, and other initiatives that can meet socio-economic needs while advancing these cacti species' recovery.

4.3 Maintain communications with the Utah State Parks and SITLA regarding conservation of the cactus populations. We will work in cooperation with the Utah Department of State Parks and Recreation and SITLA to ensure that meaningful government-to-government communication occurs regarding conservation of the species. In carrying out a working relationship, we will offer technical assistance and information. We will also pursue funding for the development and implementation of state management plans to promote the conservation of the cacti and their habitat within Utah State Parks and SITLA lands.

4.4 Establish productive communications with OHV and other interest groups. Many individuals and groups enjoy using motorized vehicles for recreational activities. As more individuals participate in OHV special interest groups, these groups may provide a means to share information about natural landscape issues in Emery, Wayne, and Sevier Counties. Education outreach to these user groups should be developed to include information about sensitive ecosystems with a focus on cacti habitats. Recovery participants should engage in discussions with special interest groups aimed at reducing land use and plant habitat conflicts. Although these discussions need to address areas of conflict between OHV use and plant habitats, their central purpose should be to work cooperatively and creatively with interested groups to achieve mutually beneficial resolutions.

4.5 Develop and implement educational and outreach programs. Generating a broad appreciation of the cacti recovery needs is essential for achieving their long-term conservation. It will be most effective to convey these needs within the broader contexts of rare plant conservation and outdoor advocacy. The public should be provided opportunities to learn about the recovery process by, for instance, disseminating informational and educational materials through school programs, exhibits, and other venues. Target audiences for these programs could include organized civic and business groups, visitors to interpretive and outdoor education facilities, and students of all ages.

4.6 Tap the growing interest in rare plant species to garner public support for the recovery. Recovery of these cacti species rests in some part on evoking a sense of wonder and respect for nature. Many groups and individuals are interested in the natural flora found in Wayne, Emery, and Sevier counties, as well their remarkable natural surroundings. The landscape itself can serve as the best catalyst for discussion about environmental issues, including the issues involved in recovering endangered plants.

4.6.1 Integrate recovery into broader interpretive programs. Although conservation of endangered plant species provides a logical basis for promoting cacti recovery, it may be more compelling to interpret recovery within a broader natural or ecological context in a way that can be conveyed to State and local civic organizations, business and other private organizations. Examples include exhibits and programs at visitor centers for parks and other public lands. Field presentations, for example, could explore a diversity of topics such as related plant communities, living soils, animal and pollinator interactions, and geological formations. Outdoor advocacy should promote connection to natural places and local diversity wherever these plants exist.

4.6.2 Develop materials and make presentations for educational institutions. Educational institutions often welcome the opportunity to provide fresh information and insights to their students. Understanding rare plant issues reinforces the inherent and learned appreciation of our natural surroundings. As individuals take pride and ownership in the environmental qualities of Emery, Sevier, and Wayne Counties, they can become more meaningfully engaged in enjoying the natural outdoors and protecting the resources, including rare plants, which are integral to this environment. Age-appropriate outreach and educational materials about the cacti and the larger natural context should be developed for elementary and secondary schools. These could be special presentations or, whenever possible, as teaching units that can be fully integrated into the outdoor education curriculum. Activities should promote the goals of the ESA and the objectives of the recovery program.

5. **Coordinate and work together with all stakeholders to achieve recovery**

   5.1 **Provide oversight and support for implementation of recovery actions.** To ensure that the recovery process moves as efficiently and effectively as possible toward achieving recovery objectives, a coordinated approach to implementing individual actions is essential. This will involve close communications, early recognition of short-term needs and potential obstacles, and identification of all possible funding opportunities. We should provide continuing oversight of recovery implementation activities and work with other Federal agencies and private conservation groups to obtain funding through traditional avenues in a regular and resolute manner. New means of funding and support should be developed with the assistance of the States, counties, and cities, as well private land developers and organizations.

   5.2 **Establish a technical working group to regularly review the status of the species and track the effectiveness of recovery actions.** A technical working group consisting of ourselves, BLM, NPS and other researchers knowledgeable about the species will be formed. This team will have annual reviews of recovery accomplishments, progress toward meeting recovery objectives, and assess research and monitoring actions essential to ensuring successful implementation of the recovery program. Standards for monitoring effectiveness and making needed adjustments should be developed by the group at the outset and applied in a consistent manner as the recovery process moves forward. The group should issue an annual report outlining progress and, when called for, significant setbacks in the recovery programs. The group should also ensure that tracking results are documented in our recovery implementation database.

   5.3 **Revise the recovery program when indicated by new information and recovery progress.** Recovery goals, objectives, criteria, and actions should be validated and, as needed, revised. Whenever possible, keeping this plan current should be done on a frequent, incremental basis. If and when the need for a significant change in recovery direction becomes apparent, the plan should be revised and reissued for public and peer review and comment.

   5.4 **Stakeholders should support recovery by providing personnel and fiscal resources yearly to implement recovery actions.** This includes providing adequate funding yearly to implement recovery actions. It also includes the resources for a team consisting of representatives from managing agencies and the Service to plan and coordinate protection, monitoring, conservation, and research needed to achieve recovery.

PART 4. IMPLEMENTATION SCHEDULE

The following Implementation Schedule outlines actions and estimated costs for the recovery program over the next 5 years. Functioning as a practical guide for meeting the species' recovery goals, this schedule indicates action priorities, action numbers, action descriptions, duration of actions, and estimated costs. In addition, parties with authority, responsibility, or expressed interest in implementing a specific recovery action are identified; however, this neither obligates nor implies a requirement for the identified party to implement the action(s) or secure funding for implementing the action(s). However, parties willing to participate may benefit by being able to show in their own budgets that their funding request is for a recovery action identified in an approved recovery plan and, therefore, is considered a necessary action for the overall coordinated effort to recover these cacti. Also, section 7(a)(1) of the ESA, as amended, directs all Federal agencies to utilize their authorities in furtherance of the purposes of the ESA by carrying out programs for the conservation of threatened and endangered species. The schedule will be updated as recovery actions are accomplished.

Key to Implementation Schedule Priorities (column 1)

PRIORITY 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

PRIORITY 2: An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

PRIORITY 3: All other actions necessary to provide for recovery of the species.

Key to Responsible Agencies (column 6)

BLM = Bureau of Land Management
NGO = Non-governmental organizations such as The Nature Conservancy or universities
NPS = National Park Service
Private = Private landowners
SITLA = Utah State Institutional Trust Lands Administration
UDOT = Utah Department of Transportation
USFWS = U.S. Fish and Wildlife Service, Region 6
UTPR = Utah Department of Parks and Recreation
UTNHP = Utah Natural Heritage Program

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
1	1.1	Protect plant populations on Federal lands through formal agreements and/or land designations to a degree comparable with Critical Habitat designations but that would not require publication of population locations.	P-1,P-2, P-3, T-1, T-4, T-6	USFWS, BLM, NPS	25	5	5	5	5	5	Includes staff time to work on developing agreements and/or land designations	5
1	1.2	Incorporate plant protection into Federal agency planning documents.	P-1,P-2, P-3, T-1, T-4, T-6	USFWS, BLM, NPS	60	2	2	2	2	2	Includes staff time to work on developing documents	30
2	1.3	Work with the Utah State Parks and SITLA to protect cactus populations on their land	P-1,P-2, P-3, T-1, T-4, T-6	USFWS, BLM, SITLA, UTPR	60	2	2	2	2	2	Staff time to work with State agencies	30
2	1.4	To the extent possible, protect plant populations on private lands.	P-1,P-2, P-3, T-1, T-4, T-6	USFWS, BLM, Private, NGO	30	1	1	1	1	1	Staff time to work with private partners	30
2	1.5.1.1	Adequate conservation measures should be incorporated into future leases	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR, UDOT, Local	10	5	1	1	1	1	Main cost is staff time for meetings with partners and draft planning documents that incorporate measures. Minimal cost after to refine and implement.	10

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	1.5.1.2	BLM should implement at minimum 400 m (1,312 ft) avoidance buffers, surface disturbance limits, and compensatory mitigation in areas where NSO is not possible.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR, UDOT, Local	10	5	1	1	1	1	Main cost is staff time for meetings with partners and draft planning documents that incorporate these measures. Minimal cost thereafter to refine and implement. Potentially less cost if included in process for above action.	10
2	1.5.1.3	Implement dust abatement measures on all roads associated with development and all construction projects in occupied habitat.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR, UDOT, Local	30	1	1	1	1	1	Cost should be low but recurring whenever work is being done.	30
2	1.5.1.4	Avoid or adequately minimize fragmentation of sites within populations.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR, UDOT, Local	10	6	1	1	1	1	Main cost is staff time for meetings with partners and draft planning documents that incorporate these measures. Minimal cost thereafter to refine and implement	10

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	1.5.1.5	BLM should develop species-specific reclamation and restoration guidelines and require these activities as part of the permitting process in suitable habitat for the species and its pollinators.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR, UDOT, Local	10	6	1	1	1	1	Main cost is staff time for meetings with partners and draft planning documents that incorporate these measures. Minimal cost thereafter to refine and implement.	10
2	1.5.2.1	Protocol (to minimize effects of road or highway projects near occupied habitat) should include evaluating whether work is planned in occupied or suitable habitat and what the potential impacts to both individual plants and habitat are.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR, UDOT, Local	10	6	1	1	1	1	Main cost is staff time for meetings with partners and draft planning documents that incorporate these measures. Minimal cost thereafter to refine and implement.	10
2	1.5.2.2	If a conflict with a road or highway project exists, develop and implement conservation measures.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR, UDOT, Local	5	5	-	-	-	-	Periodic as needed if conflicts arise. Assume 5K every five years or so.	30

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	1.6.1.1	BLM, SITLA, and NPS should identify and evaluate impacts from recreational use areas that overlap or are within 400 m (1,312 ft) of plant occurrences.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	25	5	-	-	2	-	Cost up front for evaluating current areas and then sporadically in future as new projects are proposed and need to be evaluated.	30
2	1.6.1.2	BLM, SITLA, UTPR, and NPS should develop and implement a plan to, when possible, relocate recreational use areas and facilities that are within 400 m (1,312 ft)of occupied habitat.	P-1, P-2, P-3, T-1, T-6	BLM, NPS, SITLA, UTPR	10	10	-	-	-	-	Cost up front for developing plan in future and relocating existing sites. Minimal cost thereafter.	30
2	1.6.1.3	When possible, all new recreation trails and facilities should be located at least 400 m (1,312 ft)from occupied habitat.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	-	-	-	-	-	-	Cost included in previous actions. If plans are in place and projects are evaluated cost on new projects should be negligible.	30
2	1.6.1.4	Planned development in suitable habitat should be minimized and unavoidable impacts fully mitigated.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	60	10	-	-	-	-	Some cost included in previous actions. Mitigation cost of unavoidable projects would be sporadic, assume 10k every five years.	30

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	1.6.2.1	Implement effective OHV control measures, including improved signage and enforcement of existing OHV restrictions in areas where compliance is poor.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	130	10	4	4	4	4	Includes costs for signage and barriers as well as maintenance and enforcement. Included sporadic costs for new projects or sign/barrier replacement as needed.	30
2	1.6.2.2	Evaluate high impact sites to determine if additional restrictions on OHV use, trail rerouting, or closures are necessary to protect populations or sites and implement those changes.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	10	6	2	2	2	2	Initial costs should be up front, later costs covered by action 1.6.2.1.	5
2	1.6.3.1	Protect specific sites from OHV use with fencing or other physical barriers and maintain these protections.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	-	-	-		-	-	Cost included in action 1.6.3.1 as these actions go hand in hand.	-
2	1.6.3.2	Evaluate non-OHV recreational impacts such as hiking, biking, camping, and horseback riding on cactus populations and sites to determine if changes to existing land use regulations are necessary.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	10	6	2	2	2	2	Evaluation cost and needed regulation changes should be up front cost. Enforcement after changes should be covered by action 1.6.3.1	5

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	1.6.4	Provide appropriate levels of law enforcement at the correct times and places to protect the species from recreational impacts.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	60	2	2	2	2	2	Partially covered by action 1.6.3.1 but additional funds should be provided to cover high use times at popular sites (holidays, events, etc.)	30
2	1.6.5.1	Ensure law enforcement and biologist coordination occurs when unauthorized activities that result in harm to plants or habitat are documented.	P-1,P-2, P-3, T-1, T-2, T-4, T-6	BLM, NPS, SITLA, UTPR	30	1	1	1	1	1	Cost partially covered by action 1.6.3.1 under regular enforcement duties but added some provision for incidents of unusual vandalism or damage. Average 1K per year.	30
2	1.6.5.2	Develop education and compliance program with user groups	P-1,P-2, P-3, T-1, T-2, T-4, T-6	BLM, NPS, SITLA, UTPR	35	6	1	1	1	1	Program development costs will be mostly up front, minimal costs thereafter to update materials or staff time for presentations.	30
2	1.7.1	In so far as is possible, locate livestock trails and watering areas away from populations and sites to avoid trampling	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	50	20	-	-	-	5	Up front cost to make changes then sporadic costs as issues arise.	30

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	1.7.2	Continually identify sites and populations impacted by livestock grazing and rank and prioritize them by impact.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	1500	50	50	50	50	50	Includes duties of a range conservationist, technicians, and projects costs. Requires regular monitoring of conditions in livestock utilized habitat.	30
2	1.7.3.1	As part of developing a comprehensive strategy to reduce grazing impact on the species, implement restrictions on grazing use as necessary to reduce impacts	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	1200	200	200	200	200	200	Staff time for meetings and up front costs for developing and implementing such a comprehensive plan. 200K average per year for first five years for development, minimal costs thereafter.	30
2	1.7.3.2	Protect specific sites from livestock grazing with fencing or other physical barriers and maintain these protections.	P-1,P-2, P-3, T-1, T-4, T-6	BLM, NPS, SITLA, UTPR	300	100	1	1	1	4	Includes cost of fencing plus staff time to implement and maintain. Assume some cost each year plus additional for repairs every five years or so.	30

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	1.8	Identify sites or populations which receive high levels of disturbance or impact from other large ungulates, evaluate the potential for reducing these impacts, and create and implement a management plan to effectively protect the species.	P-1,P-2, P-3, T-1, T-4, T-6	USFWS, BLM, NPS, SITLA, UTPR	30	10	2	2	2	2	Sites have already been identified from recent data collection efforts. Biggest expense would be in year 1 to write the plan.Expenses in subsequent years would depend upon actions in the plan.	30
2	1.9.1.1	Fund and implement a study to determine whether and how herbivory from insects, particularly cactus borer beetle, is increasing.	P-1, P-2, P-3, T-3, T-6	USFWS, BLM, NPS, NGO	250	50	50	50	50	50	Large research component to this for first 5 years or so to assess beetles, rodents, other pests.	5
2	1.9.1.2	Based on this study, develop and implement strategies that reduce or mitigate for climate change impacts from herbivory.	P-1, P-2, P-3, T-3, T-6	USFWS, BLM, NPS, NGO	75	27	2	2	2	2	Develop strategies based on study results. Implement strategies for next 25 years at average of 2K per year (begins after five year study completed)	25
2	1.9.1.3	Develop and implement strategies to improve habitat conditions that would allow the species to better withstand drought.	P-1, P-2, P-3, T-6	USFWS, BLM, NPS, NGO	85	27	2	2	2	2	Develop strategies based on existing knowledge. Implement strategies for next 30 years at average of 2K per year	30

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	1.9.2	Determine the potential for cacti to migrate into currently unoccupied habitat as a response to climate change and preserve such habitats for the future.	P-1, P-2, P-3, T-6	USFWS, BLM, NPS, NGO	340	50	10	10	10	10	Cost highly variable depending on whether cacti can migrate into suitable habitat. Some cost of research covered by habitat model work. Preservation cost will vary depending on areas identified. Estimate up front cost plus average of 10K per year.	30
2	1.10.1	Determine which populations experience the highest levels of illegal collection and increase the presence of law enforcement in those areas.	T-2	USFWS, BLM, NPS, SITLA, UTPR	90	3	3	3	3	3	More frequent law enforcement patrols in area likely to be the target of theft.	30
2	1.10.2	Determine ways in which managing agencies can share population and location information as needed without risking that information becoming public.	P-1,P-2, P-3, T-2	USFWS, BLM, NPS, SITLA, UTPR	5	5	-	-	-	-	Staff time for meetings to brainstorm and implement information sharing. Negligible cost thereafter.	1
2	1.11.1	Identify supporting species and communities which are important to the continued health of the cactus.	P-1, P-2, P-3, T-6	USFWS, BLM, NPS, NGO	100	20	20	20	20	20	Cost of research and staff time to develop recommendations.	5

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	1.11.2	Include supporting species considerations when developing protected areas.	P-1, P-2, P-3, T-6	USFWS, BLM, NPS, SITLA, UTPR, Private	50	10	10	10	10	10	Includes cost of staff time to develop agreements. Once protections are in place, additional cost is minimal and covered by enforcement. Protections should remain in place for the long term but these measures should be implemented in the first 5 years.	5
2	1.11.3	Incorporate protective measures such as buffers and surface disturbance limits in maintaining undisturbed areas.	P-1, P-2, P-3, T-1, T-4, T-6	USFWS, BLM, NPS, SITLA, UTPR, Private	50	10	10	10	10	10	Includes cost of staff time to develop agreements. Once protections are in place, additional cost is minimal and covered by enforcement. Protections should remain in place for the long term but these measures should be implements in the first 5 years.	5

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	1.11.4	Avoid or reduce anthropogenic disturbance in and around known occupied areas.		USFWS, BLM, NPS, SITLA, UTPR, Private	50	10	10	10	10	10	Includes cost of staff time to develop agreements. Once protections are in place, additional cost is minimal and covered by enforcement. Protections should remain in place for the long term but these measures should be implemented in the first 5 years.	5
2	1.11.5	Identify and protect suitable non-occupied habitat adjacent to existing populations.		USFWS, BLM, NPS, SITLA, UTPR, Private	50	10	10	10	10	10	Includes cost of staff time to develop agreements. Once protections are in place, additional cost is minimal and covered by enforcement. Protections should remain in place for the long term but these measures should be implements in the first 5 years.	5
1	1.12.1	Protect the in situ (onsite) seedbank of each species.		USFWS, BLM, NPS, SITLA, UTPR, Private	-	-	-	-	-	-	Costs covered under other actions that protect populations and habitat.	30

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	1.12.2	Protect seeds ex situ (offsite).		BLM, NPS, NGO	60	2	2	2	2	2	Ex situ conservation costs.	30
2	1.12.3	Develop seed collection and permitting guidelines		USFWS, BLM, NPS	2	2	-	-	-	-	Staff time to develop guidelines in first year. Cost to implement guidelines negligible once in place. Guidelines should remain in place but development should occur in 1 year.	1
2	1.12.4	Collect and store seeds representing the genetic variability of each species.		BLM, NPS, NGO	-	-	-	-	-	-	Costs included in action 1.12.2	30
2	2.1	Locate and conserve additional extant populations.	P-1, P-2, P-3, P-4, P-6	BLM, NPS, NGO, UTNHP	-	-	-	-	-	-	Costs of locating populations covered in 2.2-1-2.2.4. Costs of conserving new populations covered by Recovery Actions 1.1-1.12.4	30
2	2.2.1	Develop a suitable habitat model.	P-1, P-2, P-3, P-4, P-6	BLM, NPS	20	10	10	-	-	-	Habitat model in progress, additional costs to refine over next two years.	2
2	2.2.2	Delineate appropriate potential habitat areas and conduct surveys on Federal lands.	P-1, P-2, P-3, P-4, P-6	BLM, NPS, NGO, UTNHP	80	8	8	8	8	8	The portion of these cost related to new searches also applies to 2.1 above.	10 years or until all suitable habitat surveyed

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	2.2.3	Obtain permission from State and private landowners to conduct surveys on non-federal lands.	P-1, P-2, P-3, P-4, P-6	BLM, NPS, NGO, UTNHP	20	2	2	2	2	2	The portion of these cost related to new searches also applies to 2.1 above.	10 years or until all suitable habitat surveyed
1	2.2.4	Maintain a database for survey efforts, including negative results.	P-1, P-2, P-3, P-4, P-6	BLM, NPS, NGO, UTNHP	60	2	2	2	2	2	UTNHP already maintains a database, all agencies should share with them and keep updated. Cost staff time for data entry/organization.	30
1	2.3	Apply the protection and conservation measures detailed in recovery actions 1.1-1.12.4 to each additional population found.	P-1,P-2, P-3, P-4, P-5, T-1, T-2, T-3 T-4, T-5,	USFWS, BLM, NPS, SITLA, UTPR, Private	30	1	1	1	1	1	Already included in the costs of Recovery Action 1.1-1.12.4. May be a bit higher if many new populations are found so added $1K/year.	30
1	2.4.1	Scientifically determine appropriate disturbance thresholds for each individual threat and use them to determine if abatement action needs to be taken.	T-1, T-2, T-4, T-5, T-6	USFWS, BLM, NPS, SITLA, UTPR, Private	750	50	50	50	50	50	$50k for first 5 years to conduct monitoring and do the extensive research required to scientifically determine the disturbance threshold for each threat; then $20K/year to do monitoring and assessment, data analysis and report writing	30

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
1	2.4.2	Address threats to each population with a "top-down" approach, treating the threat causing the highest amounts of documented disturbance as the immediate priority for abatement measures.	T-1, T-2, T-4, T-5, T-6	USFWS, BLM, NPS, SITLA, UTPR, Private	300	10	10	10	10	10	Average of 10K/year for threats abatement but may vary greatly depending on results of monitoring. Likely majority of threats abatement costs will be clustered once good monitoring data is accumulated and analyzed.	30
1	2.5.1	Implement standardized monitoring on Federal lands.	All	USFWS, BLM, NPS, NGO	100	20	20	20	20	20	Costs and monitoring protocols can be combined with developing threat monitoring in action 2.4.1. Additional 20K for first five years for developing specific demographic and trend monitoring methods and establishing plots. Cost included in threats monitoring after that.	30

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
1	2.5.2	Create a database for long-term collection and evaluation of monitoring data.	All	USFWS, BLM, NPS, NGO, UTNHP	30	1	1	1	1	1	Can be combined with 2.2.4 and maintained by UTNHP. Cost of database covered by that action. Additional 1K/year for evaluation of data. Collection costs covered under action 2.5.1.	30
2	3.1	Establish a set of need-based research priorities aimed at abating or minimizing threats and increasing population health and numbers.	T-1, T-2, T-3, T-4, T-5	USFWS, BLM, NPS, NGO	6	2	-	-	-	-	Doesn't include costs of doing the research, just to identify research needs. $2K every 10 years.	Periodic through 30 years.
2	3.2	Analyze available data and identify data needed to evaluate population trends.	P-1, P-2, P-3	USFWS, BLM, NPS	90	3	3	3	3	3	Annual analysis of monitoring data	30
2	3.3	Develop standard procedures for setting annual research priorities and evaluating proposals.	All	USFWS, BLM, NPS, NGO	30	10	-	-	-	-	10K every 10 years	Periodic through 30 years
2	3.4	Establish protocols for protecting cacti populations during the course of field studies.	All	USFWS, BLM, NPS	2	2	-	-	-	-	Group effort building on Recovery Team progress.	One time cost

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
2	3.5.1	Pollinator research.	P1, P2, P3, T-6	USFWS, BLM, NPS, NGO	150	5	5	5	5	5	Costs are dependent on scope of research attempted.[2]	30
2	3.5.2	Habitat substrates and soil conditions research.	P1, P2, P3	USFWS, BLM, NPS, NGO	150	5	5	5	5	5	Costs are dependent on scope of research attempted.[1]	30
2	3.5.3	Genetic variation and reproductive biology research.	P1, P2, P3	USFWS, BLM, NPS, NGO	150	5	5	5	5	5	Costs are dependent on scope of research attempted.[1]	30
2	3.5.4	Seedbank viability and longevity research.	P1, P2, P3	USFWS, BLM, NPS, NGO	150	5	5	5	5	5	Costs are dependent on scope of research attempted.[1]	30
2	3.5.5	Parasitism, herbivory, and disease research.	T-3, T-6	USFWS, BLM, NPS, NGO	150	5	5	5	5	5	Costs are dependent on scope of research attempted.[1]	30
2	3.5.6	Nonnative weeds research.	T-1	USFWS, BLM, NPS, NGO	150	5	5	5	5	5	Costs are dependent on scope of research attempted.[1]	30
2	3.5.7	Modeling.	All	USFWS, BLM, NPS, NGO	150	5	5	5	5	5	Costs are dependent on scope of research attempted.[1]	30
2	3.5.8	Restoration and propagation research.	P1, P2, P3	USFWS, BLM, NPS, NGO	150	5	5	5	5	5	Costs are dependent on scope of research attempted.[1]	30
2	3.5.9	Response to livestock management changes.	T-1	USFWS, BLM, NPS, NGO	150	5	5	5	5	5	Costs covered under action 2.4.2	30
3	4.1	Promote effective communications with partners and stakeholders regarding the species.	All	USFWS, BLM, NPS, SITLA, UTPR, Private	60	2	2	2	2	2	Ongoing	30

[2] Research priorities should be identified under actions 3.1 and 3.3. Annual costs represented here are averaged equally amongst the topics, but money for research should be allotted based on priorities so actual costs for each area may be more or less. Additionally, some data collection costs may be covered as part of regular monitoring efforts.

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
3	4.2	Maintain an active dialogue with Federal, State, and municipal agencies and private interests about recovery issues.	All	USFWS, BLM, NPS, SITLA, UTPR, Private	60	2	2	2	2	2	Ongoing	30
3	4.3	Maintain communications with the Utah State Parks and SITLA regarding conservation of the cactus populations.	All	USFWS, BLM, NPS, SITLA, UTPR,	30	1	1	1	1	1	Ongoing	30
3	4.4	Establish productive communications with OHV and other interest groups.	T-1	USFWS, BLM, NPS, NGO	60	2	2	2	2	2	Ongoing	30
3	4.5	Develop and implement educational and outreach programs.	All	USFWS, BLM, NPS	30	2	-	2	-	2	$2K every other year	Periodic for 30 years
3	4.6.1	Integrate recovery into broader interpretive programs.	All	USFWS, BLM, NPS	30	1	1	1	1	1	Ongoing	30
3	4.6.2	Develop materials and make presentations for educational institutions.	All	USFWS, BLM, NPS	30	1	1	1	1	1	Ongoing	30
3	5.1	Provide oversight and support for implementation of recovery actions	All	USFWS, BLM, NPS	60	2	2	2	2	2	Ongoing	30

Action Priority	Action Number	Action Description	Recovery Criterion Number(s)	Responsible Parties	Total Costs (1,000's)	FY 1	FY 2	FY 3	FY 4	FY 5	Comments	Action Duration (Years)
3	5.2	Establish a technical working group to regularly review the status of the species and track the effectiveness of recovery actions.	All	USFWS, BLM, NPS	30	1	1	1	1	1	To attend Recovery Team meetings as needed each year, review documents, etc.	30
3	5.3	Revise the recovery program when indicated by new information and recovery progress.	All	USFWS, BLM, NPS	30	-	-	-	-	5	$5K every 5 years	Periodic for 30 years
3	5.4	Stakeholders should support recovery by providing personnel and fiscal resources yearly to implement recovery actions.	All	USFWS, BLM, NPS, SITLA, UTPR, NGO	-	-	-	-	-	-	Costs included in other actions in this table	30

PART 5. LITERATURE CITED

Aizen, M.A., L. Ashworth, and L. Galetto. 2002. Reproductive success in fragmented habitats: do compatibility systems and pollination specialization matter? Journal of Vegetation Science. 13: 885–892.

Arp, G. 1972. A revision of Pediocactus. Cactus and Succulent Journal. 44:218-222.

Barrett, S. C. H. & J. R. Kohn. 1991. Genetic and evolutionary consequences of small population size in plants: implications for conservation. In: Falk DA, Holsinger KE, editors. Genetics and Conservation of Rare Plants. New York: Oxford Univ. Press. p 3-30.

Beaumont, L., A. Pitman, S. Perkins, N. Zimmermann, N. Yoccoz, and W. Thuiller. 2011. Impacts of climate change on the world's most exceptional ecoregions. PNAS. 108(6): 2306–2311.

Belnap, J. 2003. The world at your feet: desert biological soil crusts. Frontiers in Ecology and the Environment 1(4): 181-189.

Belnap, J. and Gillette, D.A., 1997. Disturbance of biological soil crusts: impacts on potential wind erodibility of sandy desert soils in southeastern Utah. Land Degradation & Development, 8(4), pp.355-362.

Belnap, J., R. Prasse and K. Harper. 2001. Influence of biological soil crusts on soil environments and vascular plants in (eds) Belnap, J. and O. Lange Biological soil crusts; Structure function and management. Ecological Studies vol 150 Springer-Verlag Berlin 281-300.

Belnap, J. R. Reynolds, M. Reheis, S. Phillips, F. Urban, and H. Goldstein 2009. Sediment losses and gains across a gradient of livestock grazing and plant invasion in a cool, semi-arid grassland, Colorado Plateau, USA. Aeolian Research 1(1-2): 27-43.

Benson, L. 1982. The cacti of the United States and Canada. Stanford University Press. 1044pp.

Berg, M., E. Kiers, G. Driessen, M. van der Heijden, B. Kooi, F. Kuenen, M. Liefting, H. Verhoef, and J. Ellers. 2009. Adapt or disperse: understanding species persistence in a changing world. Glob. Chg. Biol. doi: 10.1111/j.1365–2486.2009.02014x.

Brock, J.H. and Green, D.M., 2003. Impacts of livestock grazing, mining, recreation, roads, and other land uses on watershed resources. Journal of the Arizona-Nevada Academy of Science, pp.11-22.

Brooks, M.L., and D. Pyke. 2001. Invasive plants and fire in the deserts of North America. Pages 1–14 in K. Galley and T. Wilson (eds.), Proceedings of the Invasive Species Workshop: The Role of Fire in the Control and Spread of Invasive Species. Fire Conference 2000: The First National Congress on Fire, Ecology, Prevention and Management. Miscellaneous Publications No. 11, Tall Timbers Research Station, Tallahassee, Florida.

Brooks, M.L., T.C. Esque, and T. Duck. 2003. Fuels and fire regimes in creosote bush, blackbrush, and interior chaparral shrublands. Report for the Southern Utah Demonstration Fuels Project, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Science Lab, Missoula, Montana. 18 pp.

Bureau of Land Management (BLM). 2008. Price Field Office Record of Decision and Approved Resource Management Plan. October 2008. 182 pp.

Bureau of Land Management (BLM). 2008a. Richfield Field Office Record of Decision and Approved Resource Management Plan. October 2008. 206 pp.

Bureau of Land Management (BLM). 2008b. ESA and BLM Guidance and Policy Manual 6840: Special Status Species Management. Revised manual. 48 pp.

Bureau of Land Management (BLM). 2011. Monitoring plan for San Rafael cactus (Pediocactus despainii. 28 pp.

Bureau of Land Management (BLM). 2011a. 2011 Results of Initial Repeat Inventories in BLM Price Field Office. Unpublished summary report prepared by the BLM Price Field Office. August 19, 2011. 2 pp.

Bureau of Land Management (BLM). 2011b. 2011 Results of Initial Repeat Inventories in the BLM Richfield Field Office. Unpublished summary report prepared by the BLM Richfield Field Office. 2 pp.

Bureau of Land Management (BLM). 2012. Summary report 2011: initial and repeat inventory for San Rafael cactus (Pediocactus despainii). Price Field Office. Unpublished report. 31 pp.

Bureau of Land Management (BLM). 2012a. Summary report 2012: initial and repeat inventory for San Rafael cactus (Pediocactus despainii). Price Field Office. Unpublished report. 23 pp.

Bureau of Land Management (BLM). 2013. Summary report 2011-2013: Summary of initial repeat inventory of Winkler cactus (Pediocactus winkleri). Richfield Field Office. Unpublished report. 15 pp.

Bureau of Land Management (BLM). 2013a. Threatened and Endangered Plants Program Annual Summary Report on Pediocactus despainii. Prepared by the BLM Price Field Office for the USFWS, January 2013. 23 pp.

Bureau of Land Management (BLM). 2015. Biological Assessment, Goodwater Rim Trail (Draft). Prepared by the BLM Price Field Office for the USFWS, May 2015. 38 pp.

Cane, J.H. 2001. Habitat Fragmentation and Native Bees: A Premature Verdict? Conservation Ecology 5(1): 3. [accessed online] URL: http://www.consecol.org/vol5/iss1/art3/.

Castellano, M.J. and T.J. Valone 2007. Livestock, soil compaction and water infiltration rate: Evaluating a potential desertification recovery mechanism. Journal of Arid Environments. 71:1 97-108.

Chen, I.C., J. Hill, R. Ohlemuller, D. Roy, and C. Thomas. 2011. Rapid range shifts of species associated with high levels of climate warming. Science. 333: 1024-1026.

Clark, D. 1998. Final report for "Expedition into the Parks", rare plant survey at Capitol Reef National Park. Unpublished NPS document, Capitol Reef National Park, Torrey, Utah. 13 pp.

Clark, D. 1999. 1999 Survey Results and Final Report of a two year Winkler and San Rafael cactus study. Unpublished NPS document, Capitol Reef National Park, Torrey, Utah. 10 pp.

Clark, D. 2002. Summary of the Interagency Rare Plant Inventory Project 1999 through 2002. Dixie National Forest, Teasdale District, Teasdale, Utah, Bureau of Land Management, Richfield Field Office, Richfield, Utah, Capitol Reef National Park, Torrey Utah, and Fish Lake National Forest, Supervisor's Office, Richfield, Utah. 88 pp.

Clark, D. 2008. Summary of Repeat Inventory Monitoring and Site Visit Accounts to Sclerocactus wrightiae, Pediocactus winkleri and P. despainii sites. Unpublished report prepared by the Interagency Rare Plant Team. 31 pp.

Clark, D. 2008a. Summary of two Pediocactus winkleri paired monitoring plots. 4 pp.

Clark, D. 2008b. 2008 survey results for Winkler footcactus (Pediocactus winkleri). Report for Capitol Reef National Park, Bureau of Land Management, Richfield Field Office. 8 pp.

Clark, D. 2008c. Summary and conclusions on effects of livestock trampling on Sclerocatus wrightiae, San Rafael cactus and Pediocactus winkleri. Capitol Reef National Park. Unpublished document. 14 pp.

Clark, D. 2010 Outline of Sclerocactus wrightiae, Pediocactus winkleri and Pediocactus despainii data gathered by the Interagency Rare Plant team between 1998 and 2010. Unpublished report. 7 pp.

Clark, D. 2011. Summary of Repeat Inventory Monitoring and Site Visit Accounts to Pediocactus winkleri. Unpublished NPS document, Capitol Reef National Park, Torrey, Utah. 65 pp.

Clark, D. 2011a. Comments on the August 23 Richfield BLM report for repeat inventories conducted for Sclerocactus wrightiae and Pediocactus winkleri in 2011. Unpublished report prepared for the BLM and the USFWS. 6 pp.

Clark, D. 2012. Ackland Pediocactus winkleri Plot Summary 1995-2012. Unpublished report prepared for the BLM and the USFWS.

Clark D., T. O. Clark, M. C. Duniway, and C. Flagg. 2015. Effects of ungulate disturbance and weather variation on Pediocatus winkleri: Insights from long-term monitoring. Western North American Naturalist. Vol. 75, No. 1, pp. 88-101.

Clark, T.O., and D. Clark. 2007. Sclerocactus wrightiae monitoring in Capitol Reef National Park. Unpublished report prepared for Capitol Reef National Park. 23 pp.

Clark, T. O. and D. Clark. 2008. Pediocactus winkleri Monitoring in Capitol Reef National Park. Unpublished NPS document, Capitol Reef National Park, Torrey, Utah.

Craig, J., T. Cahill, D. Ono. 2010. South County Phase 2 Particulate Study: San Luis Obispo County Air Pollution Control District. February 2010. San Luis Obispo County APCD. 108 pp.

Coles, J.J., Decker, K.L. and Naumann, T.S., 2012. Ecology and population dynamics of Sclerocactus mesae-verdae (Boissev. & C. Davidson) LD Benson. Western North American Naturalist, 72(3), pp.311-322.

Convention on International Trade in Endangered Species (CITES). 2011. Appendices I, II, and II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, valid from 27 April 2011. 42 pp.

Cronquist, A., A.H. Holmgren, N.H. Holmgren and J.L. Reveal. 1972. Intermountain flora, Volume 1. Hafner Publishing Company, Inc. New York. 270 pp.

Damschen, E., S. Harrison and J. Grace. 2010. Climate change effects on an endemic-rich edaphic flora: resurveying Robert H. Whittaker's Siskiyou sites (Oregon, USA). Ecology 91(12): 3609-3619.

Debinski, D.M. and R.D. Holt. 2000. Review: a survey and overview of habitat fragmentation experiments. Conservation Biology. 14(2) 342–355.

Deutsch, C., J. Tewksbury, R. Huey, K. Sheldon, C. Ghalambor, D. Haak, and P. Martin. 2008. Impacts of climate warming on terrestrial ectotherms across latitude. PNAS. 105(18) 6668–6672.

Duda J., D. Freeman, J. Emlen, J. Belnap, S. Kitchen, J. Zak, E. Sobek, M. Tracy, and J. Montante 2003. Differences in native soil ecology associated with invasion of the exotic annual chenopod, Halogeton glomeratus. Biology and Fertility of Soils 38:72–77.

Eckert, R. E., Jr., M. K. Wood, W. H. Blackburn & F. F. Peterson. 1979. Impacts of Off-road vehicles on infiltration and sediment production of two desert soils. Journal of Range Management 32:394-397.

eFloras. 2014. Published on the Internet http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=124250 [accessed October 20, 2014] Missouri Botanical Garden, St. Louis, MO & Harvard University Herbaria, Cambridge, MA.

Eller, B. M. 1977. Road dust induced increase of leaf temperature. Environmental Pollution 13, 99–107.

Eller, B.M. and U. Brunner. 1975. Der Einfluss von Strassenstaub auf die Strahlungabsorption durch Blatter. Archives der Meteorolgie, Geophysik, und Bioklimatologie, Series B. 23, 37–146.

Ellstrand, N.C. and D.R. Elam. 1993. Population genetic consequences of small population size: implications for plant conservation. Annual Review of Ecology and Systematics 24: 217-242.

Euskirchen, E., A. McGuire, F. Chapin, S. Yi, and C. Thompson. 2009. Changes in vegetation in northern Alaska under scenarios of climate change, 2003–2100: implications for climate feedbacks. Ecol. Apps. 19(4): 1022–1043.

Eveling, D.W. and Bataille, A. 1984. The effect of deposits of small particles on the resistance of leaves and petals to water loss. Environmental Pollution Series A, Ecological and Biological, 36(3), pp.229-238.

Everett, K. R. 1980. Distribution and properties of road dust along the northern portion of the Haul Road. Pages 101–128 in J. Brown and R. Berg, editors. Environmental engineering and ecological baseline investigations along the Yukon River–Prudhoe Bay Haul Road. CRREL Report 80-19. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, USA.

Farmer, A.M. 1993. The effects of dust on vegetation – a review. Environmental Pollution. 79: 63-75.

Fliickiger, W., Oertli, J. J. and H. Fliickiger. 1979. Relationship between stomatal diffusive resistance and various applied particle sizes on leaf surfaces. Z. Pflanzenphysiol., 91: 173–175.

Galbraith, H., D. Spooner, and C. Vaughn. 2010. Synergistic effects of regional climate patterns and local water management on freshwater mussel communities. Biol. Cons. 143: 1175–1183.

Gathmann, A., and T. Tscharntke. 2002. Foraging ranges of solitary bees. Journal of Animal Ecology. 71:757–764.

Given, D. R. 1994. Principles and Practice of Plant Conservation. Timber Press, Portland, Oregon, USA.

Glick, P., B.A. Stein, and N.A. Edelson (eds.). 2011. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. National Wildlife Federation; Washington, DC. 168 pp. Available online at http://www.nwf.org/~/media/pdfs/global-warming/climate-smart-conservation/nwfscanningtheconservationhorizonfinal92311.ashx.

Goverde, M., K. Schweizer, B. Baur, and A. Erhardt. 2002. Small-scale habitat fragmentation effects on pollinator behaviour: experimental evidence from the bumblebee Bombus veteranus on calcareous grasslands. Biological Conservation. 104: 293–299.

Greenleaf, S.S., N.M. Williams, R. Winfree, and C. Kremen. 2007. Bee foraging ranges and their relationship to body size. Plant Animal Interactions. Oecologia. 153: 589–596.

Greenleaf, S.S. 2005. Local-Scale and Foraging-Scale Habitats Affect Bee Community Abundance, Species Richness, and Pollination Services in Northern California. PhD Thesis, Princeton University. 88 pages. See pages 2-9, 15-27, 33-39, 45-52, 59-67, 72-79.

Harper, K.T., R. Van Buren, and S.G. Kitchen. 1996. Invasion of alien annuals and ecological consequences in Salt Desert shrublands of western Utah. In: Barrow J.R., McArthur E.D., Sosebee R.E., Tausch R.J. (eds) Proceedings: Shrubland Ecosystem Dynamics in a Changing Environment, 23–25 May 1995, Las Cruces, New Mexico. General technical report INT-GTR-338. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah.

Heil, K.D. 1979. Three new species of cactaceae from southeastern Utah. Cact. Succ. Jour. 51:25-30.

Heil, K., B. Armstrong and D. Schleser. 1981. A review of the genus Pediocactus. Cact. Succ. Jour. 53:17-39.

Heil, K.D. 1984. Status report on Pediocactus despainii. U.S. Fish and Wildlife Service, Denver, Colorado. 16 pp.

Heil K. D. 1987. A vegetation study of Capitol Reef National Park – final progress report for 1986. Unpublished NPS document, National Park Service, Torrey, Utah.

Heil, K.D. 1994. The effects of grazing on threatened/endangered plant species in the Hartnet and Sandy III grazing allotment, Capitol Reef National Park, UT. Unpublished report prepared for the National Park Service. San Juan College, Farmington, NM. 24 pp.

Herbel, C.H., Ares, F.N. and Wright, R.A. 1972. Drought effects on a semidesert grassland range. Ecology, 53(6), pp.1084-1093.

Hobbs, M.L. 2001. Good practice guide for assessing and managing the environmental effects of dust emissions. Published September 2001 by Ministry for the Environment. P.O. Box 10-362, Wellington, New Zealand. 58 pp.

Hochstätter, F. 1990. To the habitats of Pediocactus and Sclerocactus. Published by the Author. Mannheim, Germany. 170pp.

Hochstätter, F. 1995. Genera Pediocactus-Navajoa-Toumeya, Cactaceae, Revised: in the shadow of the Rocky Mountains, with Sclerocactus news. Published by the author, Mannheim, Germany.

Hughes, L. 2005. Arizona Strip Rare Plant Monitoring and Inventory Update 2005. Botanist, BLM St. George Field Office, St. George, Utah. 18pp.

Interagency Rare Plant Team (IA Team). 2011. Monitoring plan for Winkler cactus (Pediocactus winkleri). Joint publication of the BLM Richfield Field Office, Capitol Reef National Park, and the USFWS. 35 pp.

Interagency Rare Plant Team (IA Team). 2011a. Monitoring plan for San Rafael cactus (Pediocactus despainii). Joint publication of the BLM Richfield Field Office, BLM Price Field Office, and the USFWS. 38 pp.

Intergovernmental Panel on Climate Change. 2002. Climate Change and Biodiversity. IPCC Technical Paper V. 74 pp. + appendices. http://www.ipcc.ch/publications_and_data/publications_and_data_technical_papers.htm.

Intergovernmental Panel on Climate Change. 2007. Fourth Assessment Report Climate Change 2007: Synthesis Report Summary for Policymakers. Released on 17 November 2007. Available at <http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf>.

Intergovernmental Panel on Climate Change (IPCC). 2013a. Annex III: Glossary [Planton, S. (ed.)]. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 20 pp. Available online at http://www.climatechange2013.org/images/report/WG1AR5_AnnexIII_FINAL.pdf.

Intergovernmental Panel on Climate Change (IPCC). 2013b. Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, New York, USA. 33 pp. Available online at http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf

Intergovernmental Panel on Climate Change (IPCC). 2013c. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the

Intergovern¬mental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, New York, USA. 1535 pp. Available online at
http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf.

Jackson, Kyle. 2009. Email letter April 2009 discussing grazing allotments with the range of the three listed cacti. Bureau of Land Management, Richfield Field Office, Hanksville, Utah.

Jennersten, O. 1988. Pollination in Dianthus deltoids (Caryophyllaceae): effects of habitat fragmentation on visitation and seed set. Conservation Biology. 2: 359-366.

Jones, A. 2000. Effects of cattle grazing on North American arid ecosystems: a quantitative review. Western North American Naturalist. Vol. 60, No. 2, pp. 155-164.

Jump, A.S. and J. Peñuelas. 2005. Running to stand still: adaptation and the response of plants to rapid climate change. Ecology Letters, Vol. 8:1010–1020.

Karl, T.R., J.M. Melillo, and T.C. Peterson, (eds.). 2009. Global Climate Change Impacts in the United States. Cambridge University Press.

Kass, R.J. 1990. Final report - habitat inventory of threatened and endangered and candidate plant species in the San Rafael Swell, Utah. USDA, Bureau of Land Management, Salt Lake City, Utah. 87 pp.

Kass, R.J. 2001. Southwestern Rare and Endangered Plants: Proceedings of the Third Conference. September 25-28, 2000. Flagstaff, Arizona. USDA Proceedings RMRS-P-23.

Kolb, A. 2008. Habitat fragmentation reduces plant fitness by disturbing pollination and modifying response to herbivory. Biological Conservation: 141 (2008): 2540–2549.

Kuchler, A.W. 1964. Potential natural vegetation of the conterminous United States. American Geographical Society special publication number 36. American Geographical Society. New York. Map plus accompanying manual. 38 pp. + 116 legends.

Kuske C., C. Yeager, S, Johnson, L. Ticknor, and J. Belnap 2012. Repsonse and resilience of soil biocrust bacterial communities to chronic physical disturbance in arid shrublands. ISME Journal 6(4) 886-897.

Lennartsson, T. 2002. Extinction thresholds and disrupted plant-pollinator interactions in fragmented plant populations. Ecology. 83(11): 3060–3072.

Lienert, J. 2004. Habitat fragmentation effects on fitness of plant populations – a review. Journal for Nature Conservation 12: 53–72.

Lovich, J. E. & D. Bainbridge. 1999. Anthropogenic degradation of the southern California

desert ecosystem and prospects for natural recoverey and restoration. Environmental

Management 24:309-326.

Masters, R.A. and Sheley, R.L., 2001. Principles and practices for managing rangeland invasive plants. Journal of Range management, pp.502-517.

McGarigal, K., W. Romme, M. Crist, and E. Roworth 2001. Cumulative effects of roads and logging on landscape structure in the San Juan Mountains, Colorado (USA), Landscape Ecology 16: 327-349.

McKechnie, A., and B. Wolf. 2010. Climate change increases the likelihood of catastrophic avian mortality events during extreme heat waves. Biol. Lett. 6: 253–256.

McKelvey, K.S., J.P. Copeland, M.K. Schwartz, J.S. Littell, K.B. Aubry, J.R. Squires, S.A. Parks, M.M. Elsner, and G.S. Mauger. 2011. Climate change predicted to shift wolverine distributions, connectivity, and dispersal corridors. Ecol. Apps. 21(8): 2882–2897.

MECCA Mountain Bike Club website. http://www.biketheswell.org. Accessed 7/16/2015.

Melillo, J.M., T.C. Richmond, and G.W. Yohe (eds.). 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program. 841 pp. Available online at http://nca2014.globalchange.gov/downloads.

Moody-Weis, J. and J.S. Heywood. 2001. Pollination limitation to reproductive success in the Missouri evening primrose, Oenothera macrocarpa (Onagraceae). American Journal of Botany. 88(9): 1615–1622.

Mustajarvi, K.P. Siikamaki, S. Rytkonen, and A. Lammi. 2001. Consequences of plant population size and density for plant-pollinator interactions and plant performance. Journal of Ecology. 89: 80–87.

Myers-Smith, I.H., B.K. Arnesen, R.M. Thompson, F.S. Chapin III. 2006. Cumulative impacts on Alaskan arctic tundra of a quarter century of road dust. Ecoscience. 13(4): 503–510.

National Park Service (NPS). 2006. National Park Service biological resources management policy. 180 pp.

National Park Service (NPS). 2011. Results of Repeat Inventories of Winkler cactus (Pediocactus winkleri) in Capitol Reed National Park. Unpublished preliminary summary results prepared for Capitol Reef National Park. 2 pp.

National Park Service (NPS). 2012. 2012 Results of Repeat Inventories of Winkler cactus (Pediocactus winkleri) in Capitol Reef National Park. Unpublished preliminary summary results prepared for Capitol Reef National Park. 15 pp.

National Park Service (NPS). 2013. Cumulative and 2013 Results of Initial Repeat Inventories and Annual Repeat Sampling for Winkler cactus in Capitol Reef National Park. Unpublished preliminary summary results prepared for Capitol Reef National Park. 27 pp.

National Research Council. 2013. Abrupt impacts of climate change: anticipating surprises. Committee on Understanding and Monitoring Abrupt Climate Change and Its Impacts; Board on Atmospheric Sciences and Climate; Division on Earth and Life Studies. The National Academies Press; Washington, D.C. 250 pp. Available online at: http://www.nap.edu/catalog.php?record_id=18373&utm_expid=4418042-5.krRTDpXJQISoXLpdo-1Ynw.0

Natural Resources Conservation Service (NRCS). 2015. Draft Plan-EA for Millsite Dam rehabilitation. 87 pp.

NatureServe. 2014. Population/Occurrence Delineation and Viability Criteria. http://explorer.natureserve.org/popviability.htm [Accessed 5/12/2014]. 2 pp.

Neese, E. 1981. A vascular flora of the Henry Mountains, Utah. Unpublished Ph.D. Dissertation. Brigham Young University, Provo, Utah.

Neese, E. 1987. Final report - habitat inventory of Sclerocactus wrightiae and other associated sensitive species. Volumes 1 & 2. USDA, Bureau of Land Management, Richfield, Utah.

Newman, D. & D. Pilson. 1997. Increased probability of extinction due to decreased genetic effective population size: experimental populations of Clarkia pulchella. Evolution 51:354–362.

Ouren, D. S., C. Haas, C. P. Melcher, S. C. Stewart, P. D. Ponds, N. R. Sexton, L. Burris, T. Fancher & Z. H. Bowen. 2007. Environmental Effects of Off-Highway Vehicles on Bureau of Land Management Lands: A Literature Synthesis, Annotated Bibliographies, Extensive Bibliographies, and Internet Resources. 225 pages.

Porter, M, E. Roalson, K. D. Heil. 1999. Population Structure in Pediocactus winkleri and P. despainii (Cactaceae), based upon Chloroplast Haplotypes, Inferred from TRNL-FDNA Sequences. Draft document from Rancho Santa Ana Botanic Garden, 1500 North College.

Rawson, H.M. and Clarke, J.M. 1988. Nocturnal transpiration in wheat. Functional Plant Biology, 15(3), pp.397-406.

Ricks, G.R. and Williams, R.J.H. 1974. Effects of atmospheric pollution on deciduous woodland part 2: effects of particulate matter upon stomatal diffusion resistance in leaves of Quercus petraea (Mattuschka) Leibl. Environmental Pollution (1970), 6(2), pp.87-109.

Robinson, M. 2011. The San Rafael Cactus (Pediocactus despainii) Status Report 2011. Prepared by Rocky Mountain Environmental Research for the BLM. 325 pp.

Rogers, L.A., and D.E. Schindler. 2011. Scale and the detection of climatic influences on the productivity of salmon populations. Global Change Biology. 17: 2546–2558.

Rooks, D. 2014. Email to Tracey Switek regarding Pediocactus winkleri on BLM lands. BLM botanist, Richfield Field Office. 10 pp.

Rosentreter, R., M. Bowker, and J. Belnap. 2007. A Field Guide to Biological Soil Crusts of Western U.S. Drylands. U.S. Government Printing Office, Denver, Colorado.

Roth, D. 2003. Monitoring report: Pediocactus bradyi. Unpublished annual report prepared for the Navajo Natural Heritage Program, Window Rock, AZ. 8 pp.

Roth, D. 2004. Monitoring report: Pediocactus bradyi. Unpublished annual report prepared for the Navajo Natural Heritage Program, Window Rock, AZ. 11 pp.

Roth, D. 2008. Monitoring Report Pediocactus bradyi Marble Canyon, Coconino County, Arizona. Navajo Natural Heritage Program, Window Rock, AZ. 9p.

Roth, D. 2008a. Monitoring Report Sclerocactus mesae-verdae Transplant Project Northern Navajo Fairgrounds, Shiprock, San Juan County, New Mexico. Navajo Natural Heritage Program, Window Rock, AZ. 8p.

Sanders, T.G. and J.Q. Addo. 1993. Effectiveness and environmental impact of road dust suppressants. MPC-94-28. Fargo, ND: Mountain Plains Consortium. Available: http://www.mountain-plains.org/pubs/pdf/MPC94-28.pdf [accessed November 5, 2008].

Seager, R., T. Mingfang, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H. Huang, N. Harnik, A. Leetmaa, N. Lau, C. Li, J. Velez, and N. Naik. 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. Science 316: 1181–1184.

Schwinning, S., J. Belnap, D. R. Bowling, and J. R. Ehleringer. 2008. Sensitivity of the Colorado Plateau to change: climate, ecosystems, and society. Ecology and Society 13(2): 28. http://www.ecologyandsociety.org/vol13/iss2/art28/.

Shaffer, M.L., and B.A. Stein. 2000. In: Safeguarding our Precious Heritage. B.A Stein, L.S. Kutner, and J.S. Adams, eds. Oxford University Press. pp. 301–321.

Sharifi, M.R., Gibson, A.C., and P.W. Rundel. 1997. Surface dust impacts on gas exchange in Mohave desert shrubs. Journal of Applied Ecology. 34: 837–846.

Sharrow, S.H. 2007. Soil Compaction by grazing livestock in silvopastures as evidenced by changes in soil physical properties. Agroforestry Systems 71:215-223.

Shryock, D.F., Esque, T.C. and Hughes, L., 2014. Population viability of Pediocactus bradyi (Cactaceae) in a changing climate. American journal of botany, 101(11), pp.1944-1953.

Sinervo, B., F. Mendez-de-la-Cruz, D. Miles, B. Heulin, E. Bastiaans, M. Villagran-Santa Cruz, R. Lara-Resendiz, N. Martinez-Mendez, M. Calderon-Espinosa, R. Meza-Lazaro, H. Gadsden, L. Avila, M. Morando, I. de la Riva, P. Sepulveda, C. Rocha, N. Ibarguengoytia, C. Puntriano, M. Massot, V. Lepetz, T. Oksanen, D. Chapple, A. Bauer, W. Branch, J. Clobert, and J. Sites. 2010. Erosion of lizard diversity by climate and altered thermal niches. Science. 328: 894–899.

Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, N.L. Bindoff, Z. Chen, A. Chidthaisong, J.M. Gregory, G.C. Hegerl, M. Heimann, B. Hewitson, B.J. Hoskins, F. Joos, J.

Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T.F. Stocker, P. Whetton, R.A. Wood and D. Wratt, 2007: Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Smith, S.D., T.E. Huzman, S.F. Zitzer, T.N. Charlet, D.C. Housman, J.S. Coleman, L.K. Fenstermaker, J.R. Seeman, and R.S. Nowak. 2000. Elevated CO2 increase productivity and invasive species success in an arid system. Nature 408: 79–81.

Smith, C.I. and Farrell, B.D. 2005. Phylogeography of the longhorn cactus beetle Moneilema appressum LeConte (Coleoptera: Cerambycidae): was the differentiation of the Madrean sky islands driven by Pleistocene climate changes?. Molecular Ecology, 14(10), pp.3049-3065.

Spector, T. 2013. Impacts to federally listed cacti species from livestock on the Colorado Plateau in Utah: A Review and Summary. Utah Field Office, Ecological Services, U.S. Fish and Wildlife Service, West Valley City, UT 68 pp.

Spector, T. 2013a. Ecological effects of ground disturbance and roads on plants and recommended buffer distances with emphasis on the Uinta Basin, Utah. Utah Field Office, Ecological Services, U.S. Fish and Wildlife Service, West Valley City, UT 15 pp.

Spector, T. 2015. Presence of biological soil crust adjacent to Pediocactus winkleri (Draft). Report prepared for the USFWS, July 2015. 5 pp.

Spence, J. 1993. A monitoring program for the endangered Pediocactus bradyi L. Benson, Lees Ferry, Glen Canyon National Recreation Area. Unpublished NPS document. Glen Canyon National Recreation Area. 48pp.

Steffan-Dewenter, I., and T. Tscharntke. 1999. Effects of habitat isolation on pollinator communities and seed set. Oecologia 121:432-440. See pages 434-438.

Stoddart, L, H. Clegg, B. Markham, and G. Stewart 1951. The halogeton problem on Utah’s ranges. Journal of Range Management. 4(4): 223-227.

Tepedino, V.J. 2000. The reproductive biology of rare rangeland plants and their vulnerability to insecticides. Vol. III.5, pp. 1–10; Grasshopper Integrated Pest Management User Handbook, G.L. Cunningham & M. W. Sampson (Tech. Coord.) USDA APHIS Tech. Bull. No. 1809, Washington, D.C.

Thompson, J.R., P.W. Mueller, W. Fluckiger, A.J. Rutter. 1984. The effect of dust on photosynthesis and its significance for roadside plants. Environmental Pollution 34:171 190.

Trenberth, K.E., P.D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J.A. Renwick, M. Rusticucci, B. Soden and P. Zhai, 2007: Observations: Surface and Atmospheric Climate Change. In: Climate Change 2007: The Physical Science Basis.

Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Trombulak, S.C., and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

Truman, D. 2014. Phone call with Tracey Switek and Tova Spector regarding the distribution, threats, and variation of San Rafael cactus, 11/14/2014. BLM Botanist, Price Field Office.

Truman, D. 2015. Email to Tracey Switek with Price BLM 2014 and 2015 PEDE survey data attached. BLM Botanist, Price Field Office. 2 pp + 14 attachments.

U.S. Fish and Wildlife Service (USFWS). 1995. Utah pediocactus: San Rafael cactus (Pediocactus despainii) and Winkler cactus (Pediocactus winkleri) recovery plan. Draft. Denver Colorado. 28pp.

U.S. Fish and Wildlife Service (USFWS). 2006. Draft Guidance for Conducting Threats Assessments under the ESA. Memorandum to regional directors. 15 pp.

U.S. Fish and Wildlife Service (USFWS). 2009. Biological opinion for the grazing permit renewal for 17 allotments in the San Rafael Swell. Prepared for the BLM Price Field Office by the USFWS Utah Field Office, West Valley City, UT 84119. 53 pp.

U.S. Fish and Wildlife Service (USFWS). 2010. Biological opinion for the grazing permit renewal for Hartnet and Cathedral allotments. Prepared for the BLM Richfield Field Office by the USFWS Utah Field Office, West Valley City, UT 84119. 28 pp.

U.S. Fish and Wildlife Service (USFWS). 2014. Pediocactus GIS Analysis. Unpublished documented prepared for the USFWS Utah Field Office, Salt Lake City, UT 84119. 7pp.

Van Buren, R. and K.T. Harper. 2003. Demographic and Environmental Relations of Two Rare Astragalus species Endemic to Washington County, Utah: Astragalus holmgreniorum and A. ampullarioides. Western North American Naturalist 63(2): 236 – 243.

Van Buren, R. and K.T. Harper. 2004. Two year Annual Monitoring Report 2003 and 2004 for Astragalus ampullarioides. Submitted to BLM St. George Field Office, St. George, Utah. Prepared by Utah Valley State College, Orem, Utah. 28 pp.

Welsh S.L., N.D. Atwood, L.C. Higgins, and S. Goodrich. 1987. A Utah Flora. Great Basin Naturalist Memoirs. Brigham Young University, Provo, Utah. No. 9: 1-897.

Welsh, S.L. and S. Goodrich. 1980. Miscellaneous plant novelties from Alaska, Nevada and Utah. Great Basin Naturalist 40:78–88.

Welsh, S.L., N.D. Atwood, S. Goodrich, and L.C. Higgins. 2003. A Utah Flora. Fourth edition, revised. Brigham Young University. Provo, Utah. 1019 pp.

Wilcock, C. and R. Neiland. 2002. Pollination failure in plants: why it happens and when it matters. Trends in Plant Science Vol. 7 (6): 270-277.

Wilson, J. S. , O. J. Messinger & T. Griswold. 2009. Variation between bee communities on a sand dune complex in the Great Basin Desert, North America: implications for sand dune conservation. Journal of Arid Environments 73:666–671.

Ziska, L.H., J.B. Reeves III, B. Blank. 2005. The impact of recent increases in atmospheric CO2 on biomass production and vegetative retention of cheatgrass (Bromus tectorum): implications for fire disturbance. Global Change Biology 11: 1325 – 1332.