Colorado Hookless Cactus (*Sclerocactus glaucus*)
Technical Assessment

Prepared by the Bureau of Land Management – Colorado

ON THE COVER -

Colorado hookless cactus (*Sclerocactus glaucus*) in flower near De Beque, Colorado
Photo by: Phil Krening

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Authorship:

Phillip Krening, MS
Conservation Specialist (contractor)
Bureau of Land Management – Colorado State Office
2850 Youngfield St
Lakewood, CO 80215

Carol Dawson, PhD
Threatened and Endangered Species Program Lead
Bureau of Land Management – Colorado State Office
2850 Youngfield St
Lakewood, CO 80215

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U.S. Department of the Interior
Bureau of Land Management
Colorado State Office
Lakewood, CO

Executive summary

This technical assessment provides an up-to-date assessment of Colorado hookless cactus (*Sclerocactus glaucus*), a species of federally protected ball cactus endemic to the high deserts of western Colorado. The species was listed as threatened under the Endangered Species Act (ESA) in 1979. The considerations primary to the U.S. Fish and Wildlife Service (USFWS) decision to list the species were its small known population size, the perception of commercial exploitation by private collectors, and the ongoing curtailment of the species habitat from oil and gas development, livestock grazing, and off-road vehicle (ORV) use. Since that time, the Bureau of Land Management (BLM), with the assistance of other institutions and researchers, have worked to implement the Initial Action Plan contained in the species' Recovery Outline thereby increasing our understanding of the biology, ecology, and the threats to Colorado hookless cactus and its habitat, and providing a more complete and detailed understanding of the species current biological status and integrity as a whole. Much of this information has contributed to an understanding that Colorado hookless cactus may not be as imperiled as previously believed to be. For example; the total estimated population size has long been considered to be between 15,000 and 30,000 individual plants. Recent systematic population sampling has indicated that the total population size is likely much larger - being a minimum of 92,000 individuals in the Grand Valley and Gunnison River population alone. In addition to ongoing genetic research and demographic studies, the BLM, the agency responsible for the administration of lands which contain the vast majority of Colorado hookless cactus occurrences and habitat, has worked to implement recovery actions identified in the species recovery outline including; establishing planning processes that minimize or avoid impacts to cactus occurrences and habitat thereby limiting impacts to the species.

Contents

List of acronyms and abbreviations

ACEC – Area of Critical Environmental Concern

AFLP – Amplified Fragment Length Polymorphism

AUM – Animal Unit Month

BA – Biological Assessment

BLM – U.S. Department of the Interior Bureau of Land Management

BO – Biological Opinion

CCVI – Climate Change Vulnerability Index

CFR – Code of Federal Regulations

CNHP – Colorado Natural Heritage Program

DBG – Denver Botanic Garden

D-E NCA – Dominguez-Escalante National Conservation Area

EO – Element Occurrence

ESA – Endangered Species Act

FLPMA – Federal Land Policy and Management Act

GGV – Greater-Grand Valley population

MLP – Master Leasing Plan

NCA – National Conservation Area

NSO – No Surface Occupancy

ORV – Off-road Vehicle

PEIS – Programmatic Environmental Impact Statement

POD – Plan of Development

SDM – Species Distribution Model

SRP – Special Recreation Permit

SSR – Site Specific Relocation

RMP – Resource Management Plan

ROD – Record of Decision

ROW – Right of Way

USFWS – U.S. Department of the Interior Fish and Wildlife Service

WSA – Wilderness Study Area

CHAPTER 1. INTRODUCTION

Colorado hookless cactus (*Sclerocactus glaucus*) (K. Schumann) L.D. Benson (Cactaceae), formerly Uinta Basin hookless cactus, is a small ball to barrel-shaped cactus endemic to the high elevation deserts of the upper Colorado and Gunnison River basins and their tributary canyons in extreme western Colorado (Figure 1). A member of the genus *Sclerocactus,* commonly known as "fishhook cactus," Colorado hookless cactus has traditionally been distinguished among its congeners by the lack of a hooked central, abaxial spine. Thus, the species common nomenclature reflects this typical morphological trait; although, variations are common and individuals may possess hooked spines as well. Plants are generally small and can be relatively cryptic for most of the year, those of reproductive age typically produce striking pink flowers in the spring. Across its limited range Colorado hookless cactus is relatively abundant being known from 103 individual occurrences with total population estimates ranging from 22,000 to over a quarter million individuals. Where it's found, the species displays a patchy, generalist distribution growing primarily in small, discrete colonies of individuals in a variety of upland desert habitats and communities; ranging from alluvial river benches, to salt desert shale barrens, gravelly colluvial washes, and sparse pinyon-juniper woodlands.

The species rarity, coupled with development in and around its habitat, resulted in Colorado hookless cactus' designation as a threatened species by the U.S. Fish and Wildlife Service (USFWS) in 1979 under the Endangered Species Act of 1973, as amended (ESA) (44 FR 58868). Since that time, when relatively little was known about the species, our understanding of its biology and the factors that may affect its long-term persistence have increased substantially. Perhaps most importantly, *Sclerocactus glaucus* has undergone a series of revisions to its circumscription that have come with associated changes to its range and abundance. Initially *S. glaucus* was thought to occur in two geographically disjunct areas; western Colorado and northeastern Utah. The advent of phylogenetic analysis led to the Uinta Basin populations in northeastern Utah being reclassified in 2009 as two distinct species; *S. wetlandicus* and *S. brevispinus* (74 FR 47112). This reclassification has, on one hand, resulted in a smaller segmented range and smaller population size of Colorado hookless cactus, but has additionally rendered several threats to the species irrelevant. An example of this being oil shale and tar sands mining, both of which are prevalent in the Uinta Basin and may conflict with occurrences of *S. wetlandicus* and *S. brevispinus* but are not a meaningful factor in Colorado hookless cactus habitat. As currently described, Colorado hookless cactus is composed of two population centers limited to western Colorado.

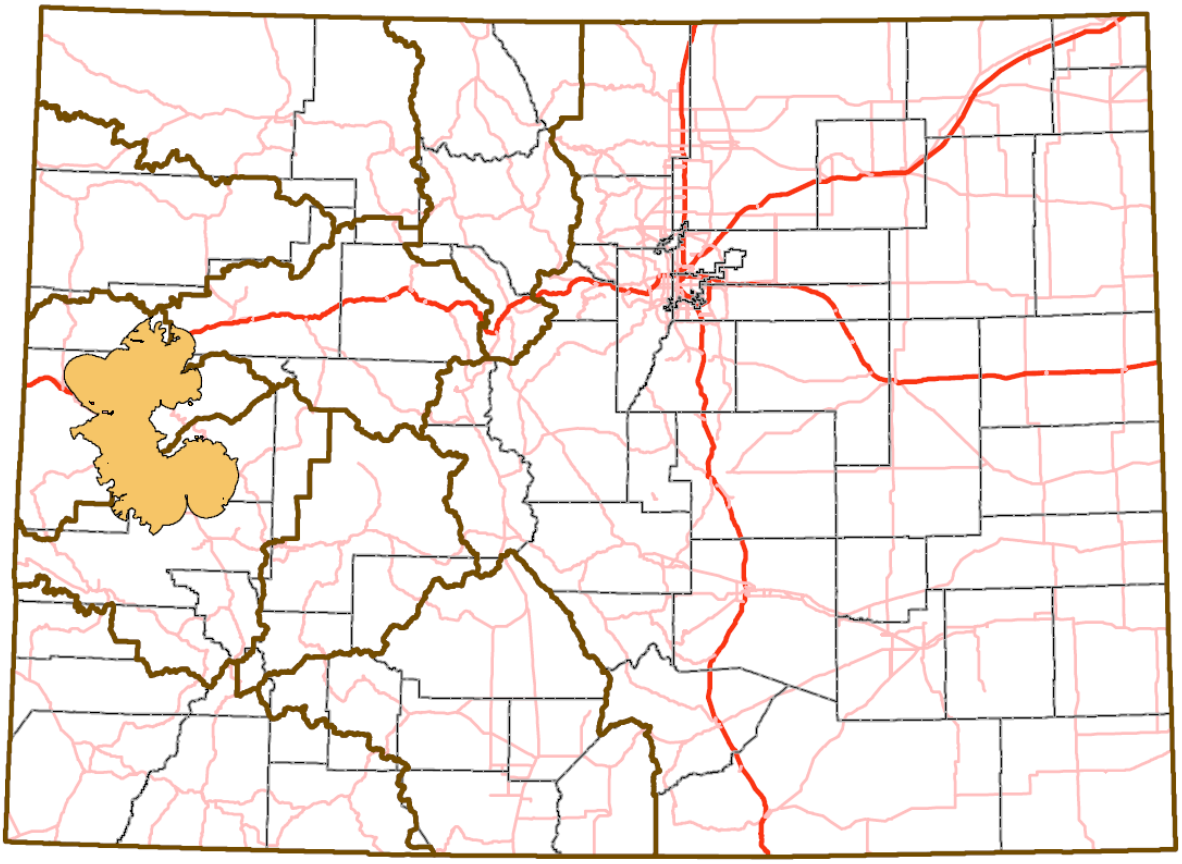

Figure 1: Colorado hookless cactus (*Sclerocactus glaucus*) range (yellow) in Colorado including county and BLM field office boundaries. Shapefile is a crude representation as defined by the USFWS Colorado hookless cactus "area of influence."

In spite of its small geographic distribution, Colorado hookless cactus is generally believed to be secure and abundant across its historical range. We have no information to suggest that there has been any meaningful reduction to its range or abundance based on human caused or environmental factors occurring presently or in the recent past. Focused inventory and monitoring has led to the understanding that Colorado hookless cactus is much more abundant than believed to be at the time of its listing; increasing its total estimated population size from around 2,000 plants at the time of the species listing to well over 92,000 individuals. Genetic investigation has untangled the species, and its relationships, redefining our understanding of its cryptic morphology and addressing concerns based in broad morphological inconsistencies, assumed to be indicative of hybridization, as not posing a significant threat to the species. Additionally, range-wide monitoring has demonstrated a stable trend over eight years and provided a more detailed understanding of population dynamics and demographic features. Adding to this understanding, the BLM has taken action to apply measures of avoidance when authorizing projects and programs that occur within Colorado hookless cactus habitat, and

established special land designations (*e.g.* Areas of Critical Environmental Concern [ACECs]) when practicable through regulatory channels in order to preserve habitat in and around core cactus areas.

Scope and technical approach

This assessment has been produced to provide land managers and research biologists with an up-to-date and thorough discussion of all the available scientific knowledge pertaining to Colorado hookless cactus. The scope of this assessment can be thought of as a detailed discussion of the species current biological status within the context of its conservation and has been developed with the 2010 Recovery Outline for Colorado hookless cactus as a guide. First, we provide an in-depth and exhaustive review of the species biology, taxonomy, and life history including the ecological requirements necessary to support the species across its range. Second, we discuss distribution and demographic features such as abundance, trends, and population dynamics. Included in this chapter is a summary of the regulatory mechanisms as they pertain to Colorado hookless cactus and its habitat, including lands that possess special management designations. Lastly, we provide an assessment and ranking of the primary threats to the species continued persistence.

In producing this assessment an extensive literature review was completed to obtain all of the available material pertaining to Colorado hookless cactus. The scope of this review included published journal articles, unpublished "grey literature" including technical / status reports, theses and dissertations, data compiled by state agencies (*e.g.* Colorado Natural Heritage Program (CNHP) element occurrence records [EOs]), and BLM internal documents, regulatory manuals, and resource management plans (RMPs). In situations where published or unpublished literature was deficient we relied heavily on communications and observations of professional botanists and others considered to have expertise related to Colorado hookless cactus. These situations constitute the experts' best professional judgement, which is ultimately subjective and not substantiated by experimentally collected data subjected to rigorous statistical analysis.

Throughout this report several terms are used in reference to the species spatial arrangement and composition on the landscape. The term "occurrence" is used in reference to a discrete collection of individuals (*i.e.* colony) that occupy a given site or locale. Occurrences of Colorado hookless cactus tend to be relatively small and may be proximal to other occurrences with which exchange of genetic material occurs. It is important to note that in this context occurrence is not necessarily synonymous with the CNHP element occurrence (EO) classification. The term "population" is used in reference to the two large assemblages of occurrences identified through genetic investigation that exist as genetically cohesive groups. These being the greater-Grand Valley population (GGV) that encompasses the southern extent of the species range from near

Montrose north, along the Gunnison River and its tributaries, to the Grand Valley. The other being the De Beque population that encompasses the species range from the mouth of De Beque canyon along the Colorado River, Plateau and Roan Creek drainages to near the town of Rifle.

CHAPTER 2. LIFE HISTORY AND BIOLOGY

In this chapter we provide a detailed background of the physical characteristics, life history, and biology of Colorado hookless cactus. This discussion includes a brief overview of the species taxonomic history, population genetic structure, and a description of the species morphology; as well as an overview of the physical environment and ecological conditions required to support both individuals and populations.

Taxonomy

Colorado hookless cactus is a member of the genus *Sclerocactus* which is made up of between 15 and 20 individual species and possesses a center of distribution in the Colorado Plateau and Mojave Desert regions of western North America (Flora North America, 2004; Hochstätter, 1993; Porter and Prince, 2011). The genus has been the subject of taxonomic confusion due to high levels of morphological plasticity resulting in inconsistency across treatments in the exact number of species belonging to the genus. As with other members of the genus, Colorado hookless cactus has been the subject of a long and complex taxonomic history that has been gradually resolved through phylogenetic analysis.

First described by C.A. Purpus in 1892 from plants collected in the Gunnison River basin, the species was assigned to the genus *Sclerocactus* in 1966 by L.D. Benson (USFWS, 1990). Since that time, *Sclerocactus glaucus* has undergone a series of taxonomic revisions first based on morphological characters; including, size of individuals and spine structure (Hochstätter, 1989; Porter et al. 2013). At the time of its listing, all hookless (straight central-spined) *Sclerocactus* in western Colorado and northeastern Utah were considered to be *Sclerocactus glaucus* (the Uinta Basin hookless cactus complex). Though, this system of taxonomy has been shown to be unreliable based on the plasticity of morphological traits across species, within taxa, and between life stages (Schwabe et al., 2015). Later phylogenetic studies, common garden experiments, and the re-evaluation of morphological characters led to the determination that the Uinta Basin hookless cactus complex is in fact three distinct species; *S. glaucus* (Colorado hookless cactus)*, S. brevispinus* (Pariette cactus)*,* and *S. wetlandicus* (Uinta Basin hookless cactus) (Heil and Porter, 2004, Hochstätter, 1993). With *S. glaucus* being restricted to the Colorado and Gunnison River basins in western Colorado and *S. brevispinus* and *S. wetlandicus* being limited to the Uinta Basin

in eastern Utah. A preliminary study by Porter et al., (2013) investigating ALFP markers, chloroplast sequences, and morphological data confirmed this treatment illustrating that *S. glaucus* showed significant divergence from plants in Utah that share a common spine morphology. This taxonomic revision was accepted by the USFWS in 2009 (74 FR 47112). All three species remain designated as threatened under the ESA.

Species description

The following description reflects Flora North America's most recent treatment of *Sclerocactus glaucus* (Flora North America, 2004).

Stems usually unbranched, cylindric to elongate cylindric, 3-12(-28) × 4-9 cm; ribs (8-)12-13(-15), tubercles evident on ribs. **Spines** slightly or not at all obscuring stems; radial spines (2-)6-8(-12) per areole, white, 0-17 mm; central spines 1-3(-5) per areole, sometimes not greatly different from radial spines; abaxial central spines 0-2 per areole, brown, reddish brown to black, straight (rarely curved or hooked), 12-26 × 0.8-1 mm; lateral central spines 2-4 per areole, similar to abaxial; adaxial central spine 1 per areole, usually white (rarely light brown), elliptic in cross section, 15-31 × 0.5-1.8 mm. **Flowers** fragrant, funnelform (rarely campanulate), 3-5(-6) × (3-)4-5 cm; outer tepals with greenish lavender midstripes and pink margins, oblanceolate, 25-30 × 4-6 mm; inner tepals pink (rarely pale pink), oblanceolate to lanceolate, 24-30(-35) × 4-6 mm; filaments green to white; anthers yellow. **Fruits** not regularly dehiscent, ovoid, barrel-shaped, 9-22(-30) × 8-12 mm, dry, with a few membranous scales, mostly near the apex. **Seeds** black, 1.5 × 2.5 mm; testa with rounded papillae.

Distribution:

The historic range of Colorado hookless cactus prior to being described is not known; though, it is likely that the species has never been widely abundant. The parapatry observed among species of *Sclerocactus* provides some evidence that Colorado hookless cactus and its congeners likely evolved as the result of sporadic dispersal of a common ancestor to novel habitats, followed by subsequent reproductive isolation resulting in genetic differentiation and the distinct ecotypes we witness across western North America. Thus, the species rarity and its limited range is likely the result of limiting factors including dispersal mechanisms and has not necessarily been reduced as the result of anthropogenic or environmental causes.

Colorado hookless cactus is limited to the Colorado and Gunnison River basins and their tributary canyons in Delta, Montrose, Mesa, and Garfield Counties in western Colorado. The species consists of two geographically defined population centers; one that occupies colluvial slopes along the Colorado River from De Beque, in the northeast, downstream toward the Grand Valley and along the Roan and Plateau Creek drainages. The second, occupying the Grand Valley and

extending south through the high desert at the toe of the Grand Mesa and along the alluvial terraces of the Gunnison River and the Dominguez and Escalante Creek drainages to near Montrose. The species westernmost point of distribution in the Grand Valley is delineated by 18 road in the north and Bang's Canyon in the south where small-flower fishhook cactus (*Sclerocactus parviflorus*) and Colorado hookless cactus relative distributions are separated by only several kilometers (McGlaughlin and Ramp-Neale, in prep).

Across its range, which encompasses approximately 2,200 square miles, Colorado hookless cactus is found primarily in small dispersed occurrences that average a couple hundred individual plants at a given site. Occurrences generally have a concentrated core surrounded by larger areas where plants are distributed at much lower densities. A study undertaken by BLM – Colorado investigating the average density of core population areas observed densities as high as 0.62 and as low as 0.02 plants/m^2, with a mean of 0.24 plants/m^2 based on 26 populations sampled (BLM, 2018). Individual occurrences generally occupy areas that are less than five acres. Occurrences have a patchy distribution across the landscape with few, if any, large areas of continuous occupation.

Focused inventory and documentation of Colorado hookless cactus and its habitat has been ongoing since the late 1970's - with the first large scale field survey and inventory efforts being initiated by J.R. Ferguson and others from the BLM Uncompahgre Field Office in 1983 (Sharp, 2009). Based on all available survey data there are ca. 10,445 acres (16.3 miles sq.) of known and mapped occupied habitat (CNHP, 2017). This number is almost certainly an underestimate of the actual occupation as any occupied habitat that is to date unknown or exists entirely on privately owned lands is not included in this total.

Land ownership

Complex patterns of land ownership and management are present across Colorado hookless cactus range. The majority of the land (ca. 73%) which comprise potential habitat occurs on public lands Federally managed by the BLM (USFWS, 2010). The vast majority of the remaining 27% occurs on lands that are privately owned, and less than 1% falls on State or local government lands (USFWS, 2010).

Population genetic structure

Phylogenetic studies aimed at resolving the genetic structure of Colorado hookless cactus relative to its congeners have been ongoing since the early 1990's. These studies have gradually provided support for taxonomic revisions to the entire genus and the reclassification of species. Until recently, several questions have remained unanswered; principally (1) what is the structure and geographic extent of Colorado hookless cactus range in western Colorado? And (2) what is the

relationship between Colorado hookless cactus and the more common, closely related, and geographically similar small-flower fishhook cactus (*Sclerocactus parviflorus*)?

Focused genetic investigation attempting to resolve these outstanding questions has identified three regionally defined genetic groups of Colorado hookless cactus in western Colorado (McGlaughlin and Ramp-Neale, in prep). (1) A northern group that inhabits the Colorado River valley, Plateau Creek, and Roan Creek canyons in the vicinity of De Beque. (2) A group that occupies the Grand Valley downstream of Plateau Creek as far west as 18 rd. in the north and Bangs Canyon in the south. And (3) a group along the Gunnison River, and its tributary canyons near Delta (Figure 2).

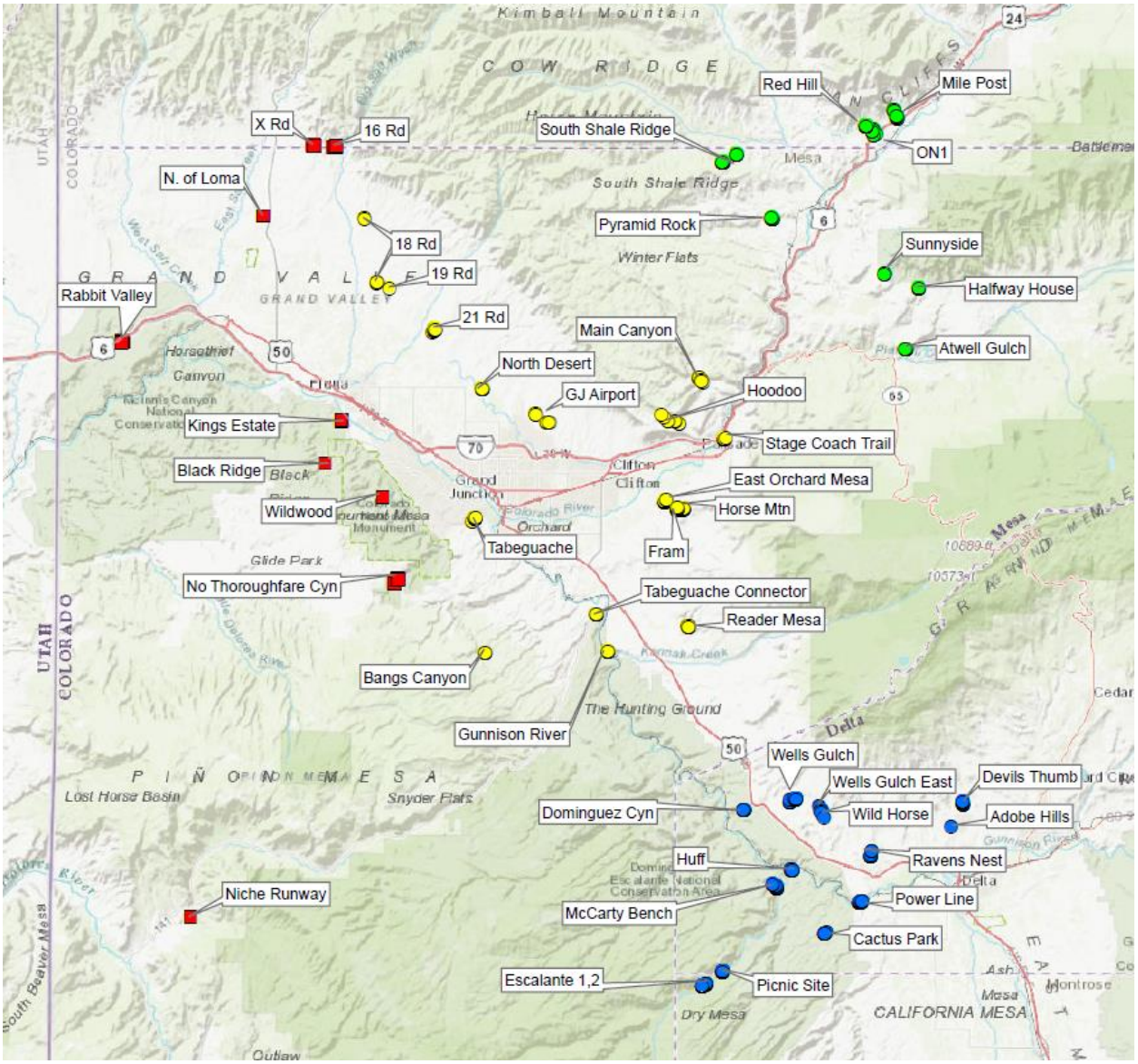

Figure 2. From McGlaughlin and Ramp-Neale (in prep) Sampling map of *S. glaucus* (circles) and *S. parviflorus*

(squares) from western Colorado. *S. glaucus* populations are shown with yellow (Grand Valley), green (Northern), or blue (Gunnison River) circles, corresponding to genetic groupings. *S. parviflorus* populations are shown with red squares.

Of these groups, the Gunnison River and Grand Valley groups show sufficient connectivity resulting in recent and ongoing genetic exchange and should be treated as a single management unit; hereafter referred to as the greater-Grand Valley (GGV) population. The northern group (De Beque population) is genetically isolated and substantially diverged from the rest of *S. glaucus*-indicating it should be treated as a separate management unit. These results are supported by more than 918 individual samples of Colorado hookless cactus from 39 occurrences across the species range. Forthcoming data from the University of Northern Colorado support a taxonomic split of these population centers into distinct species (McGlaughlin and Naibauer, in prep)

Of particular interest has been the relationship between Colorado hookless cactus and the geographically similar small-flower fishhook cactus (Schwabe, et al., 2015). The presence of plants with mixed hooked/hookless spine morphologies- particularly in individuals in Mesa County in the vicinity of Whitewater, has been thought to be indicative of hybridization (Heil and Porter, 2004). Preliminary genetic work showing that the individuals in question were genetically pure *S. glaucus* raised further questions as to the western limit of Colorado hookless cactus' range in the absence of a strong morphological indicator (Schwabe, 2012). Work by McGlaughlin and Ramp-Neale has shown that small-flower fishhook cactus is in fact distinct from Colorado hookless cactus and that while hybridization can and does occur it is localized in a minority of individuals and does not pose a threat to the genetic integrity of Colorado hookless cactus.

Morphology relative to other similar species

As previously discussed, the morphology of Colorado hookless cactus is similar to that of other closely related species of *Sclerocactus*; though, many of these characters have been shown to be highly plastic making systematics difficult to discern based on structure alone. *S. glaucus* can be distinguished from *S. wetlandicus* and *S. brevispinus* based on geography and by micromorphology of the seed coat (*S. glaucus* has convex cells on the surface of the seed coat while *S. brevispinus* and *S. wetlandicus* have flat cells on the seed coat surface) (Hochstätter, 1989). Only the more common *Sclerocactus parviflorus* shares a similar geography with *S. glaucus,* being parapatric in their relative distributions. Traditionally, the absence of hooked central spines has been considered a reliable method to distinguish *S. glaucus* from *S. parviflorus* in extreme western Colorado. This characteristic has since been found to be inconsistent – some genetically pure *S. glaucus* individuals possess hooked spines or mixed hooked and hookless morphologies (Schwabe, 2012). At this time geography is the only reliable way to discern these species from one another in the field.

Life History

Colorado hookless cactus is typically composed of a single spherical or cylindrical perennial stem growing from a taproot. Plants tend to be small, though individual size varies based on age, time of year, and quality of habitat (USFWS, 2010). Often small plants may appear to be sunken into the surrounding soil. Plants of reproductive age may produce 1-5 funnel shaped pink flowers from April into May which open in a specific diurnal pattern. Individuals of reproductive age may not flower or produce seed every year. Flowers have been observed opening from mid-morning to early afternoon and remaining open for approximately 7 hours. Flowers open in this manner for three to five days during which the color of the tepals fade and fragrance dissipates. At first opening, the anthers are appressed to the style and slowly draw away and begin shedding pollen (Heil and Porter, 1994). Over the duration of an eight year demographic monitoring study by the BLM seedlings on average took 1.6 years to reach reproductive stage. Though this figure likely underestimates the actual time it takes plants to reach sexual maturity due to the fact that detection of true seedlings in their year of germination is inconsistent. Realistically, individuals may flower in as few as four years after germination, but in many cases newly documented plants had not produced flowers in the first six years of data collection (BLM, 2018).

Fruiting occurs from May into June. Small black seeds are released after the pericarp separates horizontally near base leaving a "cup of seeds" (USFWS, 2010). Seed dispersal is believed to be a primary factor limiting the species distribution. Small black ants, identified as *Monomorius minimum* (subfamily Myrmicinae) have been identified as a primary mechanism contributing to short distance seed dispersal (Rechel, Ballard & Kelley, 1993). Flowing water from heavy summer monsoon rain events can also help to disperse seeds into the immediate area surrounding a plant. Small rodents and birds feeding on the fruit, and possibly seeds, may contribute to short – and long-distance dispersal of seeds. Some seeds may remain on the parent plant for up to a year after maturity.

While it is not known precisely how long individuals can persist in the wild; in the absence of disturbance plants are believed to be relatively long-lived. As is typical of cacti, levels of survivorship are high and recruitment low. BLM monitoring estimated high rates of survivorship from year to year for both seedlings and total individuals. Recruitment rarely exceeded one plant for every flowering individual from the previous year. Of plants that were observed on two or more consecutive years 53% persisted for five or more years (BLM, 2018).

In rare cases exceptional individuals may consist of more than 10 extant stems that originate from a single root mass that branches beneath the soil surface (BLM, 2018; McGlaughlin, 2018 pers. comm.). Branching is most commonly observed in instances where cacti have sustained mild to moderate tissue damage from crushing or trampling (USFWS, 2010). Plants may

germinate in clumps at the base of, or adjacent to, a mature individual - appearing as a tight bunch of individual cactus buttons. Cases of over fifty individual buttons forming an apron at the base of a mature individual have been documented (BLM, 2018). Without excavating the plant it is impossible to determine if these cases constitute stems of an individual; or rather, a cluster of distinct plants. It is likely that these cases are composed of a number of closely related, though not genetically identical, individual plants that are reduced over time through competition, likely resulting in one or two persistent individuals.

Reproductive biology and breeding system:

Colorado hookless cactus relies on pollinator assisted outcrossing (xenogamy) as its primary mode of genetic exchange (Bio-Logic, Inc., 2015; Janeba, 2009; Tepedino et al*.,* 2010). Numerous studies have documented pollinators that visit the flowers of cacti belonging to the genus *Sclerocactus*. Research investigating the breeding system of Colorado hookless cactus and two closely related *Sclerocactus* species in Utah demonstrated that like most other species of cacti, pollinators are necessary for sexual reproduction and that plants produced more seeds via out-crossing than selfing (Tepedino et al., 2010).

Earliest observations of pollinators visiting Colorado hookless cactus identified *Agapostemon texanus* (Halictidae) as the most frequent visitor (Rechel, Ballard & Novotny, 1999). Several additional studies suggest that the most frequent flower visitors to *Sclerocactus* are ground-nesting species of bees within the subfamily Halictinae (Janeba, 2009; Tepedino et al., 2010). In Colorado and Utah, a study of the effects of oil and gas development (*i.e.* active wells and roads) on nearby occurrences of four federally listed plant species was initiated in 2011. A study designed to determine the effects of disturbance on insect pollinators (mainly native halictine bees) was implemented on *Phacelia submutica* and three *Sclerocactus* species, including Colorado hookless cactus. Field studies were conducted from 2011 – 2013; characteristics of the Colorado hookless cactus' bee pollinator community were studied in Garfield and Mesa counties, Colorado. The bowl-trapping experiment in Colorado continued for three weeks, at eight sites. Bees collected in Colorado comprised 119 species, without including an additional 15 – 20 species of *Lasioglossum* (*Dialictus*). Megachilidae (leaf-cutting bees) and the Apidae were the most highly represented families. Of the 11,865 individual bees captured, 86% of these bees were members of the sweat bee family (Halictidae). The halictids were represented by 11 species with *Halictus tripartitus* comprising 69% of these bees.

Pollen augmentation field experiments resulted in significant increases in seed production in Colorado hookless cactus, supporting the need to maintain native bee pollinator habitat. Given the abundance of native bee pollinators at the Colorado sites, changes to the habitat that

potentially would result in the loss of native bee pollinators through time would be a concern for the conservation of Colorado hookless cactus (Bio-Logic Inc., 2015).

Habitat:

As with other endemic plants, Colorado hookless cactus is completely reliant on its immediate ecological setting to support all stages of its life cycle. Colorado hookless cactus is highly xerophytic, known only from the semi-arid high elevation deserts of Colorado's western slope. Elevation at location of species occurrence ranges from 3,900 to 6,000 feet (1,400 to 2,000 meters) in elevation (Heil and Porter, 2004). Across its range, Colorado hookless cactus occurrences are distributed with some generality relative to dominant plant community, exposure, and soil condition. Plants are often found growing in unique sheltered microhabitats under or within the canopy of dwarf shrubs and bunchgrass "nurse plants" where soils are relatively developed, intact, and cryptogrammic. Despite these tendencies, Colorado hookless cactus is by no means a specialist that is restricted in its distribution due to edaphic preference. To the contrary, it appears to be dispersed with some generality in terms of the quality and makeup of the substrate on which it is found to occur.

Generally, Colorado hookless cactus occur in shallow exposed sandy or shaley soils of sedimentary parent material or gravelly deposits of river alluvium. In many cases these sedimentary derived soils are overlain with coarse gravel and alluvium or fragments of volcanic basalt. Along the Colorado River in the vicinity of De Beque substrate tends to consist of dense compact mudstones of the Atwell Gulch member of the Wasatch formation. Soils can be hard packed resembling desert pavement. Plants found throughout the Gunnison River portion of the species range, including the Escalante and Dominguez Canyon drainages, tend to occupy terraced alluvial deposits composed of gravel and river cobbles, or soils derived of Jurassic and Triassic sandstone. Upland sites of Colorado hookless cactus distribution north of Highway 50 at the toe of the Grand Mesa and north of Grand Junction near the Book Cliffs tend to be found on alkaline badlands composed of the Mancos shale group. Exposure doesn't appear to be a factor limiting distribution, though populations are generally more abundant on dryer south-facing slopes (CNHP, 2017).

Associated vegetation is composed of a variety of desert scrubland and salt desert communities ranging from flats dominated by sagebrush (*Artemisia spp.*) and greasewood (*Sarcobatus vermiculatus*), to sparse pinyon-juniper woodlands (*Pinus edulis* and *Juniperus osteosperma*), and steep sparsely vegetated slopes of shale and alluvium (CNHP, 2017). Other commonly associated species include shadscale (*Atriplex confertifolia*), rabbitbrush (*Chrysothamnus spp.*), winterfat (*Krascheninnikovia lanata*), Indian rice grass (*Achnatherum hymenoides*), James' galleta grass (*Pleuraphis jamesii*), wild rye (*Elymus spp.*), *Yucca spp.,* and other species of cactus including

prickly pear (*Opuntia spp.*), and the look-alikes; smallflower fishhook cactus (*Sclerocactus parviflorus*), claretcup cactus (*Echinocereus triglochidiatus*), and Simpson's pincushion cactus (*Pediocactus simpsonii*). Other common components of the vegetation community include the non-native species: downy brome (*Bromus tectorum*) and halogeton (*Halogeton glomeratus*).

While there is no evidence to suggest that Colorado hookless cactus plays a foundational role in the ecological community in which it is found, it does function as an ecological attribute adding complexity and diversity to the desert scrubland community. Herbivory by desert cottontail rabbits (*Sylvilagus audubonii*), other lagomorphs, and rodents has been observed (USFWS, 2010). It is possible that lagomorphs and rodents rely on the succulent stems as a source of sustenance during periods of drought. Parasitism by the Opuntia-borer beetle (*Moneilema semipunctatum*) has been observed in some populations of Colorado hookless cactus occurring primarily in larger, mature, and reproductive individuals (USFWS, 2010).

No designation of critical habitat exists for Colorado hookless cactus under Section 4 of the ESA.

Climate:

The regional climate of Colorado hookless cactus habitat is concordant with the larger Colorado Plateau physiographic province; being dominated by continental, semi-arid, high elevation desert. Overall, regional precipitation is limited; ranging between 8-12 in. annually with an average of 8.67 in. falling between 1900 and 2016, recorded at a Grand Junction weather station (Western Regional Climate Center, 2019). The region is characterized by cold winters and hot summers with average January and July temperatures being 36.6°F and 92.9°F respectively for the same weather station and time period.

CHAPTER 3. CURRENT SPECIES CONDITION

The purpose of this chapter is to describe our best understanding of the current condition of Colorado hookless cactus. We consider foundational factors important to the overall integrity of the species including abundance, population trends, and genetic diversity. At the time that Colorado hookless cactus was listed in 1979, and even as recently as 2010 when the recovery outline for the species was drafted, our understanding of many of these important factors was deficient and constituted informed speculation at best. We also consider regulatory mechanisms that pertain to Colorado hookless cactus and its habitat as defined by BLM policy and Resource Management Plans and include an overview of lands that possess special land management designations.

Heritage records:

The Colorado Natural Heritage Program (CNHP) housed at Colorado State University is responsible for tracking and ranking occurrences of rare taxa in Colorado. CNHP's Biotics database reports a total of 103 Level 1 element occurrences (EOs) of Colorado hookless cactus (CNHP, 2017). Each individual EO contains a geographic record of a discrete example of the target element in its appropriate habitat and a variety of fields of information pertaining to the occurrence (CNHP, 2005). Standard information contained within a given EO document includes: the spatial extent of the occurrence, the condition of the EO, size of EO, landscape context, population estimate, as well as a general description of the habitat, and comments related to habitat management. Level 1 EOs occur entirely or partially on public lands. These EO documents provide us with the longest running catalogue of Colorado hookless cactus and its habitat. To date, inventory of unsurveyed habitat has continued although somewhat sporadically – usually as focused clearance surveys conducted in conjunction with a ground disturbing management action.

Rankings are assigned for each EO as a comparative measure relative to other occurrences of the same element. EO rankings are a qualitative measure providing an assessment of the likelihood that an occurrence persists for 20-100 years assuming current conditions prevail (CNHP, 2005). Of the 103 EO records 35% were assessed to have good / good to fair viability. Twenty-two percent were assessed to have fair / fair to poor viability. Sixteen percent were considered excellent / excellent to good. Thirteen percent were assessed to possess poor viability and an additional 15% were unable to be assessed (Table 1).

Basic EO Rank			
rank	**viability**	**# of EOs**	**% of EOs**
A	excellent	11	18.18%
AB	excellent / good	5	
B	good	21	40.91%
BC	good / fair	15	
C	fair	22	26.14%
CD	fair / poor	1	
D	poor	13	14.77%
E	extant	2	14.56%
H	historical	9	
F	failed to find	3	
U	unrankable	1	

Table 1. Number and proportion of Colorado hookless cactus EOs by CNHP viability rank

Abundance:

The population size (*i.e.* the total number of individual plants) of Colorado hookless cactus has been a source of debate since the time of its listing. The original recovery plan for the Uinta Basin hookless cactus speculated there being less than 2,000 individuals in Colorado (USFWS, 1990). The revised recovery outline estimated total population size at approximately 19,000 individuals (USFWS, 2010).

Today, Colorado hookless cactus is known from 103 level 1 EOs totaling approximately 22,202 individuals (CNHP, 2017). However, several factors lead to uncertainty in basing an accurate assessment of population size on a tally of EO records. Level 1 EOs occur entirely or partially on public lands. Fifteen of the EOs have not been observed in 20 or more years, or were ranked as either historical, failed to find, or no data. Population numbers reported in EO records vary between partial and total counts of individuals within a given area and population estimates. Additionally, there are no standardized methods for obtaining population estimates contained in EOs, nor are population values always representative of a complete mapped occurrence. Adding to uncertainty, not all EO records contain a population estimate nor has all of the inventory data compiled over the past five years been integrated into the Biotics database.

A study undertaken by BLM – Colorado in 2017 estimated the minimum size of the GGV population of Colorado hookless cactus at 92,000 individuals (Krening et al., in prep). This estimate was produced conservatively using a two-stage sampling procedure that applied estimates of cactus density corresponding with the lower 90% confidence interval obtained from within sampled macroplots to known mapped acreage of Colorado hookless cactus habitat in the greater-Grand Valley. Estimates of the minimum population size for the same region using the upper 90% confidence level range above 430,000 plants. To date there has not been a similar study completed for the northern population.

Trend monitoring:

Population trend monitoring has been considered a primary recovery action in order to gain an understanding of whether populations are increasing, decreasing, or stable across the species range. The 2010 Recovery Outline identifies “expanded monitoring to include a larger and more representative sample of occupied sites” (USFWS, 2010, pg. 12).

Since the time of its listing, various monitoring efforts have been focused on understanding population trends of Colorado hookless cactus (Sharp, 2009). These efforts have largely been limited in their scope, duration, or lacked consistent or statistically sound methods. Range-wide demographic population monitoring of the species began around 2007 as a partnership between

the BLM and Denver Botanic Garden (DBG). Following the standardization of monitoring protocols the study system has expanded to include over a dozen populations dispersed across the species range (Figure 3). In addition to assessing the trend and dynamics of a wide cross section of core population areas, demographic population monitoring aims to provide information on basic life history and demographic characteristics of the species, and also evaluate the impact of management actions, that occur on public lands administered by the BLM that have the potential to impact the species and its habitat.

Twelve study populations dispersed across the species range inform our analysis of the species overall trend range-wide. We used a subset of six of these sites where individual plants are marked and tracked to provide us with detailed demographic information on reproduction and recruitment rates, as well as survival probabilities.

Individual population trends fluctuated from year to year over the eight year duration of the study. Short, statistically significant, year-to-year declines have been documented at a number of sites across the study system, only two populations (Atwell Gulch and Starr Nelson) have exhibited statistically significant overall declining trends during the timeframe reported. The remaining populations have exhibited fluctuations over time but have maintained overall stable to increasing population trends (BLM, 2018) (Figure 4).

Range-wide trend has been stable to increasing between 2011 and 2018 (BLM, 2018). Monitoring year 2016 had the lowest range-wide density 0.152 plants/m^2 and 2018 had the highest range-wide density 0.250 plants/m^2 (Figure 5). When comparing range-wide trend values to the average density derived from point-in-time sampling all trend monitoring years except 2012 and 2016 fall within the 90% confidence interval indicating that our trend values are within the acceptable normal range for core population areas (Figure 6).

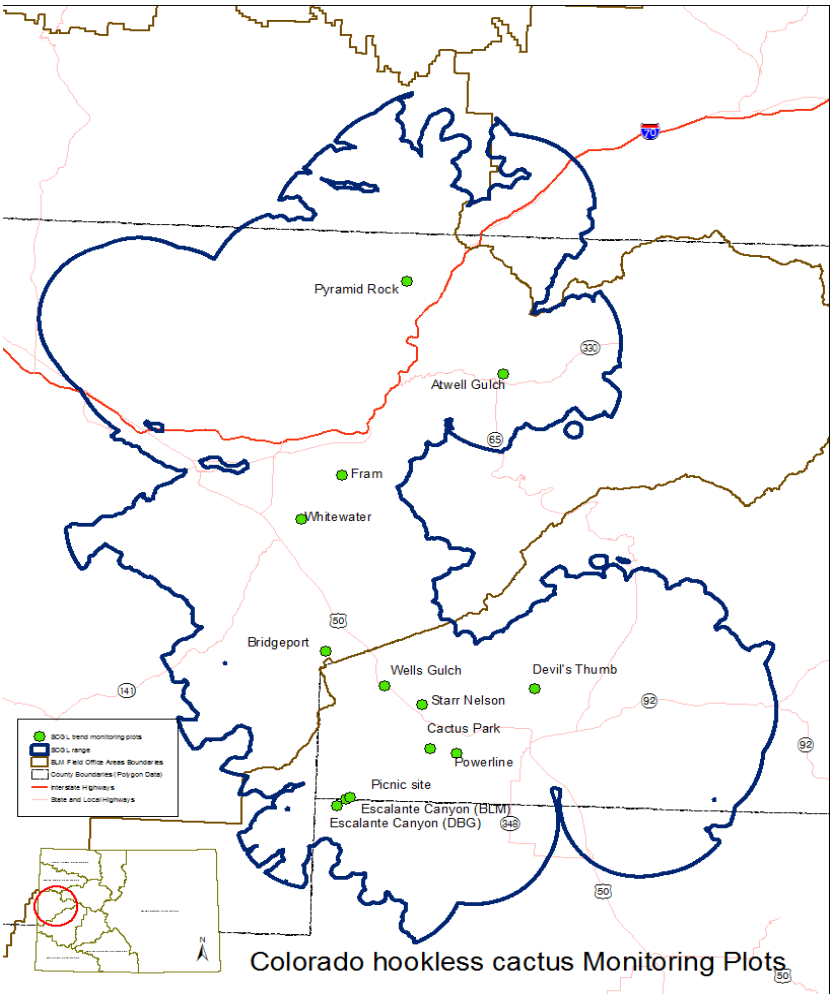

Figure 3. Colorado hookless cactus trend monitoring plot locations

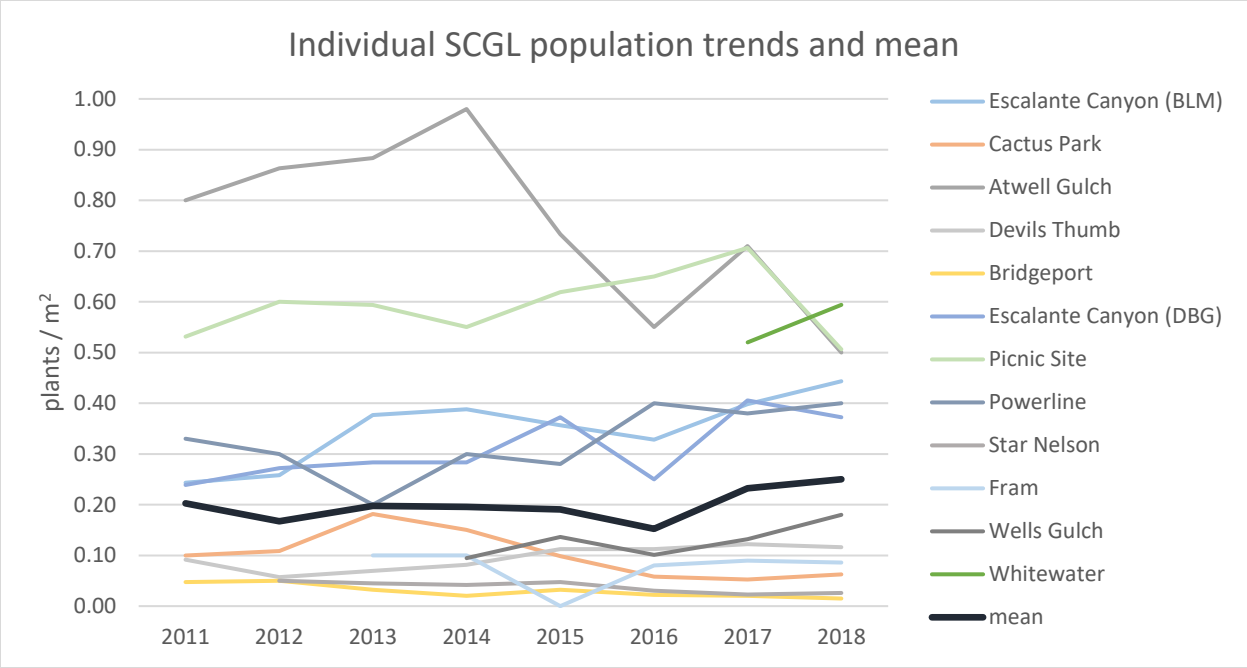

Figure 4. Individual population trends from the 12 trend monitoring sites and their mean (range-wide trend)

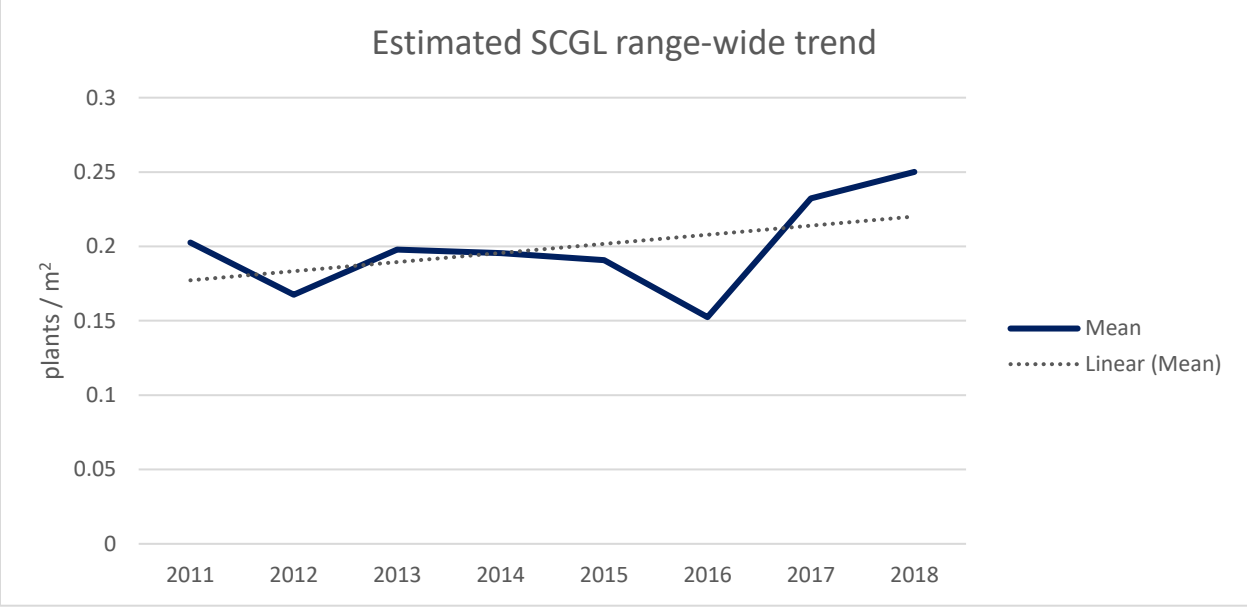

Figure 5. Estimated range-wide Colorado hookless cactus trend derived from the mean of the 12 trend monitoring sites

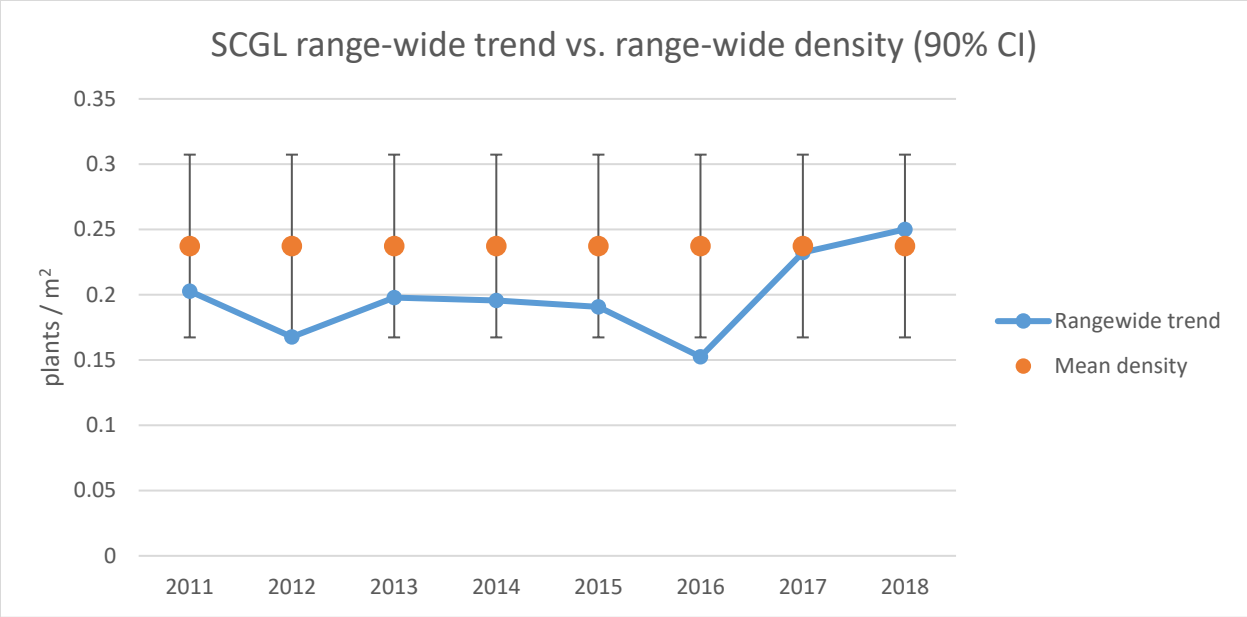

Figure 6. Range-wide Colorado hookless cactus trend (blue line) compared to estimated average population density (orange dots)

Genetic integrity:

Rare and endemic plant species may suffer genetic consequences associated with small population sizes in several ways. The first resulting from hybridization with closely related and more common species (genetic swamping). Hybridization as it relates to Colorado hookless cactus is discussed later in this document. The other primary method of genetic erosion is the loss of genetic diversity due to inbreeding (Charlesworth and Charlesworth, 1987). Inbreeding depression in plant populations can result in reduced fitness and fecundity and is therefore a concern for the long-term viability of rare species. Genetic investigation of Colorado hookless cactus by McGlaughlin and Ramp-Neale has demonstrated moderate to high levels of genetic diversity in all the populations sampled as part of their study. The southern group (Gunnison River) had the highest levels of diversity while the northern (Debeque group) had the lowest. Overall diversity levels exceeded what is normally expected within rare plants.

Additionally, levels of inbreeding were relatively low in most areas they sampled. Elevated inbreeding was observed in a number of sites within the Grand Valley region and at South Shale Ridge. Inbreeding levels were not high enough to raise concerns or demand management to increase levels of diversity, but do raise questions about how areas that have higher frequency of surface disturbance and fragmentation might be affecting populations.

Regulatory assurances and conserved areas:

In compliance with regulation under the ESA and in accordance with the BLM Manual 6840 – *Special Status Species Management* the BLM has implemented measures in planning documents including Resource Management Plans (RMPs) to minimize and avoid impacts to Colorado hookless cactus and its habitat and contribute to its conservation and recovery (BLM, 2008a). Colorado hookless cactus range spans three separate BLM field offices and two National

Conservation Areas (NCAs) each with their own set of planning documents that guide the management of lands under its preview. Both the Colorado River Valley Field Office and Grand Junction Field Office RMPs and Records of Decision (ROD) were updated and approved in 2015. The current Uncompahgre Field Office RMP and ROD dates to 1985 with an updated RMP expected to be approved with a ROD at some point during 2019. The Dominguez-Escalante National Conservation Area and Gunnison Gorge RMPs and RODs were approved in 2009 and 2004 respectively.

Planning documents for each of the three field offices and two NCAs contain slightly different language pertaining to the management of the habitat of listed species. In general, planning documents contain components that seek to limit adverse impacts of land-use to ESA-listed species including Colorado hookless cactus (e.g., prohibiting new disturbance within 200 meters of current and historically occupied and suitable habitat). These measures of avoidance provided for site and project level assurances protecting individual plants and occurrences. Regulatory assurances ascribed to Colorado hookless cactus are summarized in each of the three field offices and two NCAs Resource Management Plans, refer to those documents for detail.

Of the 2,200 square miles that defines the range of Colorado hookless cactus 470 square miles, or approximately 22%, consist of lands that possess special management designations where authorized land-use is limited, excluded, or are areas allocated specifically for the conservation of their resources (Table 2). These lands represent areas where Colorado hookless cactus occurrences are not likely to be adversely altered or disturbed by land-use actions and facilitate the maintenance and recovery of cactus occurrences. Perhaps most importantly among these areas for Colorado hookless cactus is the 210,172 acre Dominguez Escalante National Conservation Area (D-E NCA). The D-E NCA overlaps almost entirely with Colorado hookless cactus range and contains a significant amount of occupied and suitable habitat between the Gunnison River and the forested uplands of the Uncompahgre Plateau, providing for the long-term conservation and protection of Colorado hookless cactus. Other smaller parcels that have been identified as possessing outstanding or sensitive natural resources possess special management status as Areas of Critical Environmental Concern (ACEC) and Wilderness Study Areas (WSA) where surface use is limited, or excluded. A discussion of these areas and their applicable statutes follows:

Dominguez-Escalante NCA (210,172 acres)

- Dominguez Canyon Wilderness (66,280 acres)
- River Rims ACEC (5,314 acres)
- Escalante Canyon ACEC (2,282 acres)
- Gibbler Mountain ACEC (1,266 acres)

Gunnison Gorge NCA

Adobe Badlands WSA

- Adobe Badlands ACEC (6,381 acres)

Pyramid Rock ACEC (1,257 acres)

South Shale Ridge ACEC (27,838 acres)
Mt. Logan Foothills ACEC (3,969 acres)
Atwell Gulch ACEC (2,859 acres)
Indian Creek ACEC (2,345 acres)

Table 2. List of areas with special management designation and their acreage

Dominguez-Escalante National Conservation Area (D-E NCA)

The Dominguez-Escalante National Conservation Area was established through the Omnibus Public Land Management Act of 2009. Administration of the 210,172 acre NCA is guided by the Dominguez-Escalante National Conservation Area Approved RMP (BLM, 2017). In concert with the NCA's designation all Federal minerals were withdrawn under applicable laws and miles of routes were closed to mechanized and motorized travel. Forming the heart of the NCA is the 66,280 acre Dominguez Canyon Wilderness – which possesses stringent protections under the Wilderness Act of 1964. Additionally, the River Rims, Gibbler Mountain, and Escalante Canyon ACEC's prohibit surface-disturbing activities specifically to avert impacts to Colorado hookless cactus. The sprawling D-E NCA is nearly entirely concurrent with Colorado hookless cactus' range and plants are found throughout the planning area – particularly along the sloped terraces above the Gunnison River, and within Big Dominguez Canyon and Escalante Canyon. Colorado hookless cactus is considered one of several conservation priority species in the planning area. The D-E NCA approved RMP contains provisions designed to conserve, protect, and promote the recovery of Colorado hookless cactus. Despite layers of concurrent protections, not all land-use is restricted within the NCA – nearly the entire planning area is allocated to livestock grazing. Allotments are variously divided between both cattle and sheep.

- 96% of the NCA's 210,172 acres are coincidental with Colorado hookless cactus' range
- 66,280 acres are designated Wilderness
- 8,862 additional acres contained in the River Rims, Gibbler Mountain, and Escalante Canyon ACECs managed to protect the integrity of Colorado hookless cactus occurrences
- Many, large populations of Colorado hookless cactus exist throughout the planning area primarily along the Gunnison River, and lining Big Dominguez Canyon and Escalante Canyon.

Gibbler Mountain ACEC

The 1,310 acre Gibbler Mountain ACEC is located within the Dominguez-Escalante NCA providing added protection for Colorado hookless cactus occurrences in the vicinity.

- Routes reduced within 200 meters of sensitive plant occurrences
- Surface disturbing activities that pose adverse impacts to Colorado hookless cactus prohibited
- Managed as a ROW exclusion area

River Rims ACEC

The 5,314 acre River Rims ACEC is composed of four discreet units located along the terraced slopes of the Gunnison River in the Dominguez-Escalante NCA. Extensive occurrences of Colorado hookless cactus are found throughout all four units of the ACEC.

- Surface disturbing activities prohibited
- Livestock grazing and movements conducted to protect sensitive plant resources
- Competitive SRPs prohibited. Low impact commercial and organized group (commercial river outfitter) SRPs allowed
- ROW exclusion area
- Motorized and mechanized routes within 200 meters of Colorado hookless cactus occurrences reduced or re-routed

Escalante Canyon ACEC

The 2,281 acre Escalante Canyon ACEC was established within the Dominguez-Escalante NCA in order to protect the sensitive resources of Escalante Canyon including the large occurrences of Colorado hookless cactus that are found there.

- Livestock movements and grazing managed to protect sensitive plant resources
- Woodland harvest prohibited to prevent the accidental destruction of unique plant associations
- Site specific relocation (SSR) restrictions apply
- Overnight camping limited to developed campgrounds and designated campsites
- Competitive SRPs prohibited. Low impact commercial and organized SRPs allowed
- Managed as a ROW exclusion area

Gunnison Gorge National Conservation Area

The Gunnison Gorge National Conservation Area was designated in 2004. The NCA includes 52,728 acres that are concurrent with the southeast extension of Colorado hookless cactus range. Known occurrences within the planning area are few and tend to be small. Despite the lack of explicit protections that go above and beyond the standard protections afforded to listed species on Federally managed lands, the Gunnison Gorge Approved RMP does specify a heightened awareness and focus on the protection of special status species within the planning area (BLM, 2004).

Adobe Badlands ACEC

The Adobe Badlands ACEC consists of 6,380 acres of steep Mancos shale hills north of Delta and includes known Colorado hookless cactus occurrences and potential habitat. The ACEC was designated through the approved Uncompahgre Basin RMP in 1985.

- Surface occupancy and surface disturbing activities prohibited (NSO)
- Livestock forage utilization limited

Pyramid Rock ACEC

The 1,257 acre Pyramid Rock ACEC in the vicinity of De Beque is managed as a "core conservation population area" to preserve Colorado hookless cactus. The ACEC contains a significant number of Colorado hookless cactus plants for its small size. Plants in the Pyramid Rock ACEC possess the highest level of protection against land-use related impacts. Pyramid Rock ACEC was established through the 2015 approved Grand Junction Field Office RMP.

- Closed to motorized (including over-snow), mechanical, equestrian, and foot travel
- Target shooting prohibited
- SRPs not authorized
- Closed to camping
- Closed to livestock grazing
- Managed as a ROW exclusion area
- Surface occupancy and surface disturbing activities prohibited (NSO)

South Shale Ridge ACEC

The 27,800 acre South Shale Ridge ACEC is directly adjacent to Pyramid Rock and contains large occurrences of Colorado hookless cactus. The ACEC was designated through the 2015 approved Grand Junction Field Office RMP.

- SRPs not authorized
- Motorized and mechanized travel limited to designated routes
- Manage as ROW exclusion area (except to oil and gas leases issues under the 1987 RMP with valid existing lease rights)
- Surface occupancy and surface disturbing activities prohibited (NSO)

Atwell Gulch ACEC

The Atwell Gulch ACEC consists of 2,859 acres of Colorado hookless cactus habitat designated through the 2015 approved Grand Junction RMP.

- Closed to mechanized and motorized travel (including over-snow)
- SRPs not authorized
- Livestock grazing excluded on 2,600 acres
- ROWs excluded on 2,600 acres (except to oil and gas leases issues under the 1987 RMP with valid existing lease rights)
- 260 acres managed as a ROW avoidance area
- Surface occupancy and surface disturbing activities prohibited (NSO)

Mount Logan Foothills ACEC

The Mount Logan Foothills ACEC protects 3,969 acres of Colorado hookless cactus habitat. The ACEC was established through the 2015 approved Colorado River Valley Field Office RMP.

- Surface occupancy and surface disturbing activities prohibited (NSO)
- Closed to commercial timber harvest, firewood cutting, and special forest product harvest
- SRPs not authorized
- Managed as a ROW avoidance area
- Recommended for withdrawal from mineral entry
- Closed to salable minerals/mineral material disposal
- Closed to leasing of non-energy minerals
- Designated routes limited (including over-snow)

CHAPTER 4. THREATS ASSESSMENT

The following section provides an assessment of the factors, both biological and anthropogenic, that have been documented as direct or indirect threats to Colorado hookless cactus and its habitat. Principal in the decision to list Colorado hookless cactus was the threat of ongoing and future destruction, modification, and curtailment of the species habitat and range (44 FR 58868; Service, 2010). Historical and current activities that may contribute to this pattern include: surface disturbance associated with mineral and energy development including the instillation of well pads, pipelines, and roads; major utility lines and pipeline rights-of-way (ROW); water developments including check dams and irrigation projects; road construction and highway expansion; livestock grazing and its supporting activities; off-highway vehicle (OHV) and other recreational uses; and rangeland and residential development. Natural factors that impact the species include: herbivory and parasitism by insects; trampling by wildlife; the proliferation of non-native and invasive species; and climate change.

As with the biology of Colorado hookless cactus, much more is known presently about the threats to the species then at the time of its listing. Several of the threats documented in accordance with the listing decision have been shown to be irrelevant based on changes in the species range due to taxonomic revision (*e.g.* oil shale and tar sands development). Others have been shown to be of much less concern than initially believed (*e.g.* illegal collection). Following guidance under BLM Manual 6840 the BLM has taken proactive steps in order to limit the negative impacts associated with land management actions that occur in Colorado hookless cactus habitat, including engaging the USFWS in programmatic level consultation pertaining to the agencies grazing program. When and where appropriate, the BLM has established special land management designations (*e.g.* ACECs) through regulatory channels in order to conserve the

species and its habitat (BLM, 2008a). Where projects do have the potential to negatively impact Colorado hookless cactus the BLM participates in formal consultation with USFWS and supports mitigation measures as compensation for actions that may, or are likely to, effect Colorado hookless cactus and its habitat.

The following threats assessment evaluates each of the documented threats to Colorado hookless cactus on a four point scale from "low" to "very high" in terms of the threat's scope, severity, and irreversibility (Appendix 1). The procedure follows the Open Standards for the Practice of Conservation version 3.0 and is designed to develop an informed threat ranking as well as an overall understanding of the magnitude of each threat (Conservation Coaches Network, 2012). We define the "scope" of a threat as the geographic extent of the impact to Colorado hookless cactus that can reasonably be expected within 10 years under current circumstances. "Severity" is assessed as the level of damage to Colorado hookless cactus that can reasonably be expected within 10 years assuming the continuation of current circumstances. "Irreversibility" is the degree to which the effects of a given threat can reasonably be reversed or restored (Table 3).

Threat	Severity	Scope	Irreversibility	Rank
Mineral and energy development	medium	medium	high	**high**
Utility corridors	low	medium	medium	**medium**
Invasive species	medium	high	high	**high**
Collection	low	low	low	**low**
Off road vehicle (ORV) use	low	medium	medium	**medium**
Livestock grazing	high	very high	high	**very high**
Predation	high	medium	very high	**high**
Climate change	low	low	very high	**medium**
Herbicide and pesticides	low	low	medium	**low**
Hybridization	low	low	very high	**medium**

Table 3. Assessment and ranking of the threats to Colorado hookless cactus following the Conservation Coaches Network framework (CCNet, 2012)

Mineral and energy development

Summary:

Portions of Colorado hookless cactus range are coincidental with geologic formations that contain economically valuable minerals including oil and natural gas. Several mineral and energy development activities included as threats to Colorado hookless cactus and its habitat in the original listing decision and recovery plan have been shown to be minor in the scope of their impact or irrelevant based on revisions to the species range associated with taxonomic changes. These activities include oil shale, tar sands, sand and gravel quarrying, gold dredging, and building stone collecting and quarrying (USFWS, 1990). Oil shale and tar sands development are ongoing

in the Uinta Basin and may impact both *S. wetlandicus* and *S. brevispinus* but are not relevant to Colorado hookless cactus or its habitat. No information exists to suggest that sand, stone, and gravel quarrying and collecting and gold dredging is more than a minor and localized impact.

Oil and gas exploration, development, and production, hereafter "oil and gas and its related activities", remains a meaningful threat to Colorado hookless cactus and its habitat due to the severity of the impacts associated with the loss of habitat from the development of infrastructure including well pads and roads and the moderate scope to which activities are occurring in cactus habitat. Therefore this section will focus on oil and gas and its associated impacts which is ranked as HIGH in our threat assessment. To date, programmatic level consultation with the USFWS hasn't occurred for oil and gas leasing and its related activities on BLM lands in Colorado. Instead the agency has implemented a practice of avoidance in relation to Colorado hookless cactus and its habitat, consulting with the Service on a project-by-project basis when necessary.

Overview of activities:
Under the Federal Land Policy and Management Act (FLPMA) the BLM has the authority to authorize third-party operators (lessees) in actions related to the exploration, development, and production of oil and gas deposits that are a part of the agencies subsurface mineral estate. These activities routinely involve the installation of infrastructure including roads, well pads, pipelines, power and communication lines, and other production facilities including compressor stations that support the capture and transport of natural gas. Other activities related to production include the operation and regular maintenance of existing facilities. Authorized activities are subject to stipulations specified in Master Leasing Plans (MLP) that can restrict or prohibit surface disturbing activities thereby reducing the impacts from oil and gas development in areas that require special management attention including habitat occupied by special status species.

Effects:
Oil and gas and its related activities have the potential to adversely impact Colorado hookless cactus and its habitat through the modification, curtailment, and destruction of the species habitat. Infrastructure, including roads, well pads, and pipelines may result in the loss of individual plants, any associated soil seed bank, and habitat required by pollinators. Extreme cases may result in the extirpation of entire occurrences. Individual plants may be damaged by activities related to oil and gas occurring in occupied habitat. Additionally, habitat conversion may prohibit Colorado hookless cactus dispersal and colonization of adjacent unoccupied habitats. Oil and gas related development may also contribute to decreased ecological function and the proliferation of invasive, non-native plant species.

Scope:

Exposure to oil and gas related activities is not borne equally across Colorado hookless cactus range. Oil and gas related activities are concentrated in the Colorado River Valley in the northern portion of the species' range (Figure 7). Because of this, the northern De Beque population in the Colorado River Valley Field Office is particularly exposed to the negative impacts of oil and gas related activities. Conflicts exist to a lesser degree in the north desert of the Grand Valley and along the toe of the Grad Mesa East of Highway 50 from Whitewater to Delta. No mineral and energy development occurs west of Highway 50.

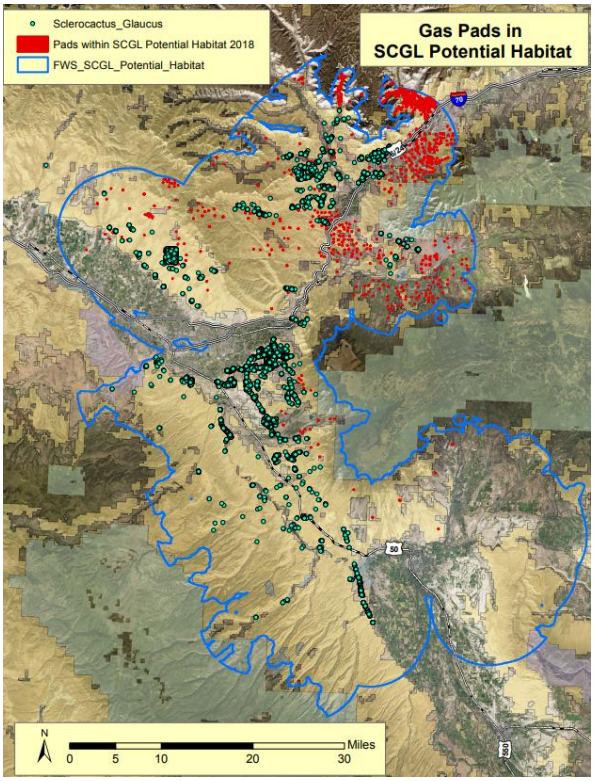

Figure 7. Location of gas pads occurring within Colorado hookless cactus' range

Regulatory Assurances:

The RMP's for the three respective field offices outline policy for the consideration of special status species in relation to oil and gas leasing. BLM maintains a commitment to protect occupied and suitable habitat for federally protected species and BLM designated sensitive species consistent with policy. To maintain or improve the quality of listed and sensitive species habitat by managing public lands activities to support species recovery and the benefit of those species with the overall objective of improving their populations so that they can be removed from these lists (BLM, 2008a; BLM, 2015a). A number of stipulations and conservation measures are applied to new leases in order to protect special status species including; buffer distances, biological inventories, and no surface occupancy stipulations (NSO). Areas identified as NSO/No Surface-disturbing Activities are open to fluid mineral leasing, but surface-disturbing activities cannot be conducted on the surface of the land unless an exception, waiver, or modification is granted.

Access to fluid mineral deposits would require directional drilling from outside the boundaries of the NSO/No Surface-disturbing Activities areas. A standard buffer distance of 200 meters is applied to current or historically occupied habitat of Colorado hookless cactus.

Utility corridors

Summary:

The instillation of utility corridor ROWs is considered a meaningful impact to Colorado hookless cactus by the 2010 Recovery Outline. Several transmission lines have been installed in Colorado hookless cactus habitat that have affected occurrences. Approximately 1,200 plants have been transplanted in association with these projects (Bio-Logic, 2008). Impacts associated with the construction of utility corridors may result in the damage or loss of individual plants. Although impacts are localized and limited in scope and severity due to the narrow nature of utility ROWs. We therefore assess utility corridors to pose a MEDIUM level of threat to Colorado hookless cactus and its habitat.

Effects and Scope:

Utility corridors and their associated surface disturbance may contribute to the damage or loss of individual Colorado hookless cactus plants and the fragmentation and curtailment of its habitat. Due to the linear nature of ground disturbance associated with utility corridors, ROWs may be especially susceptible to the proliferation of non-native invasive plant species and facilitate their transfer into previously undisturbed areas. Several transmission lines have been authorized and constructed in Colorado hookless cactus habitat. Among these is a BLM and Department of Energy designated Westwide Energy Corridor covering 70,142 acres of potential Colorado hookless cactus habitat.

Policy and Regulatory Assurances:

The construction and operation of transmission lines can only occur in a manner that minimizes adverse effects to Colorado hookless cactus and complies with the requirements of the Endangered Species Act [Section 7(a)(2)] and Bureau of Land Management regulations. Conservation plans (per Section 10 of the ESA) are required and identify the measures that the utilities commit to in order to minimize or eliminate adverse effects that might jeopardize the continued existence of the species. BLM must approve a Plan of Development (POD) that identifies the allowed actions for construction and operation of the transmission line on public lands. Whenever possible, powerlines and access routes should avoid plants and their habitat.

If Colorado hookless cactus cannot be avoided during transmission line construction, transplantation of these cacti has occurred in accordance with the USFWS Biological Opinion (BO) issued for the project. The BO will require that the transplanted cacti be monitored for a period

of 20 years. Monitoring will be conducted annually for the first 10 years, then at an established interval for the remaining years. The objective of the monitoring is to record the vigor of the transplanted cacti in comparison to control cacti and to determine whether this is a viable means of conservation for the species.

Invasive species

Summary:

Invasive plant species are those that are not part of the native plant community and possess the ability to pervade in, and exploit a variety of habitats and ecological niches in their novel environment. Non-native, invasive plant species, including cheatgrass (*Bromus tectorum*), have become a dominant component of the plant community in portions of Colorado's western slope. Introduced annual forbs such as desert madwort (*Allysum desertorum*), blue mustard (*Chorispora tanella*), tall tumblemustard (*Sisymbrium altissimum*), annual wheatgrass (*Eremopyrum triticeum*), and saltlover (*Halogeton glomeratus*) also inhabit localized disturbed sites throughout the region. Although non-native invasive plant species are found in all of the habitat types in which Colorado hookless cactus occurs and are pervasive across the species range, extreme impacts are localized. Due to their pervasiveness throughout Colorado hookless cactus habitat and their difficulty to eradicate we assess the threat from non-native invasive plant species to be HIGH.

Scope of effects:

The continued expansion of non-native invasive plant species has been recognized as the single greatest threat to the integrity of native plant communities across the western United States (Asher, 1998). The rapid expansion of invasive plants across public lands continues to be a primary cause of ecosystem degradation and control of these species one of the greatest land management challenges facing the BLM. Non-native invasive plants like cheatgrass can aggressively outcompete native vegetation, especially following surface disturbance, resulting in the displacement of important attributes of native plant communities. Left unchecked, non-native invasive plant species can create one dimensional vegetation communities (monocultures) that degrade or reduce soil productivity, water quality and quantity, species diversity and structure of native plant communities, wildlife and pollinator habitat (DiTomaso, 2000).

It is unclear exactly how areas infestations of non-native and invasive plants affect Colorado hookless cactus abundance. Cheatgrass is particular has been documented as a potential threat to Colorado hookless cactus occurrences, cited accordingly in 45% of the 103 CNHP EO records (CNHP, 2017). The salt desert and sagebrush communities tend to have the highest frequency of invasive plant species, particularly cheatgrass, while Pinon Juniper communities retain relatively

low levels of invasive forbs and grasses (Price, 2017). At least one monitoring study attributed declines in population trend as related to competition with cheatgrass (BLM, 2009).

Policy and Regulatory Assurances:
The Bureau of Land Management has internal policy and guidance on integrated vegetation management (BLM, 2008b). The respective Resource Management Plans (RMPs) for the three BLM field offices that share administration of Colorado hookless cactus habitat contain provisions outlining goals and objectives pertaining to overall vegetation condition. Plans emphasize the restoration and maintenance of healthy, productive plant communities of native and other desirable species (BLM, 2015a). In many areas cheatgrass is considered to be a naturalized part of the vegetation community where the possibility of complete eradication is unrealistic. These areas are constituted by areas of infestation that has led to complete conversion of sites from their historical reference state. Instead, RMP's contain provisions aimed at mitigating the effects of non-native invasive plants on sensitive resources and focusing resources into limiting their continued spread.

Collection and commercial trade

Summary:
The most common perceived threat to rare cacti globally is the collection of plants and seeds from wild populations for specialized collections. This perception of exploitation was a primary and significant causal factor in the decision to list Colorado hookless cactus under the ESA. The original listing stated that the species was threatened by unregulated commercial trade and collection, however, we do not have any evidence that population abundance has been altered or otherwise affected due to the removal of individuals from wild populations by collectors. Due to the lack of evidence that wild collection is occurring at more than a very minor and localized scale, and that whatever illegal wild collections are made likely only affect a small proportion of the individuals within a given occurrence we consider the overall threat ranking to Colorado hookless cactus by illegal, unregulated commercial exploitation to be LOW.

Scope and Effects:
The collection of seeds and Colorado hookless cactus plants from wild populations for commercial trade has the potential to adversely impact population abundance and genetic diversity range-wide. Many rare and economically valuable species around the globe are impacted by unregulated exploitation for commercial trade, *Astrophytum asterias* being an example of a rare cactus from the desert southwest that has been highly sought by collectors.

Policy and Regulatory Assurances:

While the collection of, and trade in, cactus species does occur at national and international levels, including of Colorado hookless cactus; at this point in time, the entire family of Cactaceae is included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which most certainly curtails collection from the wild where CITES is enforced. Additionally, the relative availability and ease of access to plants grown from seed or seeds available from *Index Seminum* collections from botanical gardens throughout the world should also curtail illegal collection. Botanic gardens collecting seeds for *Index Seminum* make these seeds available on an exchange basis, exclusively for scientific, educational and conservation purposes. Progeny raised from these seeds may not be used to generate commercial profit without prior written permission from the botanic garden, and will not be granted unless equitable sharing of benefits with the countries of wild origin, under the terms and in the spirit of the Convention on Biological Diversity, is secured.

In 2008, congress passed an amendment to the 100-year-old statute known as the Lacey Act banning commerce in illegally sourced plants and their products. The Lacey Act was amended for the purpose of combating illegal logging and expanding the Lacey Act's anti-trafficking protections to a broader set of plants and plant products. The definition of the term "plant" includes "any wild member of the plant kingdom, including roots, seeds, parts, and products thereof, and including trees from either natural or planted forest stands." Previously, the Lacey Act only covered plants native to the United States which are listed in one of the three appendices to CITES or protected by the law of a U.S. state that conserves species threatened with extinction. Now anyone who exports, transports, sells, receives, acquires or purchases illegally harvested plants or plant products in the United States, may be prosecuted.

Plant collection on BLM lands is authorized by law under FLPMA, and direction for management of this activity is established through BLM Manual 5000. The BLM allows collection of common native plant species to the general public; special consideration is given to BLM special status species under BLM Manual 6840 and as regulated by the CFR. No permits have been issued to the general public for collection of Colorado hookless cactus.

BLM policy provides for non-sale disposals that have that have a Free Use Application and Permit for vegetative and mineral material. The objective of non-sale disposals is to provide materials free of charge to qualified individuals for their personal use, and not to be used for resale purposes. This policy has a section under general recreation use that states: No permit is required for the collection of limited amounts of vegetation products by recreationists on the public land in accordance with 43 CFR 8000. Recreation collection includes, but is not limited to, dead and downed timber for campfires, flowers, berries, nuts, seeds, cones, and leaves. The harvest and removal of special status plant species is specifically prohibited (43 CFR 8000).

Off-road vehicle (ORV) recreation

Summary:

Off-road vehicle (ORV) recreation has the potential to degrade Colorado hookless cactus and its habitat by damaging or destroying individual plants and occurrences by crushing, contributing to sedimentation and erosion, and fragmenting habitat. Much of Colorado hookless cactus habitat is appealing to ORV recreation; being open landscapes where vegetation is sparse. Despite ORV use being common in Colorado hookless cactus habitat, there have been few documented impacts to plants or occurrences leading us to assess the threat from ORV recreation to be MEDIUM.

Policy and Regulatory Assurances:

The BLM manages motorized and other access on public lands in accordance with existing laws, such as FLPMA and the Endangered Species Act, Executive Orders, proclamation, regulation and policy. In addition, many recreational uses of public lands and visitor services provided by the BLM must be in conformance with applicable land use plans. Specific criteria for open, closed, and limited designations are provided in the definitions outlined in 43 CFR 8340. FLPMA requires that allowable uses and actions be prescribed through the land use planning decisions.

The BLM generally defines access to the public lands through the land use planning process, and in some cases, more area-specific activity plans. Generally, the BLM allows vehicle use and other conveyances on public lands, but in certain circumstances can close an area to all public access for specified periods of time. Consideration of habitat is a factor that influences the designation of areas as “closed” or with “access limited” to specified roads and trails. Area, road, and trail designations are prepared in consultation with biologists and other agency specialists, State and county officials, and the interested public, and are approved through the FLMPA planning and NEPA processes. Overall, the land use planning process prescribes designated routes, area and road or trail seasonal access or vehicle restrictions, management prescriptions, and monitoring to evaluate the effectiveness of management actions in achieving the specific resource objectives. Furthermore, when an immediate action is needed to protect resources, the BLM has authority to issue a decision to close an area to motorized recreation. Once a decision has been reached to permanently close a road or trail, the route may be obliterated and restored.

Livestock grazing

Summary:

Based on our assessment livestock grazing and its related activities poses the greatest management related threat to Colorado hookless cactus long-term persistence. A rank of Very High was assigned to the factor primarily based on the potential severity of impacts to individual

plants and their habitat and the broad scope of the species exposure to these impacts across its range (BLM, 2012). Nearly all of Colorado hookless cactus habitat that occurs on BLM land is coincidental with livestock grazing. Significant negative impacts to vegetation communities and overall land health have been documented associated with improper grazing practices. These impacts are related to direct threats to individuals plants from concentrated livestock use and indirect impacts to overall land health. A Programmatic Biological Opinion (PBO) issued by the Service in 2012, determined that based on the BLM's commitment to the implementation of a series of conservation measures designed to avoid or minimize impacts from grazing programs and related activities on the species, that public lands grazing is not likely to jeopardize the continued existence of the species; such that effects would not be expected to reduce, directly or indirectly, the survival or recovery of the species or adversely modify or destroy its habitat (USFWS, 2012). A summary of the BLM's grazing program its history and associated regulations and policies, its impacts, and associated conservation measures follows.

Authority, History, and Environmental Baseline:
The BLM administers its livestock grazing program as part of the mandate established under FLPMA to manage the public lands under its purview for multiple-uses and their sustained yield. Grazing permits are typically authorized and issued to operators by the BLM for a period of up to 10 years. Environmental review under the National Environmental Policy Act (NEPA) is required before a permit renewal is issued. In cases where a full NEPA review cannot be completed prior to the expiration of a grazing lease/permit, and the new permit or lease to be issued contains the same terms and conditions; it may be issued in accordance with the authority under the Appropriations Act for that year (BLM, 2011).

Livestock grazing has been widespread and prolific in Colorado hookless cactus habitat since the late 1800's; particularly in the area north of Delta along the Gunnison River to the Grand Valley. Despite current guidelines and regulations, the cumulative legacy of over a century of use by livestock is evident in the composition and structure of the vegetation communities across portions of the species range. Prior to the establishment of the Taylor Grazing Act, which organized public lands grazing into a system of allotments with use restrictions, grazing was largely unregulated with stocking rates and grazing intensities that were much higher than they are today (USFWS, 2012). Following the enactment of FLPMA, grazing allocations were again reduced. The impacts of this historic period of grazing are still evident today and include; localized alteration of hydrological function, soils, and vegetation community structure. Specifically areas where the loss of critical components of the native plant community are evident, including: the loss of salt desert and dwarf shrub communities, and their associated biological soil crusts, cool season grasses and forbs (BLM, 2013). In places this has resulted in conditions favorable for the

proliferation of exotic annual species. It is unclear how this period of intense unrestricted grazing may have affected the abundance and distribution of Colorado hookless cactus and its range.

Scope of Effects:
Livestock grazing and the interrelated and independent actions that support grazing activities are known to be detrimental to Colorado hookless cactus and its habitat (BLM, 2012). Direct impacts to Colorado hookless cactus from livestock grazing and management activities include mechanical damage to individual plants from livestock trampling and crushing. Larger cacti are more susceptible to uprooting and crushing by cattle hooves (Clark and Clark, 2007). The loss of larger, reproductive individuals may pose a demographic threat to populations. The disturbance and compaction of physical and biological soils is an added effect. Negative impacts to soils are especially acute when soils are wet, and in areas of livestock concentration particularly associated with watering, salting, trailing and bedding activities. Sheep in particular have the potential to cause damage to sites due to their tendency to graze and bed in flocks. Localized extirpation of cactus occurrences has been documented associated with concentrated use by sheep - no similar impacts associated with cattle have been observed. Herbivory of Colorado hookless cactus by domestic livestock has not been documented.

Indirect impacts to Colorado hookless cactus from grazing activities are primarily related to the deterioration of ecological function and rangeland health associated with inappropriate livestock grazing practices, timing, and levels of use. Changes in vegetation community structure can result in the loss of function and site value resulting in a proliferation of invasive exotic species on disturbed sites associated with livestock congregation and concentrated use. Invasive and exotic species common on disturbed sites throughout the area include cheatgrass (*Bromus tectorum*), Halogeton (*Halogeton glomeratus*), in addition to annual wheatgrass (*Eremopyrum triticeum*), and annual mustards (*Alyssum spp., Sisymbrium spp.*). The Mancos shale salt desert community is particularly fragile being susceptible to, and slow to recover from, degradation from livestock.

Approximately 97% of the Colorado hookless cactus “area of influence” that is coincidental with BLM surface management is allocated to livestock grazing (BLM, 2012). This area is partitioned among 104 individual grazing allotments, each assigned a class of livestock (variously divided between cattle and sheep), stocking rate, period of use, and are permitted at given number of animal unit months (AUMs) per the Taylor Grazing Act of 1934.

Standards of Rangeland Health:
Internal bureau policy requires that grazing allotments are managed to meet or exceed land health standards as established by the Colorado Standards for Public Land Health and Guidelines for Livestock Grazing Management in Colorado (BLM, 1997). Land health is defined as the “degree

to which the integrity of the soil and the ecological processes of ecosystems are sustained" (BLM 4180 Manual). There are five component Public Land Health Standards that prescribe the resource conditions necessary to maintain land health. Standard 4 specifically applies to the maintenance of special status species and their habitats. Grazing allotments are evaluated to determine whether rangeland health meets, meets with problems, or does not meet the appropriate standard (BLM, 1997). If livestock grazing management is determined to be a significant causal factor for an allotment, or a portion of an allotment, to not meet a given standard then the authorized officer must take appropriate action as soon as practicable, but no later than the beginning of the next grazing year, to bring grazing and related activities into conformance with grazing guidelines or to modify them so that significant progress can be made towards achieving land health standards (BLM 4180 Manual).

Conservation Measures:
Pursuant to the Biological Opinion for Livestock Grazing Program Effects on Three Listed Plants in the Bureau of Land Management Grand Junction, Colorado River Valley, and Uncompahgre Field Offices, the BLM has agreed to implement fifteen non-discretionary conservation measures to further the conservation and recovery of Colorado hookless cactus (Appendix 2). The terms and conditions of grazing permits that include Colorado hookless cactus habitat will be updated to reflect measures designed to avoid, minimize, and/or remediate effects of species in mapped occupied habitat.

Predation

Summary:
Predation of Colorado hookless cactus has been documented in two forms: (1) herbivory associated with the foraging activities of small ground dwelling mammals, and; (2) parasitism by the Opuntia-borer beetle (*Moneilema semipunctuatum*). Frequency of these events are likely cyclical, of varied intensity, and not well understood.

Only anecdotal evidence exists to suggest that populations of Colorado hookless cactus as currently described are the subject of parasitism by the Opuntia-borer beetle (*Moneilema semipunctuatum*). Beetle parasitism is assumed to be a significant localized threat to the species by the USFWS (Service, 2010). In studies of closely related species of *Sclerocactus*; Wright fishhook cactus (*Sclerocactus wrightiae*), in Utah, and Mesa Verde cactus (*Sclerocactus mesae-verde*), beetles prefer larger, mature, reproductive individuals and may alter the age structure at individual occurrences (Coles et al., 2012; Kass, 2001). Parasitism by Opuntia-borer beetle, has not been documented as a cause of mortality at any Colorado hookless cactus demographic monitoring sites during the period sampled. Beetles are a natural component of the ecological community and likely play a role within populations that is not well studied or understood.

Parasitism, while present, appears to be isolated occurring in a small percentage of the total population; leading to the conclusion that it is not a major threat to the long term persistence of Colorado hookless cactus in the wild.

Herbivory by lagomorphs and rodents including desert cottontail rabbits (*Sylvilagus audubonii*), Wyoming ground squirrels (*Urocitellus elegans*), and other rodents poses a significant though localized threat to populations of Colorado hookless cactus. Herbivory typically results in the partial or complete consumption of the succulent stems of cactus individuals. Excavation by the roots of individual plants has also been observed. Herbivory does not always result in mortality of the affected plant. New stems of plants that have been partially consumed have been observed budding off of their root collar in subsequent years. Due to the high severity and moderate scope of predation and that instances may decimate entire occurrences we assess predation by small ground dwelling mammals to be HIGH.

Scope and Effects:
Over the duration of a seven year demographic monitoring study (2011 - 2017) cactus herbivory by small mammals was documented in various degrees at all five monitoring sites across the study system. Monitoring years 2012 and 2013 had the highest observed levels of herbivory. Overall, herbivory was the highest attributable cause of cactus mortality across the study system - comprising 22.5% of the cases of attributable mortality occurring from 2011 to 2017.

The relationship between small, ground-dwelling mammals and cactus predation is not well understood, and is likely the product of regional climate patterns and larger ecosystem dynamics - including levels of sylvatic plague present within rodent populations. Levels of cactus predation may be higher during periods of persistent drought. Small mammals may rely on the succulent stems as a food source when other preferred forage is unavailable (BLM, 2018). Based on anecdotal evidence, burrows of Wyoming ground squirrels have increased within Colorado hookless cactus habitat since approximately 2005 (Holsinger, 2018 pers. comm.). Concerns related to the demographic impacts of herbivory on cactus population vital rates resulting in altered population structure and lower fecundity are of particular concern. Mortality attributed to herbivory does not appear to be limited to stage class. Of cactus mortality attributed to herbivory 43% were vegetative individuals and 57% were reproductive between 2011 and 2017. The timing and intensity of herbivory events appears to vary between low intensity chronic mortality and high intensity short duration events.

Climate change

Summary:

Climate change refers to a detectable change in the state of the climate that persists for an extended period of time, typically 30-years or longer (IPCC, 2007). For the purpose of this report "climate change" refers to any change in the mean or variability of one or more major climatic variable (e.g. precipitation, or temperature) that persists over time as the result of human activities, natural variability, or both. Climate's influence on species and ecosystems is paramount, therefore changes to the state of the climate can affect species both directly and indirectly in a number of ways. These influences may not be detrimental to all species, but can be beneficial, or may not have a significant impact depending on a species given ecology. The Intergovernmental Panel on Climate Change (IPCC), considered to be the preeminent authority on climate change globally, anticipates an average global increase of 1.5℃ above pre-industrial (1850-1900) levels to be very likely by mid-century (IPCC, 2018). This anticipated level of change will have impacts on vegetation communities in a variety of ways and to varying degrees but may include; changes in vegetation composition, structure, and species abundance, shifts in range, and the potential for extinction, especially those that have a decreased capacity to disperse or experience compound effects from habitat loss or other stressors.

Plants are generally considered to be at a disadvantage as rapid climatic shifts alter the location of their bioclimatic envelopes (Vitt, et al., 2010; Still et al., 2015). Predicted responses of plants to climate change include shifts in species distribution along elevational gradients, changes in phenology, and effects on demographic rates, such as survival and fecundity. Effective conservation of rare plants therefore depends upon the land managers' ability to incorporate these climate change considerations into policy and land management plans. Two methods are currently being used to determine species or habitat vulnerability due to climate change: vulnerability assessments (CCVA) and species distribution modeling (SDM).

The Climate Change Vulnerability Index (CCVI) is an example of a vulnerability assessment that predicts whether a species will decline, remain stable or increase by evaluating drivers related to exposure, sensitivity and adaptive capacity to climate change (Still et al., 2015). The Climate Change Vulnerability Index (CCVI) developed by NatureServe identifies the critical factors that are most responsible for causing species to be vulnerable to climate change. The CCVI uses a scoring system with the following components: exposure to local climate change, indirect exposure to climate change, species-specific sensitivity, and documented response to climate change. Two separate CCVI assessments were performed in Colorado by NatureServe. The first CCVI assessment was conducted by NatureServe to assess the vulnerability of 391 species of plants of the western U.S. In this assessment, the majority of species were not as vulnerable to climate change on a range-wide basis. Colorado hookless cactus received an index score of PS: not vulnerable /presumed stable on a range-wide basis. The definition of the PS category is: 'available evidence does not suggest that abundance and/or range extent within the geographical

area assessed will change (increase/decrease) substantially by 2050. Actual range boundaries may change" (Treher et al., 2012). Even though Colorado hookless cactus does not appear to be vulnerable range-wide, the CCVI conducted by the Colorado Natural Heritage Program assessed Colorado hookless cactus with a climate change vulnerability score of EV: extremely vulnerable (CNHP, 2015). Factors that contributed to this score included a lack of variation in annual precipitation in occupied habitat over the last 50 years, potential for wind and solar energy development within its range, and pollinator specificity (CNHP, 2015).

In contrast to CCVI assessments, species distribution modeling (SDM) is a spatial analytic method that uses environmental data to predict current or future areas suitable for species to grow. In this process, environmental requirements of the taxon are modeled using indicator variables (*e.g.* precipitation of the wettest and driest month) to map the geographic area where the species may occur. The potential niche of a species is inferred through the use of the species occurrence data, environmental and climatic layers. Species distribution algorithms such as MaxEnt are very useful for species that are geographically or environmentally restricted, such as Colorado hookless cactus (Still et al., 2015; Vitt et al., 2010). Still et al., (2015) analyzed the effects of climate scenarios on Colorado hookless cactus using a combination of CCVI and SDM. Both the CCVI (Treher et al., 2012) and SDM (Still et al., 2015) predict that *Sclerocactus glaucus* will not be vulnerable to climate change by 2050. In this combined scenario, "with a predicted suitable area overlap of more than 67%, a suitability score of almost 0.4, and no known limitations to dispersal, *S. glaucus* is predicted to migrate into favorable microhabitats in response to climate change" (Still et al., 2015).

In an effort to assist BLM land managers in minimizing the effects of climate change on plant populations, the Colorado State Office used SDM modeling to create four models to determine the possible future range of Colorado hookless cactus (Price, 2018). Model 1 used seventeen bioclimatic variables, predicting a slight range contraction with the predicted range mostly encompassing the current range of the species. Model 2 applied the same 5 variables used by Still et al., (2015) and essentially predicted the same results: range expansion. Models 3 and 4 were created using temperature variables and precipitation variables separately. Model 3 (temperature variables) predicted a future range contraction in areas where the cactus does not currently occur, with a small expansion across the current know range. Model 4 (precipitation variables) predicts a range expansion for the cactus. Models created by Price (2018) are summarized in Appendix 3. Given that all of these models suggest that Colorado hookless cactus may not be as vulnerable to climate change as previously thought we assess the level of threat to climate change as MEDIUM.

Herbicide and pesticide application

Summary:

The BLM routinely applies herbicide and pesticide treatments to affected areas in order to combat the spread of non-native invasive plant species and pests in order to achieve desired resource condition. Herbicide and pesticide treatments may adversely impact special status plant species if inadvertently targeted by a treatment. Extreme impacts may result in the mortality of individuals or effected occurrences. Despite the negative impacts posed to individual Colorado hookless cactus plants by herbicide and pesticide treatments we assess the threat to be LOW due to the localized nature of impacts from chemicals and the regulatory process and procedures in place before a Pesticide Use Permit (PUP) can be obtained.

Scope and Effects

Invasive vegetation and noxious weeds are the dominant vegetation on an estimated 35 million acres of public land. Invasive vegetation and noxious weeds degrade or reduce soil productivity, water quality and quantity, native plant communities, wildlife habitat, wilderness values, recreational opportunities, and livestock forage (BLM, 2007). Public lands in the western U.S. support over 1,000 plant species that have been given a special status based on their rarity or sensitivity. Special status plants include species that are federally listed as threatened or endangered, proposed for federal listing, candidates and other species designated as sensitive by the BLM. Many of these species are threatened by competition with non-native plants and other invasive species. Herbicides pose risks to terrestrial and aquatic vegetation. Several terrestrial herbicides are non-selective and could adversely impact non-target vegetation. Accidental spills and herbicides drift from treatment areas could be particularly damaging to non-target vegetation, including special status plant species. Using herbicides to slow the spread of noxious weeds may result in the loss of vegetation, however, over the long-term the plant community should experience gains in ecosystem health.

Policy and Regulatory Assurances:

The Bureau of Land Management has assessed its use of vegetation treatment methods by developing two Programmatic Environmental Impact Statements (PEIS). In 2007, BLM consulted with the USFWS and the National Marine Fisheries Service (NMFS) during development of the *Final Vegetation Treatments Using Herbicides on Bureau of Land Management Lands in 17 Western States Programmatic Environmental Impact Statement* (PEIS) as required under Section 7 of the Endangered Species Act. The Biological Assessment (BA) for this PEIS evaluated the likely impacts to over 300 species, including Colorado hookless cactus. The BA also provides broad guidance at a programmatic level for actions that will be taken by BLM to avoid adversely impacting Colorado hookless cactus (BLM, 2007b.) A second PEIS was finalized in 2016 when the BLM proposed to use three new herbicide active ingredients, aminopyralid, fluroxypyr, and

rimsulfuron to treat vegetation on BLM administered lands in the western US. In 2015, the Biological Assessment for *Vegetation Treatments Using Aminopyralid, Fluroxypyr, and Rimsulfuron on Bureau of Land Management Lands in 17 Western States* was prepared to evaluate the effects of herbicide treatments with aminopyralid, fluroxypyr or rimsulfuron on listed species, species proposed for listing, and/or critical habitat (BLM, 2015a).

The BLM continues to follow the Standard Operating Procedures (SOPs) and Mitigation Measures identified in the 2007 PEIS to ensure that risks to human health and the environment from herbicide treatment actions are kept to a minimum. Appendix A in the Record of Decision for *Vegetation Treatments Using Aminopyralid, Fluroxypyr, and Rimsulfuron* incorporates the SOPs and Mitigation Measures developed in the 2007 PEIS and included in the 2007 ROD as well as new mitigation measures developed for the three new herbicides (BLM, 2016).

As part of any proposed action involving the use of herbicides, BLM will incorporate the identified SOPs and conservation measures into local level projects. These SOPs and programmatic conservation measures are designed to minimize risks to federally listed plants and animals and designated critical habitat. BLM has also identified pesticide-specific buffers that are to be used under different application for the protection of threatened, endangered, and proposed plant species. These programmatic conservation measures for herbicide treatments incorporate the measures from the 2007 BA and are found in Appendix B-2 of the 2016 Record of Decision (BLM, 2016).

Finally, a special status species consultation protocol has been developed that will be used by the BLM at the national and local level to ensure that any action authorized, funded ,or carried out by the BLM will not jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat of such species.

Hybridization

Summary:

Taxonomic uncertainty and broad morphological inconsistencies surrounding the genus *Sclerocactus* have led to fears that hybridization may pose a genetic threat to Colorado hookless cactus. The presence of mixed hooked and hookless spine morphologies initially led to fears that Colorado hookless cactus may be impacted by hybridization with the possibility of ultimately resulting in “genetic swamping” from the geographically similar and more common small-flower fishhook cactus (*Sclerocactus parviflorus*) (USFWS, 2010). Despite the irreversible consequences of genetic introgression, based on the understanding that hybridization is limited to a small portion of Colorado hookless cactus sampled (< 5%), and that these are found in isolated areas we assess the overall threat of hybridization to Colorado hookless cactus as MEDIUM.

Effects and Scope:
Ongoing genetic investigation by Schwabe et al. and McGlaughlin and Ramp-Neale since 2009 has shown that while genetic exchange can, and does, occur between *S. parviflorus* and *S. glaucus,* that impacts are localized in a small number (4.2% of plants sampled) of individuals, and does not pose a meaningful threat to the genetic integrity of the species. Interestingly, levels of introgression were not necessarily highest in Colorado hookless cactus sampled in areas adjacent to *S. parviflorus.* Hybrids occurred at higher frequency within the core distribution of Colorado hookless cactus including the geographically distant northern De Beque population; leading to additional questions of whether or not human activity could be acting as a vector for genetic exchange.

Synthesis and key findings:

Based on the synthesis of the available scientific data and analysis of threats suggest that Colorado hookless cactus is likely considerably less imperiled than believed to be at the time it was listed as a threatened species under the ESA. Key findings as they relate to the Recovery Outline are summarized below. While Colorado hookless cactus overall appears to be biologically secure there is some concern with various portions of the species range. Of the three groups the northern group (Debeque population) has the smallest population size, lowest levels of genetic diversity, and bares the greatest exposure to the impacts of surface disturbing activities – specifically associated with oil and gas development.

Following the Initial Action Plan and Recovery Vision outlined in the species' 2010 Recovery Outline:

Surveys and Monitoring:

- The completion of comprehensive surveys throughout the species range have resulted in a detailed understanding of where Colorado hookless cactus occurs on BLM administered lands. Spatial data has contributed to the designation of "core cactus conservation areas"
- Detailed spatial data has allowed us to develop more accurate population estimates for the species at the landscape scale increasing previous estimates substantially (at least 250,000 individuals)
- Monitoring has been expanded to include a representative sample of occupied sites across the species range and has demonstrated a stable trend range-wide over eight years of data collection.

Threats Abatement:

- Cumulatively 22% of Colorado hookless cactus range is contained in areas that possess special management designations (ACECs, NCAs, and WSAs). These areas occur on BLM administered lands and possess regulatory restrictions on actions that may affect individual cactus occurrences.

- Surface disturbing activities on BLM administered lands (including oil and gas leasing and mineral extraction) are designed to avoid occupied sites by 200m (656 feet).
- Programmatic level consultations resulting in associated BAs and BOs issued by the USFWS for grazing programs and vegetation treatments on BLM administered lands including discretionary conservation measures.

Research:

- Genetic investigation has resolved the relationship with *S. parviflorus.* The species are distinct from one another. While genetic exchange can and does occur, hybridization between the two species is limited.
- Genetic investigation has defined the range of Colorado hookless cactus relative to *S. parviflorus.*
- Demographic monitoring is ongoing at multiple locations in order to answer questions related to life history, longevity of individuals, survival, reproduction, recruitment in addition to documenting the common causes of mortality.
- Multiple studies have identified important pollinators for Colorado hookless cactus as well as the species reproductive biology and breeding system.
- Several methods of assessing vulnerability to various climate scenarios have been performed (CCVI and SDM). Neither method under a range of scenarios has predicted a significant range-contraction.
- Assessment, Inventory, and Monitoring (AIM) is ongoing in the three field offices where Colorado hookless cactus occurs to develop an understanding of vegetation condition in the species' habitat

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Appendix 1 – Threat ranking classification

Adapted from materials developed by: Foundations of Success (FOS), The Nature Conservancy (TNC), and the World Wildlife Fund (WWF) as a product of the Conservation Coaches Network, 2012

Scope –

The geographic extent of the impact on the target (Colorado hookless cactus) that can reasonably be expected within ten years under current circumstances.

4 = Very High: The threat is likely to be **pervasive** in its scope, affecting Colorado hookless cactus across all or most (71-100%) of its range.
3 = High: The threat is likely to be **widespread** in its scope, affecting to Colorado hookless cactus across much (31-70%) of its range.
2 = Medium: The threat is likely to be **restricted** in its scope, affecting Colorado hookless cactus across some (11-30%) of its range.
1 = Low: The threat is likely to be **very narrow** in its scope, affecting Colorado hookless cactus across a small proportion (1-10%) of its range.

Severity –

Within the scope (see above), the level of damage to Colorado hookless cactus that can reasonably be expected within ten years under current circumstances.

4 = Very High: Within the scope, the threat is likely to **eliminate/reduce** Colorado hookless cactus by 71-100% within ten years.
3 = High: Within the scope, the threat is likely to **seriously degrade/reduce** Colorado hookless cactus by 31-70% within ten years
2 = Medium: Within the scope, the threat is likely to **moderately degrade/reduce** Colorado hookless cactus by 11-30% within ten years.
1 = Low: Within the scope, the threat is likely to **slightly degrade/reduce** Colorado hookless cactus by 1-10% within ten years.

Irreversibility –

The degree to which the effects of a threat can be reasonably be undone or restored.

4 = Very High: The effects of the threat **cannot be reversed.**

3 = High: The effects of the threat **are reversible** but it is **not practical or affordable.**

2 = Medium: The effects of the threat **can be reversed with a reasonable commitment of time and resources**

1 = Low: The effects of the threat are **easily reversible** at a **relatively low cost**.

Appendix 2 – Conservation measures outlined in the Biological Opinion for Livestock Grazing Program Effects on Three Listed Plants in the Bureau of Land Management Grand Junction, Colorado River Valley, and Uncompahgre Field Office.

Conservation measures area non-discretionary actions that the BLM agrees to implement to further the conservation and recovery of listed species.

The terms and conditions of grazing permits that include habitat occupied by Colorado hookless cactus, clay-loving wild buckwheat, or Debeque phacelia will include conservation measures designed to avoid, minimize, and/or remediate effects to species in mapped occupied habitat. Some measures include, but are not limited to the following:

1. In areas where there is a concern that Colorado hookless cactus, clay-loving wild buckwheat, and DeBeque phacelia may be present, a survey will be conducted prior to any livestock management actions such as range improvements or maintenance, or weed management. The BLM Threatened, Endangered, Sensitive species specialist will determine the need for a survey and survey scope and intensity.

2. Maps will be provided to permittees that identify sensitive areas where restrictions may apply to particular grazing-related activities for Colorado hookless cactus, clay-loving wild buckwheat, and DeBeque phacelia (individual occurrences or populations plus a 200-meter [656 feet] buffer). As new information becomes available, and as necessary, maps will be updated by the BLM and provided to permittees each year if new occurrences are found. (Note: Maps provided to permittees will include sufficient buffers and randomized perimeters to avoid disclosing exact species locations.)

3. The permittee is required to notify the BLM Rangeland Management Specialist prior to any surface disturbing range project maintenance activity (fences, stock ponds, spring developments, etc.) in any allotment (standard condition for all BLM allotments). Surveys and avoidance measures will be required where effects to listed plants may occur.

- Construction of new range developments (e.g., new fences, ponds, water troughs) would be designed to avoid impacts to listed species whenever feasible. New range developments that may affect listed species would not be permitted until completion of an additional tiered consultation

4. If a permittee wishes to apply an herbicide treatment, they must obtain prior approval from the BLM. Appropriate applicator licenses must be obtained, copies of the appropriate *Pesticide Use Proposal* must be completed and returned to BLM no later than 10 days after herbicide application (standard condition for all BLM allotments).

- The permittee must consult with the BLM Rangeland Management Specialist and Biologist/Ecologist prior to applying herbicides or pesticides within 200 meters (656 feet) of individual plants or populations. Such treatments may be restricted or modified to avoid effects to the three listed species. Depending on the field office and weed program restrictions (see following point), additional section 7 consultation may be required prior to applying herbicides. Based on existing consultations, treatments near occupied habitat may not be covered under section 7.
- All treatments will comply with the approved *Integrated Weed Management Plan* (IWMP) and section 7 consultation (completed for the GJFO and CRVFO, in progress for UFO). Not all threatments are covered under those consultations and would, therefore require separate section 7 consultation. The three field offices' IWMPs differ slightly in their requirements for avoidance distances and triggers for reinitiation of consultation. Please refer to those documents for details.

5. Within 200 meters (656 feet) of listed plants, motorized access for livestock grazing operations will be limited to existing roads and routes. Any additional access proposed for grazing operations would require additional surveys and section 7 consultations.

6. As a standard permit term and condition within occupied habitat, seasonal utilization levels on palatable perennial forage will be limited to 40 percent to the extent possible, and average utilization will not exceed 50 percent (currently the appropriate level of forage utilization in most areas on public lands). These areas will be monitored by BLM Rangeland Management Specialist and Biologist/Ecologist to ensure compliance.

7. Permits for trailing through occupied habitat will only be issued for existing livestock trailing areas identified in Appendix 1, Figure 1, of the BA.

- Where trailing occurs, minimization measures such as the following will be implemented to reduce impacts.
    - BLM will encourage the avoidance of known individuals or populations during livestock herding and trailing activities on BLM administered lands. Maps would be provided to permitted to facilitate avoidance.
    - In areas where trailing activities cannot be avoided (e.g., Escalante Canyon) monitoring of affected populations will be established. Where monitoring suggests population declines then the following measures will be considered by BLM to achieve appropriate protection:
        - Use additional herders/cowboys to direct livestock away from populations.
        - Trail smaller herds through at any given time.
        - Use temporary fencing/barricades to inhibit livestock from trailing through populations during trailing activities.
        - Should all other attempts to reduce impacts from trailing not be successful, permanent drift fences may be considered.
    - Permittee will be required to notify BLM office at least 24 hours in advance of the trailing activities.
    - Require that trailing activity will concentrated within existing road corridors as much as practicable and in a timely and efficient manner. Overnighting of livestock within occupied is prohibited unless the area has been cleared for threatened, endangered, and special status species prior to overnight activity.
    - Trailing will not be allowed during flowering or germination periods where possible.

- Any future identified trailing activities through occupied habitat will be managed accordingly to the above stated conservation measures.

8. No concentrations of livestock activities including but not limited to herding, routine trailing, bedding, salt or supplement, portable watering, and new stock ponds will be allowed within 200 meters (656 feet) of individual plants or populations, except as provided below:

- Concentrations may be allowed where separated by a fence or topographic feature (cliff) that will render the impacts to listed plants insignificant, discountable, or if impacts are wholly beneficial (distribute livestock away from listed plants).
- In allotments in which sheep bedding must occur within the 200 meters (656 feet) buffer, only dispersed bedding will be allowed. Dispersed bedding allows sheep to bed however the band has dispersed throughout the day, rather than gathering or congregating the band in any one common locale.
- To minimize sheep grazing impacts in allotments containing clay-loving wild buckwheat, limit sheep grazing within 200 meters (656 feet) of occupied habitat to 5 nights per use area.
- The BLM Rangeland Management Specialist will collaborate with the permittee to develop and employ appropriate grazing strategies for the allotment pastures and use areas to meet Colorado Public Land Health Standards, specifically standard 3 for upland plant communities and standard 4 for Threatened, Endangered Species (TES). Where possible, grazing should be limited to 15 days or less in each pasture or use area during the germination, flowering, and fruiting period for the three focus species to ensure reproduction and recruitment.

9. Monitoring will be conducted (e.g., LHAs, utilization, trend, Ecological Site Inventory) to evaluate rangeland health. If monitoring/LHAs conclude that an allotment with occupied habitat is not meeting the standards for special status plants, vegetation, or soils, and livestock grazing is identified as a significant causal factor in not meeting those standards, grazing permit modifications, mitigation, or other prescriptive measures will be required by BLM, such as:

- The BLM Rangeland Management Specialist will work with the permittee to pursue opportunities to allow portions of the allotment(s) to receive yearlong rest or deferment in order to increase plant vigor.
- Exclosures or drift fences may be considered in certain areas where individual plants or populations require special protections from livestock grazing or associated activities, as determined by the BLM.
- Permit terms and conditions may be modified to minimize impacts to listed plants (e.g., improved distribution, changes in season of use/class of livestock).

10. The BLM will seek to implement monitoring programs to assess grazing-related impacts to the species. Results from the monitoring will be used to inform future grazing management.

- BLM field offices will continue to partner with the BLM Colorado State Office and other organizations (e.g., the Service, Denver Botanic Gardens [DBG], Colorado Natural Heritage Program [CNHP], Colorado Native Plant Society, Colorado Natural Areas Program [CNAP]) to monitor listed plants.

- In areas where grazing has been identified as a threat to individuals or populations, the BLM will explore opportunities to modify existing monitoring and develop new monitoring to assess grazing-related impacts to the species.

11. To ensure the conservation of the three listed species, the BLM will coordinate with the Service to identify important areas for species conservation. This coordination may result in actions to improve species conservation, initiate adaptive management strategies to reduce grazing impacts to the three listed species, or place greater management emphasis on their conservation through BLM's planning and decision process.

12. The BLM intends to continue a similar annual inventory effort as in recent years (between 2,000 and 10,000 acres) across the three species ranges, consistent with funding and priorities. Results will be submitted to the CNHP to ensure data is compiled in a centralized database.

13. The BLM will provide the Service with monitoring data collected and will work with the Service to develop a cooperative monitoring strategy that will capitalize on partnerships to augment existing monitoring studies and data. With the Service's assistance, the BLM will work on creating partnership opportunities to design and carry out additional monitoring needs.

14. The BLM will report conservation actions taken annually to the Service highlighting the adaptive management occurring in the grazing programs. Future BLM actions, monitoring (trend, grazing utilization, and LHA), and decisions covered under or related to this programmatic consultation will be reported on annually to the Service.

15. BLM field offices will individually schedule coordination meetings throughout the year with the Service and will work to address grazing impacts to listed plants.

Appendix 3 – Predicting current and future ranges for *Sclerocactus glaucus*: Utilizing Species Distribution Modeling (SDM) in Comparison with Climate Change Vulnerability Indices (CCVI)

Prepared by Lauren Price

Introduction

Sclerocactus glaucus (Colorado Hookless Cactus) is a small cactus endemic to western Colorado. The species is known to occupy a small range within the Colorado and Gunnison River valleys. It occurs on alluvial benches in course gravelly soil in semi-arid desert habitat (BLM 2015). Historically *S. glaucus* was thought to occupy a larger range extending into Utah. Recent genetic studies revealed that the species thought to be *S. glaucus*, is actually three separate species with *S. glaucus* only occurring in Colorado.

On October 11, 1979 *S. glaucus* was designated a threatened species under the Endangered Species Act (ESA) of 1973 (44 FR 58868) due to its rarity and confined range. Though the species was later split into three separate species, each was given protected status under the initial decision (USFWS, 2007).

The species is currently the subject of a review by the United States Fish and Wildlife Service (USFWS) to determine whether the species warrants delisting. Population monitoring by the Colorado Bureau of Land Management of *S. glaucus* has occurred annually since 2011. Though fluctuations exist, trends reveal populations have remained generally stable since monitoring began (BLM 2015). While there are many possible threats to the existence of the species (mineral and energy development, off-road vehicle use, collecting and livestock grazing), it is unknown how climate change will affect *S. glaucus*.

Few studies have explored the effects of climate change on *S. glaucus,* and the few that have assert conflicting conclusions. One study found that *S.glaucus* will experience a range expansion based on Species Distribution Models (SDM) created using MaxEnt (Maximum Entropy) modeling in combination with Climate Change Vulnerability Index (CCVI) ratings (Still et al 2015). Another study using CCVI found *S. glaucus* to be "extremely vulnerable" to climate change (Treher et al 2012).

SDM is the process of mapping a species' range using biological and environmental data. This is achieved using a variety of methods, many involving statistical analysis. MaxEnt uses bioclimatic data, species occurrence points and statistical analysis to predict spatially where a species could possibly occur, based on the variables provided (Franklin 2009). The CCVI tool was developed by NatureServe to aid land managers in the assessment of plant and animal species' vulnerability to climate change (Young et al 2015). This tool is programmed in MS Excel and utilizes up to 14 factors encompassing direct exposure, indirect exposure and sensitivity and adaptive capacity to climate change. Ratings are created by evaluating how susceptible a species' range is to climate change and then using that measurement to assess how life history traits will be affected by that change. CCVI utilizes climate data from ClimateWizard, while MaxEnt uses BioClim (Table 1). Both sources supply data from the International Panel on Climate Change (IPCC) Fourth Assessment. The climate data used for CCVI includes assessment of species' responses to past climate scenarios, like historic extreme drought and precipitation. While CCVI differs greatly from SDM, both have useful implications for resource management and are important to incorporate in an ensemble of models to forecast possible future scenarios (Araujo & New 2007).

To determine how climate change will affect *S. glaucus,* the MaxEnt modeling program was used to create models of range predictions for current climate and for projections of future climate in 2050 (Phillips et al 2006). MaxEnt is a commonly used and well-regarded program that utilizes point occurrence data and environmental variables to determine the potential distribution of a species (Table 2) (Elith et al 2010). Using species point occurrence data to train the model with selected environmental factors, MaxEnt makes predictions of fundamental ranges based on statistical methods.

To determine the possible future range of *S. glaucus,* four models were created using different combinations of bioclimatic variables. One model uses five variables utilized by Still *et al* (2015) in a study combining SDM with CCVI to compare the two outcomes. While the models did not match, likely due to Still *et al* (2015) methods combining CCVI, neither predict a range contraction. One model predicted a slight range contraction, one predicted little to no

change and one predicted a range expansion. These models suggest that climate change is not a major threat to *S. glaucus'* survival.

Methods

Species Distribution Modeling (SDM) was carried out for *S. glaucus* using MaxEnt (Phillips et al 2006). Occurrence point data (n= 6749) for the species was obtained from surveys carried out by the BLM Uncompahgre Field Office. Environmental variables were obtained from WorldClim (Ficks & Hijman 2017). They were downloaded at a 5 minute resolution for both current and future conditions. Future conditions were created using the CCSM4 global climate/circulation model (GCM) which makes predictions for the year 2050. Combinations of the variables were prepared in ArcMap prior to running the models. This included masking the variables to create ASCII raster layers, defining projections of layers, and creation of testing and training datasets from point data for production and validation of the models. All models were created for the state of Colorado. Four models were created in total (Table 3). For each model Area Under Curve (AUC) scores for training data and test data are provided. This score quantifies the randomness of the prediction with a score of 0.5 indicative of random chance. A score above 0.8 is considered decent and a score of 1.0 is considered a perfect fit, meaning the model is a valid prediction.

Results

Predictions of future range of *S. glaucus* using seventeen variables (Model 1) show a slight contraction and slight decrease in occurrence probability (Fig 1). The model had an AUC score of greater than 0.9 for both the training data and test data, indicating there is a near perfect fit prediction. Precipitation of the wettest month was the most important factor in the model, with a 52.8% contribution. The next most important factors were precipitation seasonality (coefficient of variation) at 18.3% and minimum temperature of the coldest month at 15.2%. Factors with 0% contribution were maximum temperature of warmest month, annual mean temperature and mean temperature of warmest month.

Models created using the same five variables utilized by Still *et al* (2015) (Model 2) predict minimal range contraction and slight decrease of occurrence probability (Fig 2). An AUC score greater than 0.9 was reported for both the training data and test data of both current and future scenarios. Mean diurnal range had a 38.5% contribution, annual precipitation was 22.6%, precipitation of the driest quarter was 21.3%, mean temperature of wettest quarter was 11.5% and mean temperature of the warmest quarter was 6.1%. This model only minimally contradicts results from Still *et al* (2015) whose model combines SDM data with Climate Change Vulnerability Index (CCVI) assessments. Using mean models Still *et al* (2015) predict *S. glaucus* will experience a range expansion.

To understand which variables have greater influence on *S. glaucus* range predictions, models were created using temperature and precipitation variables separately. Predictions using temperature variables (Model 3) show interesting changes to *S. glaucus'* range in the future (Fig 3). This model predicts a range contraction overall, but with variations different from the other models. It is important to note here that these models utilize the bioclimatic variables based on

point occurrence data and translate these onto areas that experience the same conditions based on whatever variables are chosen. While predictions of probability of occurrence in the eastern third of the state of Colorado are predicted, this does not mean that those areas currently support populations, and are unlikely to support populations in the future. In the case of this particular model the predictions are merely a reflection of the similarity of the separate areas in terms of the specific variables chosen. This model predicts a range that extends beyond the known actual range of *S. glaucus.* The future model predicts a contraction of this range, but with the currently known range showing an expansion. The AUC score for this model was greater than 0.9. The variable that most influenced the model was annual mean temperature at 23.6%. Next was mean temperature of wettest quarter at 19.5%, maximum temperature of warmest month at 14.4%, mean temperature of coldest quarter at 13.3% and mean diurnal range (mean of monthly (max temp – min temp)) at 11.5%.

Range predictions using precipitation variables (Model 4) show a range expansion (Fig 4). This expansion reaches slightly further east of the current range and covers the northwestern portion of the state. The AUC score of this model was greater than 0.9. The variable that was of greatest influence was precipitation of coldest quarter with a 78.2% contribution. All other variables had contributions of less than 10%.

Discussion

Results of four MaxEnt models suggest that the existence of *S. glaucus* is not threatened by climate change. While one model predicts a slight contraction for the year 2050, the majority of the models find either very little to no contraction or a range expansion from the known actual range of the cactus.

For Model 1, the range contraction appears in an area that was modeled off of one point that could be considered an outlier. In this event there may not have been sufficient occurrence to train the model accurately for future predictions. This may also have been due to whichever variable had the most influence on the model, in this case precipitation of the wettest month. Regardless of the reasons for the contraction, it is slight and the predicted range still mostly encompasses the current range of the species.

Two models were created comparing predictions using temperature variables and precipitation variables, to further elucidate which component of climate might have a greater effect on *S. glaucus'* potential range. While Model 3, which utilizes temperature variables, showed interesting patterns of future contraction, Model 4, which utilizes precipitation variables, depicts a future scenario where *S. glaucus* experiences a range expansion. The expansion seen in the precipitation model suggests that changes in precipitation over the next thirty years could benefit the cactus. Patterns of contraction in the temperature model are interesting primarily because the current distribution predictions are not a reflection of the actual range of the species. The current temperature model of the predicted range shows high probability of occurrence in the eastern third of the state. While temperature variables used in this model may match conditions in this part of the state that might be considered ideal for the cactus, the species does

not actually occur there. This can also be said for predictions of occurrence in the southwestern portion of the state. *S. glaucus* is bound to its actual range by natural barriers that likely inhibit its distribution, so predicted occurrences outside this area are highly unlikely. The future predicted range using temperature variables shows contraction, but only in areas where the cactus does not actually occur. In the area of its actual range there is a small expansion and increased probability of occurrence across its known range. This suggests that increasing temperatures are not a major threat to the cactus over the next three decades.

The MaxEnt models used in this report found little range contraction and some range expansion indicating climate change is not a major threat to *S. glaucus.* This contradicts findings from NatureServe which assign a rating of "Extremely Vulnerable" based on the Climate Change Vulnerability Index (CCVI) tool. NatureServe found that vulnerability in terms of predicted sensitivity to temperature is somewhat decreased and that vulnerability to physiological thermal niche is neutral, in agreeance with the MaxEnt temperature model in this report showing that no contraction within the known range occurs when only temperature variables are used. NatureServe predicted an increase in vulnerability in terms of predicted sensitivity to changes in precipitation, hydrology, or moisture regime in both historic hydrological niche and physiological hydrological niche. These indicators reflect range and variation of precipitation historically and a prediction that with rising temperatures increased evapotranspiration rates and decreased soil moisture availability will occur. This assessment contradicts the MaxEnt precipitation model used here which predicts an expansion based on changes in precipitation in the future, though both indicate that *S. glaucus* is more sensitive to changes in precipitation than temperature. This is probably due to the differences in the two assessment methods. SDM uses point occurrence data to train the models based on the variables chosen, while CCVI creates a polygon of the known range of species and applies climate variables to understand how much that area will change in terms of a variety of factors gleaned from species' life history. When a species' life history is well documented there is more information to make more accurate predictions. While the CCVI tool is useful in evaluating species' vulnerability, the lack of sensitivity information for *S. glaucus* may inhibit accurate assessment of the species.

While NatureServe found *S. glaucus* to be "Extremely Vulnerable" using the CCVI tool, Still *et al* (2015) found the species to experience a future range expansion. Still *et al* (2015) combined CCVI ratings with MaxEnt modeling using the Spearman's rank correlation coefficient in an attempt to reconcile the limitations of each method. They acknowledge the challenges regarding both methods, specifically the lack of available information to make accurate predictions. While the models used in this report did not completely match the model created by Still *et al* (2015), the models from both sources are in agreement regarding a lack of threat from climate change to *S. glaucus.*

Much of the CCVI assessment for *S. glaucus* are based on factors like "natural barriers to movement and poor dispersal ability, physiological hydrological niche, restriction to uncommon geologic features or substrates, and pollinator specificity" (Treher et al 2012). While the assessment is based on these factor's expected sensitivity to changing climate, some of these factors are aspects of the species' life history that historically posed limitations to range

expansions. *S. glaucus* appears to have always been limited by natural barriers and poor dispersal ability based on its current distribution. If it experiences a range contraction in its already occupied area there would be cause for concern, but as range contractions in the models used in this paper occur outside of its current actual range it appears that climate change is not an urgent issue for this species. The lack of far reaching dispersal ability would be of greater concern if *S. glaucus* were seen to be following general patterns of range contraction and range expansion like in the Parmesan *et al* 1999 article documenting range shifts poleward. If *S. glaucus* were experiencing this general shift of southern range contraction and northern range expansion, dispersal ability and natural barriers would pose a greater problem as the species might not be able to disperse to new habitat.

Although the MaxEnt models presented here indicate that climate change does not pose a major threat to *S. glaucus,* they represent only one facet of the vulnerability of the species. The ranges depicted represent predictions of where the species could be found based on bioclimatic variables. While a model may predict a range expansion, this does not mean the cactus will actually occupy that range in the future. Barriers to dispersal may exist, like lack of wide-ranging seed dispersal or disturbance to critical habitat from other threats (anthropogenic disturbance, fire, etc.). All assessments should be considered together as an ensemble as each model utilizes different variables and climate data (Araujo & New 2007). Considering how much variability there is using one method, like SDM, and different combinations of variables, it is important to keep in mind that no model will be completely accurate in its predictions.

In summary, this report elucidates the vulnerability of *S. glaucus* in the face of climate change, indicating that the species is not as vulnerable as previously thought. While the models differ from CCVI analysis, they do complement Still *et al* (2015) analysis using a combination of CCVI and MaxEnt modeling. Because the models can only depict one aspect of *S. glaucus'* vulnerability, other available data should be utilized when making any management decisions regarding the species. Very little information is known about *S. glaucus'* environmental sensitivities and further research is needed to better understand these.

Conclusion

Utilizing MaxEnt modeling for *S. glaucus* reveals the lack of vulnerability the species experiences from climate change. Though this contradicts CCVI assessments done by NatureServe, they are in agreeance with analysis by Still *et al* (2015). While range modeling cannot paint a complete picture of the future existence of *S. glaucus*, it is useful to help inform management decisions. Lack of vulnerability to climate change and evidence of stable populations through continued monitoring suggest this species, though limited in range, may not be as threatened in its existence as previously thought.

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Tables

CCVI	SDM with MaxEnt
Uses species' exposure and sensitivity based on life history traits	Uses current species ranges (presence/absence) and climatic preferences
Historic responses considered for future predictions	Contemporary presence data used to make future predictions
Uses ClimateWizard for climate data	Uses BioClim for climate data
Produces ratings for multiple factors	Produces maps depicting predicted ranges

Table 1. Comparison of CCVI and SDM with MaxEnt.

Table of Bioclimatic Variables	
BIO1	Annual Mean Temperature
BIO2	Mean Diurnal Range (Mean of monthly(max temp - min temp))
BIO3	Isothermality (BIO2/BIO7)(*100)
BIO4	Temperature Seasonality (standard deviation * 100)
BIO5	Max Temperature of Warmest Month
BIO6	Min Temperature of Coldest Month
BIO7	Temperature Annual Range (BIO5 - BIO6)
BIO8	Mean Temperature of Wettest Quarter
BIO9	Mean Temperature of Driest Quarter
BIO10	Mean Temperature of Warmest Quarter
BIO11	Mean Temperature of Coldest Quarter
BIO12	Annual Precipitation
BIO13	Precipitation of Wettest Month
BIO14	Precipitation of Driest Month
BIO15	Precipitation Seasonality (Coefficient of Variation)
BIO16	Precipitation of Wettest Quarter
BIO17	Precipitation of Driest Quarter
BIO18	Precipitation of Warmest Quarter
BIO19	Precipitation of Coldest Quarter

Table 2. Depicts all possible bioclimatic variables obtained from worldclim.org.

Model 1	Annual Mean Temperature, Temperature Seasonality, Max Temperature of the Warmest Month, Minimum Temperature of the Coldest Month, Temperature Annual Range, Mean Temperature of the Wettest Quarter, Mean Temperature of the Driest Quarter, Mean Temperature of Warmest Quarter, Mean Temperature of Coldest Quarter, Annual Precipitation, Precipitation of Wettest Month, Precipitation of Driest Month, Precipitation Seasonality, Precipitation of Wettest Quarter, Precipitation of Driest Quarter, Precipitation of Warmest Quarter and Precipitation of Coldest Quarter	BIO1, BIO4, BIO5, BIO6, BIO7, BIO8, BIO9, BIO10, BIO11, BIO12, BIO13, BIO14, BIO15, BIO16, BIO17, BIO18, BIO19
Model 2	Mean Diurnal Range, Mean Temperature of Wettest Quarter, Mean Temperature of Warmest Quarter, Annual Precipitation and Precipitation of Driest Quarter	BIO2, BIO8, BIO10, BIO12, BIO17

Model 3	Annual Mean Temperature, Mean Diurnal Range, Isothermality, Temperature Seasonality, Max Temperature of Warmest Month, Minimum Temperature of Coldest Month, Temperature Annual Range, Mean Temperature of Wettest Quarter, Mean Temperature of Driest Quarter, Mean Temperature of Warmest Quarter and Mean Temperature of Coldest Quarter	BIO1, BIO 2, BIO3, BIO4, BIO5, BIO6, BIO7, BIO8, BIO9, BIO10, BIO11
Model 4	Annual Precipitation, Precipitation of Wettest Month, Precipitation of Driest Month, Precipitation of Seasonality, Precipitation of Wettest Quarter, Precipitation of Driest Month, Precipitation of Warmest Quarter and Precipitation of Coldest Quarter	BIO12, BIO13, BIO14, BIO15, BIO16, BIO17, BIO18, BIO19

Table 3. Depicts the bioclimatic variables used in each model

Figures

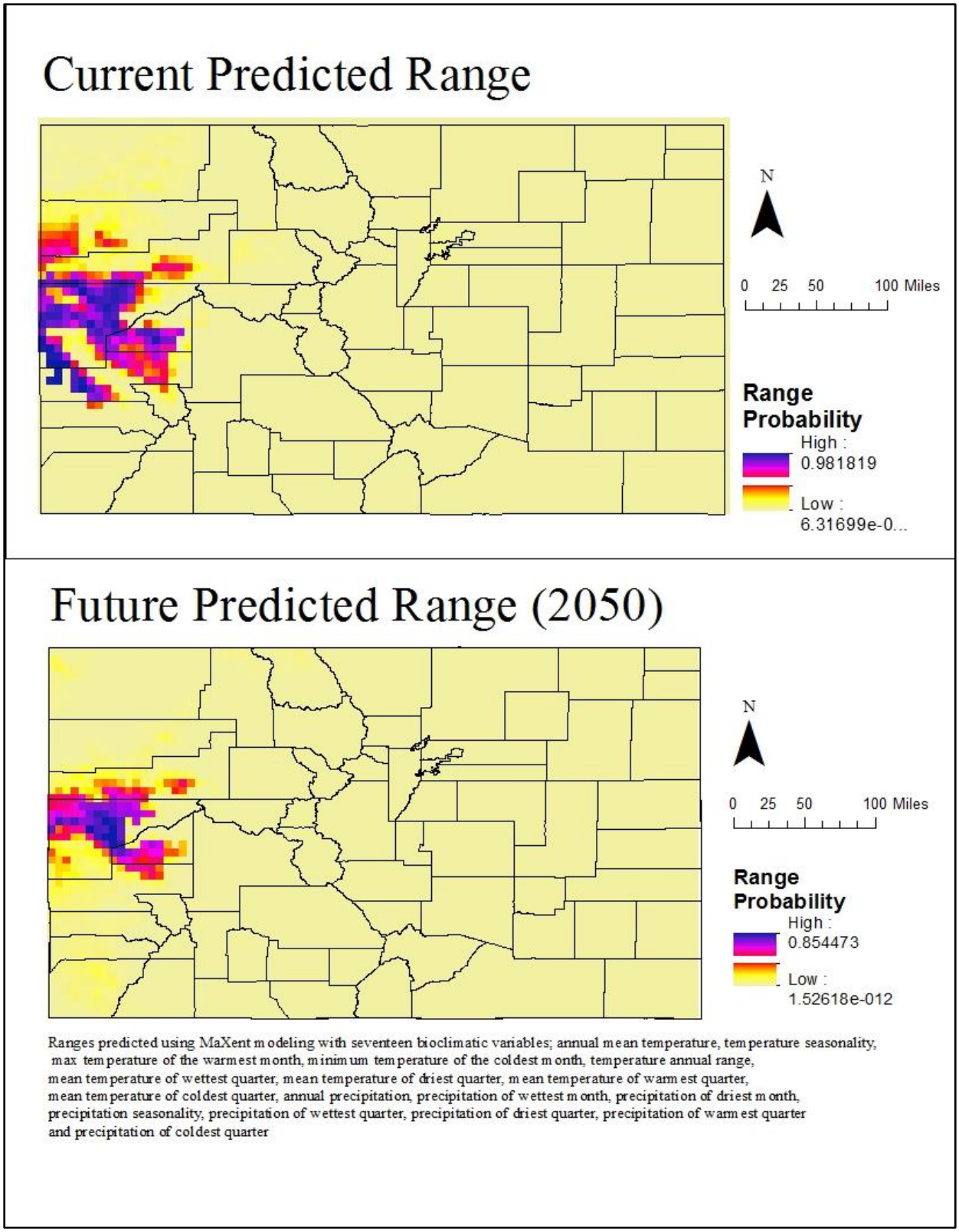

Fig 1. Depiction of Model 1 showing current and future predicted ranges using 17 bioclimatic variables.

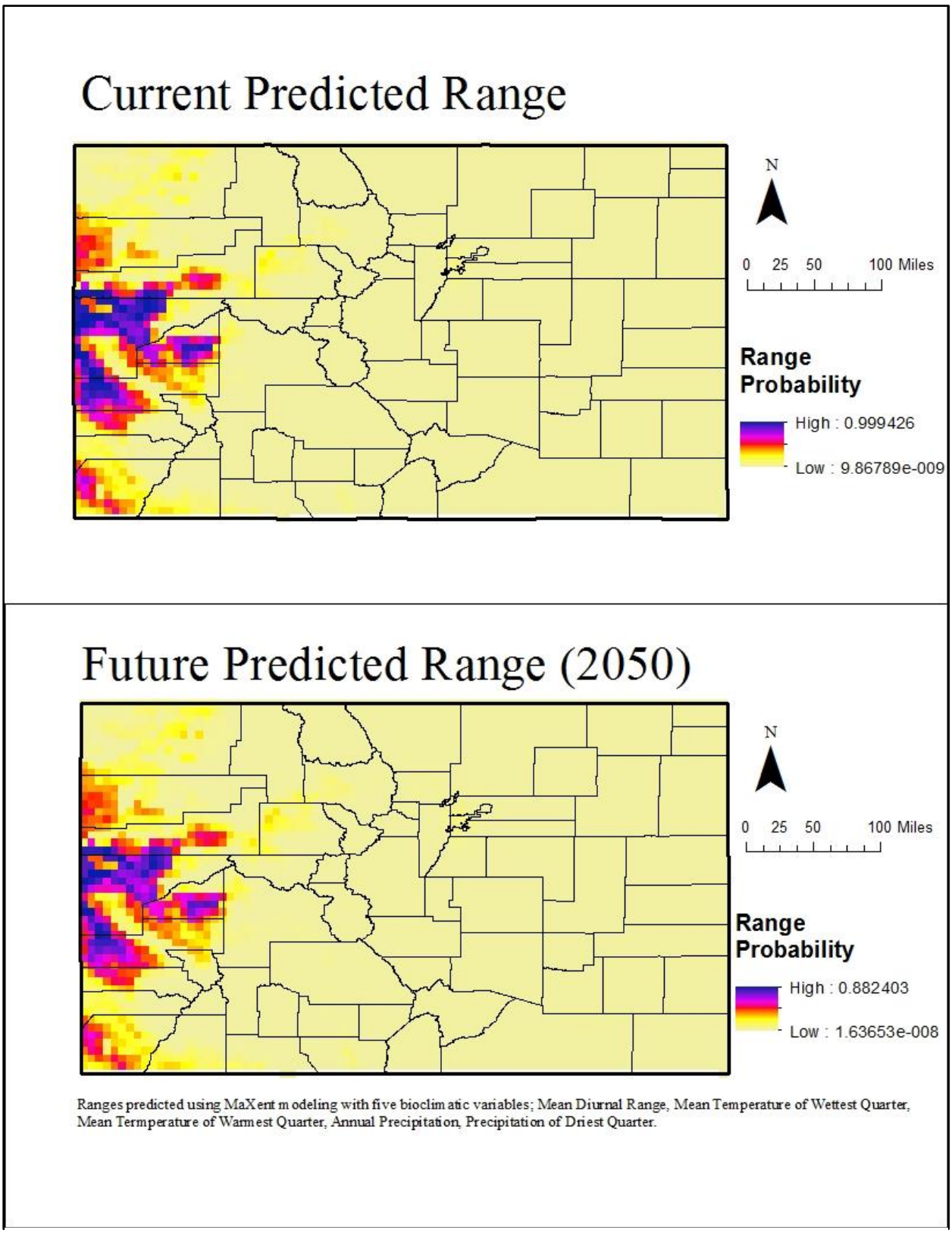

Fig 2. Depiction of Model 2 showing current and future predicted ranges based on 5 bioclimatic variables.

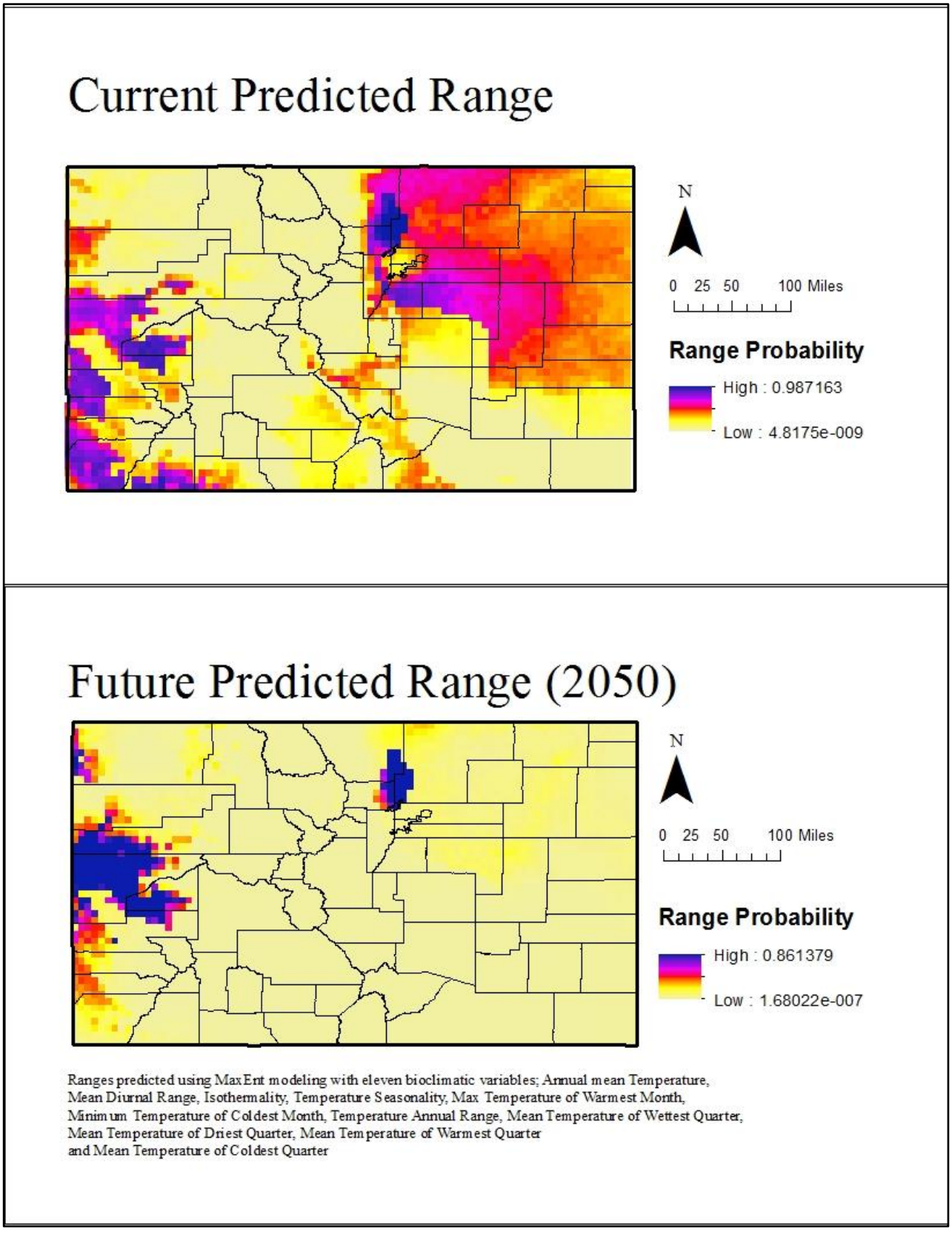

Fig 3. Depiction of Model 3 showing current and future range predictions using 11 temperature bioclimatic variables.

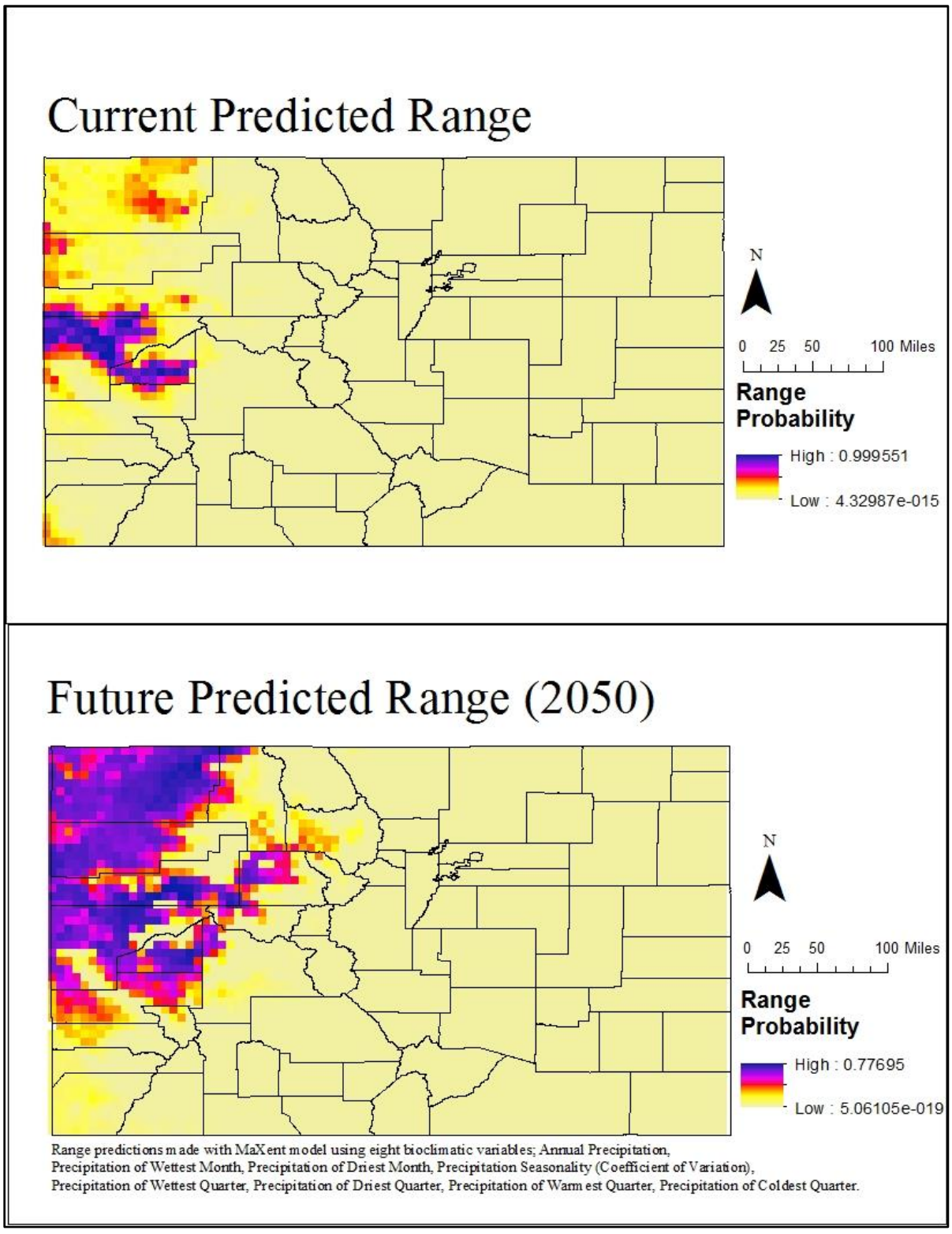

Fig 4. Depiction of Model 4 showing current and future range predictions for 7 precipitation bioclimatic variables.

Appendix 4 – Conservation, Mitigation, and Standard Operating Procedures for Applying Pesticides from the Record of Decision Vegetation Treatments Using Aminopyralid, Fluroxypyr, and Rimsulfuron on Bureau of Land Management Lands in 17 Western States Programmatic Environmental Impact Statement.

Standard Operating Procedures for Applying Pesticides (Table A-2):

Pollinators:

- Ensure proper identification of pollinator plants, as some native species that attract and support many pollinators may be easily misidentified as invasive/noxious weed species.
- Complete vegetation treatments seasonally before pollinator foraging plants bloom. •
- Time vegetation treatments to take place when foraging pollinators are least active both seasonally and daily.
- Apply herbicides at the stage of growth when the weed is most vulnerable, when application will be most successful.
- Design vegetation treatment projects so that nectar and pollen sources for important pollinators and resources are treated in patches rather than in one single treatment, or conduct spot treatments on individual invasive/noxious weed species, using the appropriate application equipment.
- Minimize herbicide application rates. Use typical rather than maximum rates where there are important pollinator resources.
- Maintain herbicide free buffer zones around patches of important pollinator nectar and pollen sources.
- Maintain herbicide free buffer zones around patches of important pollinator nesting habitat and hibernacula.
- Make special note of pollinators that have single host plant species, and minimize herbicide spraying on plants (if invasive) and in their habitats

Threatened and endangered species

- Survey for special status species before treating an area, at a time when the species can be found. Consider effects to special status species when designing herbicide treatment programs.
- Where feasible, use a selective herbicide and a wick or backpack sprayer to minimize risks to special status plants.
- Avoid treating vegetation during time-sensitive periods (e.g., nesting and migration, sensitive life stages) for special status species in area to be treated.

Mitigation Measures from 2007 PEIS (Table A-3)

For vegetation:

- To protect special status species implement all conservation measures for plants presented in the Vegetation Treatments on Bureau of Land Management Lands in 17 Western States Programmatic Biological Assessment

Programmatic Conservation Measures for Herbicide Treatments with Aminopyralid, Fluroypyr, and Rimsulfuron (including measures from 2007 BA not specific to previously approved herbicides (Appendix B-2)

- Follow the buffer distances specified in Chapter 4 of the BA (see Tables 4-1 and 4-2 and pages 4-129 through 4-131).
- In areas where wind erosion is likely, do not apply within 1.2 miles of TEP plant species (an alternative suitable buffer may be developed at the local level based on an analysis of site conditions).
- Do not use rimsulfuron in watersheds where annual precipitation exceeds 50 inches.
- In watersheds where annual precipitation exceeds 10 inches, prior to use of rimsulfuron conduct a local-level analysis of site conditions and develop suitable conservation measures for protection of TEP plant species from surface runoff.
- Survey all proposed action areas within potential habitat using a botanically qualified biologist, botanist, or ecologist to determine the presence/absence of the species.
- Establish site-specific no activity buffers using a qualified botanist, biologist, or ecologist in areas of occupied habitat within the proposed project area. To protect occupied habitat, do not conduct treatment activities within these buffers.
- Collect baseline information on the existing condition of TEP plant species and their habitats in the proposed project area.
- Establish pre-treatment monitoring programs to track the size and vigor of TEP populations and the state of their habitats. These monitoring programs would help in anticipating the future effects of vegetation treatments on TEP plant species.
- Assess the need for site revegetation post-treatment to minimize the opportunity for noxious weed invasion and establishment.
- Include the following in management plans:
    - Off-highway use of motorized vehicles associated with treatments should be avoided in suitable or occupied habitat.
    - Post-treatment monitoring should be conducted to determine the effectiveness of the project.
- Do not conduct herbicide treatments in areas where TEP plant species may be subject to direct spray by herbicides during treatments.
- To avoid negative effects to TEP plant species from off-site drift, surface runoff, and/or wind erosion, establish suitable buffer zones between treatment sites and populations (confirmed or suspected) of TEP plant species, and take site-specific precautions.
- Follow all instructions and SOPs to avoid spill and direct spray scenarios into aquatic habitats that support TEP plant species.
- Treated areas that are prone to downy brome or noxious weed invasions should be seeded with an appropriate seed mixture to reduce the probability of noxious weeds or other undesirable plants becoming established on the site.
- In suitable habitat for TEP plant species, do not use non-native species for revegetation. 6 Species/Species Group Programmatic Conservation Measures Plants (cont.)
- Vehicles and other equipment used during treatment activities should be washed prior to arriving at a new location to avoid the transfer of noxious weeds.

- Follow all BLM operating procedures for avoiding herbicide treatments during climatic conditions that would increase the likelihood of spray drift or surface runoff.