



Climate Change Vulnerability Assessment for Rare Plants of the San Juan Region of Colorado



May 2014

CNHP's mission is to preserve the natural diversity of life by contributing the essential scientific foundation that leads to lasting conservation of Colorado's biological wealth.

Colorado Natural Heritage Program

Warner College of Natural Resources
Colorado State University
1475 Campus Delivery
Fort Collins, CO 80523
(970) 491-7331

Report Prepared for:
Tres Rios Bureau of Land Management & San Juan U.S. Forest Service

Recommended Citation:

J. Handwerk, B. Kuhn, R. Rondeau, and L. Grunau. 2014. Climate Change Vulnerability Assessment for Rare Plants of the San Juan Region of Colorado. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Front Cover from the top: *Triteleia grandiflora*, © Bob Dorn; *Amsonia jonesii*, © Joe Leahy; *Eriophorum chamissonis*, © Delia Malone; *Drosera anglica*, © Sara Brinton; *Mimulus eastwoodiae*, © Lori Brummer

Climate Change Vulnerability Assessment for Rare Plants of the San Juan Region of Colorado

Jill Handwerk, Bernadette Kuhn, Renée Rondeau, and Lee Grunau
Colorado Natural Heritage Program
Warner College of Natural Resources
Colorado State University
Fort Collins, Colorado 80523



May 2014

ABSTRACT

The 5 million-acre San Juan Region lies in southwest Colorado and is considered part of the Four Corners area. The Colorado Natural Heritage Program tracks 122 plant species within this region. Recently published climate models for the Southern San Juan Region project a median decrease in May precipitation across southwestern Colorado and a 4.3^o F increase in average annual temperatures, suggesting drought may become problematic for these species in the future (Lukas et al. 2014). As of 2014, we have conducted Climate Change Vulnerability Assessments using methodology developed by NatureServe for 60 of the tracked plant species known from the region, primarily focused on federally listed or agency sensitive species. Our results indicate that nearly 60% (36 species) of these plant species are extremely vulnerable to climate change. The most vulnerable species were from alpine, cliff and canyon, barrens, and groundwater dependent wetland habitats. Spruce-fir and ponderosa pine forests, and montane grasslands had the least amount of vulnerable species. Of the 60 species assessed, 37% (22 species) are endemic to the Four Corners region and most (19 species) are extremely vulnerable. Barrens support the highest number of endemic species of any habitat (7), and all but one barrens species is extremely vulnerable. We recommend developing climate adaptation strategies for extremely and highly vulnerable species and as time permits, assessing additional rare species.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Gretchen Fitzgerald (San Juan National Forest) and Bradd Dodd (BLM) for their financial support and encouragement of this project. Special recognition goes to Gay Austin (BLM) and CNHP staff members Denise Culver, Dee Malone, and Peggy Lyon for reviewing the CCVI scores, and to Sierra Crumbaker and Alyssa Meier for assistance with report formatting and fact checking.

TABLE OF CONTENTS

Abstracti

Acknowledgementsi

Background 1

Methods 2

 NatureServe Climate Change Vulnerability Index – Overview 2

 Scoring Factors in the CCVI 3

 Target Selection 5

 Application of the CCVI for Species in the San Juan Region..... 6

Results..... 7

References18

Appendix A: List of Rare Plant Species in the San Juan Region with no Climate Change Vulnerability Assessment.....22

Appendix B: San Juan Region Rare Plant Species Vulnerability Scores and Profiles.....24

Appendix C: Climate Change Vulnerability Index Scoring Categories 144

Appendix D: San Juan Region Rare Plant Species Climate Change Vulnerability Scores 161

TABLE OF FIGURES

Figure 1. Map of San Juan/Tres Rios study area with surface ownership 1

Figure 2. San Juan rare plant species vulnerability by habitat 8

Figure 3. Number of San Juan rare plant species with CCVIs by habitat 8

Figure 4. Map of San Juan rare plant species distribution by vulnerability score 9

Figure 5. San Juan endemic plant species vulnerability and their habitats.....10

TABLE OF TABLES

Table 1. Surface ownership/management in study area 1

Table 2. Additional species assessed for this report..... 5

Table 3. Summary of vulnerability assessment results for species by Index Score..... 7

Table 4. Summary of vulnerability assessment results for species by habitat 7

Table 5. Summary of vulnerability assessment results for species by rarity rank. 9
Table 6. Climate change vulnerability scores for rare plants of the San Juan Region alphabetically by
habitat13

BACKGROUND

The San Juan / Tres Rios study area includes portions of nine counties covering nearly 5 million acres in southwestern Colorado. The area represents the Colorado portion of the San Juan River, and the southern half of the Upper Colorado-Dolores Rivers HUC4 basins.

Primary population centers include Durango (pop. 16,887), Cortez (pop. 8,482), Bayfield (pop. 2,333) Pagosa Springs (pop. 1,727), and Mancos (pop. 1,336). The majority of the area’s population lives in smaller towns or in unincorporated areas. Surface ownership (Figure 1, Table 1) is dominated by federal, state, and tribal entities, which account for about 70% of acreage within the study area. Primary economic activities in the area are farming/ranching, logging, energy resource extraction, recreation, and tourism.

Table 1. Surface ownership/management in study area.

Owner/Manager	Acres
USFS	1,865,332
BLM	674,123
NPS	53,937
State	86,174
Tribal	769,510
Other (incl. private)	1,477,914
Total	4,926,990

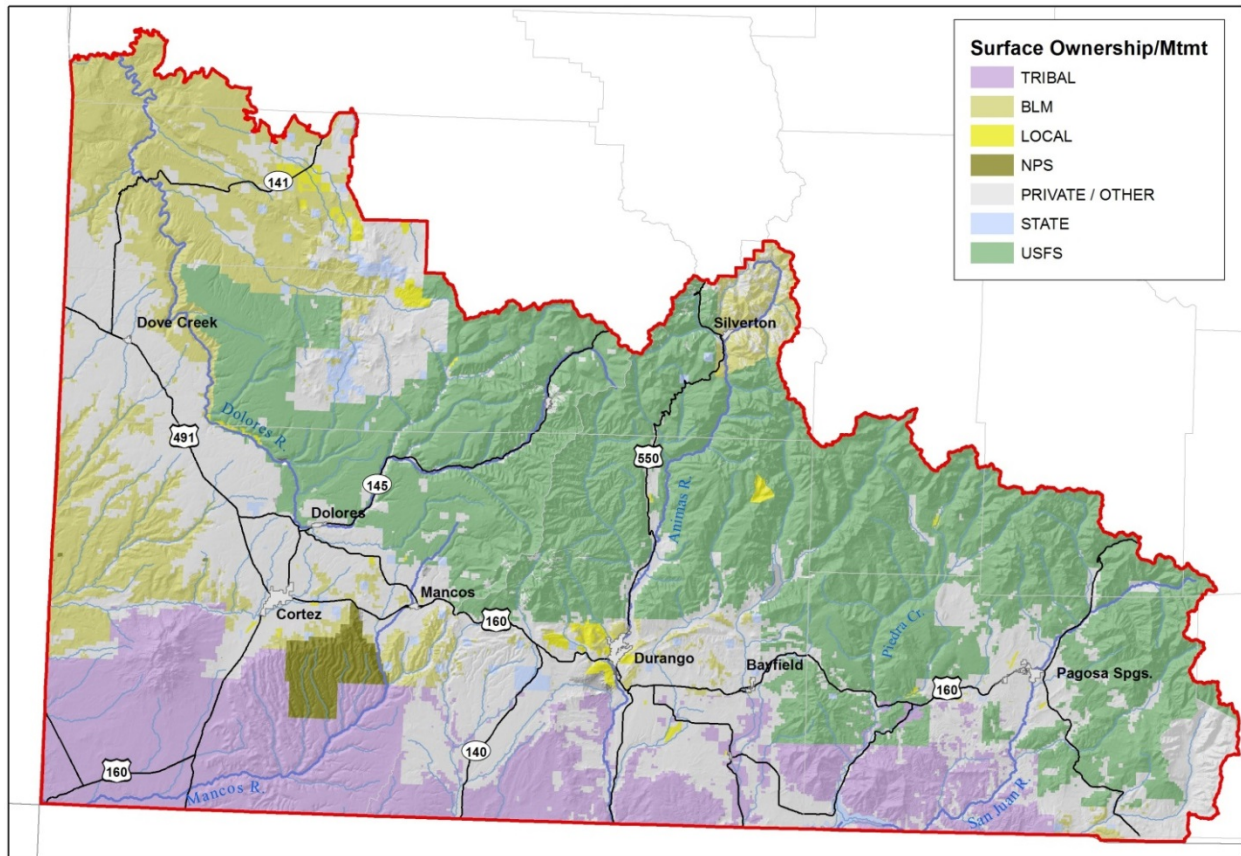


Figure 1. Map of San Juan/Tres Rios study area with surface ownership.

METHODS

We used the NatureServe Climate Change Vulnerability Index (CCVI; Young et al. 2011) to assess vulnerability of rare plant species that occur in the San Juan region of Colorado. Our objectives were to identify:

1. Species most likely to be affected by climate change, and
2. Life history factors that are most sensitive to climate change.

This project builds on previous work to assess the vulnerability of rare plant species across Colorado (CNHP 2011) and in the Gunnison Basin (Neely et al. 2011). This document describes detailed methods applied for the species assessed specifically for the San Juan region. We have also included results for species that occur in the region but were previously assessed for different geographic study areas (refer to Appendix D).

NatureServe Climate Change Vulnerability Index – Overview

This overview has been synthesized and reprinted, with permission, from Young et al. (2011). The Climate Change Vulnerability Index (CCVI), developed by NatureServe, is a Microsoft Excel-based tool that facilitates rapid assessment of the vulnerability of plant and animal species to climate change within a defined geographic area. In accordance with well-established practices (Schneider et al. 2007, Williams et al. 2008), the CCVI divides vulnerability into two components:

- **exposure** to climate change within the assessment area (e.g., a highly sensitive species will not suffer if the climate where it occurs remains stable).
- **sensitivity** of the species to climate change (e.g., an adaptable species will not decline even in the face of significant changes in temperature and/or precipitation).

Exposure to climate change is measured by examining the magnitude of predicted temperature and moisture change across the species' distribution within the study area. CCVI guidelines suggest using the downscaled data from Climate Wizard (<http://climatemwizard.org>) for predicted change in temperature. Projections for changes in precipitation are available in Climate Wizard, but precipitation estimates alone are often an unreliable indicator of moisture availability because increasing temperatures promote higher rates of evaporation and evapotranspiration. Moisture availability, rather than precipitation per se, is a critical resource for plants and animals and therefore forms the other part of the exposure measure within the CCVI, together with temperature. To predict changes in moisture availability, NatureServe and partners developed the Hamon AET: PET moisture metric as part of the CCVI.

Sensitivity is assessed using 20 factors divided into two categories: 1) indirect exposure to climate change; and 2) species specific factors (including dispersal ability, temperature and precipitation sensitivity, physical habitat specificity, interspecific interactions, and genetic factors). For each factor, species are scored on a sliding scale from greatly increasing, to having no effect on, to decreasing vulnerability. The CCVI accommodates more than one answer per factor in order to

address poor data or a high level of uncertainty for that factor. The scoring system integrates all exposure and sensitivity measures into an overall vulnerability score that indicates relative vulnerability compared to other species and the relative importance of the factors contributing to vulnerability.

The Index treats exposure to climate change as a modifier of sensitivity. If the climate in a given assessment area will not change much, none of the sensitivity factors will weigh heavily, and a species is likely to score at the Not Vulnerable end of the range. A large change in temperature or moisture availability will amplify the effect of any related sensitivity, and will contribute to a score reflecting higher vulnerability to climate change. In most cases, changes in temperature and moisture availability will combine to modify sensitivity factors. However, for factors such as sensitivity to temperature change (factor 2a) or precipitation/moisture regime (2b), only the specified climate driver will have a modifying effect.

The six possible scores are:

Extremely Vulnerable: Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050.

Highly Vulnerable: Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.

Moderately Vulnerable: Abundance and/or range extent within geographical area assessed likely to decrease by 2050.

Not Vulnerable/Presumed Stable: 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.

Not Vulnerable/Increase Likely: Available evidence suggests that abundance and/or range extent within geographical area assessed is likely to increase by 2050.

Insufficient Evidence: Available information about a species' vulnerability is inadequate to calculate an Index score.

Scoring Factors in the CCVI

The factors used to generate the CCVI score are listed in the following section. Detailed definitions of scoring categories are listed in Appendix C.

A. Exposure to Climate Change

1. **Temperature**
2. **Moisture Availability** (Hamon Moisture Metric)
3. **Exposure to sea level rise.** (Not applicable to the San Juan Region)
4. **Distribution relative to natural and anthropogenic barriers.**

5. **Predicted impact of land use changes resulting from human responses to climate change.**

C. Sensitivity

1. **Dispersal and movements.**
2. **Predicted sensitivity to temperature and moisture changes.**
 - a) Predicted sensitivity to changes in temperature.
 - b) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime.
 - c) Dependence on a specific disturbance regime likely to be impacted by climate change.
 - d) Dependence on ice, ice-edge, or snow-cover habitats.
3. **Restriction to uncommon geological features or derivatives.**
4. **Reliance on interspecific interactions.**
 - a) Dependence on other species to generate habitat.
 - b) Dietary versatility (animals only).
 - c) Pollinator versatility (plants only).
 - d) Dependence on other species for propagule dispersal.
 - e) Forms part of an interspecific interaction not covered by C4a-d.
5. **Genetic factors.**
 - a) Measured genetic variation.
 - b) Occurrence of bottlenecks in recent evolutionary history.
6. **Phenological response to changing seasonal temperature and precipitation dynamics.**

D. Documented or Modeled Response to Climate Change

1. **Documented response to recent climate change.**
2. **Modeled future change in range or population size.**
3. **Overlap of modeled future range with current range.**
4. **Occurrence of protected areas in modeled future distribution.**

Factors not considered —The Index development team did not include factors that are already considered in conservation status assessments. These factors include population size, range size, and demographic factors. The goal is for the NatureServe Climate Change Vulnerability Index to complement NatureServe Conservation Status Ranks and not to partially duplicate factors. Ideally, Index values and status ranks should be used in concert as described below under Interpreting Results.

Confidence —selecting a range of values for any particular factor tends to decrease confidence in species information according to the programming within the CCVI that calculates the Index Score. To estimate confidence in species information, the Index uses a Monte Carlo simulation to recalculate the Index using just one of the checked boxes for factors in which more than one box is

checked. The simulation runs for 1,000 iterations and assumes that all checked boxes for a particular factor are equally likely. In cases in which only one box was checked for each factor, the Monte Carlo results will always be exactly the same as the calculated Index score.

Target Selection

According to the records in CNHP’s BIOTICS database, 122 rare plant species¹ have been documented within the San Juan region. Of these, 41 species were previously assessed for vulnerability to climate change (CNHP 2011, Neely et al. 2011). Of the remaining 81 species, 21 are Sensitive Species for the BLM and/or the USFS. For this project, we prioritized the 19 BLM/USFS sensitive species that have a significant portion of their range within the study area for assessment (Table 2). As of this report there are 60 San Juan species with a CCVI. The following analysis includes all 60 species. Additional rare plants of the San Juan region for which no prior climate change vulnerability assessments have been completed to date are listed in (Appendix A).

Table 2. San Juan plant species assessed for this report.

<i>Latin Name</i>	<i>Common Name</i>	Global Status	State Status	Agency Sensitive
<i>Alsinanthe macrantha</i>	House's sandwort	G3	S2S3	
<i>Amsonia jonesii</i>	Jones blue star	G4	S2	BLM
<i>Astragalus eastwoodiae</i>	Eastwood milk-vetch	G3	S2	
<i>Astragalus proximus</i>	Aztec milkvetch	G4	S2	USFS
<i>Astragalus wetherillii</i>	Wetherill's milkvetch	G3	S3	USFS
<i>Calochortus flexuosus</i>	weak-stemmed mariposa lily	G4	S2	USFS
<i>Cryptogramma stelleri</i>	slender rock-brake	G5	S2	BLM
<i>Drosera anglica</i>	English sundew	G5	S1	USFS
<i>Epipactis gigantea</i>	giant helleborine	G4	S1	USFS
<i>Eriophorum chamissonis</i>	russet cotton-grass	G5	S1	USFS
<i>Gilia haydenii</i>	San Juan gilia	G3	S2	
<i>Mimulus eastwoodiae</i>	Eastwood monkey-flower	G3G4	S2	BLM
<i>Pediomelum aromaticum</i>	Paradox breadroot	G3	S2	BLM
<i>Penstemon breviculus</i>	little penstemon	G3	S1	
<i>Proatriplex pleiantha</i>	Mancos saltbush	G3	S1	
<i>Sphagnum angustifolium</i>	narrowleaf peatmoss	G5	S2	USFS
<i>Sphagnum balticum</i>	Baltic sphagnum	G4	S1	USFS
<i>Triteleia grandiflora</i>	large-flower triteleia	G4G5	S1	USFS
<i>Utricularia minor</i>	lesser bladderwort	G5	S2	USFS

Global/State Status: 1 – critically imperiled; 2 – imperiled; 3 – vulnerable; 4 – apparently secure, but with cause for long-term concern; 5 – demonstrably secure. Agency Sensitive: BLM – Bureau of Land Management; USFS – U.S. Forest Service.

¹ For the purposes of this report, rare plants are defined as species with NatureServe Conservation Status Ranks of G1-G3 and S1-S3.

Application of the CCVI for Species in the San Juan Region

CNHP botanists completed the draft CCVIs for target species using CNHP's BIOTICS database, available published and unpublished literature, and professional judgment. Draft CCVIs were then reviewed by wetland plant experts Gay Austin (Bureau of Land Management) and Denise Culver (CNHP), and CNHP West Slope botanists Peggy Lyon and Dee Malone. Scoring factors related to historic and predicted future climate (temperature, precipitation, and moisture availability) were calculated in GIS using the methods described below. Refer to Appendix C for additional details on scoring.

Exposure to predicted temperature increase was calculated using distribution data from CNHP's Element Occurrence Record database, and a climate prediction model averaged over the summer season (June – August) from Climate Wizard, using the high (A2) CO₂ emissions scenario. The high emissions scenario was used because it is most similar to current emissions. The analysis period was to the year 2050 (which is actually an average of projections for years 2040 – 2069). The summer season – growing season for plants – was used because it was considered the most critical time period for most species' life cycle.

Exposure to projected drying (integration of projected temperature and precipitation change, i.e., the Hamon AET: PET moisture metric) was calculated using the dataset created by NatureServe as part of the CCVI. Note that NatureServe based their moisture metric calculations on the same Climate Wizard dataset as above, *except* that they used the moderate (A1B) carbon dioxide emissions scenario. Because the modeling methods used by NatureServe were not available, we were unable to recalculate using the A2 scenario, and so used the data as provided. This decision was considered reasonable because the A1B and A2 scenarios predict similar changes through the mid-21st Century, the period used in this analysis. We calculated the percent of each species' range/distribution that falls within each rating category. All calculations used the "summer" (June – August) data subset, except for obligate wetland species, which were calculated using the annual average, as these species are likely less affected by short-term precipitation patterns during the growing season.

The historical thermal niche factor measures large-scale temperature variation that a species has experienced in recent historical times (i.e., the past 50 years), as approximated by mean seasonal temperature variation (difference between highest mean monthly maximum temperature and lowest mean monthly minimum temperature). It is a proxy for species' temperature tolerance at a broad scale. This factor was calculated in GIS by assessing the relationship between species' distributions and historical temperature variation. Historical temperature variation was measured as the mean July high minus the mean January low, using temperature data from the Cortez, Mesa Verde National Park, and Red Mountain Pass (High Plains Regional Climate Center 2013, National Resources Conservation Service 2013).

The historical hydrological niche factor measures large-scale precipitation variation that a species has experienced in recent historical times (i.e., the past 50 years), as approximated by mean annual precipitation variation across occupied cells within the assessment area. Ratings for this score were based on mean annual precipitation data from the Cortez, Mesa Verde National Park, and Red

Mountain Pass (High Plains Regional Climate Center 2013, National Resources Conservation Service 2013).

RESULTS

Nearly all of the 60 species analyzed (87%) scored as vulnerable to predicted climate change in the San Juan region. Of these 58% were extremely vulnerable, and 28% were highly to moderately vulnerable. Only 14% were presumed stable or likely to increase (Table 3). Factors that were most likely to contribute to the vulnerability of plants include: poor dispersal capability, restriction to cool or cold environments, physiological thermal niche, physiological hydrological niche, restriction to uncommon geologic features or substrates, pollinator specificity, and dependence on ice and snow. The most vulnerable groups are from the alpine, barrens, cliff and canyon, and groundwater dependent wetland habitats (Table 4 and Figure 2), a trend we see repeated across the state (Colorado Rare Plant SWAP 2011). These habitats by definition are limited in area, thus potential migration or dispersal of a species endemic to these habitats is restricted. Scores for shrubland, forest, woodland, and grassland species were variable, but in general species from these habitats tended to be less vulnerable or presumed stable. The wetland dependent species were all extremely to moderately vulnerable (Table 4).

Table 3. Summary of vulnerability assessment results for species by Index Score

CCVI Score	Number of Species	Percent of Species
Extremely Vulnerable	35	58%
Highly Vulnerable	2	3%
Moderately Vulnerable	15	25%
All Vulnerable Species	52	86%
Presumed Stable	7	12%
Increase Likely	1	2%
All Presumably Secure Species	8	14%

Table 4. Summary of vulnerability assessment results for species by habitat within the San Juan region; sorted by elevation (high to low, with the exception of wetlands).

Primary Habitat Type	Number of Species EV or HV	Number of Species MV	Number of Species PS or IL
Alpine	9	0	0
Spruce-fir	2	4	1
Ponderosa pine	2	1	0
Montane grassland	0	0	1
Pinyon-juniper woodland	3	3	3
Cliff and canyon	6	0	0
Desert shrubland	3	0	2
Barrens	6	1	1
Groundwater dependent wetlands	6	6	0

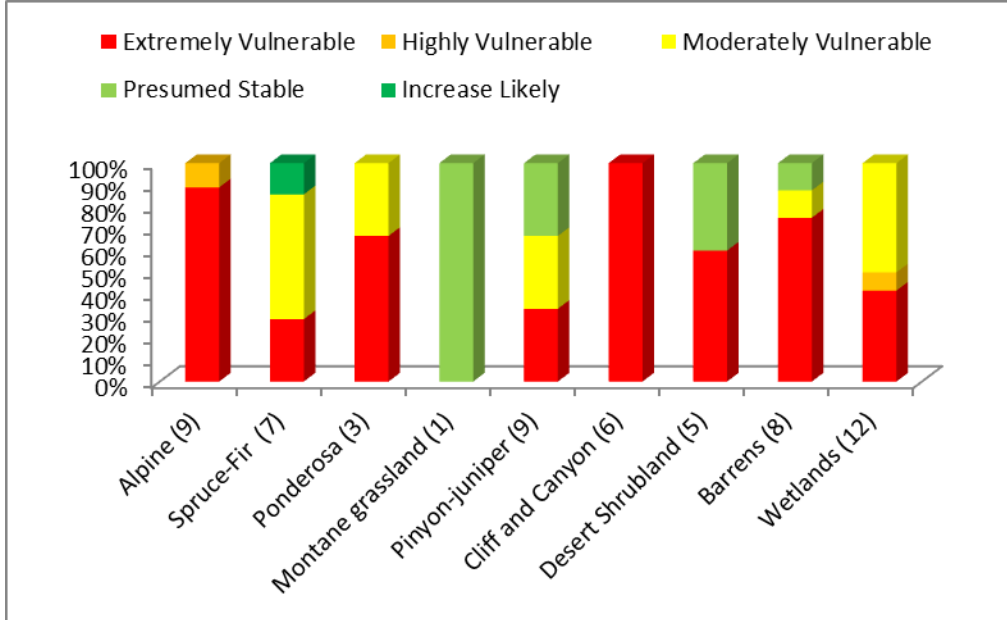


Figure 2. San Juan rare plant species vulnerability by habitat.

The habitat pattern is depicted on the map in Figure 4 spatially depicts occurrences by their vulnerability rank. The southwest corner near Mesa Verde National Park and Sleeping Ute Mountain as well as the higher elevations near the Continental Divide stand out as areas with vulnerable plants (Figure 4).

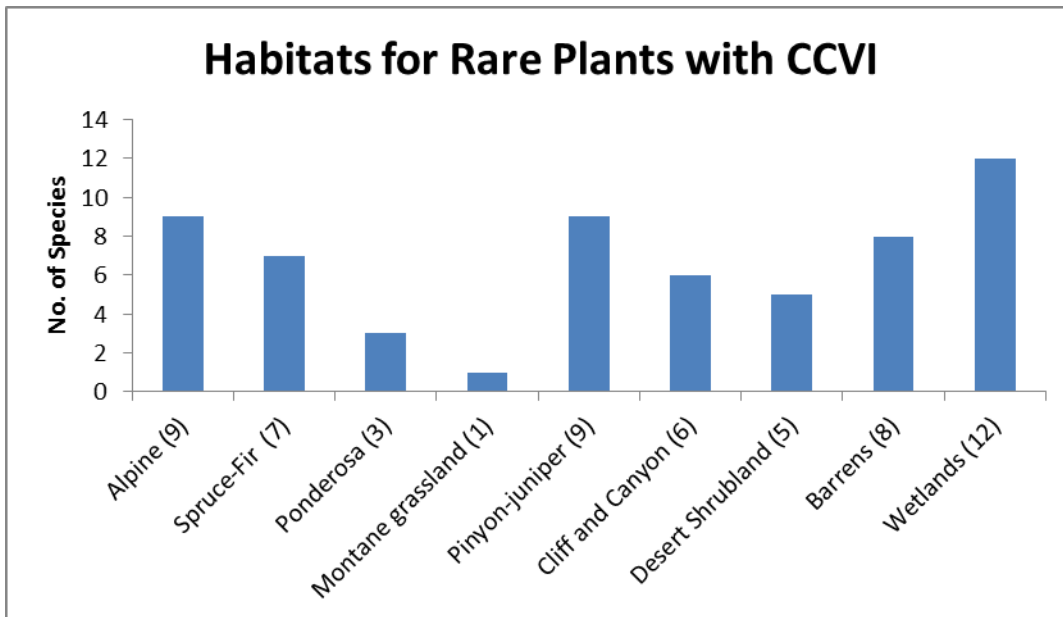


Figure 3. Number of San Juan rare plant species with CCVIs by habitat.

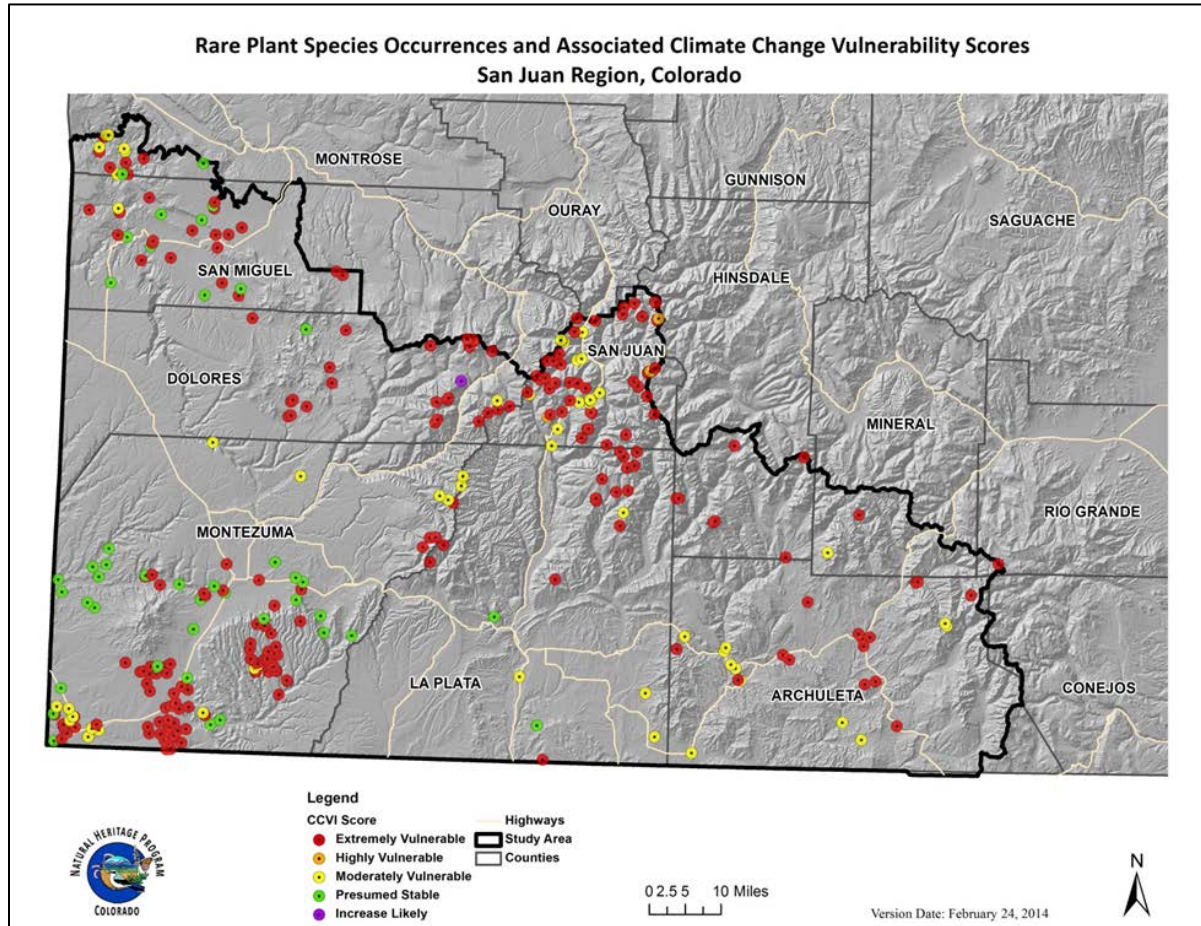


Figure 4. San Juan rare plant species distribution by vulnerability score.

The rarest species (G1-G2) were also in the most vulnerable group, regardless of habitat type. All of the G1-G2 species in the study area scored as extremely vulnerable (EV) to climate change, whereas, only three G4-G5 species (*Draba fladnizensis*, *Cryptogramma stelleri*, and *Ranunculus gelidus* ssp. *grayi*) were rated as extremely or highly vulnerable, and they are species that are found in alpine habitats (Table 5 and Appendix B). This is not surprising given the limited range and habitat specificity of the G1-G2 species versus the wider ranging, more globally common G4-G5 species.

Table 5. Summary of vulnerability assessment results for species by rarity rank.

CCVI Score	Number of Species EV or HV	Number of Species MV	Number of Species PS or IL
G1	12	0	0
G2	16	0	0
G3	5	5	5
All Globally Rare Species	34	5	5
G4	2	6	2
G5	1	4	1
All Presumably Secure Species	3	10	3

Of the 60 species assessed, 37% (22 species) are endemic to the Four Corners region and most (19 species) are extremely vulnerable (Figure 5). Barrens have the most number of endemic species of any habitat (7) and all but one species are extremely vulnerable (Figure 4). Most of the barren habitat is found at the lowest elevations in the region and often associated with Mancos Shale.

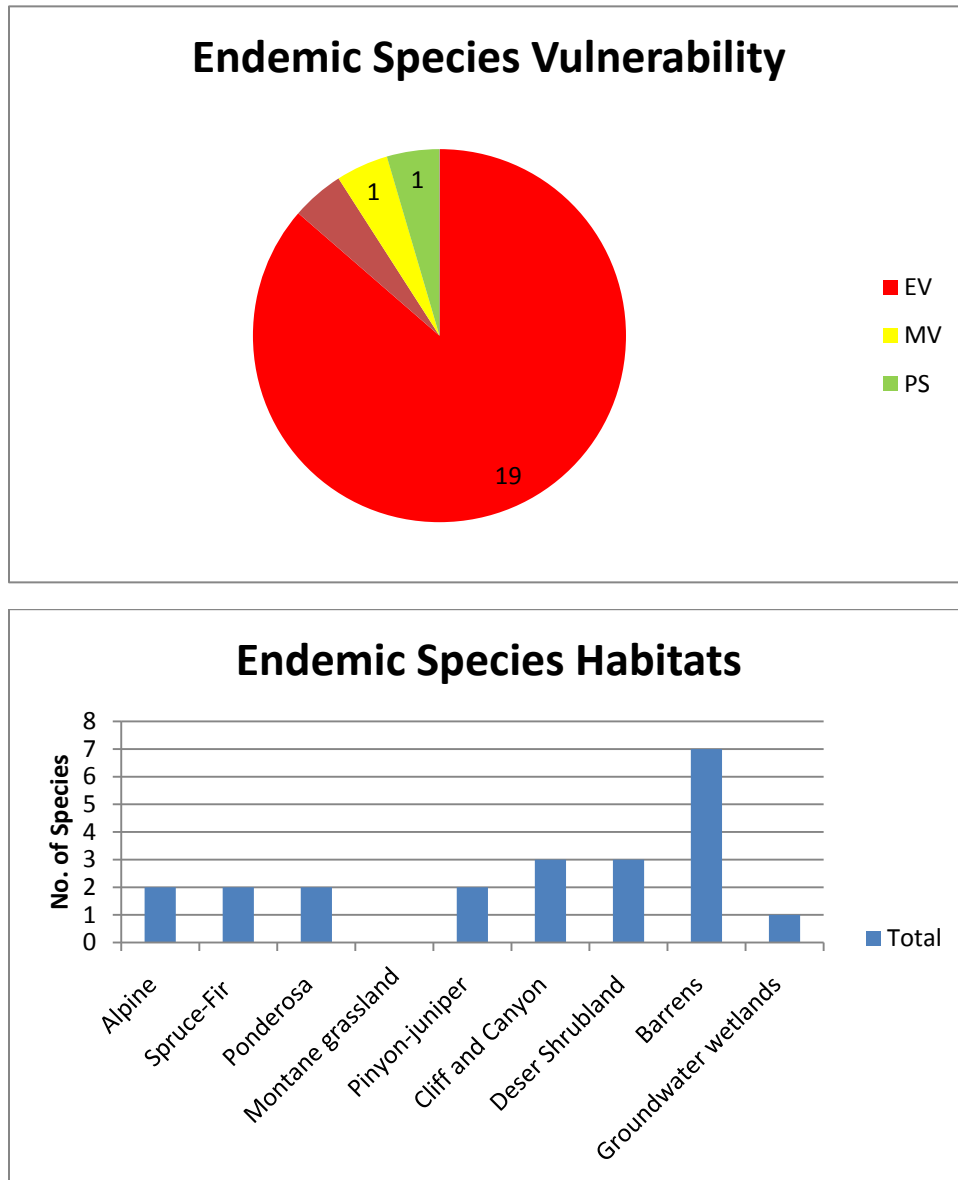


Figure 5. San Juan endemic plant species vulnerability (upper) and their habitats (lower).

Confidence in Scores

Despite the development of numerous climate change models, there remains some uncertainty about what climatic changes will actually occur and how species fitness and population stability will be affected. Of the 60 plant species evaluated in the San Juan Region, only four had low confidence ratings. The species are from a variety of habitats and the low confidence is primarily a factor of split ratings for natural and anthropogenic barriers. For the majority (86%) of the species, confidence ratings were very high.

Table 6. Climate change vulnerability scores for rare plants of the San Juan Region alphabetically by habitat.

Primary Habitat	Scientific Name	Common Name	Global Status	State Status	Federal Listing	Agency Sensitive	Vulnerability Score	Geographic Area
Alpine	<i>Alsinanthe macrantha</i>	House's sandwort	G3	S2S3			EV	San Juan Region
Alpine	<i>Castilleja puberula</i>	Downy indian-paintbrush	G2G3	S2S3			EV	State of Colorado
Alpine	<i>Descurainia kenheillii</i>	Heil's tansy mustard	G1	S1			EV	State of Colorado
Alpine	<i>Draba fladnizensis</i>	arctic draba	G4	S2			HV	Gunnison Basin
Alpine	<i>Draba graminea</i>	San Juan draba	G2	S2			EV	State of Colorado
Alpine	<i>Draba streptobrachia</i>	Colorado Divide whitlow-grass	G3	S3			EV	Gunnison Basin
Alpine	<i>Erigeron lanatus</i>	woolly fleabane	G3G4	S2			EV	Gunnison Basin
Alpine	<i>Ranunculus gelidus</i> ssp. <i>grayi</i>	tundra buttercup	GNRT4T5	S1		USFS	EV	Gunnison Basin
Alpine	<i>Townsendia rothrockii</i>	Rothrock townsend-daisy	G2G3	S2S3			EV	Gunnison Basin
Barrens	<i>Cryptantha gypsophila</i>	Gypsum Valley cateye	G2	S2		BLM	EV	State of Colorado
Barrens	<i>Gilia haydenii</i>	San Juan gilia	G3	S2			PS	San Juan Region
Barrens	<i>Gutierrezia elegans</i>	Lone Mesa snakeweed	G1	S1		BLM/USFS	EV	State of Colorado
Barrens	<i>Ipomopsis polyantha</i>	Pagosa skyrocket	G1	S1	LE	BLM/USFS	EV	State of Colorado
Barrens	<i>Lesquerella pruinosa</i>	Pagosa bladderpod	G2	S2		BLM/USFS	EV	State of Colorado
Barrens	<i>Physaria pulvinata</i>	Cushion bladderpod	G1	S1		BLM/USFS	EV	State of Colorado
Barrens	<i>Proatriplex pleiantha</i>	Mancos saltbush	G3	S1			MV	San Juan Region
Barrens	<i>Sclerocactus mesae-verdae</i>	Mesa Verde cactus	G2	S2	LT		EV	State of Colorado

Primary Habitat	Scientific Name	Common Name	Global Status	State Status	Federal Listing	Agency Sensitive	Vulnerability Score	Geographic Area
Cliff and Canyons	<i>Aletes macdougallii</i> ssp. <i>breviradiatus</i>	Mesa Verde aletes	G3T2T3	S1			EV	State of Colorado
Cliff and Canyons	<i>Astragalus deterior</i>	Cliff Palace milkvetch	G1G2	S1S2			EV	State of Colorado
Cliff and Canyons	<i>Astragalus humillimus</i>	Mancos milkvetch	G1	S1	LE		EV	State of Colorado
Cliff and Canyons	<i>Astragalus naturitensis</i>	Naturita milkvetch	G2G3	S2S3		BLM	EV	State of Colorado
Cliff and Canyons	<i>Draba smithii</i>	Smith whitlow-grass	G2	S2		USFS	EV	State of Colorado
Cliff and Canyons	<i>Hackelia gracilentia</i>	Mesa Verde stickseed	G1	S1			EV	State of Colorado
Desert shrubland	<i>Amsonia jonesii</i>	Jones blue star	G4	S2		BLM	PS	San Juan Region
Desert shrubland	<i>Astragalus cronquistii</i>	Cronquist's milkvetch	G2	S2			EV	State of Colorado
Desert shrubland	<i>Astragalus tortipes</i>	Sleeping Ute milkvetch	G1	S1	C	BLM	EV	State of Colorado
Desert shrubland	<i>Eriogonum clavellatum</i>	Comb Wash buckwheat	G2	S1		BLM	EV	State of Colorado
Desert shrubland, Desert grasslands	<i>Calochortus flexuosus</i>	weak-stemmed mariposa lily	G4	S2		USFS	PS	San Juan Region
Groundwater dependent wetland (fens)	<i>Drosera anglica</i>	English sundew	G5	S1		USFS	MV	San Juan Region
Groundwater dependent wetlands	<i>Cryptogramma stelleri</i>	slender rock-brake	G5	S2		BLM	EV	San Juan Region

Primary Habitat	Scientific Name	Common Name	Global Status	State Status	Federal Listing	Agency Sensitive	Vulnerability Score	Geographic Area
Groundwater dependent wetlands	<i>Epipactis gigantea</i>	giant helleborine	G4	S1		USFS	MV	San Juan Region
Groundwater dependent wetlands	<i>Erigeron kachinensis</i>	kachina daisy	G2	S1		BLM	EV	State of Colorado
Groundwater dependent wetlands	<i>Eriophorum chamissonis</i>	Russet cottongrass	G5	S1		USFS	MV	San Juan Region
Groundwater dependent wetlands	<i>Mimulus eastwoodiae</i>	Eastwood monkey-flower	G3G4	S2		BLM	HV	San Juan Region
Groundwater dependent wetlands	<i>Puccinellia parishii</i>	Parish's alkali grass	G2G3	S1			EV	State of Colorado
Groundwater dependent wetlands (fens)	<i>Eriophorum altaicum</i> var. <i>neogaeum</i>	Altai cottongrass	G4?T3T4	S3		USFS	EV	Gunnison Basin
Groundwater dependent wetlands (fens)	<i>Luzula subcapitata</i>	Colorado wood-rush	G3?	S3			EV	Gunnison Basin
Groundwater dependent wetlands (fens)	<i>Sphagnum angustifolium</i>	narrowleaf peatmoss	G5	S2		USFS	MV	San Juan Region
Groundwater dependent wetlands (fens)	<i>Sphagnum balticum</i>	Baltic peat moss	G4	S1		USFS	MV	San Juan Region
Groundwater dependent wetlands (fens)	<i>Utricularia minor</i>	lesser bladderwort	G5	S2		USFS	MV	San Juan Region

Primary Habitat	Scientific Name	Common Name	Global Status	State Status	Federal Listing	Agency Sensitive	Vulnerability Score	Geographic Area
Montane grassland	<i>Machaeranthera coloradoensis</i>	Colorado tansy-aster	G3	S3		USFS	PS	Gunnison Basin
Pinyon-Juniper Woodlands	<i>Astragalus eastwoodiae</i>	Eastwood milk-vetch	G3	S2			MV	San Juan Region
Pinyon-Juniper Woodlands	<i>Astragalus iodopetalus</i>	Violet milkvetch	G2	S1			EV	State of Colorado
Pinyon-Juniper Woodlands	<i>Astragalus proximus</i>	Aztec milkvetch	G4	S2		USFS	MV	San Juan Region
Pinyon-Juniper Woodlands	<i>Astragalus schmolliae</i>	Schmoll's milkvetch	G1	S1	C		EV	State of Colorado
Pinyon-Juniper Woodlands	<i>Astragalus wetherillii</i>	Wetherill's milkvetch	G3	S3		USFS	PS	San Juan Region
Pinyon-Juniper Woodlands	<i>Lepidium crenatum</i>	Alkaline pepperwort	G2	S2			EV	State of Colorado
Pinyon-Juniper Woodlands	<i>Pediomelum aromaticum</i>	Paradox breadroot	G3	S2		BLM	MV	San Juan Region
Pinyon-Juniper Woodlands	<i>Penstemon breviculus</i>	little penstemon	G3	S1			PS	San Juan Region
Pinyon-Juniper Woodlands	<i>Sporobolus flexuosus</i>	mesa dropseed	G5	S1			PS	State of Colorado
Ponderosa pine	<i>Astragalus missouriensis</i> var. <i>humistratus</i>	Missouri milkvetch	G5T1	S1		USFS	EV	State of Colorado
Ponderosa Pine	<i>Townsendia glabella</i>	Smooth Easter daisy	G2	S2			EV	State of Colorado
Ponderosa Pine	<i>Triteleia grandiflora</i>	large-flower triteleia	G4G5	S1		USFS	MV	San Juan Region
Spruce-fir	<i>Botrychium echo</i>	reflected moonwort	G3	S3			MV	Gunnison Basin
Spruce-fir	<i>Botrychium minganense</i>	Mingan's moonwort	G4G5	S2			MV	Gunnison Basin

Primary Habitat	Scientific Name	Common Name	Global Status	State Status	Federal Listing	Agency Sensitive	Vulnerability Score	Geographic Area
Spruce-fir	<i>Botrychium pallidum</i>	pale moonwort	G3	S2			MV	Gunnison Basin
Spruce-fir	<i>Botrychium pinnatum</i>	northern moonwort	G4?	S1			MV	Gunnison Basin
Spruce-Fir	<i>Draba malpighiacea</i>	whitlow-grass	G1?	S1?			EV	State of Colorado
Spruce-Fir	<i>Draba rectifruca</i>	mountain draba	G3G4	S3			IL	Gunnison Basin
Spruce-Fir	<i>Physaria scrotiformis</i>	West silver bladderpod	G1	S1		USFS	EV	State of Colorado

REFERENCES

- Aitken, S. N., S. Yeaman, J. A. Holliday, T. Wang, and S. Curtis-McLane. 2008. Adaptation, migration, or extirpation: climate change outcomes for tree populations. *Evolutionary Applications* 1:95-111.
- Archer, S. R., and K. I. Predick. 2008. Climate change and ecosystems of the southwestern United States. *Rangelands* 2008(June):23-28.
- Benito Garzón, M., R. Sánchez de Dios, and H. Sainz Ollero. 2008. Effects of climate change on the distribution of Iberian tree species. *Applied Vegetation Science* 11:169-178.
- Bruno, J. F., J. J. Stachowicz, and M. D. Bertness. 2003. Inclusion of facilitation into ecological theory. *Trends in Ecology and Evolution* 18:119-125.
- Dyer, J. M. 1995. Assessment of climatic warming using a model of forest species migration. *Ecological Modeling* 79:199-219.
- Colorado Natural Heritage Program. 2011. Colorado Wildlife Action Plan. Proposed Rare Plant Addendum. Online at http://www.cnhp.colostate.edu/download/documents/2011/rareplant_SWAP_final_june_30_2011.pdf.
- Enquist, C., and D. Gori. 2008. A Climate Change Vulnerability Assessment for Biodiversity in New Mexico, Part I: Implications of Recent Climate Change on Conservation Priorities in New Mexico. The Nature Conservancy, New Mexico.
- Gran Canaria Declaration II on Climate Change and Plant Conservation. 2006. Published by the Area de Medio Ambiente y Aguas del Cabildo de Gran Canaria Jardín Botánico Canario "Viera y Clavijo" and Botanic Gardens Conservation International. Available: http://www.bgci.org/files/All/Key_Publications/gcdccenglish.pdf.
- Hawkins, B., S. Sharrock, and K. Havens. 2008. Plants and climate change: which future? Botanic Gardens Conservation International, Richmond, United Kingdom.
- Huntley, B. 2005. North temperate responses. pg. 109-124 in Lovejoy, T. E. and L. Hannah, eds. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.
- Intergovernmental Panel on Climate Change (IPCC). 2002. Climate Change and Biodiversity (IPCC Technical Paper V). Gitay, H., A. Suárez, R. T. Watson, and D. Jon Dokken, eds. Available: http://www.grida.no/climate/ipcc_tar/biodiv/pdf/bio_eng.pdf.

- Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, eds., Cambridge University Press, Cambridge, UK, 976pp. Available: <http://www.ipcc.ch/ipccreports/ar4-wg2.htm>.
- Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: Fourth Assessment Report (IPCC-AR4). Working Group I: The Physical Science Basis: <http://ipccwg1.ucar.edu/wg1/wg1-report.html> and Working Group II: Impacts, Adaptation, and Vulnerability: <http://www.ipcc.ch/SPM040507.pdf>., Chapter 14: North America Impacts: <http://www.ipcc-wg2.org/>
- IPCC. 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.) IPCC, Geneva, Switzerland. pp 104.
- Jiguet, F., A.-S. Gadot, R. Julliard, S. E. Newson, and D. Couvet. 2007. Climate envelope, life history traits and the resilience of birds facing climate change. *Global Change Biology* 13:1672-1684.
- Johnson, G. D., W. P. Erickson, M. D. Strickland, M. F. Shepherd, D. A. Shepherd, and S. A. Sarappo. 2003. Mortality of bats at a large-scale wind power development at Buffalo Ridge, Minnesota. *American Midland Naturalist* 150:332-342.
- Koerner, C. 2005. The Green Cover of Mountains in a Changing Environment, pp. 367-375 in Huber, U. M., M. A. Reasoner, and H. K. M. Bugmann (eds.). *Global Change and Mountain Regions: An Overview of Current Knowledge*. Springer-Verlag, New York.
- Laidre, K. L., I. Stirling, L. F. Lowry, O. Wiig, M. P. Heide-Jørgensen, and S. H. Ferguson. 2008. Quantifying the sensitivity of arctic marine mammals to climate-induced habitat change. *Ecological Applications* 18:S97-S125.
- Lenoir, J., J. C. Gégout, P. A. Marquet, P. de Ruffray, and H. Brisse. 2008. A significant upward shift in plant species optimum elevation during the 20th century. *Science* 320:1768-1771.
- Loarie, S. R., B. E. Carter, K. Hayhoe, S. McMahon, R. Moe, C. A. Knight, and D. D. Ackerly. 2008. Climate change and the future of California's endemic flora. *PLoS ONE* 3:e2502.
- Midgley, G. F., L. Hannah, D. Millar, W. Thuiller, and A. Booth. 2003. Developing regional and species level assessments of climate change impacts on biodiversity in the Cape Floristic Region. *Biological Conservation* 112:87-97.
- Møller, A. P., D. Rubolini, and E. Lehikoinen. 2008. Populations of migratory bird species that did not show a phenological response to climate change are declining. *Proceedings of the National Academy of Sciences (USA)* 105:16195-16200.

NatureServe 2012. Climate Change Vulnerability Assessment Tool, version 2.1. Available online at <https://connect.natureserve.org/science/climate-change/ccvi>.

Neely, B., R. Rondeau, J. Sanderson, C. Pague, B. Kuhn, J. Siemers, L. Grunau, J. Robertson, P. McCarthy, J. Barsugli, T. Schulz, and C. Knapp. Editors. 2011. Gunnison Basin: Vulnerability Assessment for the Gunnison Climate Working Group by The Nature Conservancy, Colorado Natural Heritage Program, Western Water Assessment, University of Colorado, Boulder, and University of Alaska, Fairbanks. Project of the Southwest Climate Change Initiative.

Parmesan, C. 1996. Climate change and species' range. *Nature* 382:765-766.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution, and Systematics* 37:637-669.

Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421:37-42.

Peterson, A. T., M. A. Ortega-Huerta, J. Bartley, V. Sanchez-Cordero, J. Soberon, R. H. Buddemeier, and D. R. B. Stockwell. 2002. Future projections for Mexican faunas under global climate change scenarios. *Nature* 416:626-629.

Price, M. F. 2008. Maintaining mountain biodiversity in an era of climate change In Borsdorf, A, J. Stötter and E. Veulliet (eds.) *Managing Alpine Future*. Proceedings of International Conference October 15-17, 2007: Austrian Academy of Sciences Press, Vienna: 17-33.

Root T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenzweig, and J. A. Pounds. 2003. Fingerprints of global warming on wild animals and plants. *Nature* 421:57-60.

Saetersdal, M., and H. J. B. Birks. 1997. A comparative ecological study of Norwegian mountain plants in relation to possible future climatic change. *Journal of Biogeography* 24:127-152.

Schneider, S. H., S. Semenov, A. Patwardhan, I. Burton, C. H. D. Magadza, M. Oppenheimer, A. B. Pittock, A. Rahman, J. B. Smith, A. Suarez, and F. Yamin. 2007. Assessing key vulnerabilities and the risk from climate change. Pages 779-810 in *Climate Change 2007: Impacts, Adaptation and Vulnerability*, edited by M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Schwartz, M. W., L. R. Iverson, A. M. Prasad, S. N. Mathews, and R. J. O'Conner. 2006. Predicting extinctions as a result of climate change. *Ecology* 87:1611-1615.

Simmons, R. E., P. Barnard, W. R. J. Dean, G. F. Midgley, W. Thuiller, and G. Hughes. 2004. Climate change and birds: perspectives and prospects from southern Africa. *Ostrich* 75:295-308.

- Stirling, I., and C. L. Parkinson. 2006. Possible effects of climate warming on selected populations of polar bears (*Ursus maritimus*) in the Canadian arctic. *Arctic* 59:261-275.
- Thomas, C. D. 2005. Recent evolutionary effects of climate change. Pages 75-88 in *Climate change and biodiversity*, edited by T. E. Lovejoy and L. Hannah. Yale University Press, New Haven, Connecticut.
- Thomas, C. D., A. Cameron, R. E. Green, et al. 2004. Extinction risk from climate change. *Nature* 427:145-148.
- Thuiller, W., S. Lavorel, M. B. Araújo, M. T. Sykes, and I. C. Prentice. 2005. Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Sciences* 102: 8245–8250.
- Williams, P., L. Hannah, S. Andelman, G. Midgley, M. Araújo, G. Hughes, L. Manne, E. Martinez-Meyer, and R. Pearson. 2005. Planning for climate change: identifying minimum dispersal corridors for the Cape Proteaceae. *Conservation Biology* 19:1063-1074.
- Willis, C. G., B. Ruhfel, R. B. Primack, A. J. Miller-Rushing, and C. C. Davis. 2008. Phylogenetic patterns of species loss in Thoreau's woods are driven by climate change. *Proceedings of the National Academy of Sciences (USA)* 105:17029-17033.
- Young, B., E. Byers, K. Gravuer, K. Hall, G. Hammerson, and A. Redder. 2011. Guidelines for Using the NatureServe Climate Change Vulnerability Index, Release 2.1. NatureServe, Arlington, VA.

Appendix A: List of Rare Plant Species in the San Juan Region with no Climate Change Vulnerability Assessment

<i>Latin Name</i>	<i>Common Name</i>	<i>Global Status</i>	<i>State Status</i>	<i>Federal Listing</i>	<i>Agency Sensitive</i>
<i>Acer grandidentatum</i>	bigtooth maple	G4G5	S1		
<i>Adiantum capillus-veneris</i>	southern maiden-hair	G5	S2		
<i>Aletes sessiliflorus</i>	New Mexico false carrot	G3	S1		
<i>Aquilegia micrantha</i> var. <i>mancosana</i>	Mancos columbine	G5THQ	SH		
<i>Aralia racemosa</i>	American spikenard	G4G5	S1		
<i>Asclepias macrosperma</i>	large-seeded milkweed	G4	S1		
<i>Asplenium trichomanes-ramosum</i>	green spleenwort	G4	S1		
<i>Astragalus newberryi</i>	Newberry's milkvetch	G5	S1		
<i>Boechnera gunnisoniana</i>	a rock cress	G3	S3		
<i>Botrychium hesperium</i>	western moonwort	G4	S2		
<i>Botrychium multifidum</i>	leathery grape fern	G5	S1		
<i>Botrychium simplex</i>	least moonwort	G5	S2		
<i>Bupleurum triradiatum</i> ssp. <i>arcticum</i>	thoroughwax	G5	S1		
<i>Carex diandra</i>	lesser panicled sedge	G5	S1		USFS
<i>Carex limosa</i>	mud sedge	G5	S2		
<i>Carex retrorsa</i>	retorse sedge	G5	S1		
<i>Carex viridula</i>	green sedge	G5	S1		
<i>Castilleja lineata</i>	marsh-meadow indian-paintbrush	G4?	S2S3		
<i>Collomia grandiflora</i>	showy collomia	G5	S1		
<i>Commelina dianthifolia</i>	birdbill day-flower	G5	S1?		
<i>Cypripedium calceolus</i> ssp. <i>parviflorum</i>	American yellow lady's-slipper	G5	S2		USFS
<i>Cystopteris montana</i>	mountain bladder fern	G5	S1		
<i>Draba borealis</i>	northern rockcress	G4G5	S2		
<i>Draba crassa</i>	thick-leaf whitlow-grass	G3G4	S3		
<i>Enneapogon desvauxii</i>	spike pappusgrass	G5	S1		
<i>Erigeron philadelphicus</i>	Philadelphia fleabane	G5	S1		
<i>Eriogonum leptocladon</i> var. <i>ramosissimum</i>	Eastwood sand buckwheat	G5T5	S1		
<i>Eriogonum palmerianum</i>	Palmer buckwheat	G4	S1		
<i>Eriogonum scabrellum</i>	Westwater buckwheat	G3	S1		
<i>Forsellesia meionandra</i>	Utah greasebush	G5T3	S1		
<i>Grindelia arizonica</i>	Arizona gumweed	G4	S2		
<i>Hamatocaulis vernicosus</i>		G5	S1S3		

Latin Name	Common Name	Global Status	State Status	Federal Listing	Agency Sensitive
<i>Hippochaete variegata</i>	variegated scouringrush	G5	S1		
<i>Iliamna grandiflora</i>	large-flower globe-mallow	G3?Q	S1		
<i>Isoetes setacea ssp. muricata</i>	spiny-spored quillwort	G5?T5?	S2		
<i>Liatrix ligulistylis</i>	gay-feather	G5?	S1		
<i>Listera borealis</i>	northern twayblade	G4	S2		
<i>Oenothera coloradensis ssp. neomexicana</i>	New Mexico butterfly weed	G3T3	S1		
<i>Oenothera kleinii</i>	Wolf Creek evening primrose	GUGHQ	SX		
<i>Pellaea suksdorfiana</i>	smooth cliff-brake	G5T4?	S1		
<i>Penstemon parviflorus</i>	small-flower beardtongue	GH	SH		
<i>Penstemon utahensis</i>	Utah penstemon	G4	S2		
<i>Phacelia constancei</i>	Constance's phacelia	G4	S1		
<i>Phlox caryophylla</i>	Pagosa phlox	G4	S3		
<i>Polypodium hesperium</i>	western polypody	G5	S1S2		
<i>Polypodium saximontanum</i>		G3?	S2		
<i>Seriphidium pygmaeum</i>	pygmy sagebrush	G4	S1		
<i>Sisyrinchium demissum</i>	blue-eyed grass	G5	S2		
<i>Sphagnum girgensohnii</i>		G5	S1		
<i>Sphagnum platyphyllum</i>		G5	S1		
<i>Sporobolus nealleyi</i>	Nealley's dropseed	G5	S1		
<i>Stellaria irrigua</i>	Altai chickweed	G4?	S3		
<i>Trifolium kingii</i>	King's clover	G5	S1		
<i>Utricularia intermedia</i>	flatleaf bladderwort	G5	S1		
<i>Viola pedatifida</i>	prairie violet	G5	S1		
<i>Woodsia neomexicana</i>	New Mexico cliff fern	G4?	S2		

Global/State Status: 1 – critically imperiled; 2 – imperiled; 3 – vulnerable; 4 – apparently secure, but with cause for long-term concern; 5 – demonstrably secure; T – subspecies status; Q – taxonomic uncertainty; H – historic ; X – extirpated. Federal Listing: LE – listed Endangered; LT – listed Threatened; C – Candidate; P – Petitioned. Agency Sensitive: BLM – Bureau of Land Management; USFS – U.S. Forest Service.

Appendix B: San Juan Region Rare Plant Species Vulnerability Scores and Profiles

Aletes macdougalii ssp. *breviradiatus*

Mesa Verde aletes

G3T2T3/S1

Family: Apiaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal moisture, short seed dispersal distances, and the presence of natural barriers within Mesa Verde National Park which may restrict movement of the species. Although pinyon-juniper woodlands may increase with climate change, climate models project decreased summer precipitation and increased summer temperatures where pinyon-juniper is currently located, which may impact germination, recruitment, and reproductive success (Nydick et al. 2012). More importantly the decreased precipitation may be a more important indicator than the association with pinyon-juniper as this species is already favoring the more moist sites at Mesa Verde.

Distribution: *Aletes macdougalii* ssp. *breviradiatus* is restricted to relatively small regions in southeast Utah, southwest Colorado, and northwest NM (NatureServe 2013). In Colorado, it is known only from Mesa Verde National Park in Montezuma County (USDA, NRCS 2013; CNHP 2013).

Habitat: Crevices in rocky slopes and on sandy soil in pinyon-juniper woodlands (CNHP 2013).

Elevation: 6100-7100 feet.

Ecological System/Habitat: Cliffs and Canyons, Pinyon-Juniper Woodlands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Alsinnanthe macrantha [*Minuartia macrantha*]

House's sandwort

G3/S2S3

Family: Caryophyllaceae



Climate Vulnerability Score: Extremely Vulnerable

This San Juan region rank is based on restriction to cold alpine environments, short seed dispersal distances, the presence of high mountains that serve as natural barriers in suitable habitat, and dependence on ice and snow. Alpine habitats are likely to be reduced as Colorado becomes warmer, and presumably drier. Climate models project earlier, faster snowmelt along with decreased summer precipitation and increased summer temperatures (Nydick et al. 2012). This could result in significantly lower amounts of water stored in alpine soils during the summer.

Distribution: *A. macrantha* has been reported from Utah and Colorado in the United States (NatureServe 2013). In Colorado, it is known from Clear Creek, Dolores, Garfield, Gunnison, La Plata, Park, Pitkin, San Juan, and Summit counties (USDA, NRCS 2013; CNHP 2013). **Habitat:** Upper subalpine spruce-fir forests and alpine tundra (CNHP 2013). **Elevation:** 10,000-12,500 feet.

Ecological System/Habitat: Alpine Tundra, Spruce-Fir Forests

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Increase. This species occurs in high elevation (10,000-12,500 ft.) fens. Local mountain ranges and ridges create natural barriers for dispersal.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. *A. macrantha* occurs in upper subalpine and alpine habitats. We rated all alpine species 'Neutral' based on the assumption that these habitats are less likely to be developed in most climate mitigation scenarios.

C1) Dispersal and movements. Increase. Seeds likely fall close to parent plant.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral. Species has experienced average temperature variation (57.1-77°F/31.8-43.0°C) from 1983 to 2013. Data from the Red Mountain Snotel site (elevation: 11,200 ft.) shows a mean seasonal temperature variation of 77°F /43°C (NRCS 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Increase. Species is completely restricted to cool or cold environments that may be lost as a result of climate change.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced **average (21-40 inches/509-1,016 mm)** precipitation variation in the past 50 years. Data from the Red Mountain Pass Snotel site (elevation: 11,200 feet) shows total monthly precipitation ranging from 25.9 to 56.9 inches (NRCS 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Neutral. Species is not restricted to wetter microhabitats in the subalpine/alpine.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Somewhat Increase. Species occurs in snow-covered subalpine and alpine habitats.

C3) Restriction to uncommon geological features or derivatives. Neutral. Species is commonly found on limestone substrates, but is not restricted to them (FNA eds. 1993+).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. No data, forced score.

C4d) Dependence on other species for propagule dispersal. Neutral. Multiple means of dispersal.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford.
- National Resources Conservation Service (NRCS). 2013. Monthly Total Precipitation Data from Red Mountain Pass Snotel station. <http://www.wcc.nrcs.usda.gov/snotel/Colorado/colorado.html>. Accessed December 9, 2013.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA

Amsonia jonesii

Jones blue star

G4/S2

Family: Apocynaceae



Climate Vulnerability Score: Presumed Stable

This San Juan region rank is based on the species habitat preference for warm, arid climates, lack of restriction to specific geologic substrates and presumed pollinator versatility. Warm, dry desert shrublands are likely to increase with climate change. Climate models project decreased summer precipitation and increased summer temperatures (Nydick et al. 2012).

Distribution: *A. jonesii* is known from NE Arizona, Utah, NW New Mexico, and SW Colorado in the United States (NatureServe 2013). In Colorado, it is known from Mesa and Montezuma counties (USDA, NRCS 2013; CNHP 2013). **Habitat:** Dry, open areas with clay, sandy, or gravelly soils, in desert-steppe, rocky drainages and draws (CNHP 2013). **Elevation:** 4400-5800 feet.

Ecological System/Habitat: Desert Shrublands, Pinyon-Juniper Woodlands

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral. Species is on the northeast edge of its range, and could move north and east into suitable habitat.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Although the San Juan Basin has high potential for solar energy development, there are no planned developments for the area (NRDC 2014).

C1) Dispersal and movements. Increase. Seeds likely fall close to parent plant, although there are reports of a related species *Amsonia kearneyana* seed floating 'like corks' (USFWS 2013), therefore some seed dispersal by runoff may be inferred.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows a mean seasonal temperature variation of 86.45°F/48.02°C) (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Somewhat decrease. Species shows a preference for an environment toward the warmer end of the assessment area.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows total monthly precipitation ranging from 5.23 to 26.34 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Increase. Species is found in coarse, sandy soils often in the bottoms of draws and drainages.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Species occurs at lower elevations in arid desert shrublands and pinyon-juniper woodlands.

C3) Restriction to uncommon geological features or derivatives. Somewhat decrease. Species is reported to be widely adaptable in the nursery trade, and is reported to grow on various substrates.

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Inferred from a related species *Amsonia kearneyana* which has a wide variety of pollinators (USFWS 2013).

C4d) Dependence on other species for propagule dispersal. Neutral. No data, forced score.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford.
- High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Cortez weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.
- Natural Resources Defense Council (NRDC). 2014. Renewable Energy for America; Energy Map. <http://www.nrdc.org/energy/renewables/energymap.asp>. Accessed January 21, 2013.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.
- U.S. Fish and Wildlife Service. 2013. *Amsonia kearneyana* Kearney blue-star 5-Year Review: Summary and Evaluation. Arizona Ecological Services Tuscon Sub-office, Tuscon, Arizona.

Astragalus cronquistii

Cronquist's milkvetch

G2/S2

Family: Fabaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal moisture, short seed dispersal distances, preference for a specific geologic substrate, likelihood of energy development within its habitat, and dependence on Rhizobium bacteria to fix nitrogen. Although, desert shrublands may increase with climate change, climate models project decreased summer precipitation and increased summer temperatures which may impact germination, recruitment, and reproductive success of this rare species (Nydick et al. 2012).

Distribution: *A. cronquistii* is Known from Utah, the Navajo Nation, and southwest Colorado (NatureServe 2013). In Colorado, it is known from Montezuma County (CNHP 2013). **Habitat:** Found on low, gravelly ridges and sandy washes in desert shrub communities, often on sandstone of the Cutler and Morrison formations (CNHP 2013). **Elevation:** 4700-6300 feet.

Ecological System/Habitat: Desert Shrublands

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOl Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Astragalus deterior

Cliff Palace milkvetch

G1G2/S1S2

Family: Fabaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal moisture, short seed dispersal distances, preference for a specific geologic substrate, the presence of natural and anthropogenic barriers within Mesa Verde National Park which may restrict movement of the species, and dependence on Rhizobium bacteria to fix nitrogen. Climate models project decreased summer precipitation and increased summer temperatures which may impact germination, recruitment, and reproductive success of this rare species (Nydick et al. 2012).

Distribution: *A. deterior* is endemic to Colorado, known only from a small area in Montezuma County, primarily within Mesa Verde National Park (NatureServe 2013; CNHP 2013). **Habitat:** Found in sand-filled depressions of rimrock, on cliffs, and on adjacent sandy talus. Always associated with the white zone of the Upper Cliff House Sandstone (CNHP 2013). **Elevation:** 5740-8130 feet.

Ecological System/Habitat: Cliffs and Canyons

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Astragalus eastwoodiae

Eastwood milkvetch

G3/S2

Family: Fabaceae



Climate Vulnerability Score: Moderately Vulnerable

This San Juan region rank is based on the species habitat preference for warmer, arid climates, lack of restriction to specific geologic substrates and presumed pollinator versatility. Warm, dry desert shrublands and pinyon-juniper woodlands may increase with climate change. Climate models project decreased summer precipitation and increased summer temperatures which may impact germination, recruitment, and reproductive success (Nydick et al. 2012).

Distribution: *A. eastwoodiae* is known from eastern Utah, northwest New Mexico and western Colorado in the United States (Kartez 2013). In Colorado, it is known from Delta, Garfield, Mesa, Montezuma, Montrose and San Miguel counties (CNHP 2013). **Habitat:** Found in desert gulches along the Colorado River Valley near Grand Junction. On benches above the Dolores River Valley, it occurs on open, gentle slopes with little other vegetation. Range wide it occurs in draws and creek beds in low gravelly clay hills on gullied badlands and on clay banks or benches of arid escarpments (CNHP 2013). **Elevation:** 4880-7040 feet.

Ecological System/Habitat: Pinyon-Juniper Woodlands, Desert Shrublands, Cliffs and Canyons

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral. Species is in the mideast portion of its range, and could move north and east into suitable habitat.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Although the San Juan Basin has high potential for solar energy development, there are no planned developments for the area (NRDC 2014).

C1) Dispersal and movements. Increase. Reproduces by seed that falls close to parent plant.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows a mean seasonal temperature variation of 86.45°F/48.02°C) (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Neutral. Species shows a tolerance to a wide range of temperatures.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows total monthly precipitation ranging from 5.23 to 26.34 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Neutral. Species is not dependent on a moisture regime that is highly vulnerable to alteration with climate change.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Species occurs at lower elevations in arid desert shrublands and pinyon-juniper woodlands.

C3) Restriction to uncommon geological features or derivatives. Neutral. Species is reported to grow primarily on clay substrates associated with badlands.

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Inferred from other perennial *Astragalus* species which have a variety of species of bees as pollinators (USDA 2011, Decker 2005).

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Increase. *Astragalus* species are well known for forming symbiotic relationships with Rhizobium bacteria (Decker 2005).

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics.
Unknown.

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Decker, K. (2005, September 7). *Astragalus proximus* (Rydberg) Wootton & Standley (Aztec milkvetch): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/astragalusproximus.pdf> [Jan. 28.2014].
- Flora of North America Editorial Committee, eds. 1993+. *Flora of North America North of Mexico*. 16+ vols. New York and Oxford.
- High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Cortez weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.
- Kartesz, J.T., The Biota of North America Program (BONAP). 2013. *Taxonomic Data Center*. (<http://www.bonap.net/tdc>). Chapel Hill, N.C. [maps generated from Kartesz, J.T. 2013. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP). (in press)]
- Natural Resources Defense Council (NRDC). 2014. Renewable Energy for America; Energy Map. <http://www.nrdc.org/energy/renewables/energymap.asp>. Accessed January 21, 2013.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.
- USDA, NRCS. 2011. Technical Note: Threatened, Endangered, Candidate & Proposed Plant Species of Utah. TN Plant Materials No. 52.

Astragalus humillimus

Mancos milkvetch

G1/S1 - Listed Endangered

Family: Fabaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal moisture, short seed dispersal distances, preference for a specific geologic substrate, the presence of natural barriers and the potential for energy development within its range, which may restrict movement of the species, and dependence on Rhizobium bacteria to fix nitrogen. Climate models project decreased summer precipitation and increased summer temperatures which may impact germination, recruitment, and reproductive success of this rare species (Nydick et al. 2012).

Distribution: *A. humillimus* is known from San Juan County, New Mexico and Montezuma County, Colorado. (NatureServe 2013). **Habitat:** Sandstone ledges or mesa tops, often in cracks in the sandstone substrate or in shallow pockets of sandy soil of exfoliating Lookout Point Sandstone in the Mesa Verde series (NatureServe 2013). **Elevation:** 5240-6160 feet.

Ecological System/Habitat: Cliffs and Canyons, Pinyon-Juniper Woodlands, Desert Shrubland

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOl Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Astragalus iodopetalus

Violet milkvetch

G2/S1

Family: Fabaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal moisture, short seed dispersal distances, the potential for energy development and the presence of anthropogenic barriers within its range, which may restrict movement of the species, and dependence on Rhizobium bacteria to fix nitrogen. Climate models project decreased summer precipitation and increased summer temperatures which may impact germination, recruitment, and reproductive success of this rare species (Nydick et al. 2012).

Distribution: *A. iodopetalus* is known from northwest New Mexico and southwest Colorado in the United States (NatureServe 2013). In Colorado, it is known historically from Archuleta, Gunnison, La Plata and Montrose counties (CNHP 2013). **Habitat:** Dry stony hillsides and benches among sagebrush, or near oak thickets in the pinyon-juniper and ponderosa pine zones (CNHP 2013).

Elevation: 6500-7260 feet.

Ecological System/Habitat: Pinyon-juniper Woodlands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Astragalus missouriensis var. *humistratus*

Missouri milkvetch

G5T1/S1

Family: Fabaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal moisture, short seed dispersal distances, the potential for energy development and the presence of natural barriers within its range, which may restrict movement of the species, and dependence on Rhizobium bacteria to fix nitrogen. Climate models project decreased summer precipitation and increased summer temperatures which may impact germination, recruitment, and reproductive success of this rare species (Nydick et al. 2012).

Distribution: *A. missouriensis* var. *humistratus* is known from northwest New Mexico and southwest Colorado in the United States (NatureServe 2013). In Colorado, it is known from Archuleta and Hinsdale counties (CNHP 2013). **Habitat:** Found on dry, clay soils derived from Mancos shale on barren soils within grasslands and Ponderosa pine woodlands. (CNHP 2013). **Elevation:** 6950-8320 feet.

Ecological System/Habitat: Ponderosa Pine Forests/Deciduous Oak Shrublands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Astragalus naturitensis

Naturita milkvetch

G2G3/S2S3

Family: Fabaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal moisture, short seed dispersal distances, preference for a specific geologic substrate, the presence of natural and anthropogenic barriers within its range, which may restrict movement of the species, and dependence on Rhizobium bacteria to fix nitrogen. Climate models project decreased summer precipitation and increased summer temperatures which may impact germination, recruitment, and reproductive success of this rare species (Nydick et al. 2012).

Distribution: *A. naturitensis* is known from northwest New Mexico, southeast Utah, the Navajo Nation and southwest Colorado in the United States (NatureServe 2013, USDA, NRCS 2013). In Colorado, it is known from Garfield, Mesa, Montezuma, Montrose and San Miguel counties (CNHP 2013). **Habitat:** Usually found in small soil pockets or rock crevices in sandstone pavement along canyon rims and ledges, and in pinyon-juniper woodlands in areas with shallow soils over exposed bedrock (CNHP 2013). **Elevation:** 4830-7030 feet.

Ecological System/Habitat: Cliffs and Canyons, Pinyon-Juniper Woodlands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Astragalus proximus

Aztec milkvetch

G4/S2

Family: Fabaceae



Climate Vulnerability Score: Moderately Vulnerable

This San Juan region rank is based on the species habitat preference for warmer, arid climates, lack of restriction to specific geologic substrates and presumed pollinator versatility. Warm, dry desert shrublands to oak shrublands and pinyon-juniper woodlands may increase with climate change. Climate models project decreased summer precipitation and increased summer temperatures which may impact germination, recruitment and reproduction (Nydick et al. 2012).

Distribution: *A. proximus* is known from northwest New Mexico and southwest Colorado in the United States (NatureServe 2013). In Colorado, it is known from Archuleta, Conejos and La Plata counties (CNHP 2013). **Habitat:** Mesas, bluffs, and low hills in sandy, often alkaline clay soils derived from Lewis shale or Mancos shale (CNHP 2013). **Elevation:** 6000-8400 feet.

Ecological System/Habitat: Pinyon-Juniper Woodlands, Ponderosa Pine, Oak and Sagebrush Shrublands

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral-Somewhat Increase. The species is in the northern portion of its range where the San Juan Mountains would be a barrier to northern movement, however, the species could move northwest and east around the San Juan's into potential habitat.

B2b) Distribution relative to anthropogenic barriers. Neutral-Somewhat Increase. Occurrences in La Plata and Archuleta counties are located in a shale basin which has intense oil and gas development (Colorado Shale Viewer 2013) and is likely a barrier to dispersal for this species.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Although the San Juan Basin has high potential for solar energy development, there are no planned developments for the area (NRDC 2014).

C1) Dispersal and movements. Increase. Reproduces by seed that falls close to parent plant.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 ft.) shows a mean seasonal temperature variation of 83.6°F/46.5 (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Neutral. Species shows a tolerance to a wide range of temperatures.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 feet) shows total monthly precipitation ranging from 9.46 to 30.81 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Neutral. Species is not dependent on a moisture regime that is highly vulnerable to alteration or loss with climate change.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Species occurs at lower elevations in arid desert and sagebrush shrublands, and pinyon-juniper woodlands.

C3) Restriction to uncommon geological features or derivatives. Neutral-Somewhat Decrease. Species does not appear to have highly edaphic restrictions, but appears to favor substrates underlain by the San Jose, Animas and Nacimiento Formations (Decker 2005).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Inferred from other perennial *Astragalus* species which have a variety of species of bees as pollinators (Decker 2005).

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Increase. Although *A. proximus* has not been studied for nodulization, *Astragalus* species are well known for forming symbiotic relationships with Rhizobium bacteria (Decker 2005).

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Colorado Shale Viewer. 2013. Data mapped by The FracTracker Alliance on FracTracker.org. Original data source: Colorado Oil and Gas Conservation Commission (COGCC). Accessed on Feb. 11, 2014: <http://maps.fractracker.org/latest/?appid=3871156863a54ff2ac98b10235dfff57>
- Decker, K. (2005, September 7). *Astragalus proximus* (Rydberg) Wootton & Standley (Aztec milkvetch): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/astragalusproximus.pdf> [Jan, 28, 2014].
- Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford.
- High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Mesa Verde National Park weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.
- Natural Resources Defense Council (NRDC). 2014. Renewable Energy for America; Energy Map. <http://www.nrdc.org/energy/renewables/energymap.asp>. Accessed January 21, 2013.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Astragalus schmolliae

Schmoll's milkvetch

G1/S1 Candidate for Federal Listing

Family: Fabaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal moisture, short seed dispersal distances, the presence of natural barriers within its limited range, which may restrict movement of the species, and dependence on Rhizobium bacteria to fix nitrogen. Climate models project decreased summer precipitation and increased summer temperatures which may impact germination, recruitment, dispersal and reproductive success of this rare species (Nydick et al. 2012).

Distribution: *A. schmolliae* is known only from Chapin Mesa in Mesa Verde National Park and the Ute Mountain Ute Reservation in Montezuma County, Colorado (NatureServe 2013, CNHP 2013).

Habitat: Grows on mesa tops in openings among pinyon- juniper on thin, wind-deposited, sandy/gravelly soils (CNHP 2013). **Elevation:** 5760-7400 feet.

Ecological System/Habitat: Pinyon-Juniper Woodlands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Astragalus tortipes

Sleeping Ute milkvetch
G1/S1 Candidate for Federal Listing
Family: Fabaceae

no photo available

Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal moisture, short seed dispersal distances, the potential for energy development and the presence of natural and anthropogenic barriers within its limited range, which may restrict movement of the species, and dependence on Rhizobium bacteria to fix nitrogen. Climate models project decreased summer precipitation and increased summer temperatures which may impact germination, recruitment, dispersal and reproductive success of this rare species (Nydick et al. 2012).

Distribution: *A. tortipes* is a Colorado endemic known only from the Ute Mountain Ute Reservation in Montezuma County (NatureServe 2013). **Habitat:** Lower slopes of ridges and knolls, in gravels derived from a volcanic intrusion into Cretaceous Mancos Shale, which separates mountain foothills from desert badlands. Reported to be associated with the white zone of the Upper Cliff House Sandstone (CNHP 2013). **Elevation:** 5450-5690 feet.

Ecological System/Habitat: Desert Shrublands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Astragalus wetherillii

Wetherill's milkvetch

G3/S3

Family: Fabaceae



Photo: Bernadette Kuhn

Climate Vulnerability Score: Presumed Stable

This San Juan region rank is based on the species habitat preference for warmer, arid climates, lack of restriction to specific geologic substrates and presumed pollinator versatility. Pinyon-juniper woodlands are likely to increase with climate change. Climate models project decreased summer precipitation and increased summer temperatures (Nydick et al. 2012).

Distribution: *A. wetherillii* is known from western Colorado and one historical site near Moab, Utah (NatureServe 2013). In Colorado, it is known from Delta, Mesa, Garfield, Moffat Montrose, Ouray, and San Miguel counties (CNHP 2013). **Habitat:** Steep slopes and eroding washes, canyon benches, and talus under cliffs; in sandy clay soils derived from shale or sandstone (CNHP 2013). **Elevation:** 4800-7600 feet.

Ecological System/Habitat: Pinyon-Juniper Woodlands, Shrublands

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral. The species is at the southern edge of its range in the San Juan study area.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Although the San Juan Basin has high potential for solar energy development, there are no planned developments for the area (NRDC 2014).

C1) Dispersal and movements. Increase. Reproduces by seed that falls close to parent plant.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 ft.) shows a mean seasonal temperature variation of 83.6°F/46.5 (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Neutral. Species shows a tolerance to a wide range of temperatures.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 feet) shows total monthly precipitation ranging from 9.46 to 30.81 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Increase. Species is found in sandy soils often in the bottoms of draws and eroding washes.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Species occurs primarily at middle elevations in pinyon-juniper woodlands (Decker 2005, CNHP 2013).

C3) Restriction to uncommon geological features or derivatives. Somewhat Decrease. Species does not appear to have highly edaphic restrictions; substrates vary from Wasatch in the north to Mancos and Morrison Formations in the south (Decker 2005).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Inferred from other perennial *Astragalus* species which have a variety of species of bees as pollinators (Decker 2005).

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Increase. Although *A. wetherillii* has not been studied for nodulization, *Astragalus* species are well known for forming symbiotic relationships with Rhizobium bacteria (Decker 2005).

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics.
Unknown.

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Decker, K. (2005, December 20). *Astragalus wetherillii* Jones (Wetherill's milkvetch): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/astragaluswetherillii.pdf> [Jan. 28, 2014].
- Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford.
- High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Mesa Verde National Park weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.
- Natural Resources Defense Council (NRDC). 2014. Renewable Energy for America; Energy Map. <http://www.nrdc.org/energy/renewables/energymap.asp>. Accessed January 21, 2013.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Botrychium echo

Reflected moonwort

G3/S3

Family: Ophioglossaceae



Climate Vulnerability Score: Moderately Vulnerable

This Gunnison Basin rank is due to restriction to somewhat cool or cold environments, potential loss of habitat due to sedimentation resulting from timber harvest or forest fires, and mycorrhizae requirement for establishment. Often found growing with other *Botrychium* species.

Distribution: Northern Arizona, Northern Utah, and Colorado (Boulder, Clear Creek, Conejos, El Paso, Grand, Gilpin, Gunnison, Lake, Larimer, Park, San Juan and Teller Cos.). **Habitat:** Gravelly soils, rocky hillsides, grassy slopes, and meadows. **Elevation:** 9500-11000 feet.

Ecological System/Habitat: Spruce-Fir Forests

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral.

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Increase. Dispersal of *Botrychium* spores probably occurs over short distances via gravity (Beatty et al. 2003).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral. This species has experienced slightly lower than average (47.1-57°F/26.3-31.8°C) temperature variation in the past 50 years.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Somewhat Increase. Species is somewhat (10-50% of range) restricted to relatively cool or cold environments (upper subalpine/alpine).

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'. Elevations of known *B. echo* occurrences in Colorado range from 8,500-12,000 feet.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Decrease. Species likely has a broad moisture regime tolerance (see C2bi).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Somewhat Increase. Potential sedimentation following timber harvest and/or fires could lead to a loss of habitat for *Botrychium* species. Fire suppression could also lead to a loss of habitat (Anderson and Cariveau 2004).

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Snow cover and ice have not been documented as important element of *B. echo* habitat.

C3) Restriction to uncommon geological features or derivatives. Neutral.

C4a) Dependence on other species to generate habitat. Neutral.

C4c) Pollinator Versatility. Neutral. Does not require pollinators; disperses spores by wind and water.

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Somewhat Increase. Mycorrhizae may be the most important factor for establishment, distribution, and abundance of *Botrychium* species (Johnson-Groh 1998, Johnson-Groh 1999).

C5) Genetic factors. Neutral. Findings suggest that low genetic variability and homozygosity may not be a negative attribute for the persistence of *Botrychium*, either at the species or population level (Kolb and Spribille 2001).

C6) Phenological response to changing seasonal temperature and precipitation dynamics.
Unknown.

Literature Cited

- Anderson, D.G. and D. Cariveau. 2004. *Botrychium echo* W.H. Wagner (reflected grapefern): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region.
<http://www.fs.fed.us/r2/projects/scp/assessments/botrychiumecho.pdf>. [Accessed July 1, 2011]
- Beatty, B.L., W.F. Jennings, and R.C. Rawlinson. 2003. *Botrychium ascendens* W.H. Wagner (trianglelobe moonwort), *B. crenulatum* W.H. Wagner (scalloped moonwort), and *B. lineare* W.H. Wagner (narrowleaf grapefern): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available:
<http://www.fs.fed.us/r2/projects/scp/assessments/botrychiums.pdf>. [Accessed July 1, 2011].
- Johnson-Groh, C.L. 1998. Population demographics, underground ecology and phenology of *Botrychium mormo*. Population and Habitat Viability Assessment Workshop for the Goblin Fern (*Botrychium mormo*): Final Report. CBSG, Apple Valley, MN.
- Johnson-Groh, C.L. 1999. Population ecology of *Botrychium* (moonworts): Status report on Minnesota *Botrychium*. Permanent plot monitoring. Gustavus Adolphus College, St. Peter, MN.
- Kolb, A. and T. Spribille. 2001. Population and Habitat Characteristics of Rare Moonworts (*Botrychium* subgenus *Botrychium*) in Summit County, Colorado. Final Report submitted to the Dillon Ranger District, White River National Forest, Summit County, CO.
- National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Botrychium minganense

Mingan's moonwort

G4G5/S2

Family: Ophioglossaceae



Climate Vulnerability Score: Moderately Vulnerable

This Gunnison Basin rank is due to restriction to somewhat cool or cold environments, potential loss of habitat due to sedimentation resulting from timber harvest or forest fires, and mycorrhizae requirement for establishment. Often found growing with other *Botrychium* species.

Distribution: Among the most widespread and abundant moonworts occurring across the United States and Canada, occurring primarily in northern latitudes and at high elevations to the south.

Habitat: Varies widely from dense forest to open meadow and from summer-dry meadows to permanently saturated fens and seeps. **Elevation:** 10,000-11,000 feet.

Ecological System/Habitat: Spruce-Fir Forests

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral.

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Increase. Dispersal of *Botrychium* spores probably occurs over short distances via gravity (Beatty et al. 2003).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral. This species has experienced slightly lower than average (47.1-57°F/26.3-31.8°C) temperature variation in the past 50 years.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Somewhat Increase. Species is somewhat (10-50% of range) restricted to relatively cool or cold environments (upper subalpine/alpine).

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline, and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'. Elevations of known *B. minganense* occurrences in Colorado range from 9,000-12,000 feet.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Decrease. Species likely has a broad moisture regime tolerance (see C2bi).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Somewhat Increase. Potential sedimentation following timber harvest and/or fires could lead to a loss of habitat for *Botrychium* species. Fire suppression could also lead to a loss of habitat (Anderson and Cariveau 2004).

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Snow cover and ice have not been documented as important element of *B. minganense* habitat.

C3) Restriction to uncommon geological features or derivatives. Neutral.

C4a) Dependence on other species to generate habitat. Neutral.

C4c) Pollinator Versatility. Neutral. Does not require pollinators; disperses spores by wind and water.

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Somewhat Increase. Mycorrhizae may be the most important factor for establishment, distribution, and abundance of Botrychium species (Johnson-Groh 1998, Johnson-Groh 1999).

C5) Genetic factors. Neutral. Findings suggest that low genetic variability and homozygosity may not be a negative attribute for the persistence of Botrychium, either at the species or population level (Kolb and Spribille 2001).

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Anderson, D.G. and D. Cariveau. 2004. Botrychium echo W.H. Wagner (reflected grapefern): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. <http://www.fs.fed.us/r2/projects/scp/assessments/botrychiumecho.pdf>. [Accessed July 1, 2011].
- Beatty, B.L., W.F. Jennings, and R.C. Rawlinson. 2003. *Botrychium ascendens* W.H. Wagner (trianglelobe moonwort), *B. crenulatum* W.H. Wagner (scalloped moonwort), and *B. lineare* W.H. Wagner (narrowleaf grapefern): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/botrychiiums.pdf>. [Accessed July 1, 2011].
- Johnson-Groh, C.L. 1998. Population demographics, underground ecology and phenology of *Botrychium mormo*. Population and Habitat Viability Assessment Workshop for the Goblin Fern (*Botrychium mormo*): Final Report. CBSG, Apple Valley, MN.
- Johnson-Groh, C.L. 1999. Population ecology of *Botrychium* (moonworts): Status report on Minnesota *Botrychium*. Permanent plot monitoring. Gustavus Adolphus College, St. Peter, MN.
- Kolb, A. and T. Spribille. 2001. Population and Habitat Characteristics of Rare Moonworts (*Botrychium* subgenus *Botrychium*) in Summit County, Colorado. Final Report submitted to the Dillon Ranger District, White River National Forest, Summit County, CO.
- National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Botrychium pallidum (*B. furculatum*)

Pale moonwort

G3/S2

Family: Ophioglossaceae



Climate Vulnerability Score: Moderately Vulnerable

This Gunnison Basin rank is due to restriction to somewhat cool or cold environments, potential loss of habitat due to sedimentation resulting from timber harvest or forest fires, and mycorrhizae requirement for establishment. Often found growing with other *Botrychium* species.

Distribution: S Canada, Maine, Michigan and Colorado (Boulder, Conejos, Gunnison, Larimer, Park, San Juan and Teller Cos.) One documented location (near Molas Pass) in the San Juan Region.

Habitat: Open exposed hillsides, burned or cleared areas, old mining sites. **Elevation:** 10,000-10,500 feet.

Ecological System/Habitat: Spruce-Fir Forests

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral.

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Increase. Dispersal of *Botrychium* spores probably occurs over short distances via gravity (Beatty et al. 2003).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral. This species has experienced slightly lower than average (47.1-57°F/26.3-31.8°C) temperature variation in the past 50 years.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Somewhat Increase. Species is somewhat (10-50% of range) restricted to relatively cool or cold environments (upper subalpine/alpine).

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'. Elevations of known *B. pallidum* occurrences in Colorado range from ca. 9,000-12,000 feet.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Decrease. Species likely has a broad moisture regime tolerance (see C2bi).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Somewhat Increase. Potential sedimentation following timber harvest and/or fires could lead to a loss of habitat for *Botrychium* species. Fire suppression could also lead to a loss of habitat (Anderson and Cariveau 2004).

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Snow cover and ice have not been documented as important element of *B. pallidum* habitat.

C3) Restriction to uncommon geological features or derivatives. Neutral.

C4a) Dependence on other species to generate habitat. Neutral.

C4c) Pollinator Versatility. Neutral. Does not require pollinators; disperses spores by wind and water.

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Somewhat Increase. Mycorrhizae may be the most important factor for establishment, distribution, and abundance of *Botrychium* species (Johnson-Groh 1998, Johnson-Groh 1999).

C5) Genetic factors. Neutral. Findings suggest that low genetic variability and homozygosity may not be a negative attribute for the persistence of *Botrychium*, either at the species or population level (Kolb and Spribille 2001).

C6) Phenological response to changing seasonal temperature and precipitation dynamics.
Unknown.

Literature Cited

- Anderson, D.G. and D. Cariveau. 2004. *Botrychium* echo W.H. Wagner (reflected grapefern): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region.
<http://www.fs.fed.us/r2/projects/scp/assessments/botrychiumecho.pdf> [Accessed July 1, 2011].
- Beatty, B.L., W.F. Jennings, and R.C. Rawlinson. 2003. *Botrychium ascendens* W.H. Wagner (trianglelobe moonwort), *B. crenulatum* W.H. Wagner (scalloped moonwort), and *B. lineare* W.H. Wagner (narrowleaf grapefern): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available:
<http://www.fs.fed.us/r2/projects/scp/assessments/botrychiums.pdf>. [July 1, 2011].
- Johnson-Groh, C.L. 1998. Population demographics, underground ecology and phenology of *Botrychium mormo*. Population and Habitat Viability Assessment Workshop for the Goblin Fern (*Botrychium mormo*): Final Report. CBSG, Apple Valley, MN.
- Johnson-Groh, C.L. 1999. Population ecology of *Botrychium* (moonworts): Status report on Minnesota *Botrychium*. Permanent plot monitoring. Gustavus Adolphus College, St. Peter, MN.
- Kolb, A. and T. Spribille. 2001. Population and Habitat Characteristics of Rare Moonworts (*Botrychium* subgenus *Botrychium*) in Summit County, Colorado. Final Report submitted to the Dillon Ranger District, White River National Forest, Summit County, CO.
- National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Botrychium pinnatum

Northern moonwort

G4? /S1

Family: Ophioglossaceae



Climate Vulnerability Score: Moderately Vulnerable

This Gunnison Basin ranks is due to restriction to somewhat cool or cold environments, potential loss of habitat due to sedimentation resulting from timber harvest or forest fires, and mycorrhizae requirement for establishment.

Distribution: Widely throughout western North America from high elevations in northern California, northern Nevada, northern Arizona, Utah and Colorado (Mineral and San Juan Cos.) to near sea level in Alaska and northwestern Canada. However, it is rare throughout its range.

Habitat: Most commonly found in moist grassy sites in open forests and meadows. Often occurring near streams and other sites where soil moisture is constant. **Elevation:** 10,000-11,000 feet.

Ecological System/Habitat: Spruce-Fir Forests

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral.

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Increase. Dispersal of *Botrychium* spores probably occurs over short distances via gravity (Beatty et al. 2003).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral. This species has experienced slightly lower than average (47.1-57°F/26.3-31.8°C) temperature variation in the past 50 years.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Somewhat Increase. Species is somewhat (10-50% of range) restricted to relatively cool or cold environments (upper subalpine/alpine).

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'. Elevations of known *B. pinnatum* occurrences in Colorado range from 10,000-12,000 feet.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Decrease. Species likely has a broad moisture regime tolerance (see C2bi). It is primarily found in mesic meadows, subalpine meadows, and forested streambanks (Legler 2010).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Somewhat Increase. Potential sedimentation following timber harvest and/or fires could lead to a loss of habitat for *Botrychium* species. Fire suppression could also lead to a loss of habitat (Anderson and Cariveau 2004).

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Snow cover and ice have not been documented as important element of *B. pinnatum* habitat.

C3) Restriction to uncommon geological features or derivatives. Neutral.

C4a) Dependence on other species to generate habitat. Neutral.

C4c) Pollinator Versatility. Neutral. Does not require pollinators; disperses spores by wind and water.

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Somewhat Increase. Mycorrhizae may be the most important factor for establishment, distribution, and abundance of *Botrychium* species (Johnson-Groh 1998, Johnson-Groh 1999).

C5) Genetic factors. Neutral. Findings suggest that low genetic variability and homozygosity may not be a negative attribute for the persistence of *Botrychium*, either at the species or population level (Kolb and Spribille 2001).

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Anderson, D.G. and D. Cariveau. 2004. *Botrychium* echo W.H. Wagner (reflected grapefern): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. <http://www.fs.fed.us/r2/projects/scp/assessments/botrychiumecho.pdf> [Accessed July 1, 2011].
- Beatty, B.L., W.F. Jennings, and R.C. Rawlinson. 2003. *Botrychium ascendens* W.H. Wagner (trianglelobe moonwort), *B. crenulatum* W.H. Wagner (scalloped moonwort), and *B. lineare* W.H. Wagner (narrowleaf grapefern): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/botrychiums.pdf>. [July 1, 2011].
- Johnson-Groh, C.L. 1998. Population demographics, underground ecology and phenology of *Botrychium mormo*. Population and Habitat Viability Assessment Workshop for the Goblin Fern (*Botrychium mormo*): Final Report. CBSG, Apple Valley, MN.
- Johnson-Groh, C.L. 1999. Population ecology of *Botrychium* (moonworts): Status report on Minnesota *Botrychium*. Permanent plot monitoring. Gustavus Adolphus College, St. Peter, MN.
- Kolb, A. and T. Spribille. 2001. Population and Habitat Characteristics of Rare Moonworts (*Botrychium* subgenus *Botrychium*) in Summit County, Colorado. Final Report submitted to the Dillon Ranger District, White River National Forest, Summit County, CO.
- Legler, B. 2010. Unpublished Draft of *Botrychium* fact sheets.
- National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Calochortus flexuosus

Weak-stemmed mariposa lily

G4/S2

Family: Liliaceae



Climate Vulnerability Score: Presumed Stable

This San Juan region rank is based on the species habitat preference for warmer, arid climates and presumed pollinator versatility. Warm, dry desert shrublands are likely to increase with climate change. Climate models project decreased summer precipitation and increased summer temperatures (Nydick et al. 2012).

Distribution: *Calochortus flexuosus* is known from the Mojave Desert of Arizona, Utah, Nevada, and California. Also known from the Four Corners region of Colorado and New Mexico (NatureServe 2013). In Colorado, it is known from Montezuma and San Miguel counties, and historically from Montrose county (CNHP 2013). **Habitat:** Dry stony slopes, rocky mesas and desert hills (CNHP 2013). **Elevation:** 4600-7300 feet.

Ecological System/Habitat: Desert Shrublands, Desert Grasslands, Pinyon-Juniper Woodlands

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral. The species is at the eastern edge of its range in the San Juan study area.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Although the San Juan Basin has high potential for solar energy development, there are no planned developments for the area (NRDC 2014).

C1) Dispersal and movements. Increase. Reproduces by seed that falls close to parent plant; occasionally seed is moved with precipitation away from the parent plant (Panjabi and Anderson 2006).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows a mean seasonal temperature variation of 86.45°F/48.02°C) (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Neutral. Species shows a tolerance to a wide range of temperatures.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows total monthly precipitation ranging from 5.23 to 26.34 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Neutral. Species is not dependent on a moisture regime that is highly vulnerable to loss or alteration with climate change.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown. Although many *Calochortus* species are gap specialists and depend on disturbances such as fire to open the habitat, the specific response of *C. flexuosus* to fire has not been investigated. (Panjabi and Anderson 2006).

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Species occurs in xeric habitats (Panjabi and Anderson 2006).

C3) Restriction to uncommon geological features or derivatives. Somewhat Increase. In Colorado, the species occurs primarily on soils derived from the Mancos and Morrison formations; (Panjabi and Anderson 2006).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Inferred from other perennial *Calochortus* species that appear to be generalists (Panjabi and Anderson 2006).

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford.
- High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Mesa Verde National Park weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.
- Natural Resources Defense Council (NRDC). 2014. Renewable Energy for America; Energy Map. <http://www.nrdc.org/energy/renewables/energymap.asp>. Accessed January 21, 2013.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- Panjabi, S.S. and D.G. Anderson. (2006, July 24). *Calochortus flexuosus* S. Watson (winding mariposa lily): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/calochortusflexuosus.pdf> [date of access]. Accessed December 9, 2013.
- USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Castilleja puberula

Downy indian-paintbrush

G2G3/S2S3

Family: Scrophulariaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species' limited dispersal ability, moderate dependence on ice or snow habitats, preference for cooler temperatures and the presence of natural barriers within its range. Climate model predictions indicate that by mid-21st century, average summer daytime temperatures in the San Juan region are expected to increase +6.7 °F relative to the 1971-2000 time periods, thus reducing the seasonal duration of ice and snow habitats (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *C. puberula*.

Distribution: *C. puberula* is endemic to Colorado, known from Archuleta, Boulder, Clear Creek, Conejos, and Grand, Larimer, and Park counties (CNHP 2013). **Habitat:** Occurs in rocky tundra on high peaks of the Continental Divide. **Elevation:** 10,275-13,020 feet.

Ecological System/Habitat: Alpine, Shrub Tundra

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDO I Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Cryptantha gypsophila (Oreocarya revealii)

Gypsum Valley cateye

G2/S2

BLM sensitive

Family: Boraginaceae



Photo: Susan Panjabi

Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal moisture, short seed dispersal distances, the potential for energy development and the presence of natural barriers within its limited range, and its preference for a specific geologic substrate. Climate models project decreased summer precipitation and increased summer temperatures which may impact germination, recruitment, dispersal and reproductive success of this rare species (Nydick et al. 2012).

Distribution: Colorado endemic known from Montrose and San Miguel counties (CNHP 2013).

Habitat: Occurs on the grayish, near-barren gypsum hills of the Paradox Member of the Hermosa Formation in western Colorado. **Elevation:** 5390-6790 feet.

Ecological System/Habitat: Barrens, Pinyon-Juniper Woodlands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOI Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Cryptogramma stelleri

Slender rock-brake
G5/S2
BLM sensitive
Family: Pteridaceae



Climate Vulnerability Score: Extremely Vulnerable

This San Juan region rank is based on restriction to cool, shaded cliff faces, the presence of cliffs and canyons that serve as natural barriers in suitable habitat, restriction to calcareous cliff faces and overhangs with dripping water. Climate model predictions indicate that by mid-21st century, average summer daytime temperatures in the San Juan region are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). Summer precipitation is expected to decrease by -0.9 inches (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *C. stelleri*.

Distribution: Distribution of *C. stelleri* is nearly circumpolar (NatureServe 2013). It is widespread throughout the United States. In Colorado it has been reported from Archuleta, Conejos, Garfield, Grand, Gunnison, Ouray, San Juan, San Miguel, and Summit Counties) (CNHP 2013). **Habitat:** Occurs in cracks and crevices of limestone cliffs in moist coniferous forests, generally associated with dripping water. **Elevation:** 4700-10,900 feet.

Ecological System/Habitat: Groundwater Dependent Wetlands, Cliff and Canyon Seeps

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Somewhat Increase. Species grows on cliff walls and in shallow rock overhangs that serve as natural barriers.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Occurs cliff walls and in shallow rock overhangs. We rated all cliff and canyon species 'Neutral' based on the assumption that development in this habitat is unlikely in most mitigation scenarios.

C1) Dispersal and movements. Neutral. Although dispersal mechanisms are unknown, wind and water likely transport spores.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows a mean seasonal temperature variation of 86.45°F/48.02°C) (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Increase. Species that occur in seeps in cliffs and canyons were all rated 'Increase' under the assumption that this habitat may be lost as Colorado becomes warmer, and presumably drier.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows total monthly precipitation ranging from 5.23 to 26.34 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Greatly Increase. Species occurs on cliff walls and in shallow rock overhangs with dripping water. We rated cliff and canyon species that prefer wetter micro sites as 'Greatly Increase' based on the assumption that these habitats may be lost as Colorado's climate becomes warmer and drier.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Little dependence on snow or ice cover.

C3) Restriction to uncommon geological features or derivatives. Increase. Species is restricted to calcareous cliffs and canyons (Hulten 1968).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. *C. stelleri* is a fern that produces spores, so it does not rely on pollinators.

C4d) Dependence on other species for propagule dispersal. Unknown.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics.
Unknown.

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Barsugli, J. 2010. Hydrologic Projections for the Gunnison Basin. Presentation at Follow-up meeting for the Climate Change Adaptation Workshop. Gunnison, Colorado.

Cozzetto, K., Rangwala, I. and J. Neff. 2011. Downscaled Air Temperature and Precipitation Projections for the San Juan Mountain Region. Narrative on Regional Climate Model Projections submitted to the San Juan Public Land Center, Durango, Colorado.

High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Cortez weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.

Hulten, E. 1968. Flora of Alaska and Neighboring Territories. Stanford University Press, Stanford, CA.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozzetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Descurainia kenheilii

Heil's tansy mustard

G1/S1

Family: Brassicaceae

No photo available

Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on restriction to cold environments, inability for long distance seed dispersal, dependence on ice and snow, and the presence of natural barriers within its habitat. Climate model predictions indicate that by mid-21st century, average summer daytime temperatures in the San Juan region are expected to increase +6.7 °F relative to the 1971-2000 time periods thus reducing the presence of ice and snow (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *D. kenheilii*.

Distribution: Endemic to, San Juan County, Colorado (Stony Pass). **Habitat:** Alpine tundra on thin soil and talus slopes, on an andesite porphyry and rhyolite tuff substrate. **Elevation:** 12,200-12,950 feet.

Ecological System/Habitat: Alpine, Meadow Tundra

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDO I Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Draba fladnizensis

Arctic draba

G4/S2

Family: Brassicaceae



Climate Vulnerability Score: Highly Vulnerable

This Gunnison Basin rank is based on restriction to cold environments, inability for long distance seed dispersal, and dependence on ice and snow.

Distribution: Alaska to Greenland. It extends south in the Rocky Mountains to Colorado and Utah. Also occurs in Eurasia. **Habitat:** Rock outcrops and talus, alpine meadows, sandy gravel. **Elevation:** 11,500-12,800 feet.

Ecological System/Habitat: Alpine

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Increase and Somewhat Increase. Occurs in the upper subalpine and alpine from 11,000-14,000 ft.

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Somewhat Increase. Dispersal of tiny *Draba* seeds through boulder and scree is likely to occur over very small distances.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Greatly Increase. Species is completely or almost completely restricted to relatively cool or cold environments (upper subalpine/alpine). Alpine habitats are likely to be reduced as Colorado becomes warmer, and presumably drier. Climate models project earlier, faster snowmelt along with decreased

summer precipitation and increased summer temperatures (Barsugli 2010). This would result in significantly lower amounts of water stored in the soils during the summer.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Decrease. Species likely has a broad moisture regime tolerance (see C2bi).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Increase. Species is found in the alpine above 11,000 ft.

C3) Restriction to uncommon geological features or derivatives. Neutral. Known to occur on a range of substrates in the alpine.

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. No data, forced score.

C4d) Dependence on other species for propagule dispersal. Unknown.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

Barsugli, J. 2010. Hydrologic Projections for the Gunnison Basin. Presentation at Follow-up meeting for the Climate Change Adaptation Workshop. Gunnison, Colorado.

National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Draba graminea

San Juan draba

G2/S2

Family: Brassicaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species restriction to cold environments, inability for long distance seed dispersal, dependence on ice and snow, and the presence of natural barriers within its habitat. Climate model predictions indicate that by mid-21st century, average summer daytime temperatures in the San Juan region are expected to increase +6.7 °F relative to the 1971-2000 time periods thus reducing the presence of ice and snow (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *D. graminea*.

Distribution: Colorado endemic known from Dolores, Hinsdale, La Plata, Montezuma, Ouray, Rio Grande, San Juan, and San Miguel counties (CNHP 2013). **Habitat:** Found in the crevices of rock outcrops, talus slopes, late snowmelt areas, and alpine tundra along the Continental Divide and the greater San Juan Mountains. **Elevation:** 9600-13,690 feet.

Ecological System/Habitat: Alpine (exposed rock)

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDO I Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Draba malpighiacea

Whitlow-grass

G1? /S1?

Family: Brassicaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species restriction to cooler environments, inability for long distance seed dispersal, dependence on seasonal precipitation, and the presence of natural barriers within its habitat. Climate model predictions indicate that by mid-21st century, average summer daytime temperatures in the San Juan region are expected to increase +6.7 °F relative to the 1971-2000 time periods. Summer precipitation is expected to decrease by -0.9 inches (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *D. malpighiacea*.

Distribution: Colorado endemic, known from Hinsdale, La Plata, and Montezuma counties (CNHP 2013). **Habitat:** Found in rock outcrops and rocky slopes on alpine ridgetops and in subalpine conifer forests. **Elevation:** 9760-13,000 feet.

Ecological System/Habitat: Spruce-Fir Forests, Alpine

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDO I Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Draba rectifruca

Mountain draba

G3G4/S3

Family: Brassicaceae



Climate Vulnerability Score: Increase Likely

This Gunnison Basin rank is based on tolerance for broad moisture and climate regime.

Distribution: Arizona, Colorado, New Mexico, and Utah. **Habitat:** Found in open forests, meadows, and on open slopes. **Elevation:** 8,800-10,600 feet.

Ecological System/Habitat: Spruce-Fir Forests

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral.

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Somewhat Increase. Dispersal of tiny *Draba* seeds through montane habitats is likely to occur over very small distances.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced a greater than average temperature (>70°F/43.0°C) variation in the past 50 years (Colorado Climate Trends 2011).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Neutral.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'. Although the station is higher in elevation than known *Draba rectifruca* habitat (8,000-9,600 ft.), it offers the best available climate data in the area.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Decrease. Species likely has a broad moisture regime tolerance (see C2bi).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Little dependence on snow or ice cover.

C3) Restriction to uncommon geological features or derivatives. Neutral. Known to occur in sagebrush openings in lodgepole pine forests in the Gunnison Basin.

C4a) Dependence on other species to generate habitat. Unknown.

C4c) Pollinator Versatility. Neutral. No data, forced score.

C4d) Dependence on other species for propagule dispersal. Neutral. No data, forced score.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

Colorado Climate Trends. 2011. Total Annual Precipitation Historic Data from Cochetopa Creek weather station. <http://climatetrends.colostate.edu/>. Accessed June 6, 2011.

National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Draba smithii

Smith whitlow-grass

G2/S2

Family: Brassicaceae



Photo: Steve O'Kane

Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species restriction to cooler environments, inability for long distance seed dispersal, dependence on seasonal precipitation, the potential for energy development and the presence of natural barriers within its habitat, and its preference for a specific geologic substrate. Climate model predictions indicate that by mid-21st century, average summer daytime temperatures in the San Juan region are expected to increase +6.7 °F relative to the 1971-2000 time periods. Summer precipitation is expected to decrease by -0.9 inches (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *D. smithii*.

Distribution: Thought to be a Colorado endemic (Alamosa, Archuleta, Custer, Las Animas, Mineral, and Saguache counties), however there have been reports of the species from New Mexico (CNHP 2013). **Habitat:** Found on talus slopes and crevices between rocks in shaded, protected sites with little other vegetation; in upper montane and lower subalpine areas. **Elevation:** 7400-13,450 feet.

Ecological System/Habitat: Cliffs and Canyons, Spruce-Fir Forests

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDO I Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Draba streptobrachia

Colorado Divide whitlow-grass

G3/S3

Family: Brassicaceae



Climate Vulnerability Score: Extremely Vulnerable

This Gunnison Basin rank is based on restriction to cold environments, inability for long distance seed dispersal, and dependence on ice and snow.

Distribution: Colorado (Alamosa, Clear Creek, Conejos, Grand, Hinsdale, Jackson, Larimer, Lake, La Plata, Mineral, Park, Pitkin, Rio Grande, and San Juan counties). **Habitat:** Alpine tundra, scree, ridges, and alpine slopes. Turf, fell fields, talus slopes, crevices in rock ledges, and loose soils.

Elevation: 10,500-13,200 feet.

Ecological System/Habitat: Alpine

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Increase. Restricted to the alpine in the Gunnison Basin, with one known occurrence at 11,500 feet.

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Somewhat Increase. Dispersal of tiny *Draba* seeds through boulder and scree is likely to occur over very small distances.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Greatly Increase. Species is completely or almost completely restricted to relatively cool or cold environments (upper subalpine/alpine). Alpine habitats are likely to be reduced as Colorado becomes warmer, and presumably drier. Climate models project earlier, faster snowmelt along with decreased summer precipitation and increased summer temperatures (Barsugli 2010). This would result in significantly lower amounts of water stored in the soils during the summer.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Decrease. Species likely has a broad moisture regime tolerance (see C2bi).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Increase. Species is found in the alpine above 12,500 ft.

C3) Restriction to uncommon geological features or derivatives. Neutral.

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. No data, forced score.

C4d) Dependence on other species for propagule dispersal. Unknown.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

Barsugli, J. 2010. Hydrologic Projections for the Gunnison Basin. Presentation at Follow-up meeting for the Climate Change Adaptation Workshop. Gunnison, Colorado.

National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Drosera anglica

English sundew
G5/S1, FS sensitive
Family: Droseraceae



Climate Vulnerability Score: Moderately Vulnerable

This San Juan region rank is due to restriction to montane fens, short dispersal distance, and lack of genetic diversity.

Distribution: Eurasia; circumboreal areas of United States and Canada; south to Wyoming and Colorado (NatureServe 2013). Colorado's only known occurrence is from La Plata County (CNHP 2013). **Habitat:** Peat moss (*Sphagnum*) dominated fens. **Elevation:** 8500 feet.

Ecological System/Habitat: Groundwater Dependent Wetlands (fens)

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral. No significant barriers to movement are known.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Wetland species are ranked as neutral under the general assumption that wetlands are less likely to be developed under climate change mitigation scenarios than other habitats.

C1) Dispersal and movements. Somewhat Increase. Dispersal mechanisms include flowing water, wind, or animals, but dispersal likely occurs over short distances (Wolf et al. 2006).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced a greater than average temperature (>70°F/43.0°C) variation in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 feet) shows a mean seasonal temperature variation of 83.6°F/46.5 (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Somewhat Increase. Species is moderately restricted to cool or cold environments (fens at 8,500 ft.).

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced **average (21-40 inches/509-1,016 mm)** precipitation variation in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 feet) shows total monthly precipitation ranging from 9.46 to 30.81 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Greatly Increase. *D. anglica* is an obligate wetland species, and is restricted to groundwater dependent fens.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Increase. Species occurs in fens at 8,500 feet where snow cover likely provides insulation.

C3) Restriction to uncommon geological features or derivatives. Increase. *D. anglica* is an obligate wetland species that requires continuously wet organic soils and is found in sites with shallow water table depths (Reed 1996; Wolf et al. 2006). This species occurs in fens with peat soils. Due to the slow accumulation of peat, fens take centuries to develop and are essentially irreplaceable (Decker et al. 2006). Many of the fens in Colorado are over 10,000 years old with organic soil accumulation rates ranging from 4.3 to 16.2 inches per thousand years (U.S. Fish and Wildlife Service 1999).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Sexual reproduction is achieved almost exclusively through self-pollination (Engelhardt 1998).

C4d) Dependence on other species for propagule dispersal. Neutral. No data, forced score.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Neutral/Somewhat Increase. *D. anglica* is carnivorous, and this species derives a significant proportion of nutrients from digesting animal tissue (Wolf et al. 2006). A study of prey diversity showed that *D. anglica* trapped individuals from over 13 different arthropod orders, with Dipterans (flies) as the most common prey (Achterberg 1973 in Juniper 1989).

C5) Genetic factors. Somewhat Increase. A study of *D. rotundifolia* found little genetic variation among and within occurrences in Colorado and California. This lack of variability is expected for *D.*

anglica, as its primary mode of reproduction is also asexual, and it is similarly disjunct from major populations (Cohu 2003; Wolf et al. 2006).

C6) Phenological response to changing seasonal temperature and precipitation dynamics.

Unknown.

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Cohu, C. 2003. Population genetic analysis of Colorado's *Drosera rotundifolia* using allozyme electrophoresis. Thesis. Western State College, Gunnison, CO.
- Decker, K., D. Culver, and D.G. Anderson. 2006. *Eriophorum chamissonis* C.A. Medy. (Chamisso's cottongrass): a technical conservation assessment. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/eriophorumchamissonis.pdf>. Accessed December 12, 2013.
- Engelhardt, T.L. 1998. Pollination ecology of the round-leaved sundew, *Drosera rotundifolia* L. (Droseraceae) in Sequoia National Park, California. PhD dissertation. California State University, Fullerton, CA.
- High Plains Regional Climate Center. 2013. Historical Climate Data Summaries. Mesa Verde National Park, Colorado. Period of Record: 1940-1990. Online: <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 2, 2013.
- Juniper, B.E., R.J. Robins, and D.M. Joel. 1989. The Carnivorous Plants. Academic Press. London, UK.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- Reed, P.B. 1996. National list of plant species that occur in wetlands. Draft report. USDI Fish and Wildlife Service, St. Petersburg, FL. Available online: <http://www.fws.gov/nwi/bha/list96.html>.
- U.S. Fish and Wildlife Service. 1999. Regional policy on the protection of fens, peatland mitigation policy consideration. Ecological Services, Colorado Field Office. Lakewood, CO.
- Wolf, E., E. Gage, and D. Cooper. 2006. *Drosera anglica* Huds. (English sundew): A Technical Conservation Assessment. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/droseraanglica.pdf>. Accessed December 6, 2013.

Epipactis gigantea

Giant helleborine

G4/S1

FS sensitive

Family: Orchidaceae



Climate Vulnerability Score: Moderately Vulnerable

This San Juan region rank is due to the lack of significant natural barriers or dispersal limitations for this species. It is not significantly restricted to cool or cold environments. The following factors contribute to its vulnerability: restriction to wetlands, evidence of a specialized relationship with syrphid flies, and seeds that require mycorrhizae for germination.

Distribution: *E. gigantea* extends south from British Columbia to the western United States, reaching Texas, and one known location in Mexico (Rocchio et al. 2006). In Colorado, it is known from Archuleta, Chaffee, Delta, Mesa, Moffat, Montrose, Montezuma, and Saguache Counties (CNHP 2013). **Habitat:** Seeps, streambanks, and hanging gardens (Rocchio et al. 2006). **Elevation:** 4700-8900 feet.

Ecological System/Habitat: Groundwater Dependent Wetlands, Riparian Areas

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral. No significant barriers to movement are known.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. *E. gigantea* is an obligate wetland species. Wetland species are ranked as neutral under the general assumption that wetlands are less likely to be developed under climate change mitigation scenarios than other habitats.

C1) Dispersal and movements. Neutral. *E. gigantea* produces numerous small seeds, and are likely dispersed over long distances by wind and water (Rocchio et al. 2006; Walker and del Moral 2003).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 ft.) shows a mean seasonal temperature variation of 83.6°F/46.5 (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Neutral. Species is not significantly restricted to cool or cold environments. Although it is an obligate wetland species, it is found in low elevation sites in the San Juan Region.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 feet) shows total monthly precipitation ranging from 9.46 to 30.81 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Increase. *E. gigantea* is an obligate wetland species.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Little dependence on snow or ice cover.

C3) Restriction to uncommon geological features or derivatives. Neutral/Somewhat Increase. Several occurrences of *E. gigantea* are associated with geothermal springs (CNHP 2013).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Somewhat Increase. *E. gigantea* may attract generalist pollinators, but there is evidence of a specialized relationship with syrphid flies (Dressler 1981; Luer 1975).

C4d) Dependence on other species for propagule dispersal. Neutral. *E. gigantea* are likely dispersed over long distances by wind and water (Rocchio et al. 2006; Walker and del Moral 2003).

C4e) Forms part of an interspecific interaction not covered by C4a-d. Somewhat Increase. *E. gigantea* seeds require mycorrhizae for germination (Arditti et al. 1981; Dressler 1981).

C5) Genetic factors. Neutral. It is likely that most occurrences in USFS Region 2, which includes Colorado, contain considerable genetic variability (Thornhill 1996).

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Arditti, J., J.D. Michaud, A.P. Olivia, and P. Allison. 1981. Seed germination of North American orchids, I. Native California and related species of *Calypso*, *Epipactis*, *Goodyera*, *Piperia*, and *Platanthera*. *Botanical Gazette* 142(4):442-453.
- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Dressler, R.L. 1981. *The Orchids: Natural history and classification*. Harvard University Press, Cambridge, MA.
- High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Mesa Verde National Park weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.
- Luer, C.A. 1975. *The Native Orchids of the United States and Canada, Excluding Florida*. New York Botanical Garden, New York, NY. 362 pp.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. *Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research*. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- Rocchio, J., M. March, and D.G. Anderson. 2006. *Epipactis gigantea* Dougl. ex Hook. (stream orchid): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/epipactisgigantea.pdf>. Accessed December 11, 2013.
- Thornhill, A. 1996. *Species and occurrence-level patterns of genetic variation in Epipactis gigantea (Orchidaceae), with examination of local genetic and clonal structure in riparian and bog occurrences inferred from allozyme analysis*. Ph.D. Dissertation, University of California, Irvine, CA.
- Walker, L.R. and R. del Moral. 2003. *Primary Succession and Ecosystem Rehabilitation*. Cambridge University Press, Cambridge, UK.

Erigeron kachinensis

Kachina daisy

G2/S1 - BLM sensitive

Family: Asteraceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on restriction to cool, shaded cliff faces, the presence of cliffs and canyons that serve as natural barriers in suitable habitat, restriction to sandstone cliff faces and overhangs with dripping water, and limited dispersal ability. Climate model predictions indicate that by mid-21st century, average summer daytime temperatures in the San Juan region are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). Summer precipitation is expected to decrease by -0.9 inches (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *E. kachinensis*.

Distribution: Endemic to the Colorado Plateau in southeast Utah and southwest Colorado. In Colorado, known from Dolores, Gunnison, Mesa, Montrose, and San Miguel counties (USDA, NRCS 2013, and CNHP 2013). **Habitat:** Found in wet, saline soils in alcoves, seeps, and hanging gardens on sandstone cliffs and canyon walls. **Elevation:** 4700-6650 feet.

Ecological System/Habitat: Groundwater Dependent Wetlands, **Cliff** and Canyon Seeps

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Erigeron lanatus

Woolly fleabane

G3G4/S2

Family: Asteraceae

no photo available

Climate Vulnerability Score: Extremely Vulnerable

This Gunnison Basin rank is based on restriction to cold environments, inability for long distance seed dispersal, and dependence on ice and snow.

Distribution: British Columbia, S Alberta, NW Montana. Disjunct in Wyoming and Colorado (Chaffee, Gunnison and Pitkin Cos.). **Habitat:** Steep alpine scree and talus slopes. **Elevation:** 12,500-13,500 feet.

Ecological System/Habitat: Alpine

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Increase. Known occurrences have been documented above 11,500 feet.

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Neutral. Seeds are wind-dispersed, and characterized by moderate dispersal capability.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Greatly Increase. Species is completely or almost completely restricted to relatively cool or cold environments (alpine). Alpine habitats are likely to be reduced as Colorado becomes warmer, and presumably drier. Climate models project earlier, faster snowmelt along with decreased summer precipitation and increased summer temperatures (Barsugli 2010). This would result in significantly lower amounts of water stored in the soils during the summer.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were

rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Decrease. Species likely has a broad moisture regime tolerance (see C2bi).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Increase. Species is found in the alpine above 11,500 ft.

C3) Restriction to uncommon geological features or derivatives. Somewhat Increase. Species is found growing on limestone talus (FNA eds. 1993+).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. No data, forced score.

C4d) Dependence on other species for propagule dispersal. Neutral. Plumed achenes are likely wind-dispersed.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

Barsugli, J. 2010. Hydrologic Projections for the Gunnison Basin. Presentation at Follow-up meeting for the Climate Change Adaptation Workshop. Gunnison, Colorado.

Flora of North America Editorial Committee (FNA), eds. 1993+. Flora of North America North of Mexico. 12+ vols. New York and Oxford.

National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Eriogonum clavellatum

Comb wash buckwheat
G2/S1, BLM sensitive
Family: Polygonaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the potential for energy development and the presence of anthropogenic barriers within suitable habitat, limited seed dispersal, and dependence on seasonal moisture. Climate model predictions indicate that by mid-21st century summer precipitation is expected to decrease by -0.9 inches in the San Juan region. Average summer daytime temperatures are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *E. clavellatum*.

Distribution: This species is known from New Mexico, Utah, and Colorado (USDA, NRCS 2013). In Colorado it is known only from Montezuma County (CNHP 2013). **Habitat:** Occurs on fine textured soils with shadscale and blackbrush. **Elevation:** 4800-6030 feet.

Ecological System/Habitat: Desert Shrublands, Barrens

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Eriophorum altaicum var. *neogaeum*

Altai cottongrass

G4? T3T4/S3

Family: Cyperaceae



Photo: Peggy Lyon

Climate Vulnerability Score: Extremely Vulnerable

This Gunnison Basin rank is based on the species restriction to high elevation fens. Although fens treated as a plant community are ranked “Low” for vulnerability, individual species within fens often occur on the margins, and are likely susceptible to small changes in the alteration of hydrology.

Distribution: Alaska, British Columbia, Uinta Mountains in Utah, and Colorado (Eagle, Park and San Juan, San Miguel, and Saguache Cos.).

Habitat: Fens. **Elevation:** 9500-14,000 feet.

Ecological System/Habitat: Groundwater Dependent Wetlands (fens)

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Somewhat Increase. *E. altaicum* var. *neogaeum* has been documented in the Gunnison Basin above 11,500 feet.

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Somewhat Increase. Dispersal is likely by wind and water, as this is a wetland/fen species.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Greatly Increase. Species is moderately restricted to relatively cool or cold environments (fens above 11,500 ft.).

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Greatly Increase. *E. altaicum var. neogaeum* is a species found in wet meadows and fens, and requires continuously moist or saturated soils.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Increase. Species is found in fens at or above treeline, and likely depends on deep snow cover.

C3) Restriction to uncommon geological features or derivatives. Increase *E. altaicum var. neogaeum* is a species found in wet meadows and fens, and requires continuously moist or saturated soils.

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Likely wind-pollinated.

C4d) Dependence on other species for propagule dispersal. Neutral. Seeds are likely dispersed through wind and water.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Eriophorum chamissonis

Russet cottongrass
G5/S1, FS sensitive
Family: Cyperaceae



Climate Vulnerability Score: Moderately Vulnerable

This San Juan region rank is due to the species restriction to high elevation fens, presence of high mountains that serve as natural barriers in suitable habitat, and dependence on ice and snow.

Distribution: Circumpolar distribution including Eurasia, Canada, most of the northern United States south to Colorado (NatureServe 2013). Known from four counties in Colorado: Eagle, Gunnison, La Plata, Pitkin, and San Juan (CNHP 2013). **Habitat:** Fens, marshes, and sedge hummocks in montane and subalpine areas (CNHP 2013). **Elevation:** 10,100-11,800 feet.

Ecological System/Habitat: Groundwater Dependent Wetlands (fens)

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Somewhat Increase. This species occurs in high elevation (10,100-11,800 ft.) fens. Local mountain ranges and ridges create natural barriers for dispersal.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Wetland species are ranked as neutral under the general assumption that wetlands are less likely to be developed under climate change mitigation scenarios than other habitats.

C1) Dispersal and movements. Neutral. Achenes of *E. chamissonis* are plumed, an adaptation that presumably aids in wind dispersal (Burrows 1975). Wind is also a likely dispersal agent (Decker et al. 2006). Seeds must land in suitable fen or wetland with saturated organic soils to germinate.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral. Species has experienced average temperature variation (57.1-77°F/31.8-43.0°C) in the past 50 years. Data from the Red Mountain Snotel site (elevation: 11,200 ft.) shows a mean seasonal temperature variation of 77°F /43°C (NRCS 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Greatly Increase. Species is completely restricted to cool or cold environments (10,100-11,800 ft.).

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced **average (21-40 inches/509-1,016 mm)** precipitation variation in the past 50 years. Data from the Red Mountain Pass Snotel site (elevation: 11,200 feet) shows total monthly precipitation ranging from 25.9 to 56.9 inches (NRCS 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Greatly Increase. *E. chamissonis* is an obligate wetland species, and is typically found in Colorado in subalpine wet meadows and fens with saturated peat soils, where graminoids and forbs dominate (Dorn 1992; Ball and Wujek 2002; Decker et al. 2006).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Increase. Species occurs in fens and wet meadows above 10,100 feet where snow cover likely provides insulation. In alpine regions, wet meadows typically form on snowbeds or in small depressions lying below late-melting snow patches (Decker et al. 2006).

C3) Restriction to uncommon geological features or derivatives. Increase. *E. chamissonis* is an obligate wetland species restricted to groundwater dependent fens and wet meadows with peat soils. Due to the slow accumulation of peat, fens take centuries to develop and are essentially irreplaceable (Decker et al. 2006). Many of the fens in Colorado are over 10,000 years old with organic soil accumulation rates ranging from 4.3 to 16.2 inches per thousand years (U.S. Fish and Wildlife Service 1999).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. *Eriophorum* species are wind pollinated (Cronquist 1988).

C4d) Dependence on other species for propagule dispersal. Neutral. *E. chamissonis* achenes contain long perianth bristles that are presumed to aid in wind dispersal (Burrows 1975). Water may also aid in dispersal (Decker et al 2006).

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics.
Unknown.

Literature Cited

- Ball, P.W. and D.E. Wujek. 2002. *Eriophorum*. Pages 21-27 in Flora of North America, Vol. 23. Magnoliophyta: Commelinidae (in part): Cyperaceae. Oxford University Press, New York, NY.
- Burrows, F.M. 1975. Wind-borne seed and fruit movement. *New Phytologist* 75:405-418.
- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Cronquist, A. 1988. The Evolution and Classification of Flowering Plants. The New York Botanical Garden, New York, NY.
- Decker, K., D. Culver, and D.G. Anderson. 2006. *Eriophorum chamissonis* C.A. Medy. (Chamisso's cottongrass): a technical conservation assessment. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/erriophorumchamissonis.pdf>. Accessed December 12, 2013.
- Dorn, R.D. 1992. Vascular Plants of Wyoming. Second Edition. Mountain West Publishing, Cheyenne, WY.
- Lukas, J +24 authors. 2014. Climate Change in Colorado. A Synthesis to Support Water Resources Management and Adaptation. Updated Edition, Draft Version 3. CIRES Western Water Assessment, University of Colorado, Boulder, CO. Available online at <http://cwcb.state.co.us/environment/climatechange/documents/climatechangecoreportdraft.pdf>.
- National Resources Conservation Service (NRCS). 2013. Monthly Total Precipitation Data from Red Mountain Pass Snotel station. <http://www.wcc.nrcs.usda.gov/snotel/Colorado/colorado.html>. Accessed December 9, 2013.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- U.S. Fish and Wildlife Service. 1999. Regional policy on the protection of fens, peatland mitigation policy consideration. Ecological Services, Colorado Field Office. Lakewood, CO.

Gilia (Aliciella) haydenii

San Juan gilia

G3/S2

Family: Polemoniaceae



Climate Vulnerability Score: Presumed Stable

This San Juan region rank is based on the species habitat preference for warmer, arid climates, the ability to disperse short distances, preference for substrates that are not uncommon in the study area, and some pollinator versatility. Warm, dry desert shrublands and pinyon-juniper woodlands are likely to increase with climate change. Climate models project decreased summer precipitation and increased summer temperatures (Nydick et al. 2012).

Distribution: *Gilia haydenii* is known from the NE Arizona, SE Utah, NW New Mexico and SW Colorado. (Kartez 2013). In Colorado, it is known from Dolores, La Plata, Mesa, Montrose, Montezuma, and San Miguel counties. (CNHP 2013). **Habitat:** Dry places, often on clay knolls, colluvial fans or shaley sandstone outcrops. (CNHP 2013). **Elevation:** 4600-8300 feet.

Ecological System/Habitat: Barrens, Desert Shrublands, Pinyon-Juniper Woodlands, Ponderosa Pine Woodlands

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral. The species is at the center of its range in the San Juan study area.

B2b) Distribution relative to anthropogenic barriers. Neutral-Somewhat Increase. Occurrences in La Plata and Archuleta counties are located in a shale basin which has intense oil and gas development (Colorado Shale Viewer 2013) and is likely a barrier to dispersal for this species.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Although the San Juan Basin has high potential for solar energy development, there are no planned developments for the area (NRDC 2014).

C1) Dispersal and movements. Somewhat Increase. Reproduces by seed, and is likely occasionally wind blown away from parent plant, as inferred from other *Gilia* species in Colorado (Anderson 2004, Beatty et al. 2004).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 ft.) shows a mean seasonal temperature variation of 83.6°F/46.5 (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Neutral. Species shows a tolerance to a wide range of temperatures.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 feet) shows total monthly precipitation ranging from 9.46 to 30.81 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Neutral. Species is not dependent on a moisture regime that is highly vulnerable to loss with climate change.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Species occurs in xeric habitats (CNHP 2013).

C3) Restriction to uncommon geological features or derivatives. Somewhat Increase. In Colorado, the species occurs primarily on barren clay derived from the San Jose and Mancos Formation (CNHP 2013).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral-Somewhat Increase. Inferred from other mid elevation *Gilia* species that appear to be pollinated primarily by solitary and bumble bee species (Anderson 2004, Beatty et al 2004.).

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Anderson, D.G. (2004, August 9). *Gilia sedifolia* Brandeg. (stonecrop gilia): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/giliasedifolia.pdf> Accessed January 31, 2014
- Beatty, B. w. Jennings, and R. Rawlinson. (2004, February 9). *Gilia penstemonoides* M.E. Jones (Black Canyon gilia): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/calochortusflexuosus.pdf> Accessed January 31, 2014.
- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Colorado Shale Viewer. 2013. Data mapped by The FracTracker Alliance on FracTracker.org. Original data source: Colorado Oil and Gas Conservation Commission (COGCC). Accessed on Feb. 11, 2014: <http://maps.fractracker.org/latest/?appid=3871156863a54ff2ac98b10235dfff57>
- Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford.
- High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Mesa Verde National Park weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.
- Kartesz, J.T., The Biota of North America Program (BONAP). 2013. *Taxonomic Data Center*. (<http://www.bonap.net/tdc>). Chapel Hill, N.C. [maps generated from Kartesz, J.T. 2013. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP). (in press)]
- Natural Resources Defense Council (NRDC). 2014. Renewable Energy for America; Energy Map. <http://www.nrdc.org/energy/renewables/energymap.asp>. Accessed January 21, 2013.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Gutierrezia elegans

Lone Mesa snakeweed
G1/S1, BLM & FS sensitive
Family: Asteraceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species limited dispersal ability, dependence on seasonal precipitation, substrate specificity, and the presence of natural and anthropogenic barriers and the potential for energy development within its habitat. Climate model predictions indicate that by mid-21st century summer precipitation is expected to decrease by -0.9 inches in the San Juan region. Average summer daytime temperatures are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *G. elegans*.

Distribution: Colorado endemic, known only from Dolores County (CNHP 2013). **Habitat:** This species is found on outcrops of grayish, argillaceous, bare Mancos shale outcrops with thin soil over the shale. **Elevation:** 7530-7800 feet.

Ecological System/Habitat: Barrens

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Hackelia gracilentia

Mesa Verde stickseed

G1/S1

Family: Boraginaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species limited dispersal ability, dependence on seasonal precipitation, and the presence of anthropogenic barriers within its habitat. Climate model predictions indicate that by mid-21st century summer precipitation is expected to decrease by -0.9 inches in the San Juan region. Average summer daytime temperatures are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *H. gracilentia*.

Distribution: Endemic to Colorado, known only from Mesa Verde National Park in Montezuma County (CNHP 2013). **Habitat:** Dense litter of oakbrush canyons; deep loam or sandy soil associated with pinyon-juniper woodlands. **Elevation:** 6180-8180 feet.

Ecological System/Habitat: Cliffs and Canyons, Pinyon-Juniper Woodlands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Ipomopsis polyantha

Pagosa skyrocket

G1/S1, Listed Endangered

Family: Polemoniaceae



Photo: Steve O'Kane

Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species limited dispersal ability, dependence on seasonal precipitation, substrate specificity, and the presence of natural and anthropogenic barriers and the potential for energy development within its limited habitat. Climate model predictions indicate that by mid-21st century summer precipitation is expected to decrease by -0.9 inches in the San Juan region. Average summer daytime temperatures are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *I. polyantha*.

Distribution: Colorado endemic, known only from Archuleta County (CNHP 2013) **Habitat:** Found on rocky clay soils of the Mancos Shale Formation, typically on road shoulders where the soil has been disturbed, however, highest densities are found under Ponderosa pine forests with montane grassland understory. **Elevation:** 6770-7360 feet.

Ecological System/Habitat: Barrens, Ponderosa Pine Woodlands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Lepidium crenatum

Alkaline pepperwort

G2/S2

Family: Brassicaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species limited dispersal ability, dependence on seasonal precipitation, the presence of natural and anthropogenic barriers and the potential for energy development within its limited habitat. Climate model predictions indicate that by mid-21st century summer precipitation is expected to decrease by -0.9 inches in the San Juan region. Average summer daytime temperatures are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *L. crenatum*.

Distribution: Known from six counties in eastern Utah, two counties in northwest New Mexico, and six counties in western Colorado (USDS, NRCS 2013). **Habitat:** Found in openings in pinyon-juniper woodlands, also found on arroyo banks and greasewood flats; may be associated with Mancos shale (CNHP 2013). **Elevation:** 6060-8130 feet.

Ecological System/Habitat: Pinyon-Juniper Woodlands, Desert Shrublands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDO I Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Lesquerella (Physaria) pruinosa

Pagosa bladderpod

G2/S2, BLM & FS sensitive

Family: Brassicaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species limited dispersal ability, dependence on seasonal precipitation, substrate preference, the presence of natural and anthropogenic barriers and the potential for energy development within its limited habitat. Climate model predictions indicate that by mid-21st century summer precipitation is expected to decrease by -0.9 inches in the San Juan region. Average summer daytime temperatures are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *L. pruinosa*.

Distribution: Known from southern Colorado (Archuleta County, and the extreme southern portion of Hinsdale County) and northern New Mexico (Rio Arriba County). **Habitat:** Limited to soils derived from Mancos Shale, it is found in open clay barrens surrounded by montane grasslands and open ponderosa pine woodlands (NatureServe 2013). **Elevation:** 6830-8500 feet.

Ecological System/Habitat: Barrens

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Luzula subcapitata

Colorado wood-rush

G3?/S3

Family: Juncaceae



Photo: Joanna Lemly

Climate Vulnerability Score: Extremely Vulnerable

This Gunnison Basin rank is based on the species restriction to high elevation fens. Although fens treated as plant communities were ranked “Low” for vulnerability, individual species within the fen often occur on the margins, and are likely susceptible to small changes in the alteration of hydrology.

Distribution: Colorado endemic (Boulder, Chaffee, Clear Creek, Eagle, Gilpin, Grande, Gunnison, Lake, Larimer, Pitkin, San Juan, and Summit Cos.). **Habitat:** Subalpine and alpine bogs. **Elevation:** 10,500-12,200 feet.

Ecological System/Habitat: Groundwater Dependent Wetlands (fens)

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Somewhat Increase. *L. subcapitata* has been documented in fens of the Gunnison Basin above 10,500 feet (FNA 1993+).

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Somewhat Increase. Dispersal is likely by wind and water, as this is a wetland/fen species.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Increase. Species is moderately restricted to relatively cool or cold environments (fens above 10,500 ft.).

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Greatly Increase. *L. subcapitata* is a species found in wet meadows and fens, and requires continuously moist or saturated soils.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Increase. Species is found in fens in the subalpine or above treeline, and likely depends on deep snow cover.

C3) Restriction to uncommon geological features or derivatives. Increase. *L. subcapitata* is a species found in fens, and requires continuously moist or saturated soils.

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Likely wind-pollinated.

C4d) Dependence on other species for propagule dispersal. Neutral. No data, forced score.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

Flora of North America Editorial Committee (FNA), eds. 1993+. Flora of North America North of Mexico. 12+ vols. New York and Oxford.

National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Machaeranthera coloradoensis

Colorado tansy-aster

G3/S3

Family: Asteraceae



Climate Vulnerability Score: Presumed Stable

This Gunnison Basin rank is due to the species capability for long distance seed dispersal. Species is known to occur on a very wide range of substrates. Also, the species is likely adapted to a broad moisture and temperature regime.

Distribution: Endemic to SC Wyoming and Colorado (Gunnison, Hinsdale, La Plata, Lake, Mineral, Park, Pitkin, Saguache and San Juan Cos.). **Habitat:** Gravelly areas in mountain parks, slopes, and rock outcrops up to dry tundra. **Elevation:** 8500-12,500 feet.

Ecological System/Habitat: Montane Grasslands, Montane Sagebrush

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral and Somewhat Increase. Occurrences in the Gunnison Basin are located in montane habitats ranging from 9,000-10,000 feet (Beatty et al. 2004).

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Neutral. Seeds of *M. coloradoensis* contain a bristly pappus that likely acts as a parachute, so it is likely wind dispersed (Beatty et al. 2004).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral. *M. coloradoensis* has experienced average temperature variation in the last 50 years.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Neutral and Somewhat Increase. Species is somewhat (10-50% of range) restricted to relatively cool or cold environments (upper subalpine) in the Gunnison Basin.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Decrease. Species likely has a broad moisture regime tolerance (see C2bi).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Little dependence on snow or ice cover, as it is known to occupy sparsely vegetated, steep, rocky slopes (Beatty et al. 2004).

C3) Restriction to uncommon geological features or derivatives. Neutral. Known to occur on the following substrates: limestone, dolomite, shale, volcanic ash, and granite (Beatty et al. 2004).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. No data, forced score.

C4d) Dependence on other species for propagule dispersal. Neutral. Bristly pappus on achene aids in wind-dispersal.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Neutral. No data, forced score.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

Barsugli, J. 2010. Hydrologic Projections for the Gunnison Basin. Presentation at Follow-up meeting for the Climate Change Adaptation Workshop. Gunnison, Colorado.

Beatty, B.L., W.F. Jennings, and R.C. Rawlinson. 2004. *Machaeranthera coloradoensis* (Gray)

Osterhout (Colorado tansyaster): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/machaerantheracoloradoensis.pdf> [Accessed July 2, 2011].

National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Mimulus eastwoodiae

Eastwood's monkeyflower

G3G4/S2

BLM sensitive

Family: Scrophulariaceae



Climate Vulnerability Score: Highly Vulnerable

This San Juan region rank is based on restriction to cool, shaded cliff faces that may become warmer and drier in Colorado. Other contributing factors are the presence of cliff faces that serve as natural barriers in suitable habitat, reliance on hummingbirds for pollination, restriction to seeps on canyon walls composed of the Wingate or Mesa Verde Formation. Climate model predictions indicate that by mid-21st century, average summer daytime temperatures in the San Juan region are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). Summer precipitation is expected to decrease by -0.9 inches (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *M. eastwoodiae*.

Distribution: *M. eastwoodiae* has been reported Utah, Arizona, and Colorado. Occurrences in Colorado have been documented in Delta, Mesa, Montrose, and San Miguel Counties (CNHP 2013).

Habitat: Occurs in hanging garden communities around seeps on steep canyon walls and in shallow caves. **Elevation:** 4700-5800 feet.

Ecological System/Habitat: Groundwater Dependent Wetlands, Cliff and Canyon Seeps

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Somewhat Increase. Species occurs on steep canyon walls that serve as natural barriers.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Occurs in shallow caves and seeps on steep canyon walls, and we rated all cliff and canyon species 'Neutral' based on the assumption that development in this habitat is unlikely in most mitigation scenarios.

C1) Dispersal and movements. Neutral. Although dispersal mechanisms are unknown, wind and water likely transport *M. eastwoodiae* seeds.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows a mean seasonal temperature variation of 86.45°F/48.02°C) (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Increase. Species that occur in seeps in cliffs and canyons were all rated 'Increase' under the assumption that this habitat may be lost as Colorado becomes warmer, and presumably drier.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows total monthly precipitation ranging from 5.23 to 26.34 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Greatly Increase. Species occurs in hanging garden communities around seeps on steep canyon walls and in shallow caves. We rated cliff and canyon species that prefer wetter micro sites as 'Greatly Increase' based on the assumption that these habitats may be lost as Colorado's climate becomes warmer and drier.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Little dependence on snow or ice cover.

C3) Restriction to uncommon geological features or derivatives. Somewhat Increase. Species is restricted to cliffs and canyons, usually occurring on Wingate sandstone or Mesa Verde Formation cliff alcoves (CNHP 2013).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Somewhat Increase. *M. eastwoodiae* is hummingbird pollinated (Vickery 1978). No data is available on how many species of hummingbirds pollinate this species.

C4d) Dependence on other species for propagule dispersal. Neutral. No data, forced score.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics.
Unknown.

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Cortez weather station.
<http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Vickery, R.K. JR. 1978. Case studies in the evolution of species complexes in *Mimulus*. *Evolutionary Biology* 11:404-506.

Pediomelum aromaticum

Paradox breadroot

G3/S2

Family: Fabaceae



Climate Vulnerability Score: Moderately Vulnerable

This San Juan Region rank is based on the species habitat preference for warmer, arid climates, sandy soils, and pollinator specialization. Warm, dry shrublands and pinyon-juniper woodlands are likely to increase with climate change. Climate models project decreased summer precipitation and increased summer temperatures (Nydick et al. 2012).

Distribution: *Pediomelum aromaticum* is known from northern Arizona, SE Utah, and SW Colorado (Kartez 2013). In Colorado, it is known from Mesa, Montrose and possibly Montezuma counties. (CNHP 2013, Kartez 2013). **Habitat:** Adobe hills or sandy soils in open pinyon-juniper woodlands. **Elevation:** 4600-6700 ft.

Ecological System/Habitat: Pinyon-Juniper Woodlands

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral. The species is at the center of its range in the San Juan study area.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Although the San Juan Basin has high potential for solar energy development, there are no planned developments for the area (NRDC 2014).

C1) Dispersal and movements. Increase. Reproduces by seed that falls close to parent plant.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows a mean seasonal temperature variation of 86.45°F/48.02°C) (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Neutral. Species shows a tolerance to a wide range of temperatures.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows total monthly precipitation ranging from 5.23 to 26.34 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Increase. Species occurs in loose, sandy soils that are sensitive to changes in precipitation.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Species occurs in xeric habitats (CNHP 2013).

C3) Restriction to uncommon geological features or derivatives. Neutral. In Colorado, the species prefers loose, sandy soils (CNHP 2013).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Somewhat Increase. Inferred from other related species that are bee pollinated (Colorado Plant Database 2007).

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Increase. Although *P. aromaticum* has not been studied for nodulization, legume species are well known for forming symbiotic relationships with nitrogen fixing bacteria. (CSU extension).

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

- Colorado Plant Database. Sponsored by the Colorado Native Plant Master Program. Colorado State University Extension, 2007. Web. Accessed 4 February 2014. <<http://jeffco.us/coopext/intro.jsp>>
- Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford.
- High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Cortez weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.
- Kartesz, J.T., The Biota of North America Program (BONAP). 2013. *Taxonomic Data Center*. (<http://www.bonap.net/tdc>). Chapel Hill, N.C. [maps generated from Kartesz, J.T. 2013. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP). (in press)]
- Natural Resources Defense Council (NRDC). 2014. Renewable Energy for America; Energy Map. <http://www.nrdc.org/energy/renewables/energymap.asp>. Accessed January 21, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDO Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Penstemon breviculus

Little penstemon

G3/S1

Family: Scrophulariaceae



Climate Vulnerability Score: Presumed Stable

This San Juan region rank is based on the species habitat preference for warmer, arid climates, substrates that are not uncommon in the study area, and some pollinator versatility. Warm, dry shrublands and pinyon-juniper woodlands are likely to increase with climate change. Climate models project decreased summer precipitation and increased summer temperatures (Nydick et al. 2012).

Distribution: *Penstemon breviculus* is known from NE Arizona, SE Utah, NW New Mexico and SW Colorado. (Kartez 2013). In Colorado, it is known from Montrose, Montezuma, and San Miguel counties. (CNHP 2013, Kartez 2013). **Habitat:** Occurs on sandstone and shale, in clay loam soils in open pinyon-juniper woodlands and sagebrush shrublands. **Elevation:** 4900-7900 ft.

Ecological System/Habitat: Pinyon-Juniper Woodlands, Desert Shrublands

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral. The species is at the center of its range in the San Juan study area.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Although the San Juan Basin has high potential for solar energy development, there are no planned developments for the area (NRDC 2014).

C1) Dispersal and movements. Increase. Reproduces by seed that falls close to parent plant.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 ft.) shows a mean seasonal temperature variation of 83.6°F/46.5 (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Neutral. Species shows a tolerance to a wide range of temperatures.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 feet) shows total monthly precipitation ranging from 9.46 to 30.81 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Neutral. Species is not dependent on a moisture regime that is highly vulnerable to loss or alteration with climate change.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Species occurs in xeric habitats (CNHP 2013).

C3) Restriction to uncommon geological features or derivatives. Neutral. In Colorado, the species does not show an affinity for a specific substrate or geologic feature. (CNHP 2013).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Somewhat Increase. The specific pollinators are not known, but common visitors to other species of *Penstemon* in Colorado include bees, wasps, flies, and beetles (Beatty et al. 2004).

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Beatty, B. W. Jennings, and R. Rawlinson. (2004, February 23). *Penstemon degeneri* Crosswhite (Degener's beardtongue): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/penstemonbreviculus.pdf> Accessed January 31, 2014.
- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford.
- High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Mesa Verde National Park weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.
- Kartesz, J.T., The Biota of North America Program (BONAP). 2013. *Taxonomic Data Center*. (<http://www.bonap.net/tdc>). Chapel Hill, N.C. [maps generated from Kartesz, J.T. 2013. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP). (in press)]
- Natural Resources Defense Council (NRDC). 2014. Renewable Energy for America; Energy Map. <http://www.nrdc.org/energy/renewables/energymap.asp>. Accessed January 21, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDO I Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Physaria pulvinata

Cushion bladderpod

G1/S1, BLM & FS sensitive

Family: Brassicaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species limited dispersal ability, dependence on seasonal precipitation, substrate preference, the presence of natural and anthropogenic barriers and the potential for energy development within its limited habitat. Climate model predictions indicate that by mid-21st century summer precipitation is expected to decrease by -0.9 inches in the San Juan region. Average summer daytime temperatures are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *P. pulvinata*.

Distribution: Endemic to Colorado; known from San Miguel and Dolores counties (CNHP 2013).

Habitat: Occurs on outcrops of grayish Mancos shale, in openings between low shrubs (CNHP 2013). **Elevation:** 7540-8490 ft.

Ecological System/Habitat: Barrens

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Physaria scrotiformis

West silver bladderpod

G1/S1, FS sensitive

Family: Brassicaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species limited dispersal ability, dependence on seasonal precipitation, the presence of natural barriers and the potential for energy development within its limited habitat. Climate model predictions indicate that by mid-21st century summer precipitation is expected to decrease by -0.9 inches in the San Juan region. Average summer daytime temperatures are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *P. scrotiformis*.

Distribution: Endemic to Colorado, known only from the upper sub-alpine-lower alpine zone of the San Juan Mountains in La Plata County (CNHP 2013). **Habitat:** Grows on windswept, nearly barren exposures of Leadville limestone in a matrix of *Picea engelmannii* islands and tundra. **Elevation:** 11,560-11,830 ft.

Ecological System/Habitat: Spruce-Fir Forests, Barrens, Meadow Tundra

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Proatriplex pleiantha

Mancos saltbush

G3/S1

Family: Chenopodiaceae



Climate Vulnerability Score: Moderately Vulnerable

This San Juan region rank is based on the species habitat preference for warmer, arid climates, saline clay soils, and microsites which accumulate moisture. Suitable barren habitat may be reduced with climate change. Further, climate models project decreased summer precipitation and increased summer temperatures (Nydick et al. 2012).

Distribution: *Proatriplex pleiantha* is known from the Four Corners region of NE Arizona, SE Utah, and SW Colorado. (Kartez 2013). In Colorado, it is known only from a small area in Montezuma county. (CNHP 2013, Kartez 2013). **Habitat:** Occurs on barren, saltbrush badlands; on highly dissected and eroded gray shale and clay of the Mancos Formation (CNHP 2013). **Elevation:** 4700-5100 ft.

Ecological System/Habitat: Barrens, Desert Shrublands

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral. The species is at the center of its range in the San Juan study area.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Although the San Juan Basin has high potential for solar energy development, there are no planned developments for the area (NRDC 2014).

C1) Dispersal and movements. Increase. Reproduces by seed that falls close to parent plant (FNA 1993+).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows a mean seasonal temperature variation of 86.45°F/48.02°C (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Neutral. Species shows a tolerance to a wide range of temperatures.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Cortez weather station (elevation: 6,180 ft.) shows total monthly precipitation ranging from 5.23 to 26.34 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Increase. Species occurs in moisture accumulating microsites which are highly vulnerable to loss with climate change.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Species occurs in xeric habitats (CNHP 2013).

C3) Restriction to uncommon geological features or derivatives. Increase. In Colorado, the species is found on saline soils derived from the Mancos Formation. (CNHP 2013).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Inferred from other *Atriplex* species which are wind pollinated (Howard 2003).

C4d) Dependence on other species for propagule dispersal. Neutral.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Beatty, B. W. Jennings, and R. Rawlinson. (2004, February 23). *Penstemon degeneri* Crosswhite (Degener's beardtongue): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/penstemonbreviculus.pdf> Accessed January 31, 2014.
- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford.
- High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Cortez weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.
- Howard, Janet L. 2003. *Atriplex canescens*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: <http://www.fs.fed.us/database/feis/> [2014, February 3].
- Kartesz, J.T., The Biota of North America Program (BONAP). 2013. *Taxonomic Data Center*. (<http://www.bonap.net/tdc>). Chapel Hill, N.C. [maps generated from Kartesz, J.T. 2013. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP). (in press)]
- Natural Resources Defense Council (NRDC). 2014. Renewable Energy for America; Energy Map. <http://www.nrdc.org/energy/renewables/energymap.asp>. Accessed January 21, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Puccinellia parishii

Parish's alkali grass

G2G3/S1

Family: Poaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on a wetland habitat and seasonal precipitation, and the presence of natural and anthropogenic barriers within its limited habitat. Climate model predictions indicate that by mid-21st century summer precipitation is expected to decrease by -0.9 inches in the San Juan region. Average summer daytime temperatures are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *P. parishii*.

Distribution: Known from California, Colorado, Arizona and New Mexico (USDA, NRCS 2013). In Colorado it is known from San Miguel County (CNHP 2013). **Habitat:** Grows on low, open areas with seasonally wet seeps and alkaline soils. Associated plant communities are dominated by alkaline grasses, and *Artemisia nova* shrub/grasslands (CNHP 2013). **Elevation:** 7620-7950 feet.

Ecological System/Habitat: Groundwater Dependent Wetlands, Sagebrush Shrublands, Montane Grasslands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Ranunculus gelidus ssp. grayi [*R. grayi*]

Tundra buttercup

GNRT4T5/S1

Family: Ranunculaceae

No photo available

Climate Vulnerability Score: Extremely Vulnerable

This Gunnison Basin rank is based on the species restriction to cold environments and dependence on ice and snow. Documented occurrences are located on the edge of melting snowbanks. This species may be just outside of the San Juan region and was included due to its proximity in Hinsdale and Ouray County.

Distribution: Eastern Siberia, Alaska, south to Montana and Colorado (Boulder, Chaffee, Clear Creek, Gunnison, Hinsdale, Lake, Park and Summit Cos.). **Habitat:** Among rocks and scree on exposed summits, slopes. **Elevation:** 12,000-14,100 feet.

Ecological System/Habitat: Alpine

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Increase. Occurs above 12,000 feet.

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Neutral. No data, forced score.

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Greatly Increase. Species is completely or almost completely restricted to relatively cool or cold environments (alpine). Alpine habitats are likely to be reduced as Colorado becomes warmer, and presumably drier. Climate models project earlier, faster snowmelt along with decreased summer precipitation and increased summer temperatures (Barsugli 2010). This would result in significantly lower amounts of water stored in the soils during the summer.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and

subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as 'Increase' or 'Greatly Increase', having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked 'Somewhat Decrease'.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Decrease. Species likely has a broad moisture regime tolerance (see C2bi).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Greatly Increase. Species is found in the alpine above 12,000 ft., and is found in snow-melt areas on the edges of snowfields.

C3) Restriction to uncommon geological features or derivatives. Neutral. Parent material for soils at documented occurrences are reported as igneous, gneiss, schist, and limestone (Spackman et al. 2006).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Unknown. No data, forced score.

C4d) Dependence on other species for propagule dispersal. Neutral. No data, forced score.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

Barsugli, J. 2010. Hydrologic Projections for the Gunnison Basin. Presentation at Follow-up meeting for the Climate Change Adaptation Workshop. Gunnison, Colorado.

National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Panjabi, S.S. and D.G. Anderson. 2006. *Ranunculus karelinii* Czern. (ice cold buttercup): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/ranunculuskarelinii.pdf>. [Accessed May 5, 2011].

Sclerocactus mesae-verdae

Mesa Verde cactus

G2/S2 Listed Threatened

Family: Cactaceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal precipitation, the presence of natural barriers and energy development within its habitat, limited dispersal ability, and substrate preferences. Climate model predictions indicate that by mid-21st century summer precipitation is expected to decrease by -0.9 inches in the San Juan region. Average summer daytime temperatures are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *S. mesae-verdae*.

Distribution: Occurs only in parts of Montezuma County, Colorado and San Juan County, New Mexico. Mostly on Navajo Indian Reservation lands (NatureServe 2013). **Habitat:** Dry low exposed hills and mesas on Mancos or Fruitland clays (CNHP 2013). **Elevation:** 5050-5770 feet.

Ecological System/Habitat: Barrens, Desert Shrublands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Sphagnum angustifolium

Iron fen

G5/S2 FS sensitive

Family: Sphagnaceae



Climate Vulnerability Score: Moderately Vulnerable

This San Juan region rank is based on restriction to cold, high elevation fens fed by groundwater, short dispersal distance, and reliance on snow as insulation.

Distribution: This species is also found in iron fens and poor fens in Colorado, Wyoming, Washington, Oregon, Idaho, North Dakota, Utah, Montana, Canada, and Europe (Austin 2007; NatureServe 2013). **Habitat:** Restricted to fens. In Colorado, most occurrences are limited to iron fens (Austin 2007; Weber and Wittmann 2007). **Elevation:** 9000-12,000 ft.

Ecological System/Habitat: Groundwater Dependent Wetlands (fens)

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Increase. Species has been documented at elevations ranging from 9,000-12,000 feet in Colorado, so species could still shift upward in elevation (CNHP 2013).

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Wetland species are ranked as neutral under the general assumption that wetlands are less likely to be developed under climate change mitigation scenarios than other habitats.

C1) Dispersal and movements. Somewhat Increase. Primary dispersal mechanism is wind (Cooper et al. 2002).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral. Species has experienced average temperature variation (57.1-77°F/31.8-43.0°C) in the past 50 years. Data from the Red Mountain Snotel site (elevation: 11,200 ft.) shows a mean seasonal temperature variation of 77°F /43°C (NRCS 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Increase. Species is moderately restricted to cool or cold environments (fens at 9,000-10,000 ft.).

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced **average (21-40 inches/509-1,016 mm)** precipitation variation in the past 50 years. Data from the Red Mountain Pass Snotel site (elevation: 11,200 feet) shows total monthly precipitation ranging from 25.9 to 56.9 inches (NRCS 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Greatly Increase. *S. angustifolium* is an obligate wetland species, and is restricted to groundwater dependent fens with acidic conditions.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Increase. Species is found in montane, subalpine and alpine fens where snow cover likely provides insulation.

C3) Restriction to uncommon geological features or derivatives. Increase. *S. angustifolium* occurs in groundwater fens with peat soils. Due to the slow accumulation of peat, fens take centuries to develop and are essentially irreplaceable (Decker et al. 2006). This species requires wet organic soils, and is sensitive to changes in hydrology (Austin 2007). Due to the slow accumulation of peat, fens take centuries to develop and are essentially irreplaceable (Decker et al. 2006). Many of the fens in Colorado are over 10,000 years old with organic soil accumulation rates ranging from 4.3 to 16.2 inches per thousand years (U.S. Fish and Wildlife Service 1999).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Species is non-vascular, and does not require pollinators.

C4d) Dependence on other species for propagule dispersal. Neutral. Primary dispersal mechanism is wind (Vitt 1998, McQueen 1990).

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Austin, G. 2007. *Sphagnum angustifolium*. U.S. Forest Service Region 2 Species Evaluation Form. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5301155.pdf. Access 9 December 2013.
- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Cooper, D.J., R.A. Andrus, and C.D. Arp. 2002. *Sphagnum balticum* in a southern Rocky Mountain iron fen. *Madrono* 49:186-188.
- Decker, K., D. Culver, and D.G. Anderson. 2006. *Eriophorum chamissonis* C.A. Medy. (Chamisso's cottongrass): a technical conservation assessment. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/eriophorumchamissonis.pdf>. Accessed December 12, 2013.
- McQueen, C. 1990. *Field guide to the peat mosses of boreal North America*. Hanover NH: University Press of New England.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.
- National Resources Conservation Service (NRCS). 2013. Monthly Total Precipitation Data from Red Mountain Pass Snotel station. <http://www.wcc.nrcs.usda.gov/snotel/Colorado/colorado.html>. Accessed December 9, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- U.S. Fish and Wildlife Service. 1999. Regional policy on the protection of fens, peatland mitigation policy consideration. Ecological Services, Colorado Field Office. Lakewood, CO.
- Vitt, Dale H., J. E. Marsh, R. B. Bovey, 1988. *Mosses, Lichens & Ferns of Northwest North America*. Lone Pine Publishing, Canada.
- Weber, W. and R.C. Wittmann. 2007. *Bryophytes of Colorado: Mosses, Liverworts and Hornworts*. 231 pp. Pilgrims Process, Inc. Santa Fe, NM.

Sphagnum balticum

Baltic peat moss

G4/S1

FS sensitive

Family: Sphagnaceae

No photo available

Climate Vulnerability Score: Moderately Vulnerable

This San Juan region rank is based on restriction to cold, high elevation fens fed by groundwater, short dispersal distance, and reliance on snow as insulation.

Distribution: Known from arctic and subarctic Greenland, North America, Scandinavia, British Isles, Russia and China. In North America, only two occurrences are known from the lower 48 United States. They are both in Colorado (Austin 2009; Cooper et al. 2002; CNHP 2013; NatureServe 2013). **Habitat:** Restricted to fens. In Colorado, the two known occurrences are limited to iron fens (Cooper et al. 2002; CNHP 2013). **Elevation:** 9650-9809 ft.

Ecological System/Habitat: Groundwater Dependent Wetlands (fens)

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Increase. Species has been documented at elevations ranging from 9,650-9,800 feet in Colorado, so species could still shift upward in elevation (CNHP 2013).

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Wetland species are ranked as neutral under the general assumption that wetlands are less likely to be developed under climate change mitigation scenarios than other habitats.

C1) Dispersal and movements. Somewhat Increase. Primary dispersal mechanism is wind (Cooper et al. 2002).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral. Species has experienced average temperature variation (57.1-77°F/31.8-43.0°C) in the past 50 years. Data from the Red Mountain Snotel site (elevation: 11,200 ft.) shows a mean seasonal temperature variation of 77°F /43°C (NRCS 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Increase. Species is moderately restricted to cool or cold environments (fens at 9,650-9,800 ft.).

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced **average (21-40 inches/509-1,016 mm)** precipitation variation in the past 50 years. Data from the Red Mountain Pass Snotel site (elevation: 11,200 feet) shows total monthly precipitation ranging from 25.9 to 56.9 inches (NRCS 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Greatly Increase. *S. balticum* is an obligate wetland species, and is restricted to groundwater dependent fens.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Increase. Species is found in montane fens where snow cover likely provides insulation.

C3) Restriction to uncommon geological features or derivatives. Increase. *S. balticum* occurs in groundwater fens with peat soils. Due to the slow accumulation of peat, fens take centuries to develop and are essentially irreplaceable (Decker et al. 2006). This species requires wet organic soils, and is sensitive to changes in hydrology and water chemistry (Austin 2009). Due to the slow accumulation of peat, fens take centuries to develop and are essentially irreplaceable (Decker et al. 2006). Many of the fens in Colorado are over 10,000 years old with organic soil accumulation rates ranging from 4.3 to 16.2 inches per thousand years (U.S. Fish and Wildlife Service 1999).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Species is non-vascular, and does not require pollinators.

C4d) Dependence on other species for propagule dispersal. Neutral. Primary dispersal mechanism is wind (Vitt 1998, McQueen 1990).

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

Austin, G. 2009. *Sphagnum balticum*. U.S. Forest Service Region 2 Species Evaluation Form.

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5301155.pdf. Access 9 December 2013.

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

- Cooper, D.J., R.A. Andrus, and C.D. Arp. 2002. *Sphagnum balticum* in a southern Rocky Mountain iron fen. *Madrono* 49:186-188.
- Decker, K., D. Culver, and D.G. Anderson. 2006. *Eriophorum chamissonis* C.A. Medy. (Chamisso's cottongrass): a technical conservation assessment. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/eriophorumchamissonis.pdf>. Accessed December 12, 2013.
- McQueen, C. (1990). *Field guide to the peat mosses of boreal North America*. Hanover NH: University Press of New England.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.
- National Resources Conservation Service (NRCS). 2013. Monthly Total Precipitation Data from Red Mountain Pass Snotel station. <http://www.wcc.nrcs.usda.gov/snotel/Colorado/colorado.html>. Accessed December 9, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- U.S. Fish and Wildlife Service. 1999. Regional policy on the protection of fens, peatland mitigation policy consideration. Ecological Services, Colorado Field Office. Lakewood, CO.
- Vitt, Dale H., Janet E. Marsh, Robin B. Bovey, 1988. *Mosses, Lichens & Ferns of Northwest North America*. Lone Pine Publishing, Canada.
- Weber, W. and R.C. Wittmann. 2007. *Bryophytes of Colorado: Mosses, Liverworts and Hornworts*. 231 pp. Pilgrims Process, Inc. Santa Fe, NM.

Sporobolus flexuosus

Mesa dropseed
G5/S1, FS sensitive
Family: Poaceae

No photo available

Climate Vulnerability Score: Presumed Stable

This statewide rank is based on the species tolerance to fluctuations in temperature and precipitation, ability to disperse and the presence of some natural barriers within its habitat. Warm, dry shrublands and pinyon-juniper woodlands are likely to increase with climate change. Climate models project decreased summer precipitation and increased summer temperatures (Nydick et al. 2012).

Distribution: Known from the southwest United States from California to Texas and north to Kansas and Montana (USDS, NRCS 2013). In Colorado it is known from Mesa, Moffat, Montezuma, Montrose and San Miguel counties (CNHP 2013). **Habitat:** Found on mesas and deserts in sandy and rocky soils, often in stands of blackbrush; also on rimrock in pinyon- juniper woodlands (CNHP 2013). **Elevation:** 4690-5370 feet.

Ecological System/Habitat: Pinyon-Juniper Woodlands, Desert Shrublands

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- USDA, NRCS. 2013. The PLANTS Database (<http://plants.usda.gov>, 9 December 2013.) National Plant Data Team, Greensboro, NC 27401-4901 USA.

Townsendia glabella

Smooth Easter daisy

G2/S2

Family: Asteraceae



Climate Vulnerability Score: Extremely Vulnerable

This statewide rank is based on the species dependence on seasonal precipitation, the presence of natural and anthropogenic barriers and energy development within its habitat, limited dispersal ability, and substrate preferences. Climate model predictions indicate that by mid-21st century summer precipitation is expected to decrease by -0.9 inches in the San Juan region. Average summer daytime temperatures are expected to increase +6.7 °F relative to the 1971-2000 time periods (Nydick et al. 2012). These hotter and drier conditions may result in a loss of suitable habitat for *T. glabella*.

Distribution: Colorado endemic; known from Archuleta, La Plata, Montezuma and Rio Grande counties (CNHP 2013). **Habitat:** This species grows on steeply sloping shale slopes, on the Smokey Hill Member of the Mancos Formation. **Elevation:** 6350-9680 feet.

Ecological System/Habitat: Ponderosa Pine Forests, Barrens, Pinyon-Juniper Woodlands

Literature Cited

Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Townsendia rothrockii

Rothrock townsend-daisy

G2G3/S2S3

Family: Asteraceae



Climate Vulnerability Score: Extremely Vulnerable

This Gunnison Basin rank is based primarily on this perennial forb's species adaptability to a variety of substrates including limestone, sandstone and volcanic substrates, dependence on ice and snow habitats, and presence of natural barriers within its habitat.

Distribution: Colorado in counties southwest of Summit Co. as well as New Mexico. **Habitat:** Found in dry, open places in rocky soil, especially alpine fell fields. **Elevation:** 8000-13,500 feet.

Ecological System/Habitat: Alpine, Spruce-Fir Forests

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Increase. Known occurrences range from 8,000-13,500 feet, although the majority are located above 10,000 feet (Beatty et al. 2004).

B2b) Distribution relative to anthropogenic barriers. Neutral.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. It is unlikely that any mitigation-related land use changes will occur within this species' range within the study area.

C1) Dispersal and movements. Somewhat Increase. Details of seed dispersal mechanisms in *Townsendia rothrockii* have not been studied. *Townsendia rothrockii* flowers and seeds are close to the ground where wind (common at high elevations), water movement (e.g., sheets of rain, snow melt off), soil movement (e.g., erosion), and animal vectors (e.g., small mammals, ants) could possibly disperse the seeds. This species has bristles on the achenes that could facilitate dispersal (Zomlefer 1994). Presumably, dispersal success of *T. rothrockii* may depend on wind and

precipitation patterns, substrate characteristics, animal activities, topographic heterogeneity, and availability of suitable “safe” sites (Beatty et al. 2004).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral. This species has experienced slightly lower than average (47.1-57°F/26.3-31.8°C) temperature variation in the past 50 years.

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Increase. Species is restricted to relatively cool or cold environments (alpine). Alpine habitats are likely to be reduced as Colorado becomes warmer, and presumably drier. Climate models project earlier, faster snowmelt along with decreased summer precipitation and increased summer temperatures (Barsugli 2010). This would result in significantly lower amounts of water stored in the soils during the summer.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Somewhat Decrease. Initially, ratings for this factor were calculated in GIS by overlaying the species’ distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from ClimateWizard, and subtracting the lowest pixel value from the highest value. Using this method, alpine species were rated as ‘Increase’ or ‘Greatly Increase’, having a very low precipitation variation. However, precipitation variation in the alpine in the last 50 years has been high. In order to reflect this variation, we used data from a Snotel site at Schofield Pass (10,070 feet). Historical Accumulated Precipitation data from the site ranges from 34.6 to 69.8 inches for water years 1986-2011 (NRCS 2011). Although the station is below treeline, and not in true alpine, it is the highest elevation Snotel site in the Gunnison Basin. Thus, this alpine species has experienced **greater than average (> 40 inches/1,016 mm)** precipitation variation in the past 50 years, and is ranked ‘Somewhat Decrease’.

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Somewhat Decrease. Species likely has a broad moisture regime tolerance (see C2bi).

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Increase. Species is found between 8,000 and 13,500 feet (Beatty et al. 2004).

C3) Restriction to uncommon geological features or derivatives. Neutral. *T. rothrockii* has since been found on a variety of substrates, such as rocky soils, steep talus, dry rocky soil, granite talus, lava cliffs, limestone outcrops, red sandstone, thin red soil, loam soil, and limey substrates (Beatty et al. 2004).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. No data, forced score.

C4d) Dependence on other species for propagule dispersal. Unknown.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics.
Unknown.

Literature Cited

Barsugli, J. 2010. Hydrologic Projections for the Gunnison Basin. Presentation at Follow-up meeting for the Climate Change Adaptation Workshop. Gunnison, Colorado.

Beatty, B.L., W.F. Jennings, and R.C. Rawlinson. 2004. *Townsendia rothrockii* Gray ex Rothrock (Rothrock's Townsend daisy): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/townsendiarothrockii.pdf>. [Accessed June 1, 2011].

National Resource Conservation Service (NRCS). 2011. Historical climate data from Snotel site at Schofield Pass, Colorado. Available online: <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=737&state=co>.

Zomlefer, W. 1994. Guide to Flowering Plant Families. University of North Carolina Press: Chapel Hill, NC.

Triteleia grandiflora

Large-flower triteleia

G4G5/S1

FS sensitive

Family: Liliaceae



Climate Vulnerability Score: Moderately Vulnerable

This San Juan region rank is due to the species restriction to seasonally moist forest openings that may be lost due to warmer and drier growing conditions.

Distribution: *Triteleia grandiflora* has been reported from British Columbia in Canada, and Washington, Oregon, California, Idaho, Utah, Montana, Wyoming, and Colorado in the United States (Ladyman 2007). In Colorado, it is known from a single occurrence in the San Juan National Forest in Montezuma County (CNHP 2013). **Habitat:** Seasonally moist openings in ponderosa pine forest (Ladyman 2007). **Elevation:** 7700-7900 feet.

Ecological System/Habitat: Ponderosa Pine Forests

CCVI Scoring

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Neutral. No significant barriers to movement are known.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change.

Somewhat Decrease. *T. grandiflora* occurs in forested areas, and we rated all forest species 'Somewhat Decrease' based on the assumption that forest management may be improved in the future in the interest of carbon sequestration.

C1) Dispersal and movements. Neutral. Although dispersal mechanisms are unknown, *T. grandiflora* seeds have no characteristics that suggest animal dispersal. Seeds likely fall close to the parent plant (Ladyman 2007).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Somewhat Decrease. Species has experienced greater than average temperature variation (>77°F/43°C) in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 ft.) shows a mean seasonal temperature variation of 83.6°F/46.5 (High Plains Regional Climate Center 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Somewhat Increase. Species is somewhat restricted to cool or cold environments that may be lost as a result of climate change. Temperatures in the *T. grandiflora* occupied habitat (7,700-7,900 ft.) can dip below freezing any month of the year.

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced average (21-40 inches/509-1,016 mm) precipitation variation in the past 50 years. Data from the Mesa Verde National Park weather station (elevation: 6,960 feet) shows total monthly precipitation ranging from 9.46 to 30.81 inches (High Plains Regional Climate Center 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Increase. Species occurs in seasonally moist openings in ponderosa pine forests.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Unknown.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Neutral. Little dependence on snow or ice cover.

C3) Restriction to uncommon geological features or derivatives. Neutral. Species is not restricted to specific geologic features or substrates (Ladyman 2007).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. Although *T. grandiflora* is likely insect pollinated, specific pollinator assemblages are unknown (Ladyman 2007).

C4d) Dependence on other species for propagule dispersal. Neutral. No data, forced score.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Unknown.

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- High Plains Regional Climate Center. 2013. Monthly Total Precipitation Data from Mesa Verde National Park weather station. <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 4, 2013.
- Ladyman, J.A.R. (2007, January 29). *Triteleia grandiflora* Lindley (largeflower triteleia): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/triteleiagrandiflora.pdf>. Accessed December 4, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDO I Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.

Utricularia minor

Lesser bladderwort

G5/S2, FS sensitive

Family: Lentibulariaceae



Climate Vulnerability Score: Moderately Vulnerable

This San Juan region rank is due to the species restriction to fens and shallow, high elevation lakes, reliance on snow cover for insulation, and natural barriers to movement created by local mountain ranges.

Distribution: Circumpolar distribution including Canada, Alaska, and most of the northern United States south to California and Arizona (NatureServe 2013). Known from ten counties in Colorado: Alamosa, Boulder, Delta, Gunnison, Jackson, Larimer, Mesa, Montezuma, Park, and Summit counties (CNHP 2013).

Habitat: Groundwater Dependent Wetlands (fens)

Elevation: 8900-11,500 feet.

CCVI Scoring

Ecological System/Habitat: Groundwater-dependent wetlands (fens) and shallow lakes

B1) Exposure to sea level rise. Neutral.

B2a) Distribution relative to natural barriers. Somewhat Increase. This species occurs in high elevation (8,900-11,500 ft.) fens and shallow lakes. Local mountain ranges and ridges create natural barriers for dispersal.

B2b) Distribution relative to anthropogenic barriers. Neutral. No significant anthropogenic barriers are known.

B3) Impact of land use changes resulting from human responses to climate change. Neutral. Wetland species are ranked as neutral under the general assumption that wetlands are less likely to be developed under climate change mitigation scenarios than other habitats.

C1) Dispersal and movements. Somewhat Increase. Small vegetative structures of *U. minor*, called turions are thought to be dispersed by waterfowl and flowing water (Victorin 1940; Araki and Kadono 2003).

C2ai) Predicted sensitivity to temperature: historic thermal niche. Neutral. Species has experienced average temperature variation (57.1-77°F/31.8-43.0°C) in the past 50 years. Data from the Red Mountain Snotel site (elevation: 11,200 ft.) shows a mean seasonal temperature variation of 77°F /43°C (NRCS 2013).

C2aii) Predicted sensitivity to temperature: physiological thermal niche. Increase. Species is moderately restricted to cool or cold environments (fens at 8,900-11,500 ft.).

C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche. Neutral. The species has experienced **average (21-40 inches/509-1,016 mm)** precipitation variation in the past 50 years. Data from the Red Mountain Pass Snotel site (elevation: 11,200 feet) shows total monthly precipitation ranging from 25.9 to 56.9 inches (NRCS 2013).

C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche. Greatly Increase. *U. minor* is an obligate wetland species, and is restricted to groundwater dependent fens with peat soils and high elevation, shallow lakes.

C2c) Dependence on a specific disturbance regime likely to be impacted by climate change. Neutral. No data, forced score.

C2d) Dependence on ice, ice-edge, or snow cover habitats. Increase. Species occurs in fens above 8,900 feet where snow cover likely provides insulation.

C3) Restriction to uncommon geological features or derivatives. Increase. *U. minor* is an obligate wetland species restricted to groundwater dependent fens and shallow, high elevation lakes. Due to the slow accumulation of peat, fens take centuries to develop and are essentially irreplaceable (Decker et al. 2006).

C4a) Dependence on other species to generate habitat. Neutral. No data, forced score.

C4c) Pollinator Versatility. Neutral. The primary mode of reproduction for *U. minor* is thought to be vegetative, although few studies have been conducted on sexual reproduction features (Neid 2006).

C4d) Dependence on other species for propagule dispersal. Neutral. Small vegetative structures of *U. minor*, called turions, are thought to be dispersed by waterfowl and flowing water (Victorin 1940; Araki and Kadono 2003). No studies have been conducted examining which waterfowl species contribute to turion dispersal.

C4e) Forms part of an interspecific interaction not covered by C4a-d. Neutral. *U. minor* is an obligate carnivore. No studies have investigated the contents of *U. minor* bladders, but other species of *Utricularia* have been shown to contain a wide range of organisms including insects, algae, diatoms, protists, and copepods (Neid 2006; Richards 2001).

C5) Genetic factors. Unknown.

C6) Phenological response to changing seasonal temperature and precipitation dynamics. Unknown.

Literature Cited

- Araki, S. and Y. Kadono. 2003. Restricted seed contribution and clonal dominance in a free-floating aquatic plant *Utricularia australis* R. Br. in southwestern Japan. *Ecological Research* 18:599-609.
- Colorado Natural Heritage Program (CNHP). 2013. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Colorado State University, Fort Collins.
- Decker, K., D. Culver, and D.G. Anderson. 2006. *Eriophorum chamissonis* C.A. Medy. (Chamisso's cottongrass): a technical conservation assessment. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/eriphorumchamissonis.pdf>. Accessed December 12, 2013.
- High Plains Regional Climate Center. 2013. Historical Climate Data Summaries. Mesa Verde National Park, Colorado. Period of Record: 1940-1990. Online: <http://www.hprcc.unl.edu/data/historical/index.php>. Accessed December 2, 2013.
- NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U.S.A. Available <http://www.natureserve.org/explorer>. Accessed December 9, 2013.
- Neid, S.L. 2006. *Utricularia minor* L. (lesser bladderwort): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/utriculariaminor.pdf>. Accessed December 11, 2013.
- Nydick, K., Crawford, J., Bidwell, M., Livensperger, C., Rangwala, I., and Cozetto, K. 2012. Climate Change Assessment for the San Juan Mountain Regions, Southwestern Colorado, USA: A Review of Scientific Research. Prepared by Mountain Studies Institute in cooperation with USDA San Juan National Forest Service and USDOJ Bureau of Land Management Tres Rios Field Office. Durango, CO. Available for download from: www.mountainstudies.org.
- Richards, J.H. 2001. Bladder function in *Utricularia purpurea* (Lentibulariaceae): is carnivory important? *American Journal of Botany* 88:170-176.
- Victorin, M. 1940. About *Utricularia purpurea*. *Rhodora* 42:24.

APPENDIX C: CLIMATE CHANGE VULNERABILITY INDEX SCORING CATEGORY

Definitions

Reprinted with permission from Young, B., E. Byers, K. Gravuer, K. Hall, G. Hammerson, and A. Redder. 2011. Guidelines for Using the NatureServe Climate Change Vulnerability Index, Release 2.1. NatureServe, Arlington, VA.

Section A – Exposure to Local Climate Change

Temperature: percent of species known range/distribution that is expected to experience temperature increase, in categories defined by the CCVI. Exposure to predicted temperature increase was calculated using distribution data from CNHP's Element Occurrence Record database, and a climate prediction model averaged over the summer season (June – August) from Climate Wizard, using the high (A2) CO₂ emissions scenario. The high emissions scenario was used because it is most similar to current emissions. The analysis period was to the year 2050 (which is actually an average of projections for years 2040 – 2069). The summer season – growing season for plants – was used because it was considered the most critical time period for most species' life cycle.

AET: PET Moisture Metric: This index integrates projected temperature and precipitation changes to indicate how much drying will take place. This metric was created by NatureServe as part of the CCVI. We used a GIS calculation to determine the percent of each species' range/distribution (represented by EORs) that fall within each rating category. Categories are:

< -0.119
-0.097 - -0.119
-0.074 - -0.096
-0.051 - -0.073
-0.028 - -0.050
>-0.028

Section B – Indirect Exposure to Climate Change

1. **Exposure to sea level rise:** not applicable to Colorado. All species rated 'Neutral.'
2. **Distribution relative to natural barriers:** degree to which species' vulnerability is influenced by its ability to shift range/distribution in response to climate change. The geographical features of the landscape where a species occurs may naturally restrict it from dispersing to inhabit new areas (IPCC 2002, Midgley et al. 2003, Simmons et al. 2004, Koerner 2005, Thuiller et al. 2005, Jiguet et al. 2007, Benito Garzón et al. 2008, Hawkins et al. 2008, Loarie et al. 2008, Lenoir et al. 2008, Price 2008). Similarly, dispersal may be hindered by intervening anthropogenically altered landscapes such as urban or agricultural areas for terrestrial species or dams and culverts for aquatic species (Parmesan 1996).

Scoring categories for both natural barriers and anthropogenic barriers are:

Greatly Increase Vulnerability:	Barriers completely OR almost completely surround the current distribution such that the species' range in the assessment area is unlikely to be able to shift significantly with climate change, or the direction of climate change-caused shift in the species' favorable climate envelope is fairly well understood and barriers prevent a range shift in that direction. See Neutral for species in habitats not vulnerable to climate change.
	Examples for natural barriers: lowland terrestrial species completely surrounded by high mountains (or bordered closely and completely on the north side by high mountains); cool-water stream fishes for which barriers would completely prevent access to other cool-water areas if the present occupied habitat became too warm as a result of climate change; most non-volant species that exist only on the south side of a very large lake in an area where habitats are expected to shift northward with foreseeable climate change.
	Examples for anthropogenic barriers: species limited to small habitats within intensively developed urban or agricultural landscapes through which the species cannot pass, A specific example of this category is provided by the quino checkerspot butterfly (<i>Euphydryas editha quino</i>), a resident of northern Baja California and southern California; warming climates are forcing this butterfly northward, but urbanization in San Diego blocks its movement (Parmesan 1996, <i>Nature</i> 382:765).
Increase Vulnerability:	Barriers border the current distribution such that climate change-caused distributional shifts in the assessment area are likely to be greatly but not completely or almost completely impaired.
	Examples for natural barriers: certain lowland plant or small mammal species whose ranges are mostly (50-90%) bordered by high mountains or a large lake.
	Examples for anthropogenic barriers: most streams inhabited by a fish species have dams that would prevent access to suitable habitat if the present occupied habitat became too warm as a result of climate change; intensive urbanization surrounds 75% of the range of a salamander species.
Somewhat Increase Vulnerability:	Barriers border the current distribution such that climate change-caused distributional shifts in the assessment area are likely to be significantly but not greatly or completely impaired.
	Examples for natural barriers: certain lowland plant or small mammal species whose ranges are partially but not mostly bordered by high mountains or a large lake.
	Examples for anthropogenic barriers: 10-50% of the margin of a plant species' range is bordered by intensive urban development; 25% of the streams occupied by a fish species include dams that are likely to impede range shifts driven by climate change.
Neutral:	Significant barriers do not exist for this species, OR small barriers exist in the assessment area but likely would not significantly impair distributional shifts with climate change, OR substantial barriers exist but are not likely to contribute significantly to a reduction or loss of the species' habitat or area of occupancy with projected climate change in the assessment area.
	Examples of species in this category: most birds (for which barriers do not exist); terrestrial snakes in extensive plains or deserts that may have small barriers that would not impede distributional shifts with climate change; small alpine-subalpine mammal (e.g., ermine, snowshoe hare) in extensive mountainous wilderness area lacking major rivers or lakes; fishes in large deep lakes or large main-stem rivers that are basically invulnerable to projected climate change and lack dams, waterfalls, and significant pollution; a plant whose climate envelope is shifting northward and range is bordered on the west by a barrier but for which no barriers exist to the north.

3. Impact of land use changes resulting from human responses to climate change: This factor is intended to identify species that might be further threatened by strategies designed to mitigate

or adapt to climate change. Strategies designed to mitigate greenhouse gases, such as creating large wind farms, plowing new cropland for biofuel production, or planting trees as carbon sinks, have the potential to affect large tracts of land and the species that use these areas in both positive and negative ways (Johnson et al. 2003).

Definitions of scoring categories are:

<p>Increase Vulnerability:</p>	<p>The natural history/requirements of the species are known to be incompatible with mitigation-related land use changes that are likely to very likely to occur within its current and/or potential future range. This includes (but is not limited to) the following:</p> <ul style="list-style-type: none"> ✓ Species requiring open habitats within landscapes likely to be reforested or afforested. If the species requires openings within forests that are created/maintained by natural processes (e.g., fire), and if those processes have a reasonable likelihood of continuing to operate within its range, a lesser impact category may be appropriate. ✓ Bird and bat species whose migratory routes, foraging territory, or lekking sites include existing and/or suitable wind farm sites. If numerous wind farms already exist along the species' migratory route, negative impacts have been found in relevant studies; if such studies exist but negative impacts have not been found, a lesser impact category may be appropriate. ✓ Greater than 20% of the species' range within the assessment area occurs on marginal agricultural land, such as CRP land or other open areas with suitable soils for agriculture ("prime farmland", etc.) that are not currently in agricultural production OR > 50% of the species' range within the assessment area occurs on any non-urbanized land with suitable soils, where there is a reasonable expectation that such land may be converted to biofuel production. ✓ The species occurs in one or more river/stream reaches not yet developed for hydropower, but with the potential to be so developed. ✓ Species of deserts or other permanently open, flat lands with potential for placement of solar arrays. ✓ Species dependent on dynamic shoreline habitats (e.g., active dunes or salt marshes) likely to be destroyed by human fortifications against rising sea levels.
<p>Somewhat Increase Vulnerability:</p>	<p>The natural history/requirements of the species are known to be incompatible with mitigation-related land use changes that <i>may possibly</i> occur within its current and/or potential future range, including any of the above (under Increase).</p>
<p>Neutral:</p>	<p>The species is unlikely to be significantly affected by mitigation-related land use changes that may occur within its current and/or potential future range, including any of the above; OR it is unlikely that any mitigation-related land use changes will occur within the species' current and/or potential future range.</p>
<p>Somewhat Decrease Vulnerability:</p>	<p>The species is likely to benefit from mitigation-related land use changes that may occur within its current and/or potential future range. This includes (but is not limited to) the following:</p> <ul style="list-style-type: none"> ✓ Forest-associated species currently found within a landscape with < 40% forest cover, where increases in forest cover may occur as a result of reforestation or afforestation projects.

	<ul style="list-style-type: none"> ✓ Species currently subject to a higher frequency of fires than experienced historically, where there may now be greater incentive to control such fires. ✓ Species occurring on unprotected lands which may be protected and managed for conservation due to their carbon storage and/or sequestration ability.
Decrease Vulnerability:	The species is likely to benefit from mitigation-related land use changes that are likely to very likely to occur within its current and/or potential future range, including any of the above (under Somewhat Decrease).

Section C - Sensitivity

1. **Dispersal and movement.** Species with poor dispersal abilities may not be able to track fast-moving, favorable climates (Dyer 1995, Midgley et al. 2003, Williams et al. 2005, Jiguet et al. 2007).

Definitions of scoring categories are:

Greatly Increase Vulnerability:	Species is characterized by severely restricted dispersal or movement capability. This category includes species represented by sessile organisms that almost never disperse more than a few meters per dispersal event. Examples include: plants with large or heavy propagules for which the disperser is extinct or so rare as to be ineffective; species with dispersal limited to vegetative shoots, buds, or similar structures that do not survive (at least initially) if detached from the parent.
Increase Vulnerability:	Species is characterized by highly restricted dispersal or movement capability. This category includes species that rarely disperse through unsuitable habitat more than about 10 meters per dispersal event, and species in which dispersal beyond a very limited distance (or outside a small isolated patch of suitable habitat) periodically or irregularly occurs but is dependent on highly fortuitous or rare events. Examples include: plants dispersed ballistically; plant or animal species with free-living propagules or individuals that may be carried more than 10 meters by a tornado or unusually strong hurricane or large flood but that otherwise rarely disperse more than 10 meters; plants that do not fit criteria for Greatly Increase but lack obvious dispersal adaptations (i.e., propagules lack any known method for moving more than 10 meters away from the source plant).
Somewhat Increase Vulnerability:	Species is characterized by limited but not severely or highly restricted dispersal or movement capability. A significant percentage (at least approximately 5%) of propagules or individuals disperse approximately 10-100 meters per dispersal event (rarely farther), or dispersal capability likely is consistent with one of the following examples. Examples include; species that exist in small isolated patches of suitable habitat but regularly disperse or move among patches that are up to 100 meters (rarely farther) apart; many ant-dispersed plant species; plants whose propagules are dispersed primarily by small animals (e.g., some rodents) that typically move propagules approximately 10-100 meters from the source (propagules may be cached or transported incidentally on fur or feathers); plants dispersed by wind with low efficiency (e.g., species with inefficiently plumed seeds and/or that occur predominantly in forests).

Neutral:	Species is characterized by moderate dispersal or movement capability. A significant percentage (at least approximately 5%) of propagules or individuals disperse approximately 100-1,000 meters per dispersal event (rarely farther), or dispersal capability likely is consistent with one of the following examples. Examples include: species whose individuals exist in small isolated patches of suitable habitat but regularly disperse or move among patches that are 100-1,000 meters (rarely farther) apart; many plant species dispersed by wind with high efficiency (e.g., species with efficiently plumed seeds or very small propagules that occur predominantly in open areas); plant and animal species whose propagules or individuals are dispersed by small animals (e.g., rodents, grouse) that regularly but perhaps infrequently move propagules approximately 100-1,000 meters from the source).
Somewhat Decrease Vulnerability:	Species is characterized by good dispersal or movement capability. Species has propagules or dispersing individuals that readily move 1-10 kilometers from natal or source areas (rarely farther), or dispersal capability likely is consistent with one of the following examples. Examples include: plant species regularly dispersed up to 10 km (rarely farther) by large or mobile animals (e.g., plant has seeds that are cached, regurgitated, or defecated 1-10 kilometers from the source by birds [e.g., corvids, songbirds that eat small fleshy fruits] or mammals or that are transported on fur of large mobile animals such as most Carnivora or ungulates).
Decrease Vulnerability:	Species is characterized by excellent dispersal or movement capability. Species has propagules or dispersing individuals that readily move more than 10 kilometers from natal or source areas, or dispersal capability likely is consistent with one of the following examples.
	Examples include: plant or animal species whose individuals often or regularly are dispersed more than 10 kilometers by migratory or otherwise highly mobile animals, air or ocean currents, or humans, including species that readily become established outside their native ranges as a result of intentional or unintentional translocations by humans.

2. **Sensitivity to temperature and moisture changes:** This factor pertains to the breadth of temperature and precipitation conditions, at both broad and local scales, within which a species is known to be capable of reproducing, growing, or otherwise existing. Species requiring specific moisture and temperature regimes may be less likely to find similar areas as climates change and previously-associated temperature and precipitation patterns uncouple (Saetersdal and Birks 1997, Thomas 2005, Thuiller et al. 2005, Gran Canaria Declaration 2006, Hawkins et al. 2008, Laidre et al. 2008).

(a.i) **historical thermal niche:** This factor measures large-scale temperature variation that a species has experienced in recent historical times (i.e., the past 50 years), as approximated by mean seasonal temperature variation (difference between highest mean monthly maximum temperature and lowest mean monthly minimum temperature). It is a proxy for species' temperature tolerance at a broad scale.

Definitions of scoring categories are:

Greatly Increase Vulnerability:	Considering the mean seasonal temperature variation for occupied cells, the species has experienced very small (< 37° F/20.8° C) temperature variation in the past 50 years. Includes cave obligates and species occurring in thermally stable groundwater habitats.
Increase Vulnerability:	Considering the mean seasonal temperature variation for occupied cells, the species has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.
Somewhat Increase Vulnerability:	Considering the mean seasonal temperature variation for occupied cells, the species has experienced slightly lower than average (47.1 - 57° F/26.3 - 31.8° C) temperature variation in the past 50 years.
Neutral:	Considering the mean seasonal temperature variation for occupied cells, the species has experienced average (57.1 - 77° F/31.8 - 44.0° C) temperature variation in the past 50 years.
Somewhat Decrease Vulnerability:	Considering the mean seasonal temperature variation for occupied cells, the species has experienced greater than average (> 77° F/43.0° C) temperature variation in the past 50 years.

(a.ii.) **physiological thermal niche:** This factor assesses the degree to which a species is restricted to relatively cool or cold environments that are thought to be vulnerable to loss or significant reduction as a result of climate change.

Definitions of scoring categories are:

Greatly Increase Vulnerability:	Species is completely or almost completely (> 90% of occurrences or range) restricted to relatively cool or cold environments that may be lost or reduced in the assessment area as a result of climate change.
Increase Vulnerability:	Species is moderately (50-90% of occurrences or range) restricted to relatively cool or cold environments that may be lost or reduced in the assessment area as a result of climate change.
Somewhat Increase Vulnerability:	Species is somewhat (10-50% of occurrences or range) restricted to relatively cool or cold environments that may be lost or reduced in the assessment area as a result of climate change.
Neutral:	Species distribution is not significantly affected by thermal characteristics of the environment in the assessment area, or species occupies habitats that are thought to be not vulnerable to projected climate change.
Somewhat Decrease Vulnerability:	Species shows a preference for environments toward the warmer end of the spectrum.

(b.i.) **historical hydrological niche:** This factor measures large-scale precipitation variation that a species has experienced in recent historical times (i.e., the past 50 years), as approximated by mean annual precipitation variation across occupied cells within the assessment area.

Definitions of scoring categories are:

Greatly Increase Vulnerability:	Considering the range of mean annual precipitation across occupied cells, the species has experienced very small (< 4 inches/100 mm) precipitation variation in the past 50 years.
Increase Vulnerability:	Considering the range of mean annual precipitation across occupied cells, the species has experienced small (4 - 10 inches/100 - 254 mm) precipitation variation in the past 50 years.
Somewhat Increase Vulnerability:	Considering the range of mean annual precipitation across occupied cells, the species has experienced slightly lower than average (11 - 20 inches/255 - 508 mm) precipitation variation in the past 50 years.
Neutral:	Considering the range of mean annual precipitation across occupied cells, the species has experienced average (21 - 40 inches/509 - 1,016 mm) precipitation variation in the past 50 years.
Somewhat Decrease Vulnerability:	Considering the range of mean annual precipitation across occupied cells, the species has experienced greater than average (> 40 inches/1,016 mm) precipitation variation in the past 50 years.

(b.ii.) **physiological hydrological niche:** This factor pertains to a species' dependence on a narrowly defined precipitation/hydrologic regime, including strongly seasonal precipitation patterns and/or specific aquatic/wetland habitats (e.g., certain springs, vernal pools, seeps, seasonal standing or flowing water) or localized moisture conditions that may be highly vulnerable to loss or reduction with climate change.

Definitions of scoring categories are:

Greatly Increase Vulnerability:	Completely or almost completely (>90% of occurrences or range) dependent on a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change AND the expected direction of moisture change (drier or wetter) is likely to reduce the species' distribution, abundance, or habitat quality. If this second condition is not met (e.g., species dependent on springs tied to a regional aquifer that would not be expected to change significantly with climate change), the species should be scored as Neutral. Examples for Greatly Increase include plants that are exclusively or very strongly associated with localized moist microsites (e.g., "hanging gardens" in arid landscapes).
--	---

Increase Vulnerability:	Moderately (50-90% of occurrences or range) dependent on a strongly seasonal hydrologic regime and/or a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change AND the expected direction of moisture change (drier or wetter) is likely to reduce the species' distribution, abundance, or habitat quality. If this second condition is not met, the species should be scored as Neutral. Examples for Increase include certain plants whose life cycles are highly synchronized with Mediterranean precipitation patterns in areas vulnerable to large changes in the amount and seasonal distribution of precipitation. Also included are desert or semi-desert plants that frequently occur in but are not restricted to or almost restricted to moisture-accumulating microsites, as well as plants (and animals that depend on these species) for which >50% of populations occur in areas such as sandy soils that are sensitive to changes in precipitation.
Somewhat Increase Vulnerability:	Somewhat (10-50%) dependent on a strongly seasonal hydrologic regime and/or a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change AND the expected direction of moisture change (drier or wetter) is likely to reduce the species' distribution, abundance, or habitat quality. If this second condition is not met, the species should be scored as Neutral. Examples: plants (and animals that depend on these species) for which 10-50% of populations occur in areas such as sandy soils that are sensitive to changes in precipitation; certain plants with ranges restricted to seasonal precipitation environments (e.g., summer rainfall deserts) and which have a moderate degree of adaptation to that seasonality.
Neutral:	Species has little or no dependence on a strongly seasonal hydrologic regime and/or a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change OR hydrological requirements are not likely to be significantly disrupted in major portion of the range.
Somewhat Decrease Vulnerability:	Species has very broad moisture regime tolerances OR would benefit by the predicted change in hydrologic regime. Examples include water-limited species that could increase with increasing precipitation or arid-adapted species that could increase in areas with decreasing moisture availability.

c.) **dependence on specific disturbance regime:** This factor pertains to a species' response to specific disturbance regimes such as fires, floods, severe winds, pathogen outbreaks, or similar events. Species dependent on habitats such as prairies, longleaf pine forests, and riparian corridors that are maintained by regular disturbances (e.g., fires or flooding) are vulnerable to changes in the frequency and intensity of these disturbances caused by climate change (IPCC 2007, Archer and Predick 2008).

Definitions of scoring categories are:

Increase Vulnerability:	Strongly affected by specific disturbance regime, and climate change is likely to change the frequency, severity, or extent of that disturbance regime in a way that reduces the species' distribution, abundance, or habitat quality. For example, many sagebrush-associated species in regions predicted to experience increased fire frequency/intensity would be scored here due to the anticipated deleterious effects of increased fire on their habitat.
Somewhat Increase Vulnerability:	Moderately affected by specific disturbance regime, and climate change is likely to change the frequency, severity, or extent of that disturbance regime in a way that reduces the species' distribution, abundance, or habitat quality, OR strongly affected by specific disturbance regime, and climate change is likely to change that regime in a way that causes minor disruption to the species' distribution, abundance, or habitat quality. For example, plants in a river scour community that are strongly tied to natural erosion and deposition flood cycles, which may shift position within the channel rather than disappear as a result of climate change.
Neutral:	Little or no response to a specific disturbance regime or climate change is unlikely to change the frequency, severity, or extent of that disturbance regime in a way that affects the range or abundance of the species.
Somewhat Decrease Vulnerability:	Moderately affected by specific disturbance regime, and climate change is likely to change the frequency, severity, or extent of that disturbance regime in a way that increases the species' distribution, abundance, or habitat quality. Many fire-adapted plants can be scored here if a predicted increase in fire frequency/intensity is anticipated to be beneficial.
Decrease Vulnerability:	Strongly affected by specific disturbance regime, and climate change is likely to change the frequency, severity, or extent of that disturbance regime in a way that increases the species' distribution, abundance, or habitat quality (e.g., in areas predicted to experience increased fire frequency, invasive grasses that have a strong positive response to fire (e.g., ecosystem function-altering) could be scored here.

(d.) **dependence on ice, ice-edge, or snow covered habitats:** The extent of oceanic ice sheets and mountain snow fields are decreasing as temperatures increase, imperiling species dependent on these habitats (Stirling and Parkinson 2006, IPCC 2007, Laidre et al. 2008).

Definitions of scoring categories are:

Greatly Increase Vulnerability:	Highly dependent (>80% of subpopulations or range) on ice- or snow-associated habitats; or found almost exclusively on or near ice or snow during at least one stage of the life cycle.
Increase Vulnerability:	Moderately dependent (50-80% of subpopulations or range) on ice- or snow-associated habitats; or often found most abundantly on or near ice or snow but also regularly occurs away from such areas.

Somewhat Increase Vulnerability:	Somewhat (10-49% of subpopulations or range) dependent on ice- or snow-associated habitats, or may respond positively to snow or ice but is not dependent on it. For example, certain alpine plants are often associated with long-lasting snow beds but also commonly occur away from such areas; certain small mammals experience increased survival and may develop relatively large populations under winter snow cover but do not depend on snow cover. Species that benefit from a minimum thickness of ice or snowpack for winter insulation should also be scored here.
Neutral:	Little dependence on ice- or snow-associated habitats (may be highly dependent in up to 10% of the range).

3. Restriction to uncommon geological features or derivatives - This factor pertains to a species' need for a particular soil/substrate, geology, water chemistry, or specific physical feature (e.g., caves, cliffs, active sand dunes) for reproduction, feeding, growth, or otherwise existing for one or more portions of the life cycle (e.g., normal growth, shelter, reproduction, seedling establishment). Species requiring specific substrates, soils, or physical features such as caves, cliffs, or sand dunes may become vulnerable to climate change if their favored climate conditions shift to areas without these physical elements (Hawkins et al. 2008). It focuses on the commonness of suitable conditions for the species on the landscape, as indicated by the commonness of the features themselves combined with the degree of the species' restriction to them. Climate envelopes may shift away from the locations of fixed (within at least a 50 year timeframe) geological features or their derivatives, making species tied to these uncommon features potentially more vulnerable to habitat loss from climate change than are species that thrive under diverse conditions.

Definitions of scoring categories are:

Increase Vulnerability:	Very highly dependent upon, i.e., more or less endemic to (> 85% of occurrences found on) a particular highly uncommon geological feature or derivative (e.g., soil, water chemistry). Such features often have their own endemics. Examples include serpentine (broad and strict) endemic plants, plants of calcareous substrates where such substrates are uncommon (e.g., California, southeastern U.S.), plants restricted to one or a few specific rock strata, organisms more or less restricted to inland sand dunes or shale barrens, obligate cave-dwelling organisms, and springsnails restricted to springs with high dissolved CO ₂ . This category could also include fish species that require a highly uncommon substrate particle size for their stream bottoms, such as the Colorado pikeminnow (<i>Ptychocheilus lucius</i>) that spawns only on rare cobble bars cleared of debris by strong upstream currents.
--------------------------------	--

Somewhat Increase Vulnerability:	Moderately to highly dependent upon a particular geological feature or derivative, i.e., (1) an indicator of but not an endemic to (65-85% of occurrences found on) the types of features described under Increase, OR (2) more or less restricted to a geological feature or derivative that is not highly uncommon within the species' range, but is not one of the dominant types. Examples of the latter include species more or less restricted to active coastal sand dunes, cliffs, salt flats (including shorebirds that require sodic soils), inland waters within a particular salinity range, and non-dominant rock types such as occasional igneous rock intrusions within a landscape mostly dominated by sedimentary and/or metamorphic rocks. This category could also include fish species that require a specific substrate particle size for their stream bottoms, if that type of stream bottom is not one of the dominant types within the species' range.
Neutral:	Having a clear preference for (> 85% of occurrences found on) a certain geological feature or derivative, where the feature is among the dominant types within the species' range. For example, red spruce prefers acidic, organic soils (not uncommon within its range), although it is occasionally found on other soil types. Many species whose habitat descriptions specify one pH category (acidic, neutral, or basic) and/or one soil particle size (e.g., rocky, sandy, or loamy) will probably fall here, upon confirmation that the substrate type is not particularly uncommon within the species' range.
Somewhat Decrease Vulnerability:	Somewhat flexible but not highly generalized in dependence upon geological features or derivatives, i.e., found on a subset of the dominant substrate/water chemistry types within its range. Most habitat descriptions that mention more than one type of relatively widespread geological feature should probably go here; however, if all types mentioned are uncommon within the species' range, Somewhat Increase may be appropriate. This category also encompasses species not strongly tied to any specific geological feature or derivative, such as many birds and mammals.
Decrease Vulnerability:	Highly generalized relative to dependence upon geological features or derivatives, i.e., the species is described as a generalist and/or a significant proportion of its occurrences have been documented on substrates or in waters that represent opposite ends of the spectrum of types within the assessment region (e.g., many occurrences known from both acidic and basic soils or waters, or from both sandy and clay soils). Species such as common yarrow (<i>Achillea millefolium</i>) and coyote (<i>Canis latrans</i>) should be assigned to this category.

4. **Reliance on specific interactions** - The primary impact of climate change on many species may occur via effects on synchrony with other species on which they depend, rather than through direct physiological stress. Because species will react idiosyncratically to climate change, those with tight relationships with other species may be threatened (Bruno et al. 2003, Hampe 2004, Simmons et al. 2004, Hawkins et al. 2008, Laidre et al. 2008).

(a) **Dependence on other species to generate habitat:**

Definitions of scoring categories are:

Greatly Increase Vulnerability:	Required habitat generated primarily by one species, and that species is highly to extremely vulnerable to climate change within the assessment area.
Increase Vulnerability:	Required habitat generated primarily by one species, and that species is at most moderately vulnerable to climate change within the assessment area. See examples of species requiring other species to generate habitat under Greatly Increase Vulnerability. If the climate change vulnerability of the habitat-generating species is unknown, check both Greatly Increase and Increase Vulnerability.
Somewhat Increase Vulnerability:	Required habitat generated primarily by one or more of not more than a few species. For example, a certain degree of specificity exists between particular cactus species and certain nurse plants; burrowing owls (<i>Athene cunicularia</i>) depend on excavations made by relatively few species of burrowing mammals; certain plant species depend on large grazing animals to generate disturbance required for establishment and early growth.
Neutral:	Required habitat generated by more than a few species, or does not involve species-specific processes.

(b) **Dietary versatility:** animals only. This factor pertains to the diversity of food types consumed by animal species. Dietary specialists are more likely to be negatively affected by climate change than are species that readily switch among different food types.

Definitions of scoring categories are:

Increase Vulnerability:	Completely or almost completely (>90%) dependent on one species during any part of the year. For example, Clark's nutcracker (<i>Nucifraga columbiana</i>) depends heavily on the seeds of whitebark pine (<i>Pinus albicaulis</i>).
Somewhat Increase Vulnerability:	Completely or almost completely (>90%) dependent during any part of the year on a few species from a single guild that may respond similarly to climate change. For example, the larvae of various fritillary butterflies rely heavily on a few species of violets; the great purple hairstreak is dependent on a few mistletoe species.
Neutral:	Diet flexible; not dependent on one or a few species. For example, the diet of the great horned owl (<i>Bubo virginianus</i>) is flexible and not strongly dependent on one or a few species (although its diet may be dominated by one or a few species in a particular location).
Somewhat Decrease Vulnerability:	Omnivorous diet including numerous species of both plants and animals.

(c) **Pollinator versatility:** plants only

Definitions of scoring categories are:

Increase Vulnerability:	Completely or almost completely dependent on one species for pollination (> 90% of effective pollination accomplished by 1 species) or, if no observations exist, morphology suggests very significant limitation of potential pollinators (e.g., very long corolla tube).
Somewhat Increase Vulnerability:	Completely or almost completely dependent on 2-4 species for pollination (> 90% of effective pollination accomplished by 2-4 species) or, if no observations exist, morphology suggests conformation to a specific "pollination syndrome" (e.g., van der Pijl 1961, Evolution 15: 44-59, http://www.fs.fed.us/wildflowers/pollinators/syndromes.shtml).
Neutral:	Pollination apparently flexible; five or more species make significant contributions to pollination or, if no observations exist, morphology does not suggest pollinator limitation or pollination syndrome.

(d) **Dependence on other species for propagule dispersal:**

Definitions for scoring categories are:

Increase Vulnerability:	Completely or almost completely (roughly > 90%) dependent on a single species for propagule dispersal. For example, whitebark pine would fit here because Clark's nutcracker is the primary dispersal agent.
Somewhat Increase Vulnerability:	Completely or almost completely (roughly > 90%) dependent on a small number of species for propagule dispersal. For example, a freshwater mussel for which only a few species of fish can disperse larvae.
Neutral:	Disperses on its own (most animals) OR propagules can be dispersed by more than a few species.

(e) **Other inter-specific interactions:** This factor refers to interactions unrelated to habitat, seedling establishment, diet, pollination, or propagule dispersal. Here an inter-specific interaction can include mutualism, parasitism, commensalism, or predator-prey relationship.

Definitions for scoring categories are:

Increase Vulnerability:	Requires an interaction with a single other species for persistence.
Somewhat Increase Vulnerability:	Requires an interaction with a one member of a small group of taxonomically related species for persistence. Could also include cases where specificity is not known for certain, but is suspected. Many Orchidaceae will be in this category because of their requirement for a specific fungal partner for germination (Tupac Otero and Flanagan 2006, TREE 21: 64-65).
Neutral:	Does not require an interspecific interaction or, if it does, many potential candidates for partners are available.

5. **Genetic factors:** A species' ability to evolve adaptations to environmental conditions brought about by climate change is largely dependent on its existing genetic variation (Huntley 2005, Aitken et al. 2008).

(a) **Measured genetic variation:** Species with less standing genetic variation will be less able to adapt because the appearance of beneficial mutations is not expected to keep pace with the rate of 21st century climate change. Throughout this question, "genetic variation" may refer neutral marker variation, quantitative genetic variation, or both. To answer the question, genetic variation should have been assessed over a substantial proportion of a species' range.

Definitions for scoring categories are:

Increase Vulnerability:	Genetic variation reported as "very low" compared to findings using similar techniques on related taxa, i.e., lack of genetic variation has been identified as a conservation issue for the species.
Somewhat Increase Vulnerability:	Genetic variation reported as "low" compared to findings using similar techniques on related taxa.
Neutral:	Genetic variation reported as "average" compared to findings using similar techniques on related taxa.
Somewhat Decrease Vulnerability:	Genetic variation reported as "high" compared to findings using similar techniques on related taxa.

(b) **Occurrence of bottlenecks in recent evolutionary history (use only if C5a is unknown.** In the absence of rangewide genetic variation information (C5a), this factor can be used to infer whether reductions in species-level genetic variation that would potentially impede its adaptation to climate change may have occurred. Only species that suffered population reductions and then subsequently rebounded qualify for the Somewhat Increase or Increase Vulnerability categories.

Definitions of scoring categories are:

Increase Vulnerability:	Evidence that total population was reduced to ≤ 250 mature individuals, to one occurrence, and/or that occupied area was reduced by $>70\%$ at some point in the past 500 years.
Somewhat Increase Vulnerability:	Evidence that total population was reduced to 251-1000 mature individuals, to less than 10 occurrences, and/or that occupied area was reduced by 30-70% at some point in the past 500 years.
Neutral:	No evidence that total population was reduced to ≤ 1000 mature individuals and/or that occupied area was reduced by $> 30\%$ at some point in the past 500 years.

6. Phenological response to changing seasonal temperature or precipitation dynamics: Recent research suggests that some phylogenetic groups are declining due to lack of response to changing annual temperature dynamics (e.g., earlier onset of spring, longer growing season), including European bird species that have not advanced their migration times (Moller et al. 2008), and some temperate zone plants that are not moving their flowering times (Willis et al. 2008) to correspond to earlier spring onset. This may be assessed using either published multi-species studies such as those cited above or large databases such as that of the U.S. National Phenology Network.

Definitions of scoring categories are:

<i>Increase Vulnerability:</i>	Seasonal temperature or precipitation dynamics within the species' range show detectable change, but phenological variables measured for the species show no detectable change
<i>Somewhat Increase Vulnerability:</i>	Seasonal temperature or precipitation dynamics within the species' range show detectable change, and phenological variables measured for the species show some detectable change, but the change is significantly less than that of other species in similar habitats or taxonomic groups.
<i>Neutral:</i>	Seasonal temperature or precipitation dynamics within the species' range show detectable change, and phenological variables measured for the species show detectable change which is average compared to other species in similar habitats or taxonomic groups, OR seasonal dynamics within the species' range show no detectable change.
<i>Somewhat Decrease Vulnerability:</i>	Seasonal temperature or precipitation dynamics within the species' range show detectable change, and phenological variables measured for the species show detectable change which is significantly greater than that of other species in similar habitats or taxonomic groups.

Section D – Documented or modeled response to climate change

1) ***Documented response to recent climate change.*** Although conclusively linking species declines to climate change is difficult (Parmesan 2006), convincing evidence relating declines to recent climate patterns has begun to accumulate in a variety of species groups (Parmesan 1996, Parmesan and Yohe 2003, Root et al. 2003, Enquist and Gori 2008). This criterion incorporates the results of these studies when available into the calculation of the Index.

2) ***Modeled future change in range or population size.*** The change in area of the predicted future range relative to the current range is a useful indicator of vulnerability to climate change (Midgley et al. 2003, Thomas et al. 2004).

3) ***Overlap of modeled future range with current range.*** A spatially disjunct predicted future range indicates that the species will need to disperse in order to occupy the newly favored area, and geographical barriers or slow dispersal rates could prevent the species from getting there (Peterson et al. 2002, Schwartz et al. 2006).

4) ***Occurrence of protected areas in modeled future distribution.*** For many species, future ranges may fall entirely outside of protected areas and therefore compromise their long-term viability (Williams et al. 2005).

Appendix D: San Juan Region Rare Plant Species Climate Change Vulnerability Scores



Species	English Name	Geographic Area	Temperature Scope					Hamon AET:PET Moisture Metric Scope					Sea level	Natl barriers	Anth barriers	CC mitigation	Dispersal/Movement	historical thermal niche	physiological thermal niche	historical hydrological niche	physiological hydrological niche	Disturbance	Ice/snow	Phys habitat	Other spp for hab	Diet	Pollinators	Other spp disp	Other spp interaction	Genetic var	Gen bottleneck	Phenol response	Doc response	Modeled change	Modeled overlap	Protected Areas	Index	
			A >5.5F	A 5.1F	A 4.5F	A 3.9F	A <3.9F	< -0.1 19	-0	-0	-0	-0																										> 0.0 28
<i>Descurainia kenheilii</i>	Heil's tansy mustard	State of Colorado	100							100			U	Inc	N	N	Inc	N	Inc	GI	N	N	SI	N	N	N/A	U	N	U	U	U	U	U	U	U	U	EV	
<i>Draba fladnizensis</i>	arctic draba	Gunnison Basin	100					50	50				N	Inc-SI	N	N	SI	N	GI	SD	SD	SD	SD	Inc	N	N	N/A	N	U	U	U	U	U	U	U	U	U	HV
<i>Draba graminea</i>	San Juan whitlow-grass	State of Colorado	100						75	25			N	Inc	N	N	Inc	N	Inc	SI	GI	N	GI	N	N	N/A	N	N	N	U	U	U	U	U	U	U	U	EV
<i>Draba malpighiacea</i>	whitlow-grass	State of Colorado	100						100				N	Inc	N	SD	Inc	N	N	Inc	Inc	SI	N	N	N	N/A	U	N	U	U	U	U	U	U	U	U	U	EV
<i>Draba rectifruca</i>	mountain draba	Gunnison Basin	100						100				N	N	N	N	SI	SD	N	SD	SD	N	N	N	N	N/A	N	U	U	U	U	U	U	U	U	U	U	IL
<i>Draba smithii</i>	Smith Whitlow-grass	State of Colorado	54	46				1	26	35	14	24	N	Inc	N	Inc	Inc	N	Inc	N	Inc	N	N	SI	N	N/A	N	N	N	U	U	U	U	U	U	U	U	EV
<i>Draba streptobranchia</i>	Colorado Divide whitlow-grass	Gunnison Basin	100						100				N	Inc	N	N	SI	N	GI	SD	SD	N	Inc	N	N	N/A	N	U	U	U	U	U	U	U	U	U	U	EV
<i>Drosera anglica</i>	English sundew	San Juan Region	100	0	0	0	0	0	0	100	0	0	0	N	N	N	N	SI	SD	SI	N	GI	N	Inc	Inc	U	N/A	N	N	SI-N	SI	N/A	U	U	U	U	U	MV
<i>Epipactis gigantea</i>	giant helleborine	San Juan Region	100	0	0	0	0	0	0	33	67	0	0	N	N	N	N	N	SD	N	N	Inc	U	N	SI-N	N	N/A	SI	N	SI	N	N/A	U	U	U	U	U	MV
<i>Erigeron kachinensis</i>	Kachina daisy	State of Colorado	100						100				N	Inc	SI	N	Inc	N	Inc	GI	GI	N	N	SI	N	N/A	U	N	U	U	U	U	U	U	U	U	EV	
<i>Erigeron lanatus</i>	woolly fleabane	Gunnison Basin	100					100					N	Inc	N	U	N	N	GI	SD	SD	N	Inc	SI	N	N/A	N	N	U	U	U	U	U	U	U	U	EV	
<i>Eriogonum clavellatum</i>	Comb Wash buckwheat	State of Colorado	100							100	0.5		N	N	SI	Inc	Inc	N	N	GI	Inc	SI	N	N	N/A	U	N	U	U	U	U	U	U	U	U	U	EV	
<i>Eriophorum altaicum var. neogaeum</i>	altai cottongrass	Gunnison Basin	100						100				N	SI	N	N	SI	N	GI	SD	GI	N	Inc	Inc	N	N/A	N	N	U	U	U	U	U	U	U	U	EV	
<i>Eriophorum chamissonis</i>	russet cottongrass	San Juan Region	100	0	0	0	0	0	0	100	0	0	0	N	SI	N	N	N	N	GI	N	GI	N	Inc	Inc	N	N/A	N	N	U	U	U	U	U	U	U	U	MV
<i>Gilia haydenii</i>	San Juan gilia	San Juan Region	100	0	0	0	0	0	0	51	49	0	0	N	N	SI-N	N	SI	SD	N	N	N	U	N	SI	N	N/A	SI-N	N	U	U	U	U	U	U	U	PS	
<i>Gutierrezia elegans</i>	Lone Mesa snakeweed	State of Colorado	100						100				N	Inc	SI	Inc	Inc	N	N	GI	Inc	N	N	Inc	N	N/A	U	N	U	U	U	U	U	U	U	U	EV	
<i>Hackelia gracilentia</i>	Mesa Verde stickseed	State of Colorado	100						100				N	N	SI	N	Inc	N	N	Inc	Inc	SI	N	N	N/A	U	N	U	U	U	U	U	U	U	U	U	EV	
<i>Ipomopsis polyantha</i>	Pagosa skyrocket	State of Colorado		100					100				N	Inc	Inc	Inc	Inc	SD	N	GI	Inc	N	N	Inc	N	N/A	N	N	U	U	U	U	U	U	U	U	EV	
<i>Lepidium crenatum</i>	alkaline pepperwort	State of Colorado	100					24	25	51			N	SI	SI	Inc	Inc	N	N	SI	Inc	SI	N	N	N/A	U	N	U	U	U	U	U	U	U	U	U	EV	
<i>Lesquerella pruinosa</i>	Pagosa bladderpod	State of Colorado		100				1	95	4			N	Inc	SI	Inc	Inc	SD	N	Inc	Inc	N	N	Inc	N	N/A	N	N	N	U	U	U	U	U	U	U	EV	
<i>Luzula subcapitata</i>	Colorado wood-rush	Gunnison Basin	100					100					N	SI	N	N	SI	N	Inc	SD	GI	N	Inc	N	U	N/A	N	U	N	U	U	U	U	U	U	U	EV	
<i>Machaeranthera coloradoensis</i>	Colorado tansy-aster	Gunnison Basin	100						100				N	SI-N	N	N	N	N	SI-N	SD	SD	N	N	N	N/A	N	N	U	U	U	U	U	U	U	U	U	PS	
<i>Mimulus eastwoodiae</i>	Eastwood's monkeyflower	San Juan Region	100	0	0	0	0	0	0	0	0	100	0	N	SI	N	N	N	SD	Inc	N	GI	N	N	SI	N/A	SI	N	U	U	U	U	U	U	U	U	HV	
<i>Pediomelum aromaticum</i>	Paradox breadroot	San Juan Region	100	0	0	0	0	0	0	0	0	100	0	N	N	N	N	Inc	SD	N	N	SI	U	N	N	N/A	SI	N	Inc	U	U	U	U	U	U	MV		
<i>Penstemon breviculus</i>	little penstemon	San Juan Region	100	0	0	0	0	0	0	0	31	69	0	N	N	N	N	Inc	SD	N	N	N	U	N	N	N/A	SI	N	U	U	U	U	U	U	U	PS		
<i>Physaria pulvinata</i>	cushion	State of Colorado	100						100				N	Inc	SI-N	Inc	Inc	N	N	Inc	Inc	N	N	Inc	N	N/A	U	N	U	U	U	U	U	U	U	U	EV	



Species	English Name	Geographic Area	Temperature Scope					Hamon AET:PET Moisture Metric Scope					Sea level	Nat'l barriers	Anth barriers	CC mitigation	Dispersal/Movement	historical thermal niche	physiological thermal niche	historical hydrological niche	physiological hydrological niche	Disturbance	Ice/snow	Phys habitat	Other spp for hab	Diet	Pollinators	Other spp disp	Other spp interaction	Genetic var	Gen bottleneck	Phenol response	Doc response	Modeled change	Modeled overlap	Protected Areas	Index			
			A >5.5F	A 5.1F	A 4.5F	A 3.9F	A <3.9F	< -0.1	-0	-0	-0	-0																										> 0.0	B1	B2a
	bladderpod																																							
<i>Physaria scrotiformis</i>	West Silver bladderpod	State of Colorado	100							100				N	Inc	N	Inc	Inc	N	N	GI	Inc	N	N	SD	N	N/A	U	N	U	U	U	U	U	U	U	EV			
<i>Proatriplex pleiantha</i>	Mancos saltbush	San Juan Region	100	0	0	0	0	0	0	0	0	0	100	N	N	N	N	Inc	SD	N	N	Inc	U	N	Inc	N	N/A	SI	N	U	U	U	U	U	U	U	MV			
<i>Puccinellia parishii</i>	Parish's alkali grass	State of Colorado	100						100					N	Inc	SI	N	N	N	N	GI	GI	N	N	N	N	N/A	N	N	U	U	U	U	U	U	U	U	EV		
<i>Ranunculus gelidus</i>	tundra buttercup	Gunnison Basin	100						67	34				N	Inc	N	N	N	N	GI	SD	SD	N	GI	N	N	N/A	N	N	U	U	U	U	U	U	U	U	EV		
<i>Sclerocactus mesa-verde</i>	Mesa Verde hookless cactus	State of Colorado	100									100		N	Inc	N	Inc	Inc	N	N	GI	Inc	N	N	Inc	N	N/A	SI	N	U	U	U	U	U	U	U	U	U	EV	
<i>Sphagnum angustifolium</i>	narrowleaf peat moss	San Juan Region	100	0	0	0	0	0	0	65	35	0	0	N	Inc	N	N	SI	N	Inc	N	GI	N	Inc	Inc	N	N/A	N	U	U	U	U	U	U	U	U	U	MV		
<i>Sphagnum balticum</i>	Baltic peat moss	San Juan Region	100	0	0	0	0	0	0	72	28	0	0	N	Inc	N	N	SI	N	Inc	N	GI	N	Inc	Inc	N	N/A	N	N	U	U	U	U	U	U	U	U	U	MV	
<i>Sporobolus flexuosus</i>	mesa dropseed	State of Colorado	67	33	0	0	0	0	45	40	15	0	0	N	Inc	N	N	N	SD	SD	SI	SD	N	N	N	U	N/A	N	N	U	U	N	U	U	U	U	U	U	U	PS
<i>Townsendia glabella</i>	Gray's townsend-daisy	State of Colorado	47	53					77	23				N	Inc	SI-N	Inc	Inc	SD	N	SI	Inc	N	N	Inc	N	N/A	N	N	U	U	U	U	U	U	U	U	U	U	EV
<i>Townsendia rothrockii</i>	Rothrock townsend-daisy	Gunnison Basin	100					16	42	31	11			N	Inc	N	N	SI	N	Inc	SD	SD	N	Inc	N	N/A	N	N	U	U	U	U	U	U	U	U	U	U	EV	
<i>Triteleia grandiflora</i>	largeflower triteleia	San Juan Region	100	0	0	0	0	0	0	100	0	0	0	N	N	N	SD	Inc	SD	SI	N	Inc	U	N	N	N	N/A	N	N	U	U	U	U	U	U	U	U	U	MV	
<i>Utricularia minor</i>	lesser bladderwort	San Juan Region	100	0	0	0	0	0	0	100	0	0	0	N	SI	N	N	SI	N	Inc	N	GI	N	Inc	U	U	N/A	N	N	SI-N	U	U	U	U	U	U	U	U	U	MV