Eriogonum coloradense Small (Colorado buckwheat): A Technical Conservation Assessment

Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project

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Cover Photo Credit

Eriogonum coloradense (Colorado buckwheat). Photograph by Bill Jennings. Used with permission.

The broad gray summit is barren and desolate-looking in general views, wasted by ages of gnawing storms; but looking at the surface in detail, one finds it covered by thousands and millions of charming plants with leaves and flowers so small they form no mass of color visible at a distance of a few hundred yards. Beds of azure daisies smile confidingly in moist hollows, and along the banks of small rills, with several species of Eriogonum...

John Muir
FROM *MY FIRST SUMMER IN THE SIERRA*

Summary of Key Components for Conservation of *Eriogonum coloradense*

Status

Eriogonum coloradense (Colorado buckwheat) is known from 22 occurrences in five counties (Chaffee, Gunnison, Park, Pitkin, and Saguache) in Colorado. Sixteen or 18 occurrences are known to reside on USDA Forest Service land on the Gunnison National Forest, White River National Forest, and San Isabel National Forest. Other occurrences are known on privately-owned lands and Bureau of Land Management lands. The ownership of eight occurrences is unknown due to vague location information, and 16 occurrences have not been seen in over 20 years. It is found in a restricted area but across a broad elevation range (8,870 to 12,840 feet) associated with many different substrates and habitats. It has a somewhat bimodal distribution, with most known occurrences in alpine sites but some in grassland and open, subalpine sites as well. The total population size of *E. coloradense* is unknown, but current data suggest a population size of 4,700 to 5,000 individuals. The largest and best-known occurrences (and most of the known population) are found in Gunnison and Pitkin counties, with approximately half of the known population occurring in one occurrence. It is ranked globally imperiled (G2) by NatureServe and imperiled in the state (S2) by the Colorado Natural Heritage Program. *Eriogonum coloradense* is not included on the sensitive species list of the USDA Forest Service Region 2 (USDA Forest Service 2003), and it is not listed as threatened or endangered under the Endangered Species Act of 1973 (U.S.C. 1531-1536, 1538-1540). It is included on the sensitive species list for the Bureau of Land Management Gunnison Field Office (Bureau of Land Management 2000). There is some evidence suggesting that *E. coloradense* is a high elevation form of *E. lonchophyllum*, but there has been no rigorous investigation to verify or refute this.

Primary Threats

Observations and quantitative data have shown that there are several threats to the persistence of *Eriogonum coloradense*. In order of decreasing priority, these are recreation impacts, grazing and its secondary effects, right-of-way management, residential development and human population growth, exotic species invasion, effects of small population size, mining, rust, global climate change, and pollution. Some threats are more urgent at some sites than at others; thus this hierarchy of threats is different for each occurrence.

Primary Conservation Elements, Management Implications and Considerations

Most occurrences of *Eriogonum coloradense* are found on public land, where they are less likely to be impacted by some threats such as residential development. Of the 16 to 18 occurrences found on USDA Forest Service land, at least eight and possibly 12 are in either designated wilderness areas or in a research natural area. However, *E. coloradense* has no special status designation with the USDA Forest Service, so consideration with respect to management is not required for this species. Because 16 of the 22 known occurrences have not been revisited in over 20 years, the current status of most occurrences is uncertain and more current information is badly needed. The precise locations of many occurrences are also not known, so they may not benefit from management efforts on their behalf. Thus species inventory efforts are badly needed for *E. coloradense*. Taxonomic research and common garden studies are needed to determine the taxonomic status of *E. coloradense* with respect to *E. lonchophyllum*. Research is also needed to investigate the population biology and autecology of *E. coloradense* so that conservation efforts on its behalf can be most effective. Current information suggests that sensitive species status for *E. coloradense* may help to ensure the viability of occurrences on USDA Forest Service land, which make up the large majority of those known for this species.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). *Eriogonum coloradense* (Colorado buckwheat) is the focus of an assessment because of its rarity in Region 2. It is listed as sensitive by the Bureau of Land Management (BLM) Gunnison Field Office (Bureau of Land Management 2000), but it is not currently on the Region 2 sensitive species list (USDA Forest Service 2003). It was considered for sensitive species status, but a lack of information precluded its listing (USDA Forest Service 2004). This assessment addresses the biology of *E. coloradense* throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological backgrounds upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e. management implications). Furthermore, it cites management recommendations proposed elsewhere and, when management recommendations have been implemented, the assessment examines the success of the implementation.

Scope of Assessment

The *Eriogonum coloradense* assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although some of the literature relevant to the species originates from field investigations outside the Region 2, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *E. coloradense* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. All known publications, reports, and element occurrence records for *Eriogonum coloradense* are referenced in this assessment, and all of the available experts on this species were consulted during its synthesis. All available specimens of *E. coloradense* were viewed to verify populations and to incorporate specimen label data. Specimens were searched for at COLO (University of Colorado Herbarium), CS (CSU Herbarium), RM (Rocky Mountain Herbarium), SJNM (San Juan College Herbarium), CC (Carter Herbarium), Great Sand Dunes National Park Herbarium, GREE (University of Northern Colorado Herbarium), NMCR (New Mexico State University Range Science Herbarium), and UNM (University of New Mexico Herbarium). This assessment emphasizes refereed literature because this is the accepted standard in science. Some non-refereed literature was used in the assessment when information was unavailable elsewhere, but this was regarded with greater skepticism. Unpublished data (e.g. state natural heritage program records) were important in estimating the geographic distribution, and contain the vast majority of the useful information known on *E. coloradense*. However, these data required special attention because of the diversity of persons and methods used in collection.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, we must rely on observations, inference, good thinking, and models to guide our understanding of ecological relations. Confronting uncertainty, then, is not prescriptive. In this assessment, we note the strength of evidence for particular ideas, and we describe alternative explanations where appropriate.

Treatment of this Document as a Web Publication

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review of this Document

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

Management Status and Natural History

Management Status

Eriogonum coloradense is presently not considered a sensitive species in Region 2 of the USFS (USDA Forest Service 2003). It is listed on the BLM Colorado State Sensitive Species List in the Gunnison Field Office (Bureau of Land Management 2000). NatureServe considers *E. coloradense* to be globally imperiled (G2). Only found in Colorado, it is also considered imperiled (S2) by the Colorado Natural Heritage Program. It is considered imperiled because it is known from approximately 22 occurrences, many of which either have not been revisited in over 20 years or have very low numbers of individuals. For explanations of NatureServe's ranking system, see the Definitions section of this document. *Eriogonum coloradense* is not listed as threatened or endangered under the Endangered Species Act of 1973 (U.S.C. 1531-1536, 1538-1540), nor has it ever been a candidate species or petitioned for listing.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Since *Eriogonum coloradense* is not listed as threatened or endangered under the Endangered Species Act of 1973 (U.S.C. 1531-1536, 1538-1540), there are no laws concerned specifically with its conservation. It is listed on the sensitive species list of the Gunnison Field Office of the BLM, so project planners with that agency must give consideration to this species so as to maintain its habitat and population persistence. It is not currently considered a sensitive species by the USFS Region 2.

Eight (and possibly 12) of the 16 (possibly 18) occurrences of *Eriogonum coloradense* documented on USFS lands of Region 2 are on lands with special designation (**Table 1**). Seven (and possibly 11) occurrences are in designated wilderness areas (Maroon Bells-Snowmass Wilderness Area and possibly Raggeds Wilderness Area and Collegiate Peaks Wilderness Area) (**Table 2**). These areas are protected by the Wilderness Preservation Act passed by Congress in 1964. The use of mechanized or motorized equipment, including mountain bikes, is prohibited in designated wilderness areas. However, a broad range of other activities, including hiking, horseback riding, camping, hunting, fishing and grazing is permitted. Although these wilderness area designations do not explicitly protect *E. coloradense*, occurrences in wilderness areas are likely to be somewhat more protected than occurrences on lands where more use is permitted. An additional occurrence (EOR 5 in **Table 3**) is known from the Gothic Research Natural Area where it is also protected from many potential impacts as in wilderness areas, and is protected from grazing impacts. However, the author was unable to determine whether the management objectives for the research natural area included specific mention of *E. coloradense*. *Eriogonum coloradense* is a conservation target for ecoregional planning in the Southern Rocky Mountain Ecoregion (Neely et al. 2001).

Adequacy of current laws and regulations

Eriogonum coloradense has no legal protection unto itself that would prevent the destruction of individual plants or their habitat. Because it is listed as a sensitive species by the Gunnison Field Office of the BLM, planning activities must give consideration to this species so as to maintain its habitat and population persistence. However, it is only known from one (possibly three) occurrences on BLM land, and none of these occurrences have been revisited in over 20 years. As of this writing, a conservation strategy has not been written for this species at a national or regional level by the USFS or any other federal agency. Occurrences located in wilderness areas benefit from some of the protections cited above, where current laws and regulations may adequately protect them.

Table 1. Summary of land ownership status of the 22 known occurrences of *Eriogonum coloradense*. Because some occurrences may be found on more than one land ownership type, the total number of occurrences is less than the sum of the rows in this table. Also, because one occurrence is known from two forests, the total number of USDA Forest Service occurrences is less than the sum of the numbers of occurrences in each forest. Numbers in parentheses are possible additional occurrences, but because their precise location is uncertain the land ownership status is also uncertain. Please see **Table 3** for land ownership of specific occurrences.

Land Ownership Status	Number of Occurrences	Subtotals
USDA Forest Service	16 (2)	
Gunnison National Forest		10 (1)
San Isabel National Forest		1
White River National Forest		6 (1)
Bureau of Land Management	1 (2)	
Private	1 (2)	
TOTAL	22	

Table 2. Summary of special land status designation for the occurrences of *Eriogonum coloradense* known from USDA Forest Service lands. Numbers in parentheses are possible additional occurrences, but because their precise location is uncertain the land status is also uncertain. Please see **Table 3** for land ownership of specific occurrences.

Land Status	Number of Occurrences
Gothic Research Natural Area	1
Maroon Bells-Snowmass Wilderness Area	7 (2)
Raggeds Wilderness Area	(1)
Collegiate Peaks Wilderness Area	(1)

Most occurrences are in somewhat inaccessible or rarely visited sites. With the dearth of information on this species, it is not known to what extent it has been subjected to human impacts in which the adequacy of current laws could be fully assessed.

Adequacy of current enforcement of laws and regulations

There have been no known cases in which an occurrence of *Eriogonum coloradense* was extirpated due to human activities or the failure to enforce any existing regulations. However, this does not necessarily indicate that current regulations or their enforcement are adequate for its protection.

Biology and Ecology

Classification and description

Eriogonum coloradense Small is a member of the buckwheat family (Polygonaceae). The Polygonaceae is a large family composed mainly of herbs. It is comprised of about 30 genera and 750 species worldwide (Heywood 1993). It is a cosmopolitan family but is more common in the north temperate regions (Zomlefer 1994). The Polygonaceae is in the dicot group, subclass Caryophyllidae, and order Polygonales (Heywood 1993, USDA Natural Resources Conservation Service 2001). The Polygonales is a monofamilial order. *Eriogonum coloradense* is in the subfamily Eriogonoideae. The genus *Eriogonum* includes about 250 species, almost all of which are found in North America (Reveal 1981, Reveal 1985). The combination of isolated mountain ranges and many unusual soil types in the intermountain west has resulted in a high degree of endemism in recently evolved taxa of *Eriogonum* (The Nature Conservancy and the Association for Biodiversity Information 2000). Forty-nine species of *Eriogonum* are known from Colorado (Weber and Wittmann 2000, Weber and Wittmann 2001a and b); many of these are rare. The Colorado Natural Heritage Program tracks 16 species of *Eriogonum* as rare. One Colorado species, *E. pellinophilum*, is a federally listed endangered species.

History of knowledge and taxonomic status

Eriogonum coloradense was first collected by Frederic E. Clements in 1896 on Mt. Harvard in Chaffee County, Colorado. His holotype specimen (66) is

Table 3. Summary information for the known occurrences of *Eriogonum coloradense*. Precision codes are: S = seconds record (precise location known), M = minutes record (location known to within approximately one square mile), and G = general record (location cannot be accurately determined with available data).

Arbitrary EOR Number	County	Ownership	Date of Last Observation	Location	Precision	Elevation (ft.)	Habitat and notes	Population Size	Source I.D.
1	Chaffee	Probably USDA Forest Service (USFS): San Isabel National Forest, Collegiate Peaks Wilderness Area	1896	Mount Harvard	G	Unknown	Not reported.	Not reported	Clements 66 (NY)
2	Gunnison	USFS: Gunnison National Forest, Maroon Bells Wilderness Area	7/1/1951	Conundrum Pass	M	12,600	Near meadow.	Not reported	CNHP EO 2
3	Gunnison	Probably USFS: Gunnison National Forest, Maroon Bells Wilderness Area	7/5/1948	Copper Lake Trail	G	10,760 to 12,400	Not reported.	Not reported	CNHP EO 19
4	Gunnison	USFS: White River National Forest	8/4/2001	Crystal Ridge	S	12,220 to 12,460	Total tree cover: 0 percent. Total shrub cover: 0 percent. Total forb cover: 5 percent. Total graminoid cover: 5 percent. Total moss/lichen cover: 0. Total bare ground cover: 10 percent (mostly broken rock). Associated plant community: *Erigeron* spp., *Potentilla* spp., *Carex* spp. Habitat type: alpine. Aspect: southeast to southwest. Slope: 0 to 60 percent. Slope shape: straight to convex. Light exposure: full sun up to early afternoon. Topographic position: ridge and steep side shoot. Moisture: dry, seasonal snow melt. Parent material: Gothic Formation of Langenheim (ridge and upper slope), Belden Formation (lower part of steep side shoot). Geomorphic land form: glaciated ridge, upper side slope, and steep side shoot in broken rock. Soil texture: pockets of fine soil. Moisture: dry, seasonal snow melt. Many small (young?) plants in population. Evidence of threats and disturbance: no evidence of hikers using the ridge. Possible mining claim area. Evidence of threats and disturbance: hiking, an informal trail parallels the ridge, a few feet to the west of the ridge. Several plants growing on the trail.	94 counted, estimate 70 more	CNHP EO 20
5	Gunnison	USFS: Gunnison National Forest, Gothic Research Natural Area	1986	Gothic	M	11,000	Subalpine forest (open spots of floor). Also in the Tall Shrublands- Extremely Rocky community.	Cover = 0.4 percent in one plot	CNHP EO 4

Arbitrary EOR Number	County	Ownership	Date of Last Observation	Location	Precision	Elevation (ft.)	Habitat and notes	Population Size	Source I.D.
6	Gunnison	Private or USFS: Gunnison National Forest	1954	Gothic Earthflow	M	~9,500	On stable shale of the earthflow. Associated plant community: Perennial Forb. Associated species: *Chaenactis alpina*, *Taraxacum officinale*, *Artemisia dracunculus*, *Erigeron speciosus*, *Agoseris glauca*, *Aster bigelovii*, *Artemisia tridentata*, grass species, *Agropyron trachycaulum*, *Ipomopsis aggregata*, *Elymus elymoides*, *Penstemon strictus*, *Bromus polyanthus*, *Hackelia florbunda*.	~15	Langenheim 1956
7	Gunnison	USFS: Gunnison National Forest	7/6/1969	Gothic Mountain	M	11,500	Mountain; gravelly soil; spruce-fir-aspen community.	Not reported	CNHP EO 12
8	Gunnison	USFS: Gunnison National Forest	9/22/2001	Mount Baldy	S	11,840	Total tree cover: 10 percent krummhotz. Total shrub cover: 5 percent. Total forb cover: 5 percent. Total graminoid cover: 2 percent. Total moss/lichen cover: not observed. Total bare ground cover: 80 percent. Habitat type: alpine (krummholz-spruce/fir). Associated plant species: *Picea engelmannii*, *Abies lasiocarpa* (krummholz), *Salix* spp., *Carex* spp., *Poa alpina*, *Heterotheca villosa*, *Ivesia gordonii*, *Chaenactis alpina*, *Lupinus* spp., *Ligularia* spp., *Erigeron* spp. Aspect: southeast, northeast, northwest. Slope: 0 to 60 percent. Slope shape: convex; ridge and sideslope. Topographic position: ridge and upper back slope. Moisture: dry (seasonal snow melt). Parent material: Kmu Mancos Shale (upper member) for sites 1, 2, and 4. Qmp quartz monzonite porphyry for site 2. Geographic land form: glaciated mountain slope and ridge. Phenology: 100 percent in fruit. Symbiotic or parasitic relationships: no evidence of disease, predation or injury: no reproductive success: no young plants observed, most plants are mats 6” to 16” in diameter. Evidence of threats and disturbance: elk prints in soft soil, no evidence of human traffic, no trail to this ridge.	~800	CNHP EO 21
9	Gunnison	USFS: Gunnison National Forest, Maroon Bells Wilderness Area	7/14/2001	Mount Bellview	S	12,240	Total tree cover: 0 to 10 percent krummholz. Associated plant communty: krummholz, shrubs, grasses, forbs; *Oxytropis* spp., *Erigeron pinnatisectus*, *Potentilla* spp., *Eriogonum* spp., *Antennaria spp*, *Smelowskia* spp., *Dryas* spp., *Carex spp*, *Senecio porteri*, *Taraxacum eriophorum*, *Crepis nana*, *Penstemon harbourii*, *Claytonia* spp. Habitat type: alpine/sub alpine. Aspect: southwest. Slope: 20 to 60 percent. Slope shape: straight and convex. Light exposure: full sun. Topographic position: mid slope and ridge. Moisture: dry, seasonal snow melt. Parent material: blue clay talus from Mancos shale, also sandy loam soil. Geomorphic landform: glaciated mountain slope and ridge. No young plants observed; the most abundant species on this slope. Several well-used game trails follow contours through this site (elk, deer). Hiking trail follows narrow ridge. Some plants growing on the trail. This is not a formal trail. More survey work is needed in this area.	~2,500	CNHP EO 1

Arbitrary EOR Number	County	Ownership	Date of Last Observation	Location	Precision	Elevation (ft.)	Habitat and notes	Population Size	Source I.D.
10	Gunnison	Private or USFS: White River National Forest (or possibly Gunnison National Forest)	7/1/1955	North Pole Basin	G	11,000	Subalpine forest and tundra.	Not reported	CNHP EO 8
11	Gunnison	USFS: Gunnison National Forest, possibly in Raggeds Wilderness Area	7/24/1967	Robinson Basin	M	11,300	Krummholz, dry meadow. Eastern exposure, 25 degree slope; in fine gravel & rocks.	Not reported	CNHP EO 11
12	Gunnison	Probably USFS: Gunnison National Forest, possibly Maroon Bells Wilderness Area	7/31/1981	Virginia Basin	M	12,000 to 12,200	Growing on east- and west-facing slopes and on a windy saddle. Growing in loose soil and on sandstone talus in full sun. In fellfield community; also with *Valeriana* spp., *Penstemon* spp., and *Festuca* spp. Sandstone parent material. Perianth white.	"scarce"	CNHP EO 3
13	Gunnison/ Pitkin	USFS: Gunnison National Forest and White River National Forest, Maroon Bells Wilderness Area	8/11/2001	Bellview Mountain	S	12,840	Total tree cover: 0 percent. Total shrub cover: 0 percent. Total forb cover: 5 percent. Total graminoid cover: 5 percent. Total moss/lichen cover: 0 percent. Total bare ground cover: 10 percent (mostly broken rock). Associated plant community: *Chaenactis alpina*, *Ligularia* spp., *Erigeron* spp., *Carex* spp. Habitat type: alpine. Aspect: southeast - southwest. Slope: 0 to 10 percent. Slope shape: straight. Light exposure: full sun. Topographic position: ridge, upper side slope. Moisture: dry. Parent material: mapped as Pipm Maroon Formation. Geographic land formation: ridge. Soil texture: fine soil within broken rock. Size ranges from 3 in. diameter up to 12 in. diameter mats. Size of area covered by population: 1/2 acre. Phenology: 100 percent of plants blooming. Symbiotic or parasitic relationships: none. Evidence of disease, predation or injury: none. Reproductive success: 12 in. diameter mat (one plant) has up to 50 flower clusters. Evidence of threats and disturbance: none - few hikers venture onto this ridge, access is not obvious.	~200	CNHP EO 22
14	Park	Private or BLM: Royal Gorge Field Office	8/5/1952	Como	M	9,700	Open slopes. Flowers whitish.	Not reported	CNHP EO 14
15	Park	BLM: Royal Gorge Field Office	7/5/1978	Red Hill Pass	M	9,520	East base of Red Hill Pass. Loose, sandy soil. Occurrence could not be found in 2000.	Not reported	CNHP EO 5
16	Park	Private or BLM: Royal Gorge Field Office	7/11/1954	South Park	M	9,500	On blue, clayey site, margin of wet meadow.	Not reported	CNHP EO 6
17	Park	Probably private	8/15/1961	South Platte River	M	8,870	Arid sandy semi-desert grassland in vast flat river valley with *Artemisia frigida* and *Bouteloua* spp. Arid valley floor.	Not reported	CNHP EO 24

Arbitrary EOR Number	County	Ownership	Date of Last Observation	Location	Precision	Elevation (ft.)	Habitat and notes	Population Size	Source I.D.
18	Pitkin	USFS: White River National Forest, Maroon Bells Wilderness Area	8/12/1982	Capitol Peak	M	12,500	Growing in granite scree above timberline. One localized patch of shrubby plants, growing in mounds 2 ft in diameter and up to 1 ft high.	"one localized patch"	CNHP EO 18
19	Pitkin	USFS: White River National Forest, Maroon Bells Wilderness Area	8/10/1982	Capitol Peak-Mt. Daly Saddle	M	12,400	Geology: granite. Aspect: east. Soil: scree and talus. A few plants confined to east-facing rock outcrop; not seen elsewhere in vicinity of Capitol Peak or Snowmass Mountain.	"few"	CNHP EO 13
20	Pitkin	USFS: White River National Forest, Maroon Bells Wilderness Area	7/21/1996	East Creek	S	12,600	Along ridge top and in crevices of cliffs, both as a component of tundra community and alone in otherwise barren sites. Associated species: *Oxytropis deflexa*, *Oxytropis viscida*, *Cirsium scopulorum*, *Senecio holmii*, *Senecio fremontii* var. *blitoides*, *Trifolium dasyphyllum*, *Astragalus molybdenus*. In flower.	over 1,000	CNHP EO 23
21	Pitkin	USFS: White River National Forest, Maroon Bells Wilderness Area	8/26/1938	Gothic Basin (Castle Peak)	M	12,000	Mats in gravel along crest of alpine ridge. Flowers white and pink.	Not reported	CNHP EO 15
22	Saguache	USFS: Gunnison National Forest	7/1/1950	Archuleta Creek	M	9,700	On volanic ash deposits along road.	Not reported	CNHP EO 10

currently deposited at the New York Botanical Garden (New York Botanical Gardens 2002). This specimen was verified as *E. coloradense* in 1965 by Dr. James Reveal. *Eriogonum coloradense* was first recognized as a species by John Kunkel Small, who described it in 1906. In her 1936 monograph of the genus *Eriogonum*, Susan Stokes included *E. coloradense* as a subspecies of *E. multiceps*. However, subsequent treatments have unanimously recognized this taxon as a full species, and no other names have been proposed. The genus *Eriogonum*, including *E. coloradense*, was revised in 1969 by Dr. James Reveal.

Dr. James Reveal, the foremost authority on the genus *Eriogonum*, doubts the validity of *E. coloradense* as a species. He has opined that *E. coloradense* may ultimately prove to be a high elevation form of *E. lonchophyllum*. However, he has not attempted to ascertain this with any degree of certainty, and there have been no morphometric or molecular systematic studies to investigate this. It is certain, however, that *E. lonchophyllum* is the closest relative of *E. coloradense*. Due to the lack of research to suggest otherwise, Dr. Reveal is retaining *E. lonchophyllum* and *E. coloradense* at the rank of species in his forthcoming treatment of *Eriogonum* in the Flora of North America. *Eriogonum coloradense* is also allied to *E. exilifolium* (Reveal 1967a, Reveal 2003, Anderson 2004).

The broad habitat tolerance observed thus far in *Eriogonum coloradense* may be viewed as evidence that there are questions regarding its taxonomic validity. However, for it and other modal species, there are other equally parsimonious explanations of broad ecological ranges and unusual distribution patterns.

One hypothesis regarding the origin and phylogeny of *Eriogonum coloradense*, offered by Dr. Reveal, might explain its close affinity with *E. lonchophyllum*. *Eriogonum lonchophyllum* is relatively common and includes several varieties that are described by Welsh et al. (1993). During the Hypsithermal event of approximately 6,000 years ago, temperatures throughout North America were significantly warmer than at present. There is ample evidence that plant distribution patterns, including treeline, responded to this climate by moving up in elevation and latitude. It is possible that during this period, *E. lonchophyllum*, which now occurs between 5,500 and 6,500 feet on the west slope of Colorado, was present at higher elevations. As it colonized open, high elevation sites, it undoubtedly encountered and responded to new selective pressures. When temperatures cooled again at the end of the Hypsithermal, *E. lonchophyllum* retreated to lower elevations, but disjunct populations remained at high elevations. These populations would have encountered strong selective pressures that resulted in plants that were of shorter stature and more suited to subalpine and alpine conditions. Although *E. coloradense* can be distinguished reliably from *E. lonchophyllum* using morphological characteristics, it is not known if there are also genetic differences. Thus, *E. coloradense* may merely be an environmentally-induced phase of *E. lonchophyllum* that has begun a path towards allopatric speciation, but remains genetically similar to *E. lonchophyllum*. This issue has been addressed in the literature for other species of *Eriogonum*. Spellenberg et al. (1988) found that *E. densum*, a rare endemic in New Mexico, appears to be an environmentally-induced phase of *E. polycladon*, and Smith and Bateman (2002) drew similar conclusions from their work on the subspecific taxa of *E. shockleyi*. However, another study of such a case supports the taxonomic validity of *E. robustum* (Kuyper et al. 1997). The latter scenario bears many similarities to that of *E. coloradense* and *E. lonchophyllum*, since *E. robustum* and *E. lobbii* are geographically, ecologically, and reproductively isolated from each other. Morphometric, molecular systematic, and common garden studies could be used to successfully address these questions for *E. coloradense*. Testing this hypothesis is arguably the greatest research need for *E. coloradense*, since knowledge of its taxonomic status is fundamental to its conservation.

As a narrow endemic, *Eriogonum coloradense* is a distinctive element of the flora of the southern Rocky Mountains. It is among a very few high elevation members of the genus *Eriogonum* and the only high elevation *Eriogonum* species in the southern Rocky Mountains. Other high elevation congeners are found in the Sierra Nevada, but these are not close relatives of *E. coloradense* (Reveal personal communication 2002).

Overall, knowledge of *Eriogonum coloradense* is sparse and incomplete. Other than the various papers on its systematics, there have been almost no quantitative or qualitative studies yielding information specific to this species. The paucity of information on *E. coloradense* has forced the author to rely heavily on personal communications with botanists that have had some experience with the species, and to draw inferences from other members of the genus *Eriogonum* where possible for this assessment.

Recent surveys by Vince Rossignol of the USDA Forest Service and by Peggy Lyon of the Colorado Natural Heritage Program have yielded valuable habitat, location, and population size information. Plot data presented in

Langenheim (1956) and Johnston et al. (2001) offer the only quantitative cover data on the species.

Non-technical description

Eriogonum coloradense is a matted, densely caespitose herbaceous perennial with a thick central taproot and spreading branches borne from a subterranean woody caudex (**Figure 1** and **Figure 2**; Harrington 1954, Reveal 1969). Mats are typically 5 to 15 centimeters in diameter (Reveal 1969) but may get as large 60 centimeters in diameter (Colorado Natural Heritage Program 2002). The branches may proliferate underground, giving the appearance of multiple individuals in some cases. Barrell (1969, p. 342) noted that "what seemed to be four individual plants about two and a half inches high turned out to be just the top of an underground plant ten inches wide." The leaves are basal with lanceolate to oblanceolate blades, revolute (rolled under), 1 to 4 (and up to 5) centimeters long, and 3 to 6 (and up to 8) millimeters wide (Reveal 1969, Spackman et al. 1997). They are green and hairless (or become hairless) above but densely tomentose (covered in wooly hairs) below. The flowering stems are leafless, up to 6 centimeters long, and either hairless or densely lanate (Reveal 1969). The flowers are borne in heads containing three to four involucres (**Figure 3**). The perianth is composed of tepals that are oblong to ovate. Members of the genus *Eriogonum*, including *E. coloradense*, have 3-merous flowers with nine stamens (Zomlefer 1994). The flowers are generally white (Reveal 1969) but may also be rose-colored (Harrington 1954). The fruit is an achene, containing a single seed that readily dehisces when ripe and falls away from the flower (Reveal personal communication 2002). The achenes are brown and 2.5 to 3.5 millimeters long (Reveal 1969).

As in many alpine and arctic species, the leaves are marcescent, meaning that they remain attached to the stem after they senesce (Small 1906, Reveal personal communication 2002). This interesting adaptation provides the dual benefit of both insulating the plant from cold temperatures during the growing season, and fertilizing the soil beneath the plant as the leaves slowly decompose and leach nutrients (Savile 1972, Goldstein and Meinzer 1983).

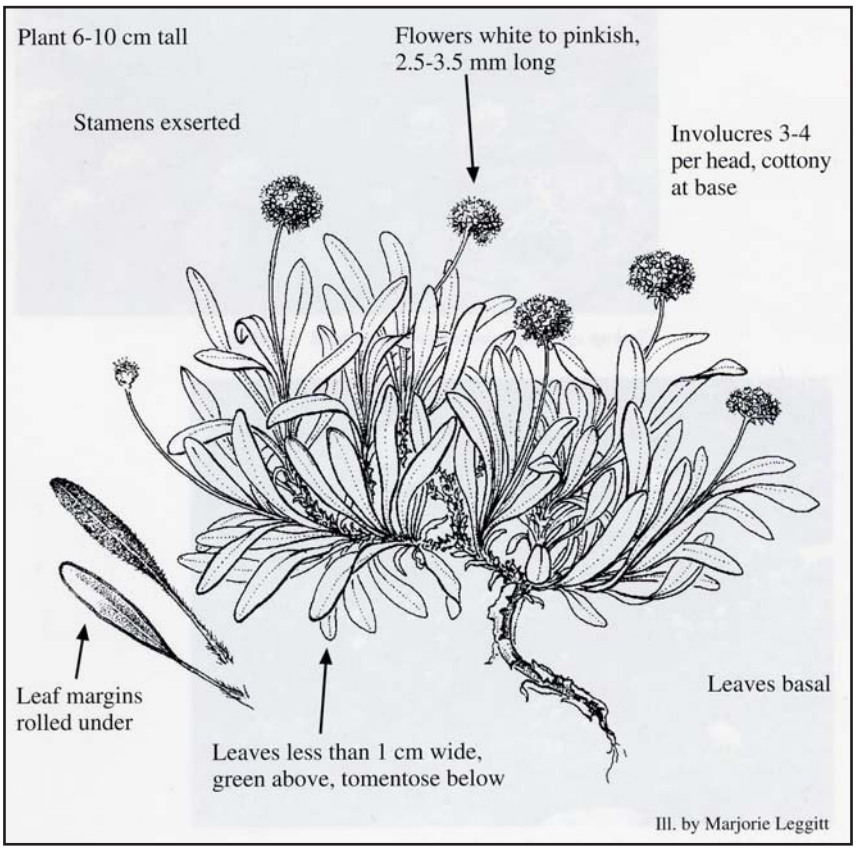

Figure 1. Illustration of *Eriogonum coloradense* showing diagnostic features (from Spackman et al. 1997).

Figure 2. *Eriogonum coloradense*. Photograph provided by Bill Jennings.

Figure 3. Close-up of the inflorescence of *Eriogonum coloradense*. Photograph provided by Bill Jennings.

The genus *Eriogonum* is distinguished from other members of the Polygonaceae in that its members do not have an ocrea at the leaf base (Harrington 1954). The ocrea is a sheath around the stem formed from the stipules that is common throughout most of the Polygonaceae (Harris and Harris 1999).

Eriogonum coloradense shares many traits with *E. lonchophyllum*, its closest relative. It also bears many similarities to *E. brandegeei* (Colorado Natural Heritage Program 2002). Fortunately for the field botanist, it does not co-occur with either species. It is distinguished from *E. lonchophyllum* primarily by its smaller stature. The inflorescence of *E. lonchophyllum* is a branching cyme, appearing more diffuse than that of *E. coloradense*. The leaves of *E. lonchophyllum* are 5 to 10 centimeters long, while those of *E. coloradense* do not typically exceed 6 centimeters. The leaves of *E. brandegeei* are tomentose on both sides, while those of *E. coloradense* are only tomentose below. The stature of *E. coloradense* is generally shorter than that of *E. brandegeei*, but taller individuals that approach the maximum height of *E. brandegeei* have been documented in favorable sites.

Sources for photographs, illustrations, and descriptions

Several sources are available for further technical information on *Eriogonum coloradense*. Spackman et al. (1997) includes a description, illustration (**Figure 1**), photographs of the plant (cover photograph, **Figure 2** and **Figure 3**) and its habitat, a range map, and diagnostic field identification characteristics. This resource is also available online. Descriptions of the species are found in Small (1906), Harrington (1954), Barrell (1969), Reveal (1969), and Rickett (1973). Among these, Reveal (1969) is the most thorough. A photograph of the type specimen, housed at the New York Botanical Garden, is available on their Web site (http://www.nybg.org/gsci/hcol/vasc/; New York Botanical Garden 2002).

Distribution and abundance

Eriogonum coloradense is narrowly endemic to the mountains of central Colorado in Chaffee, Gunnison, Park, Pitkin, and Saguache counties (**Figure 4** and **Figure 5**). All the known occurrences are found in four areas, two of which contain several occurrences. These areas are separated from each other by 30 to 53 miles. The center of distribution appears to be the mountains in and around the Maroon Bells-Snowmass Wilderness in Pitkin and Gunnison counties, where 16 of the 22 known occurrences have been found. Other occurrences appear to be disjunct from the concentration of occurrences in the Maroon Bells-Snowmass Wilderness, but this may be due to the lack of focused efforts to search areas between them. Four occurrences have been documented in Park County, but none of them have been seen in over 20 years. Attempts by Susan Spackman to relocate and assess two of these occurrences in 2001 (EORs 15 and 22 in **Table 3**) were not successful (Colorado Natural Heritage Program 2002). The type specimen collected from Mt. Harvard in 1896 is the only occurrence known from Chaffee County. The single record of *E. coloradense* known from Saguache County has not been seen since it was first documented in 1950. This is the most disjunct occurrence of the species, and it is one of only two occurrences documented from a volcanic substrate ("on volcanic ash deposits along road").

No thorough, range-wide inventory has been conducted for *Eriogonum coloradense*. Occurrences to date have been documented through herbarium collections, survey work by the Colorado Natural Heritage Program and the USFS, and two published sources (Langenheim 1956, Johnston et al. 2001).

The largest known occurrences of *Eriogonum coloradense* (and the large majority of the total known population) are in the Maroon Bells-Snowmass Wilderness cluster, which contains the only occurrences in which there is any indication of population size (**Figure 5**). All of these occurrences are located on USFS land. The largest known occurrence, visited most recently by Rossignol (2001), is found on Mount Bellview and contains approximately 2,500 individuals (EOR 9 in **Table 3**). Lyon (1996) reported a careful estimate of over 1,000 plants along the ridge between East Creek and Hawk Creek (EOR 20 in **Table 3**). Rossignol (2001) reported 800 plants in the vicinity of Gothic (EOR 8 in **Table 3**) and 200 plants at Bellview Mountain (EOR 13 in **Table 3**). Another smaller occurrence at Crystal Ridge contains approximately 164 individuals (EOR 4 in **Table 3**). Langenheim (1956; EOR 6 in **Table 3**) observed approximately 15 individuals in a plot on the Gothic Earthflow but gave no indication of the size of the total population size of this occurrence. These are the only records in which observers provided a quantitative population size estimate. *Eriogonum coloradense* appeared in a randomly placed vegetation plot in the Gothic Research Natural Area (EOR 5 in **Table 3**) where it contributed to 0.4 percent of the vegetation cover (Komárková 1986, Johnston et al. 2001). No population size estimate was made at this occurrence. Other records from this area describe the occurrences as "one localized patch," "a few plants confined to an east facing rock outcrop,"

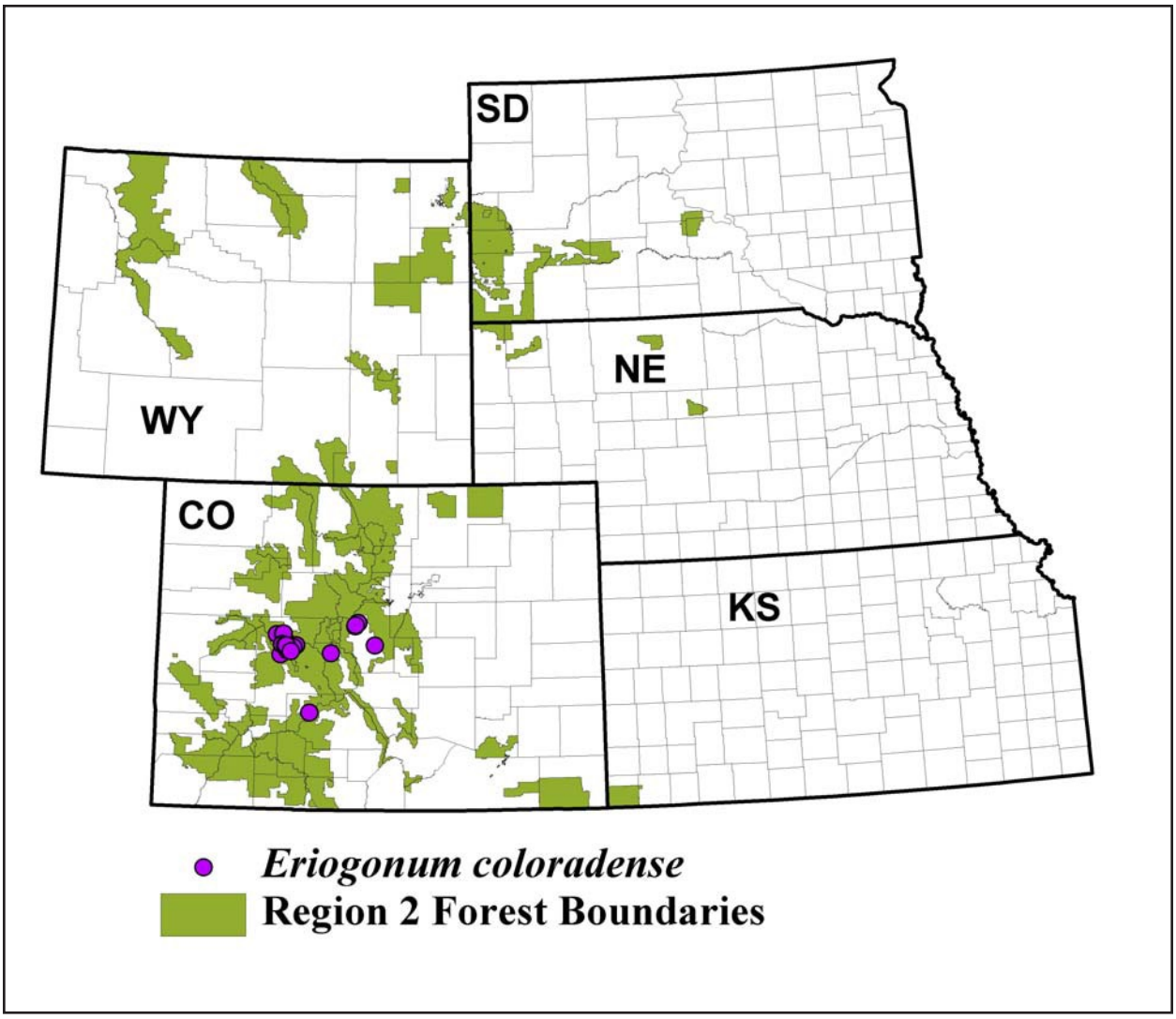

Figure 4. The distribution of *Eriogonum coloradense* in the states of USDA Forest Service Region 2.

"scarce," and "most abundant species on the slope." From these sparse data we might safely estimate a minimum population size for the species at 4,700 to 5,000 individuals, but it is likely to be greater than this. Obviously, further inventory work to improve our knowledge of the distribution and population size of this species is a high priority. As other inhabited sites are found, some occurrences may be found to be less isolated than currently believed.

The genus *Eriogonum* is of North American origin, and it is almost entirely limited to North America with only two species found in South America (Stokes 1936, Reveal 1967b, Reveal 1969, Heywood 1993). The genus is particularly diverse in the western United States.

Population trend

Based on element occurrence data, there is no evidence of either a population decline or increase in *Eriogonum coloradense*. The overall population trend cannot be accurately assessed at this time because it is highly likely that many occurrences remain to be discovered, and very little population data of any sort have been gathered overall for *E. coloradense*. Because several observations have documented small population sizes, there is a relatively high probability that these occurrences have been extirpated by human activities or natural processes.

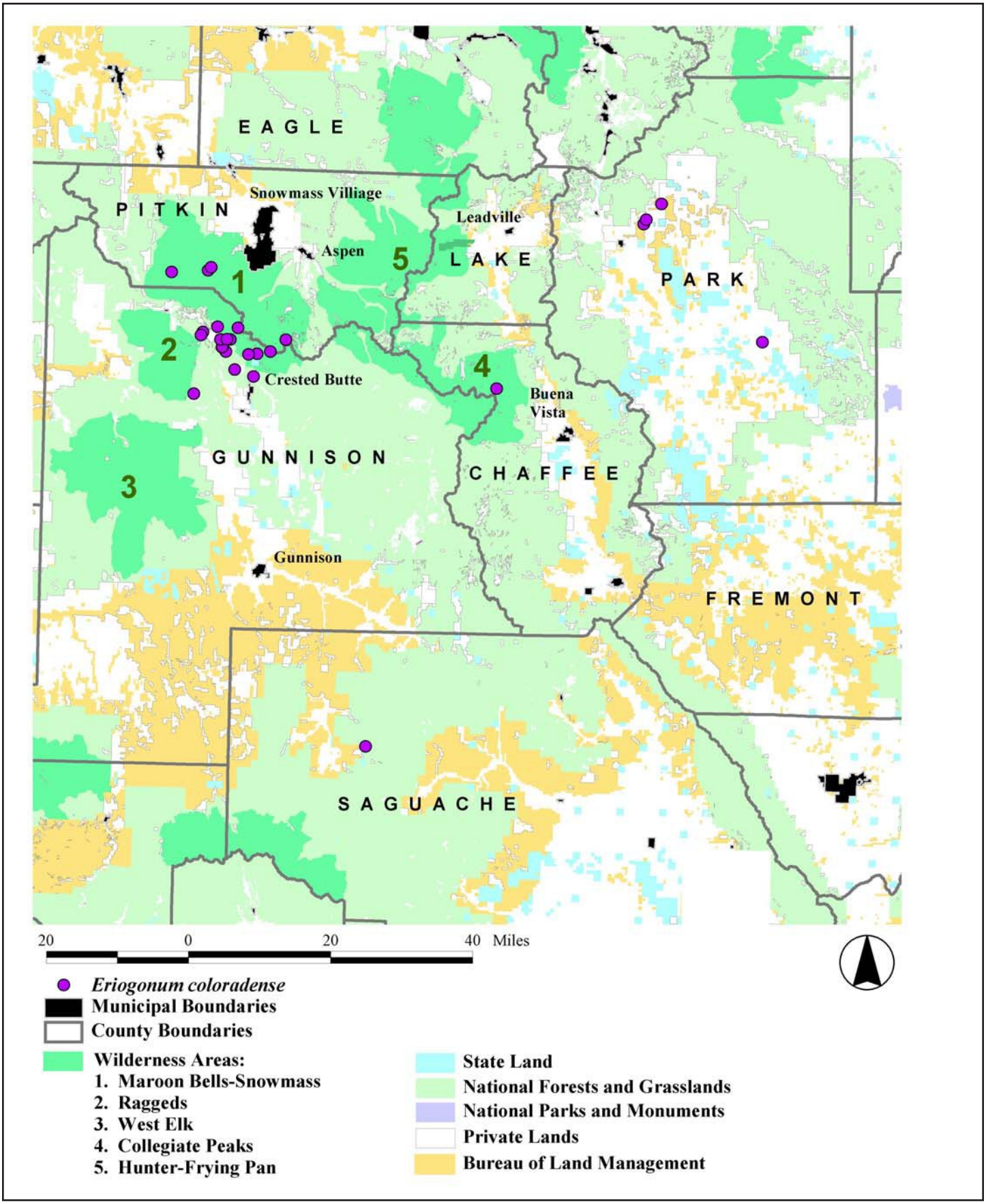

Figure 5. The global distribution of *Eriogonum coloradense* with respect to land status designations, municipal boundaries, and county boundaries.

Habitat

Eriogonum coloradense is unusual in that it has an extremely broad ecological range. It has been documented on every soil texture, slope, and aspect. It has been found on sedimentary, granitic, and volcanic substrates, with *Artemisia* species (sagebrush) and *Bouteloua gracilis* (blue grama) and also with alpine cushion plants. It is found on a variety of geomorphic landforms, usually on talus, fellfields, rock shoots, and ridges, but also on roadsides. Reveal (personal communication 2002) described the habitat as rocky talus on the margins of meadows, grassland communities, high elevation sagebrush, sometimes with montane or subalpine conifers, and on sandy to gravelly flats and slopes. The best information currently available on *E. coloradense* is from high elevation sites, so these are treated in greater detail in this report. More work is needed to better understand the habitat of *E. coloradense* throughout its range. See **Table 3** for habitat descriptions reported for the known occurrences of *E. coloradense*.

All known occurrences are open and somewhat xeric. Cole (1967) noted that narrowly distributed species of *Eriogonum* in California tend to be found in their own distinctly different and unique habitats. This is more or less true of all the other rare species of *Eriogonum* in Colorado as well, many of which are limited to outcrops of one particular geologic formation. Thus the wide variation in habitats occupied by *E. coloradense* is highly atypical of narrowly endemic members of *Eriogonum*.

The elevation range of occurrences of *Eriogonum coloradense* documented thus far is 8,870 to 12,840 feet (Colorado Natural Heritage Program 2002). Small (1906) and Reveal (1969) report an elevation range of 8,500 to 12,500 feet.

Elevation ranges in each of the four areas inhabited by *Eriogonum coloradense* is markedly different (**Table 4**). All occurrences in the Maroon Bells-Snowmass Wilderness Area (Pitkin and Gunnison Counties) are above 10,700 feet, except for the Gothic Earthflow occurrence, which at 9,500 feet is somewhat anomalous. If Chaffee County still supports occurrences of *E. coloradense*, they too may be alpine, but an investigation of the details of Clements' collecting trip (*sensu* Weber 1958) would help to establish where on Mt. Harvard he collected *E. coloradense*. Occurrences in Saguache and Park counties are much lower in elevation, in sites that bear little climatic semblance to those in the alpine. An entirely different suite of associated species and environmental variables is found at the low elevation sites.

Table 4. Elevation ranges by county for occurrences of *Eriogonum coloradense*.

County	Elevation Range (feet)
Chaffee	Unknown[a]
Gunnison	(9,500)[b] to 12,840
Park	8,870 to 9,520
Pitkin	12,000 to 12,840
Saguache	9,700

[a]Type specimen from Mt. Harvard
[b]Approximate elevation of the occurrence at the Gothic Earthflow

A noteworthy observation regarding the distribution of *Eriogonum coloradense* cited by Johnston (personal communication 2002) is its bimodal distribution pattern in which it is primarily found at either extreme of its elevational range. **Table 4** illustrates this distribution pattern well. Several other species in Colorado (e.g. *Tetraneuris acaulis*, *Potentilla subjuga*, *Townsendia rothrockii*, and *Machaeranthera coloradensis*) have a similar bimodal distribution pattern. However, in none of these species are the ecological underpinnings of the pattern understood. Johnston (personal communication 2002) speculates that *E. coloradense* depends on relatively open sites, so forested areas of the montane and subalpine are not suitable for it. Thus, sagebrush at low elevations and tundra above treeline, as well as meadows within forested areas, offer the only open sites for this species within its elevational range. *Eriogonum coloradense* has been documented in all such sites. Populations might also have been stranded at low elevations at the end of the Pleistocene.

Records of *Eriogonum coloradense* document its presence on several different geological substrates. Most

commonly it has been reported from areas underlain by high elevation sedimentary rocks, particularly in the Maroon Bells-Snowmass Wilderness. The geology of this area is very complex, with highly folded strata and numerous Tertiary intrusions. Strata associated with occurrences in the vicinity of Mt. Bellview include the Maroon Formation and the Mancos Formation. Outcrops of Mancos shale are rare at such high elevations because it is so easily eroded. Throughout the Intermountain West, numerous highly endemic plant species are found on Mancos shale. However, at Mount Baldy in Gunnison County *E. coloradense* is found on both Mancos shale (upper member) and on quartz monzonite porphyry, an intrusive igneous rock. On the Gothic Earthflow, Langenheim (1956; EOR 6 in **Table 3**) documented *E. coloradense* on a substrate composed of shale fragments. Other substrates documented in the Maroon Bells-Snowmass Wilderness and the surrounding area include the Gothic Formation and Belden Formation, both of which are sedimentary strata composed of shale, limestone, and sandstone. On Capitol Peak in Pitkin County, *E. coloradense* was documented on granite scree.

Eriogonum coloradense is also found on a variety of substrates in Park and Saguache counties. In Park County, records document *E. coloradense* on "loose, sandy soil" and on a "blue clayey site." The geologic substrate was not noted by the observers at these sites, but they too are underlain chiefly by sedimentary rocks of late Cretaceous (Pierre Shale) and Tertiary (South Park Formation, composed mostly of sandstone and shale) age (Tweto 1979). The occurrence in Saguache County (EOR 22 in **Table 3**) is on Tertiary igneous rocks, probably ash-flow tuff or pre-ash-flow andesitic rocks (Tweto 1979).

Most observers who made any notes on substrate properties associated with *Eriogonum coloradense* mention that the surface is rocky, often because it is growing in talus or scree. It has been documented growing in broken rock, talus (sandstone is specified in one record), granite scree (Colorado Natural Heritage Program 2002), and broken shale in the Gothic Earthflow (Langenheim 1956). Soil textures range from clayey to gravelly. Notes on texture include "sandy to gravelly," "in gravel," "pockets of fine soil," "fine soil with broken rock," "loose soil," and "clay." Many element occurrence records report occurrences on either east- or west-facing slopes, with many others on ridgelines.

Plants at high elevation sites have been documented on fellfields, ridges, rocky slopes, talus, and in crevices of cliffs. Rocky or open sites in the subalpine such as talus slopes and meadows are also inhabited. Vegetation associated with *Eriogonum coloradense* at high elevation sites depends on the topography and elevation of the site. Vegetation is low and sparse on fellfields in the alpine, but near treeline *E. coloradense* is often associated with krummholz. Several observations note that few or no other plant species co-occur with *E. coloradense*. Johnston et al. (2002) include *E. coloradense* among plants found in the Tall shrublands-Extremely Rocky community type where it grows with two shrub species (*Juniperus communis* and *Ribes montigenum*) and grasses. In subalpine sites it may be found on the margins of grassy meadows.

At low elevation sites in Park and Saguache counties, *Eriogonum coloradense* has been documented on roadsides and in arid shrublands. The most complete description of habitat for a low elevation site in Park County is "arid sandy semi-desert grassland in vast flat valley of the South Platte River, on arid valley floor" (EOR 17 in **Table 3**). Near Como it was also found on "open slopes." Dr. William Weber noted it on the margin of a wet meadow in Park County (EOR 16 in **Table 3**).

Alpine habitats in which *Eriogonum coloradense* has been documented tend to be late-seral, or areas of arrested succession due to chronic disturbance. Meadows inhabited by *E. coloradense* may be seral habitats, depending on the nature and periodicity of processes that formed and maintain them.

One of two quantitative studies involving *Eriogonum coloradense* is that of Langenheim (1956), in which plant succession was studied on the Gothic Earthflow. The Gothic Earthflow is an interesting geomorphic feature in the Elk Range near Gothic, Colorado. The earthflow formed in 1923 and probably resulted from lubrication and saturation of deep soil and shale bedrock by a combination of heavy rain and a leaky irrigation canal. The slope failed catastrophically and resulted in large areas of unvegetated soil with some islands of surviving vegetation. The earthflow is approximately one mile long and 1/4 mile wide, and it ranges in elevation from 9,200 feet near the valley bottom to 9,950 feet at the head break. Plots were established on the earthflow in 1947 in representative vegetation types and sampled for seven consecutive years. In 1949, *E. coloradense* appeared in the "perennial forb" community, where it persisted through 1954. An increase in density in 1954 suggests that it was still increasing in abundance in this community type when the study was completed.

These observations suggest that it took 26 years for *Eriogonum coloradense* to appear at this site, but it is likely that it was present at the site before it appeared in Langenheim's plots. It apparently did not behave like a pioneer but was undoubtedly acting as a seral species at this location. The climax community at this site is probably subalpine forest dominated by spruce and fir, the presence of which would probably exclude *E. coloradense*. However, if site topography results in meadows or other openings within the forest, then *E. coloradense* may persist at this location. The origin of the migrants to this location is not known, but many known occurrences are nearby. The recently disturbed substrate described by Langenheim closely matches that seen in many other higher elevation occurrences, so this site, though destined to be reforested, possessed the right combination of substrate, openness, and disturbance.

It is not clear why *Eriogonum coloradense* is not more common in the mountains of Colorado. Its apparent tolerance of a broad range of substrates, adaptations to xeric conditions at high elevations, and ability to disperse effectively all suggest that it is a species that could flourish throughout the southern Rocky Mountains. However, careful surveys in areas that contain apparently suitable habitat have confirmed its absence at some sites. For example, sedimentary strata are found throughout the alpine and subalpine of the Mosquito Range, but *E. coloradense* has not been found there despite some extensive and careful surveys (e.g., Spackman et al. 2001). High elevation granitic substrates are abundant in Colorado, but many areas that have been thoroughly surveyed are not inhabited by *E. coloradense*.

Reproductive biology and autecology

Reproduction

In the CSR (Competitive/Stress-Tolerant/Ruderal) model of Grime (2001), characteristics of *Eriogonum coloradense* most closely approximate those of stress-tolerant species. Stress-tolerant attributes of *E. coloradense* include long life span, adaptations to xeric fellfield conditions, and low reproductive output.

Although its characteristics are primarily those of a stress-tolerator, *Eriogonum coloradense* also has some qualities that typify both competitive and ruderal species. Reveal (personal communication 2002) notes that *Eriogonum* species tend to be somewhat competitive in certain circumstances. This may be a product of their exquisite adaptations to the arid environments in the intermountain west, where they are sometimes the dominant species. As a long-lived perennial species that probably devotes several years to vegetative growth before reproducing, the life history pattern of *E. coloradense* may be classified as ruderal, or *K*-selected (using the classification scheme of MacArthur and Wilson 1967). It is interesting, however, that it appeared in early seres at the Gothic Earthflow, as documented by Langenheim (1956). This is somewhat suggestive of the behavior of an r-selected species such as *Chaenactis alpina*, another early seral species at the earthflow and a commonly mentioned associated species with *E. coloradense*.

The response of *Eriogonum coloradense* to disturbance is not known, but the habitats in which it is often found suggest that it is tolerant of chronic surface disturbance caused by frost heave and mass wasting. Its appearance on the Gothic Earthflow in 1947 suggests that it is capable of responding favorably to disturbance. On some steep scree and talus slopes there are few if any associated plant species with *E. coloradense*, suggesting that it possesses adaptations to this environment that other species do not have. Other species of *Eriogonum* respond positively to disturbance and can be aggressive colonists (Reveal personal communication 2002). The tolerance of *E. coloradense* to various types of disturbance is a key question to answer for its appropriate management and stewardship.

Most perennial members of the genus *Eriogonum* reproduce both vegetatively and sexually. The relative importance of these modes of reproduction varies considerably within the genus. Clonal propagation may be the primary mode of reproduction in *E. ovalifolium* var. *williamsiae* (U.S. Fish and Wildlife Service 1995), while other species, particularly annuals, rely heavily or entirely on reproduction by seed. Many species of *Eriogonum*, particularly caespitose, low elevation species, are highly tolerant of fragmentation by the action of the hooves of herbivores. These species have a deep-seated, vertical taproot and an extensive system of lateral caudex branches. The lateral branches often produce adventitious roots, and if the branch is broken away from the main body of the plant, it will proceed to grow as a clone of the parent plant and produce a new taproot. This mechanism of reproduction is highly plausible for high elevation species as well when they are broken by disturbance of their substrate.

Pollination ecology

Species of *Eriogonum* are typically pollinated by generalist pollinators (Reveal personal communication 2002, Tepedino 2002). Individuals of *E. ovalifolium*

var. *williamsiae* were transplanted to containers at the Nevada Division of Forestry nursery and produced seed successfully, suggesting that this species does not depend on the pollination services of a highly specific pollinator. It probably self-pollinated or was pollinated by a generalist pollinator at the nursery (U.S. Fish and Wildlife Service 1995).

Like many *Eriogonum* species, *E. coloradense* is polygamo-dioecious. Polygamo-dioecious plants are polygamous (in the case of *Eriogonum*, this means that plants have both male and hermaphroditic flowers) but are primarily dioecious. Reveal (personal communication 2002) explained the floral biology of *Eriogonum* as follows. The anthers mature a day or two before the stigma is receptive. On the first day, a given flower opens, and six stamens dehisce and shed pollen while the style and stigma remain coiled around the unripened achene (fruit) within the flower. At this time the flower is functionally androgynous and cannot self-pollinate. The flower will close that night and open again the next day. On the second day, the remaining three stamens dehisce and shed pollen, and the stigma and style uncoil. At this time the stigma is receptive, and it may be pollinated by selfing or outcrossing. If pollination has not occurred by the end of the second day, the flower will self-pollinate when it closes that night, assuring that a seed will be produced either by outcrossing or selfing.

There is no specific information on pollinators for *Eriogonum coloradense*. Most *Eriogonum* species throughout the Rockies, Sierra Nevada, and Cascades are visited by a broad range of generalist pollinators, with no clear examples of specialization (Reveal personal communication 2002, Tepedino 2002). Plants with very little floral specialization are considered 'promiscuous plants' because they utilize unspecialized, generalist pollinators as pollen vectors (Grant 1949, Bell 1971). Reliance on a broad suite of pollinators for pollinator services probably buffers promiscuous plants from population swings of any one pollinator (Parenti et al. 1993). The floral biology of *E. coloradense* must be investigated to ensure that conservation actions on its behalf include the protection of its pollinators.

Eriogonum species offer a small amount of nectar at the base of the filaments and ovaries. This reward and pollen attracts bees, flies, and ants. The efficacy of ants as pollinators of *E. coloradense* is not known, but they have been observed thoroughly covering themselves in its pollen in the alpine (Reveal personal communication 2002).

Phenology

Eriogonum coloradense flowers from July to August and bears fruit into September (Spackman et al. 1997, Reveal personal communication 2002). *Eriogonum* species produce numerous small flowers in umbels. One seed is produced per flower and is borne within an achene that dehisces from the flower when ripe. Plants are green and visible through September. Young plants with poorly developed root systems are probably more vulnerable to desiccation than mature plants. Thus, the periodicity of successful recruitment may coincide with periods of one or several wet years during which they can become established.

Fertility and propagule viability

Given the large seed size of *Eriogonum coloradense*, it is likely that seeds are able to survive in the seed bank for several years. Seeds of other species of *Eriogonum* often endure in the seed bank for tens of years (Reveal personal communication 2002). However, seed viability of other *Eriogonum* species was very low in two studies. Viability tests of seeds of *E. ovalifolium* var. *williamsiae* yielded less than 1 percent live seed (U.S. Fish and Wildlife Service 1995). Seeds of *E. annuum* recovered from sandhill prairie soil samples in Nebraska also showed less than 1 percent germination (Perez et al. 1998).

Seed dispersal

The seeds of *Eriogonum* species are dispersed by wind, rain, streams, and animals (Stokes 1936). Due to their high oil content, the seeds float and are readily moved by flowing water and sheeting of water during heavy rains. Stokes (1936) also cites birds and vehicles as likely dispersal vectors, particularly for annual species of *Eriogonum*. *Eriogonum ovalifolium* var. *williamsiae* is primarily wind dispersed (U.S. Fish and Wildlife Service 1995). Bonde (1969) found disseminules of numerous taxa in snow samples from St. Mary's Glacier, Colorado, exhibiting the efficacy of wind as a dispersal agent in the alpine. Thus, seeds from plants growing on ridgelines are probably dispersed effectively by wind.

Of particular interest for the possible dispersal of *Eriogonum coloradense* are ants. Many species of *Eriogonum* actively engage ants in their seed dispersal. *Eriogonum* seeds have abundant, oil-rich endosperm (Reveal personal communication 2002) and are a valuable food source for many animals (Stokes

1936). Some *Eriogonum* species also have specialized structures on the seed called elaiosomes, which store oil and attract ants. However, these structures have not been documented on the seeds of *E. coloradense*. Ants will often carry seeds of *Eriogonum* underground where they are provided a safe site for germination (Reveal personal communication 2002). Ants are often observed with *E. coloradense* and may also play a role in pollination.

Phenotypic plasticity

Eriogonum species show varying degrees of phenotypic plasticity. One taxon, *E. densum*, had been considered one of the rarest taxa in New Mexico until it was shown to be a rare, environmentally induced phase of *E. polycladon* (Spellenberg et al. 1988). *Eriogonum coloradense* is highly morphologically and ecologically variable (Johnston personal communication 2002, Reveal personal communication 2002).

Ecophenic variation is common among several species of coastal and inland California *Eriogonum* (Cole 1967). Two species that have a prostrate, matted growth form in their native habitat grew erect when grown in a greenhouse. Thus the prostrate growth form is a phenotypic response to strong wind and unstable soil in species that live on the coast, and these plants appear morphologically similar to inland species in the absence of these conditions. It is thus somewhat plausible to expect this response in other *Eriogonum* species. Some very large, robust *E. coloradense* individuals have been documented, and they may be expressing this type of variation by being located in a particularly favorable site. At one occurrence, plants were described by the observers as "shrubby," suggesting an erect growth form. This underscores the value of conducting common garden experiments with *E. coloradense* to clarify species relationships.

Mycorrhizae

Roots of *Eriogonum coloradense* have not been assayed for the presence of mycorrhizal symbionts, and its role as a mycorrhizal host has not been investigated. Apparently no research on the mycorrhizal symbiosis has been conducted on *Eriogonum* species. Reveal (personal communication 2002) suspects that *E. coloradense* is mycorrhizal, but that mycorrhizae are of limited importance in its autecology.

Hybridization

Several stable hybrids have been documented in the genus *Eriogonum* (Stokes 1936). However, there is no evidence of hybridization in *E. coloradense*. At most sites there are no other members of the genus *Eriogonum* that could provide the opportunity for hybridization. However, the plot data of Johnston et al. (2001) include *E. subalpinum* and *E. umbellatum* var. *aureum* with *E. coloradense*.

Demography

Although there has been much work on the systematics of *Eriogonum* (e.g. Small 1906, Stokes 1936, Reveal 1969, Reveal 1985, Kuyper et al. 1997), there have been few studies of population genetics of *Eriogonum* species. Nonetheless, some meaningful inferences can be drawn regarding the population genetics of *E. coloradense* based on this work.

Two studies have found surprisingly high levels of genetic diversity in *Eriogonum* species. Populations of the extremely rare and federally listed *E. ovalifolium* var. *williamsiae* have high levels of polymorphic loci, with many more alleles per locus and greater heterozygosity than expected for such a narrow endemic (Archibald et al. 2001). Other tests in this study showed no evidence for inbreeding and evidence for random mating. This was surprising, given the floral biology of the species. Overall, the genetic variability of *E. ovalifolium* var. *williamsiae* exceeds that typically seen in a common, widespread taxon. Another federally listed endangered taxon, *E. ovalifolium* var. *vineum*, is highly outcrossed, with apparent selective pressure against homozygosity (Neel et al. 2001). The results of this study indicate that conservation of this species will require the maintenance of large populations to prevent increases in inbreeding and to support pollinator communities to facilitate outcrossing. These studies underscore the importance of understanding the population genetics for species conservation (as described by Hamrick et al. 1979, Brown 1989, Hamrick and Godt 1989, and Loveless and Hamrick 1989).

The value of these data for drawing inferences regarding *Eriogonum coloradense* is unknown. However, gross observations of *E. coloradense* suggest that there may be high genetic variability within and among occurrences. The phenotypic variation observed

in *E. coloradense* may be a product of high genetic variability. These observations underscore the need to investigate the genetics of *E. coloradense*, as cited by Reveal (personal communication 2002).

Eriogonum coloradense is known from four areas, two of which contain a single occurrence. Thirty to 53 miles separate each of these areas. Occurrences within each of the four areas are somewhat isolated, but geneflow might be occurring between them. However, geneflow among the four areas is likely to be extremely limited. Endemic and rare taxa often have low genetic variability (Hamrick and Godt 1989, Karron 1991). They also tend to have greater rates of self-pollination and inbreeding (Inoue and Kawahara 1990, Karron 1991). The level of genetic variability in *E. coloradense* has not been measured. No readily observable effects of inbreeding depression have been documented in *E. coloradense*.

The life history characteristics of *Eriogonum coloradense* have not been investigated. The large radial size of some individuals (over two feet) in high elevation sites suggests that it reaches ages of many tens of years, probably over 100 years, and possibly hundreds of years (Colorado Natural Heritage Program 2002, Reveal personal communication 2002). Some shrubby *Eriogonum* species have been aged in California, and these species commonly live over 100 years (Reveal personal communication 2002). Individuals in the genus *Dedeckera*, a close relative of *Eriogonum*, have been aged using annual growth rings and exceed 150 years in age (Reveal personal communication 2002). *Eriogonum coloradense* and other low, alpine perennial species of *Eriogonum* are probably periodically disrupted by disturbance from grazers, frost heave, and mass wasting of their substrate. This could result in the fragmentation and clonal propagation of the plants. Thus, a single product of a sexual reproduction event may persist for an extraordinarily long period of time (Reveal personal communication 2002). Only one element occurrence (EOR 4 in **Table 3**) makes a note of apparent successful recruitment of new plants by noting that there are many small (young?) plants in the population. **Figure 6** illustrates the life cycle of *E. coloradense*, and **Figure 7** illustrates the life cycle graph of *E. coloradense* after Caswell (2001).

No Population Viability Analysis (PVA) has been performed for *Eriogonum coloradense*. Apparently there has never been a PVA of any member of the genus *Eriogonum* from which inferences could be drawn for this report. Archibald et al. (2001) studied genetic relationships and population structure of *E. ovalifolium* var. *williamsiae*, a federally endangered species. The results of their study are included herein where relevant.

Many life history parameters remain unknown in *Eriogonum coloradense*. Of particular value would be information on seeds and recruitment. Seed production, seed longevity, seed dormancy, and variables controlling these parameters would help to reveal potential bottlenecks in the survival of *E. coloradense* (Colorado Natural Heritage Program 2002). Longevity is also unknown, yet critical for understanding the demography of this species.

The probability of dispersal of seeds and other propagules decreases rapidly with increasing distance from the source (Barbour et al. 1987). Thus, long distance dispersal events are rare. Pollinator-mediated pollen dispersal is largely limited to the flight distances of pollinators (Kearns and Inouye 1993). Due to the formidable physical limitations to dispersal of seeds and pollen between populations, there is probably very little geneflow among occurrences of *Eriogonum coloradense*. Forested areas and other unsuitable habitat for *E. coloradense* undoubtedly act as sinks when seeds are moved to these areas.

Community ecology

Records of many of the 22 known locations of *Eriogonum coloradense* document associated taxa (**Table 3**). Associated species that have been documented with *E. coloradense* are summarized in **Table 5**. At high elevations in Pitkin and Gunnison counties, associated taxa include *Antennaria* spp., *Carex* spp., *Chaenactis alpina*, *Cirsium scopulorum*, *Crepis nana*, *Dryas* spp., E*riogonum pinnatisectus*, *Festuca* spp., *Ligularia* spp., *Oxytropis deflexa*, *O. viscida*, *Oxytropis* spp., *Penstemon harbourii*, *Penstemon* spp., *Potentilla* spp., *Senecio holmii*, *S. fremontii* var. *blitoides*, *S. porteri*, *Smelowskia calycina*, *Taraxacum eriophorum*, *Trifolium dasyphyllum*, *Valeriana* spp. It has also been found with *Astragalus molybdenus*, another rare Colorado endemic (EOR 20 in **Table 3**). Several records note that *E. coloradense* is growing by itself or with few other species. Near treeline it is also found with krummholz (*Picea engelmannii* and *Abies bifolia*) and *Salix* spp., *Poa alpina*, *Heterotheca villosa*, *Ivesia gordonii*, and *Lupinus* spp. There is no information on associated nonvascular taxa.

Johnston et al. (2001) include *Eriogonum coloradense* as a component of the Rocky Tall-Shrublands Ecological Series, Tall Shrublands-

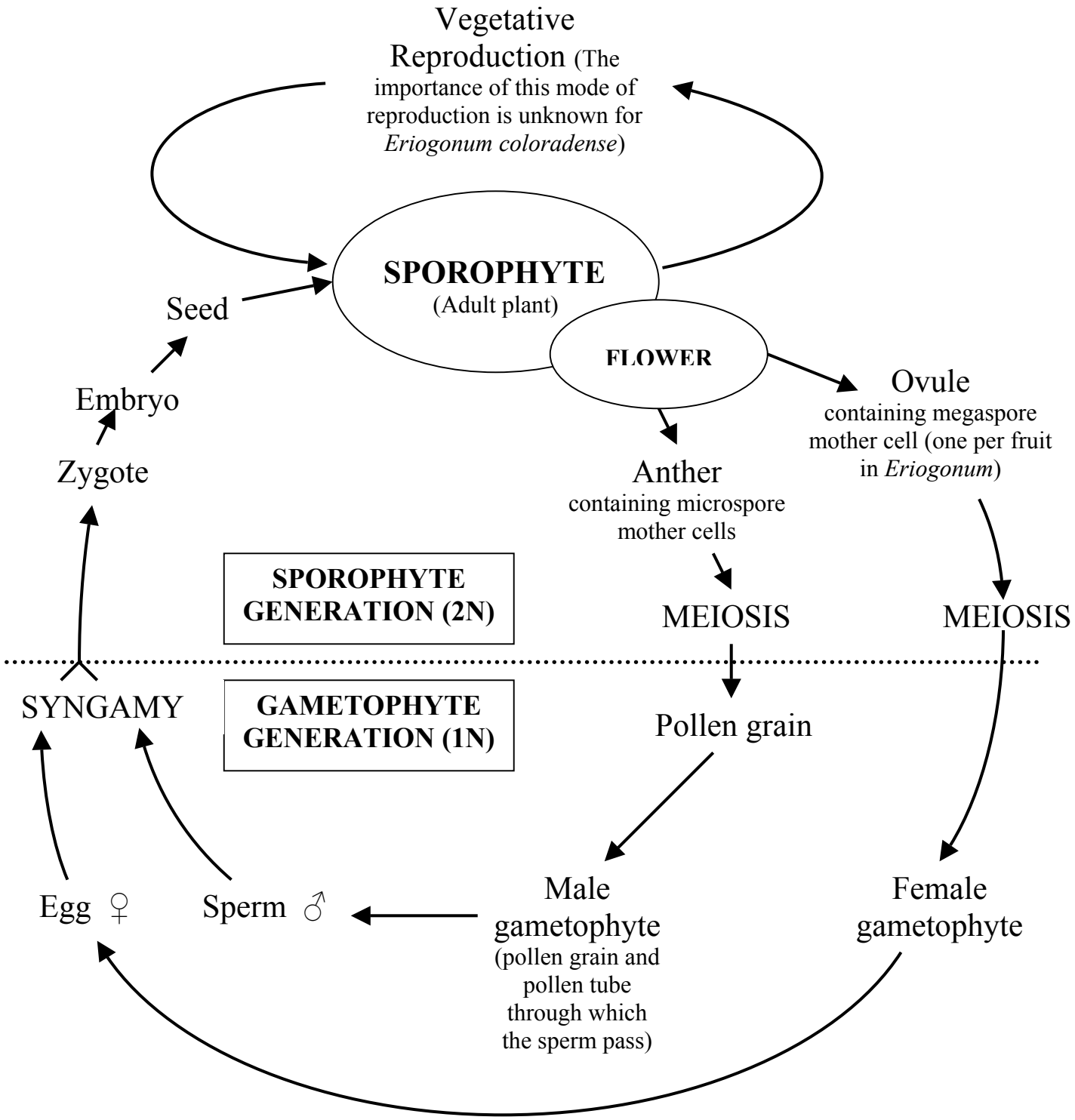

Figure 6. Life cycle diagram for *Eriogonum coloradense* (after Stern 1994).

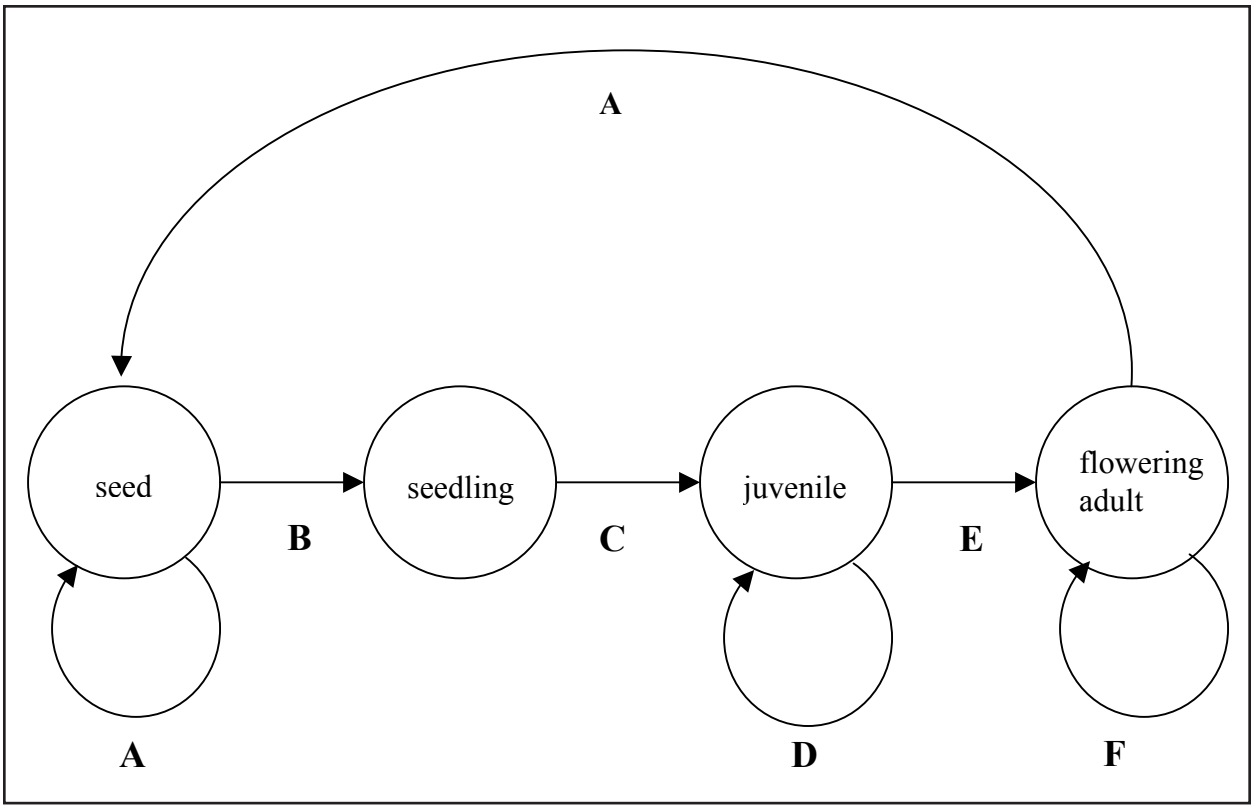

Figure 7. Hypothetical life cycle graph (after Caswell 2001) for *Eriogonum coloradense*. There has been no investigation of the life history stages of this species. No transition probabilities are known for *E. coloradense*, and there has been no demographic monitoring of other species of *Eriogonum* from which valuable inferences can be drawn. The value of A probably varies from year to year depending on climatic variables. No seedlings have ever been observed, so there are no data from which to infer B and C. The duration of the juvenile stage is not known (D). Given a probable slow growth rate and the large size of some individuals, and observations of other species cited by Reveal (personal communication 2002), plants probably survive for many tens of years or perhaps 100 years as flowering adults (F). The role of vegetative reproduction in *E. coloradense* is not known.

Extremely Rocky community type. The dominant species in the plot that included *E. coloradense* is *Juniperus communis* (80 percent cover). Other associated species include *Bromopsis porteri*, *Chamerion danielsii*, *Elymus trachycaulus*, *Erigeron speciosus*, *Festuca thurberi*, *Poa fendleriana*, *Potentilla hookeriana*, *Ribes montigenum*, and *Thalictrum fendleri*. *Eriogonum coloradense* is a minor component of this community, at only 0.4 percent cover. This community has high species richness compared to many other sites occupied by *E. coloradense*.

Eriogonum coloradense is also a component of the perennial forb community at the Gothic Earthflow (Langenheim 1956; EOR 6 in **Table 3**). Plot data from this study document the presence of several species that co-occurred with *E. coloradense* for more than one year. These species are *Aster bigelovii*, *Artemisia dracunculus*, *A. tridentata* (possibly *A. tridentata* ssp. *vaseyana*), *Chaenactis alpina*, *Elymus elymoides*, *Penstemon strictus*, and *Taraxacum officinale*.

In low elevation sites in Park County, *Eriogonum coloradense* has been documented with *Artemisia frigida* and *Bouteloua gracilis*. Reveal (personal communication 2002) has also observed *E. coloradense* with *A. tridentata* ssp. *vaseyana* at an unknown site. No associated species data are available for Saguache and Chaffee counties.

The forage value of high elevation habitat for *Eriogonum coloradense* is probably very low. Sparse vegetation, steep, treacherous, rocky slopes, and low primary production in many sites probably deter many herbivores, and many sites are virtually inaccessible to them (Johnston personal communication 2002).

Table 5. Associated species that have been documented with *Eriogonum coloradense*. Taxa listed in published sources are indicated. Taxa listed in bold are considered rare by the Colorado Natural Heritage Program (2002).

Scientific Name	Langenheim 1956	Komárková 1986, Johnston et al. 2001	Scientific Name	Langenheim 1956	Komárková 1986, Johnston et al. 2001
Abies lasiocarpa (Krummholz)			*Ipomopsis aggregata*	X	
Adenolinum lewisii		X	*Ivesia gordonii*		X
Agoseris glauca	X		*Juniperus communis*		X
Antennaria spp.			*Ligularia* spp.		
Artemisia dracunculus	X		*Lupinus* spp.		
Artemisia frigida			*Oxytropis deflexa*		
Artemisia tridentata	X		*Oxytropis* spp.		
Aster bigelovii	X		*Oxytropis viscida*		
Astragalus molybdenus			*Packera porteri*		
Bouteloua c.f. *gracilis*			*Penstemon harbourii*		
Bromopsis porteri		X	*Penstemon* spp.		
Bromus polyanthus	X		*Penstemon strictus*	X	
Campanula rotundifolia		X	*Phacelia sericea*		X
Carex spp.			*Picea engelmannii*		
Chaenactis alpina	X		*Poa alpina*		
Chamerion danielsii		X	*Poa fendleriana*		X
Cirsium scopulorum			*Populus tremuloides*		
Claytonia c.f. *megarhiza*			*Potentilla hookeriana*		X
Conioselinum scopulorum		X	*Potentilla* spp.		
Crepis nana			*Pseudocymopterus montanus*		X
Dryas spp.			*Ribes montigenum*		X
Elymus elymoides	X		*Salix* spp.		
Elymus trachycaulus	X	X	*Senecio amplectens* var. *holmii*		
Erigeron pinnatisectus			*Senecio fremontii* var. *blitoides*		
Erigeron spp.			*Smelowskia calycina*		
Erigeron speciosus	X	X	*Taraxacum eriophorum*		
Eriogonum spp.			*Taraxacum officinale*	X	X
Eriogonum umbellatum var. *aureum*		X	*Thalictrum fendleri*		X
Festuca spp.			*Trifolium dasyphyllum*		
Festuca thurberi		X	*Trisetum spicatum*		X
Grass	X		*Valeriana* spp.		
Hackelia floribunda	X		*Viola sororia*		X
Heterotheca villosa		X			

Habitat that falls into the Rocky Tall-Shrublands Ecological Series of Johnston et al. (2002) is avoided by domestic sheep due to the instability of the substrate. Bighorn sheep use areas in the Rocky Tall Shrublands heavily, sometimes having a considerable effect on the vegetation. However, it is unlikely that *E. coloradense* is eaten often when more desirable shrub species are present. Deer and elk may also find cover in this community type. Pikas or other small mammals may forage on *E. coloradense* at high elevation, rocky sites.

There is no information on competitors for biotic and abiotic resources with *Eriogonum coloradense*. If competitive interactions are important in the autecology of *E. coloradense*, some of the associated species cited above are the most probable competitors. Some species of *Eriogonum* are competitive and respond positively to disturbance (Reveal personal communication 2002). However, stress-tolerant species do not typically need to be good competitors, since highly competitive species are not capable of withstanding the chronic stress regime to which stress tolerators are supremely adapted (Grime 2001). Thus, they typically do not share the same resource pool with species such as *E. coloradense*. An envirogram is presented in **Figure 8** that portrays the generalized interactions between *E. coloradense* and its environment.

INDIRECT ENVIRONMENT 2	INDIRECT ENVIRONMENT 1	DIRECT ENVIRONMENT
		RESOURCES
	Canopy openness	Light energy
	Slope, aspect, albedo	Thermal energy (climate)
Local geology	Soil texture	Soil moisture
	Climate	
		Oxygen, carbon dioxide
		Nutrients
		REPRODUCTION
	Other plant resources	Pollinators
	Nest sites	
	Other *E. coloradense* individuals	Genetic diversity
	Microsite attributes	Safe sites
	Wind	
	Seed dispersers	
		PREDATORS/ HERBIVORES
	Drought	Fungal rust (?)
	Other food resources	Herbivores (pikas?)
	Site accessibility	Humans (collectors)
		Seed predators
		MALENTITIES
	Industrial complex	Airborne pollutants
		Thermal energy (climate)
Economic variables	Human population density	Humans (off-road vehicle users, hikers, miners)
	Site/microsite attributes	Competitors
	Drought	Soil moisture

Eriogonum coloradense

Figure 8. Envirogram for *Eriogonum coloradense*, showing resources, reproduction, predators/herbivores, and malentities (after Niven and Liddle 1994).

No studies or observations of *Eriogonum coloradense* have noted any effects from parasites and disease. However, *Eriogonum* species are commonly attacked by the rust *Uromyces intricatus* (Savile 1966). This species includes six varieties, all of which attack various members of the genus *Eriogonum* throughout western North America. The occurrence of rust has been documented on several Colorado species including the rare species *E. brandegeei* (Colorado Natural Heritage Program 2002). In the case of *E. brandegeei*, over half of some populations appeared to be severely affected by the rust, but it is unknown whether this epidemic resulted in any mortality or lasting impacts on the populations.

The wide range of habitats occupied by *Eriogonum coloradense* makes it difficult to identify dominant species-environment relationships. Rock cover, slope, and canopy cover would likely fall out in a canonical analysis as environmental factors that are highly correlated with *E. coloradense*.

Conservation

Threats

Numerous reports, observations, and opinions of experts show that there are several threats to the persistence of *Eriogonum coloradense*. In order of decreasing priority these are recreation impacts, grazing and its secondary effects, right-of-way management, residential development and human population growth, exotic species invasion, effects of small population size, mining, rust, global climate change, and pollution. The occurrences known from National Forest System lands are unlikely to be threatened by right-of-way management, but all other threats are relevant to these occurrences to some extent. These threats and the hierarchy ascribed to them are somewhat speculative, and more complete information on the biology and ecology of this species may elucidate other threats. A few other additional potential threats are mentioned below, but they are highly speculative. Assessment of threats to this species will be an important component of future inventory and monitoring work. Please see the following sections for specific treatments of these threats to habitat and individuals, and from exotic species and over-utilization.

Direct human impacts from hiking, trampling, and other recreational use present a significant threat to *Eriogonum coloradense*, particularly for the high elevation occurrences. Most of the known population is concentrated in popular recreation areas near Crested Butte, although *E. coloradense* has most often been documented from less frequently visited sites. Two occurrences on the White River National Forest (EORs 4 and 9 in **Table 3**) are bisected by hiking trails.

Grazing by sheep may be a concern at high elevation sites and by horses and cattle at low elevation sites, but *Eriogonum* species are often tolerant of some level of grazing. For very small populations, grazing is of much greater concern, as are any land use activities that could result in plant mortality. Abundance data for five occurrences on Forest Service land (EORs 6, 12, 13, 18, 19 in **Table 3**) suggest that they are vulnerable to impacts that could result in the loss of any plants.

Direct impacts from residential development in surrounding areas might be negligible, but indirect impacts from increased visitation might be substantial in some populations in the future.

Exogenous environmental factors are likely to affect all alpine species in the near future. Global climate change projections based on current atmospheric CO_2 trends suggest that average temperatures will increase while precipitation will decrease. This will have significant effects on nutrient cycling, vapor pressure gradients, and a suite of other environmental variables. Temperature increase could cause treeline to climb 350 feet in elevation for every degree Fahrenheit of warming (U.S. Environmental Protection Agency 1997). Effects on *Eriogonum coloradense* and its alpine habitats are difficult to project given this scenario, but this species may be more adaptable than other strictly alpine species because it is also found at low elevations. However, through genetic drift, high elevation plants may have lost alleles that would increase their fitness in low elevation sites.

Atmospheric nitrogen deposition (of both organic and inorganic forms) is increasing worldwide. Experimental nitrogen enrichment of alpine sites suggests that ecosystem processes will be altered and result in species turnover (Bowman et al. 1993, Bliss and Gold 1999). Relatively low levels of nitrogen enrichment are advantageous to some species while deleterious to others, making it difficult to predict species- and community-level responses.

Influence of management activities or natural disturbances on habitat quality

The tundra communities that support most of the known occurrences of *Eriogonum coloradense* respond differently to human and natural disturbances. Some sites that are chronically disturbed may be somewhat

resilient to human impacts, while others such as fellfields can be quickly degraded. Certain habitats for *E. coloradense* (meadows and fellfields) would not sustain motorized recreational use well due to their fragility and long recovery time. Several occurrences on Forest Service land that are not protected in wilderness areas are potentially vulnerable to motorized recreational use based on available habitat descriptions (EORs 4, 6, 7, 8, 10, 11, 12, 22 in **Table 3**). Steep areas are also vulnerable to erosion. Effects on habitat for *E. coloradense* will depend on many variables such as the periodicity and intensity of human disturbance. Human impacts resulted in the Gothic Earthflow, which ironically created a great deal of habitat for *E. coloradense*.

It is unlikely that fire occurs frequently in most *Eriogonum coloradense* occurrences. However, the presence of *E. coloradense* in South Park on BLM land suggests that it is at least somewhat tolerant of fire. It is possible that fires create openings that *E. coloradense* colonizes as a seral species in the montane and subalpine; thus fire suppression may result in negative impacts.

Indirect effects on habitat quality for *Eriogonum coloradense* caused by fragmentation and hydrologic alteration are unknown. The impact of these actions on habitat quality for *E. coloradense* depends largely on the importance of ecological connectivity between populations, which is not known.

Influence of management activities or natural disturbances on individuals

Because occurrences of *Eriogonum coloradense* probably remain to be documented, surveys should be conducted before management actions are taken within potential habitat. Although many occurrences are in remote locations, some are accessible by popular hiking trails and receive fairly heavy recreational use. Occurrences noted previously on Forest Service land (EORs 4, 6, 7, 8, 10, 11, 12, 22 in **Table 3**) that are not protected within wilderness areas are most susceptible to recreation impacts. However, there has been no documentation of recreational impacts to the species. While many members of the genus *Eriogonum* are resilient and can be good competitors, *E. coloradense* is a long-lived, stress-tolerant, slow-growing subalpine/alpine perennial, and it is possible that it would respond poorly to disturbance from heavy recreational use.

The effects of livestock grazing on *Eriogonum coloradense* are not known. The observations of Reveal (personal communication 2002) suggest that grazing is not a significant threat to *Eriogonum* species in general, given their adaptations to fragmentation, but this needs to be verified for *E. coloradense* due to its rarity. Although details regarding grazing regime are not known, grazing impacts may have been heavy on the Gothic Earthflow occurrence, where Langenheim (1956; EOR 6 in **Table 3**) reported that 1,200 cattle were grazed periodically during the study from 1947 to 1954. Populations in South Park (EOR 16 in **Table 3**) and near Archuleta Creek on the Gunnison National Forest (EOR 22 in **Table 3**) are likely to experience cattle or other livestock grazing. At high elevations, sheep generally avoid habitat for *E. coloradense*, or they simply cannot get to it. This is particularly true for occurrences on talus or other unstable substrates (Johnston personal communication 2002). The greatest impact to *E. coloradense* is probably from hiking in heavily used areas of the Maroon Bells-Snowmass Wilderness and surrounding area. Three occurrences (EORs 3, 4, and 9 from **Table 3**) appear more vulnerable than other occurrences on Forest Service land to impacts from non-motorized recreation. Hiking and camping in the Gothic Research Natural Area (EOR 5 in **Table 3**) has some potential for impacts to *E. coloradense* as well.

Residential development and human population growth appear to pose a significant and increasing threat to the quality and availability of habitat for *Eriogonum coloradense*. Between 1990 and 2000, significant population growth occurred in all counties in which *E. coloradense* occurs (**Table 6**) (U.S. Census Bureau 2003). While this does not directly threaten most known

Table 6. Percent human population growth from 1990 to 2000 in the counties in which *Eriogonum coloradense* is known to occur (data from U.S. Census Bureau 2003).

County	Population Growth (%)
Chaffee	28.1
Gunnison	35.9
Pitkin	17.5
Saguache	28.1

occurrences of *E. coloradense*, it could impact known EORs 16 and 22 (**Table 3**) in South Park and Saguache County. Six occurrences of *E. coloradense* are known within eight miles of Crested Butte on National Forest System land (EORs 5, 6, 7, 8, 9, 11) that are not within wilderness areas and where there is the possibility that lands could be traded to permit further development. Subdivision of property into ranchettes and dispersed development, which is occurring throughout the Colorado mountains, fragments large areas of natural habitat (Knight et al. 2002). Increased populations will also result in greater recreational use of areas inhabited by *E. coloradense*.

Rust attack has been cited by numerous observers as a threat to some *Eriogonum* species, particularly *E. brandegeei* (Colorado Natural Heritage Program 2002). However, it appears that the rust does not usually kill its hosts or cause long-term damage. Although rust outbreaks are probably a natural phenomenon in populations of *Eriogonum* species, it is possible that plants that are already stressed or disturbed by human impacts may succumb more easily to rust attacks. In this scenario, rust is part of a syndrome that could augment the decline of populations.

Occurrences within rights-of-way are highly susceptible to impacts from road maintenance such as mowing, spraying for weeds, and road widening. These threats are ongoing and will be difficult to full ameliorate. For example, plants within 23 feet of the pavement (or 15 feet, depending on the size of the mower used) may be mowed repeatedly throughout the growing season along state highways (Powell personal communication 2003). EORs 15 and 22 (Gunnison National Forest) (**Table 3**) are most vulnerable to this threat.

Interaction of the species with exotic species

No impacts from exotic plant species have been observed on *Eriogonum coloradense*. It is possible that an insipient weed could favor the habitat for *E. coloradense* when it arrives, and require costly management efforts for its control. Langenheim (1956; EOR 6 in **Table 3**) documented the presence of *Taraxacum officinale* in plots with *E. coloradense*. *Bromus inermis* was also documented on the Gothic Earthflow in this study but not in the plots with *E. coloradense*. The presence of *Linaria vulgaris* in an occurrence should be regarded as a threat. *Linaria vulgaris* has been documented in Gunnison and Pitkin counties (University of Colorado Herbarium 2004). Future surveys for *E. coloradense* should note any impacts from these and other non-native species.

Threats from over-utilization

There are no known commercial uses for *Eriogonum coloradense*. There is potential for over-utilization of *Eriogonum* species if they become popular in the herb trade. Harvest of wild populations of *E. coloradense* would present a tangible threat if it's use became common. Members of the genus *Eriogonum* are variously reputed to be good plants for honey production (Lovell 1969). However, this is highly unlikely to have any impacts to *E. coloradense* given the non-consumptive nature of this impact and the remoteness of most occurrences. Native Americans have used the roots of some *Eriogonum* species for medicinal purposes (Kearney and Peebles 1960). There are no reports of any toxicity concerns for *Eriogonum* (Burrows and Tyrl 2001). Over-collection for scientific purposes, particularly in small occurrences, is also a potential threat. However, collection of specimens is very important for documentation and research purposes. Following collection guidelines (Wagner 1991, Pavlovic et al. 1992) will ensure that small occurrences of *E. coloradense* are not impacted by collection.

Conservation Status of the Species in Region 2

Is distribution or abundance declining in all or part of its range in Region 2?

There are no reports that suggest that any particular occurrence of *Eriogonum coloradense* is in decline or has been extirpated due to human or natural influences. Because the pre-settlement population size and extent of *E. coloradense* are not known, and because there remain significant gaps in our understanding of the distribution and abundance of this species, it is difficult to assess the effects of recreation, infrastructure, and management regimes on abundance. Because this species is found primarily in areas that receive limited human and livestock use, it is unlikely that serious impacts are occurring as a result of recreation and grazing at present. Further focused inventory and monitoring work will help to determine the current population trend of this species.

Do habitats vary in their capacity to support this species?

The high variation in population size and density documented thus far in populations suggests that habitats vary greatly in their capacity to support *Eriogonum coloradense*. However, the underlying ecological reasons for this variation are unknown and difficult to

speculate on until research is conducted to clarify the relationships between *E. coloradense* and its habitat.

Vulnerability due to life history and ecology

Assessing the vulnerability of *Eriogonum coloradense* due to its life history and ecology is complicated, given the paucity of information available in these regards. As a long-lived, stress-tolerant perennial, it is buffered somewhat from the effects of environmental stochasticity such as drought. Because it has effective mechanisms for selfing, it may also be buffered from impacts that affect its pollinators. However, in *E. ovalifolium* var. *williamsiae*, maintaining heterozygosity appears to be important for maintaining the fitness of the population. Preventing the buildup of homozygous loci in the population will require frequent outcrossing, which will be augmented by the presence of appropriate pollinators and sufficiently large population sizes (Neel et al. 2001). If this is also true for *E. coloradense*, then it is vulnerable to inbreeding depression and impacts to its pollinators. The minimum viable population size is not known for *E. coloradense*, but even small populations by the standards of the 50/500 rule of Soulé (1980) may still be viable and of conservation importance. Somewhat arbitrarily, the Colorado Natural Heritage Program considers any population containing 10 or more plants as viable, but this threshold will be revised when a minimum viable population size is determined.

Eriogonum coloradense is somewhat vulnerable to habitat alteration, since some occurrences are in areas that potentially receive either heavy recreational use or livestock grazing. Alpine habitats in particular have the potential for negative impacts from human activities, but Johnston (personal communication 2002) states that occurrences he has seen are not typically in the sorts of habitat toward which hikers tend to gravitate. Revisits to the low elevation occurrences are needed to assess impacts from land uses.

Like all rare plants, *Eriogonum coloradense* is vulnerable to unforeseen impacts from noxious weeds. New exotic species are arriving constantly, and it may be only a matter of luck that the habitat for *E. coloradense* has not already been substantially invaded by exotics. *Taraxacum officinale* and *Bromus inermis*, which have been documented with or near *E. coloradense*, and *Linaria vulgaris*, which threatens mountain areas throughout Colorado, are species of particular concern for *E. coloradense*.

Evidence of populations in Region 2 at risk

There is much evidence to suggest that occurrences of *Eriogonum coloradense* are at risk. Its peculiar habitat specificity, high level of endemism, small number of occurrences, and high degree of isolation of individual occurrences all suggest that *E. coloradense* is imperiled. Small occurrences (e.g., EORs 12, 18, and 19 on Forest Service lands in **Table 3**) are particularly vulnerable to human impacts and stochastic events. Many occurrences of *E. coloradense* are disjunct and are probably genetically isolated from other occurrences. Two occurrences (EORs 17 and 22 in **Table 3**) are disjunct by 22 and 53 miles, respectively, from other known occurrences.

Eriogonum coloradense is very poorly understood, which is a liability because well-intended conservation actions cannot be as effective when basic information is not available. Sixteen occurrences apparently have not been visited and assessed in over 20 years; some occurrences have not been seen since the 1930s and one not since 1896. This adds a great deal of uncertainty to any assessment using these data. Often when a species thought to be rare is actively sought and inventoried, it is found that the species is not as rare as previously believed.

Most occurrences of *Eriogonum coloradense* are found in designated wilderness areas in remote locations, and much of the area it inhabits remains sparsely populated at present. However, wilderness area designation does not prevent some of the threats to *E. coloradense*. Occurrences in the Maroon Bells-Snowmass Wilderness are in popular hiking destinations near Aspen, Crested Butte, and Gunnison and are heavily used. Numerous mining claims are present in the area around Crested Butte and Gothic; these would be cause for concern if they became active. Low elevation occurrences in Park and Saguache counties are at risk from road construction and maintenance, residential development, and potentially livestock grazing. Occurrences on private land (EOR 17 and possibly EORs 6, 10, 14, 16) are at risk from possible future development. Development might also negatively impact some of the pollinator species on which *E. coloradense* depends by reducing nectar resources in the area.

Management of the Species in Region 2

Implications and potential conservation elements

The most current data available suggest that *Eriogonum coloradense* is imperiled due to small population sizes and a small number of occurrences. Thus, the loss of any occurrence is significant and will probably result in the loss of important components of the genetic diversity of the species. It is likely that the disjunct, low elevation occurrences have many alleles not present in the high elevation occurrences, so loss of these occurrences will result in a significant loss of genetic diversity.

Desired environmental conditions for *Eriogonum coloradense* include sufficiently large areas where the natural ecosystem processes on which *E. coloradense* depends can occur, permitting it to persist unimpeded by human activities and their secondary effects, such as weed introduction. This includes a satisfactory degree of ecological connectivity between populations to provide corridors and other nectar resources for pollinators. Given the current paucity of information on this species, it is unknown how far this ideal is from being achieved. It is possible that most or all of the ecosystem processes on which *E. coloradense* depends are functioning properly at the locations of many or most of the populations of this species. Further research on the ecology and distribution of *E. coloradense* will help to develop effective approaches to management and conservation. Until a more complete picture of the distribution and ecology of this species is obtained, priorities lie with conserving the known occurrences, particularly those that support large populations, that are in excellent condition, and in which the surrounding landscape remains largely intact.

Within the last 15,000 years, the climate in the southern Rocky Mountains has been both warmer and colder than it is at present. There is much evidence to suggest that the elevational and latitudinal distributions of many plant species were much different in these periods than they are today. Given the changes predicted in the global climate for the next 100 years, incorporation of higher elevation refugia for *Eriogonum coloradense* into preserve designs and conservation plans will help to ensure this species' long-term viability.

Tools and practices

Species and habitat inventory

It is relatively easy to develop a search image for *Eriogonum coloradense* at high elevation sites since there are only a few other *Eriogonum* species in the alpine. Some habitat units are discrete enough that they can be searched fairly thoroughly when visited by one to three field botanists, but this is not typical and it can be difficult to determine the full extent of an occurrence. Searching for *E. coloradense* is facilitated by the sparse vegetation and the relative ease of seeing the plants in open sites, but survey work is much more effective during flowering since the vegetative portion of the plant often does not stand out. The greatest difficulty in conducting inventories for *E. coloradense* is in accessing appropriate habitat, since this species favors steep, rocky, remote sites.

Eriogonum coloradense could benefit greatly from inventory and mapping using Global Positioning System technology to precisely mark occurrence boundaries. This would provide land managers with useful data for generating land use plans and permits, for example. The value of such a project would be greatly augmented by the collection of quantitative census data with ecological data.

Aerial photography, topographic maps, soil maps, and geology maps can be used to refine surveys of large areas. Such technology is most effective for a species about which we have basic knowledge of its substrate and habitat specificity from which distribution patterns and potential search areas can be deduced. Given the current paucity of information regarding the habitat needs of *Eriogonum coloradense*, it will be difficult to narrow the search area using these techniques. Instead, searching apparently suitable habitat in the vicinity of known occurrences is an effective starting point for species inventory work.

Searches for *Eriogonum coloradense* could be aided by modeling habitat based on the physiognomy of known occurrences. The intersection of topography, geologic substrate, and vegetation could be used to generate a map of a probabilistic surface showing the likelihood of the presence of *E. coloradense* in given locations. This may be a valuable tool for guiding and

focusing future searches. Techniques for predicting species occurrences are reviewed extensively by Scott et al. (2002). Habitat modeling has been done for other sensitive plant species in Wyoming (Fertig and Thurston 2003), and these methods apply to *E. coloradense* as well. However, the inferential power of this method is limited for species like *E. coloradense* that have been documented in so many different habitats and apparently have low substrate specificity.

Population monitoring

Monitoring of selected occurrences of *Eriogonum coloradense* could answer many important questions. A monitoring program that addresses recruitment, seed production, plant longevity, and pollinators would generate data useful to managers and the scientific community. Population monitoring would also be a useful means of detecting population trends under different management and human use scenarios. A monitoring program for *E. coloradense* targeting robust occurrences in both natural and unnatural settings could incorporate an investigation of human impacts such as recreation and grazing. Monitoring sites under a variety of land use scenarios will help to identify appropriate management practices for *E. coloradense* and will help to understand its population dynamics and structure.

U.S. Fish and Wildlife Service (1995, page 23) provides basic guidelines for monitoring *Eriogonum ovalifolium* var. *williamsiae* that are largely applicable to monitoring *E. coloradense* as well. Recommendations include collecting baseline information, developing a baseline map of the known occurrences, and conducting periodic monitoring. Lesica (1987) described a technique for monitoring populations of non-rhizomatous perennial plant species that would apply to *E. coloradense*. Standard monitoring methods generally employ the use of randomly arrayed systematic sampling units. Within each plot, plants are marked and tracked using aluminum tags or other field markers. Recruitment within each plot is quantified by counting seedlings. To reduce the chance of missing seedlings, a quadrat frame subdivided with tight string can help observers search each quadrat systematically and objectively. Elzinga et al. (1998) offers additional suggestions regarding this method.

Monumentation is likely to be difficult in many sites occupied by *Eriogonum coloradense*. Several methods of monumentation are recommended in Elzinga et al. (1998), depending on the site physiography and the frequency of human visitation to the site. This is an important consideration that will reap long-term benefits if done properly at the outset of the monitoring program.

Estimating cover and/or abundance of associated species within the plots described above could permit the investigation of interspecific relationships through ordination or other statistical techniques. Understanding environmental constraints on *Eriogonum coloradense* would facilitate the management of this species. Gathering data on edaphic characteristics (moisture, texture, and lysimetry) from the permanent plots described above would permit the canonical analysis of species-environment relationships. These data would facilitate hypothesis generation for further studies of the ecology of this species. Comparing lysimetry data between occupied and unoccupied habitat could help explain why some apparently suitable sites are not occupied by *E. coloradense*.

Meaningful population trend data could probably be obtained from a subset of the known occurrences. Selecting monitoring sites throughout the range of *Eriogonum coloradense* at a variety of substrates and elevations is needed to assess the relative performance of populations. Ideally, monitoring sites could be established at readily accessible occurrences to reduce the effort and cost needed to conduct monitoring.

Resampling of monitoring plots every two to three years should be sufficient for *Eriogonum coloradense*, given its slow growth and long lifespan (Reveal personal communication 2002). Visiting populations in mid-summer while the plants are flowering would allow researchers to observe pollinator visitation. It should also be possible to count seedlings at this time. Measuring seed production will require another visit later in the summer.

Adding a photo point component to this work, following the recommendations offered in Elzinga et al. (1998), could facilitate the tracking of individuals and add valuable qualitative information. A handbook on photo point monitoring (Hall 2002) is available, and it offers excellent instructions on establishing photo point monitoring plots. Monitoring sites should be selected carefully and in sufficient number, if the data are intended to detect population trends.

Present research priorities for *Eriogonum coloradense* lie in gathering baseline data on distribution and population sizes. Gathering population size data can be done rapidly and requires only a small amount of additional time and effort (Elzinga et al. 1998). Thus,

presence/absence monitoring is not recommended for *E. coloradense*.

To investigate the metapopulation structure of *Eriogonum coloradense*, one approach might be to select highly suitable but unoccupied sites and attempt to observe colonization events. However, selection of such sites would require more *a priori* research on the habitat requirements of *E. coloradense*, and the probability of observing a colonization event is extremely low. Given the life history characteristics of *E. coloradense*, it is possible that many years of data would be needed before meaningful inferences could be made about its metapopulation structure. Concurrent observations of local extinctions, which are fairly likely to occur in the smaller known occurrences, would also add to our understanding of the metapopulation structure of *E. coloradense*.

Habitat monitoring

The use of photo points for habitat monitoring is described in Elzinga et al. (1998). This is a powerful technique that can be done quickly in the field. Although it does not provide detailed cover or abundance data, it can help to elucidate patterns observed in quantitative data.

Habitat monitoring of known occurrences would help alert managers of new impacts, such as weed infestations and trampling. For *Eriogonum coloradense*, monitoring all the known populations with a visit every third year is feasible. This could be incorporated into the field forms used for the quantitative sampling regimen described above. Observer bias is a significant problem with habitat monitoring (Elzinga et al. 1998). Thus, habitat monitoring is usually better at identifying new impacts than at tracking change in existing impacts. For estimating weed infestation sizes, using broad size classes helps to reduce the effects of observer bias. To assess trampling impacts, using photos of impacts to train field crews will help them to consistently rate the severity of the impact.

Beneficial management actions

Further inventory and monitoring efforts would be highly beneficial to *Eriogonum coloradense*. Identifying high quality occurrences in which the population size, condition, and the landscape context are excellent will help managers to prioritize conservation efforts. Developing a better understanding of its distribution will assist in the development of regional management protocols that favor the persistence of *E. coloradense*.

Surveys prior to management actions within potential habitat would help to alleviate threats to this species from human impacts to individuals. Complete and detailed surveys are needed wherever there is the potential for impact to *Eriogonum coloradense*. This will help to identify new occurrences and to avert impacts to occurrences from development activities.

Management actions that reduce impacts to *Eriogonum coloradense* and its habitat are likely to procure significant benefits for the species. Routing new trails and rerouting any existing trails around known occurrences are probably the best ways to reduce human impacts to *E. coloradense*. Since many occurrences are in wilderness areas, mitigating impacts from motorized vehicle recreation is not required.

Although mowing and weed control efforts have the potential to negatively impact some portions of populations of *Eriogonum coloradense*, including those near Highway 285 (EORs 15 and 22 (Gunnison National Forest) [and possibly others] in **Table 3**), right-of-way management practices can be modified to mitigate these impacts. Hand-pulling weeds where possible and appropriate probably would have the least impact on occurrences of *E. coloradense*. Limiting the use of herbicides within occurrences of *E. coloradense* to direct application to target species will mitigate the loss of plants due to overspray and indiscriminate application. Avoiding right-of-way mowing in *E. coloradense* occurrences from June until late August or September (after fruit has dried and seeds are released) might also be beneficial. Clearances of areas in question by someone who is familiar with *E. coloradense* will help to prevent impacts to occurrences during road projects such as utility line installation and alterations or widening of roads. Obtaining better data on the precise locations of these occurrences is needed to effectively mitigate impacts from right-of-way management.

Potentially beneficial management actions with respect to grazing are difficult to determine given our dearth of information on the response of *Eriogonum coloradense* to grazing. The best approach to determining the impacts from grazing is to incorporate grazed and ungrazed areas into a monitoring protocol, as recommended among the recovery steps for the federally listed species *E. gypsophilum* (Limerick 1984). As previously noted, grazing actually stimulates growth in some species of *Eriogonum*. The trampling action of hooves can break the plants apart, which may facilitate vegetative reproduction under certain grazing regimes. For many *Eriogonum* species, when a plant is fragmented and separated from the taproot, the

prostrate stems can send out roots and regenerate a new plant. Because they are not as palatable as many other rangeland species, they may be competitively released by grazing as well. Whether or not this is the case for *E. coloradense* is unknown. The high elevation habitat of *E. coloradense* and probable slow growth rates and limited competition with other species are factors that may not be as prevalent for most species of *Eriogonum*. However, the matted growth form of *E. coloradense* suggests that it too could be fairly tolerant of fragmentation.

No protected areas have been designated that include the conservation of *Eriogonum coloradense* habitat or occurrences as an explicit goal. However, several occurrences of *E. coloradense* are in areas where they receive some degree of protection. As many as 12 of the 22 known occurrences are found in designated wilderness areas and the Gothic Research Natural Area, where they are protected from many potentially threatening land use activities including off-road vehicle use, ski area development, and road building. However, these areas offer little protection from grazing or trampling by hikers.

An additional level of protection for this species has been its designation as a sensitive species by the BLM's Gunnison Field Office. USFS sensitive species status in Region 2 would benefit *Eriogonum coloradense* by requiring biological evaluations for the species in project areas containing suitable habitat. Because the majority of known occurrences (16, or possibly 18, of 22) are found on lands owned and managed by the USFS, *E. coloradense* would garner significant protection from sensitive species designation in Region 2.

Seed banking

No seeds or genetic material are currently in storage for *Eriogonum coloradense* at the National Center for Genetic Resource Preservation (Miller personal communication 2002). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2002). Collection of seeds for long-term storage will be useful if future restoration work is necessary.

Information Needs

Distribution

Further species inventory work is among the top priorities for research on *Eriogonum coloradense*. Until we have a better picture of its distribution and population size, it will not be possible to accurately assess the conservation needs and priorities for this species.

Much suitable habitat between known occurrences remains to be searched. Recent searches of the Maroon Bells area by Lyon (Colorado Natural Heritage Program) and Rossignol (USDA Forest Service) have been lucrative, and have yielded some of the best data currently available on population size. More work of this sort is needed. Revisiting and assessing the historic occurrences is needed as well as searches of other areas. Substrate specificity information is needed to help refine searches for new occurrences.

Some of the best potential habitat for *Eriogonum coloradense* is found in wilderness areas in central Colorado (**Figure 5**), including those in which it is currently known (Maroon Bells-Snowmass, Collegiate Peaks, and possibly Raggeds) and others where it has not yet been documented (Hunter-Frying Pan, Holy Cross, and Eagle's Nest). Because these wilderness areas include large areas at high elevations, they represent excellent places in which to focus search efforts.

Lifecycle, habitat, and population trend

Very little is known about the population ecology of *Eriogonum coloradense* and other members of the genus *Eriogonum*. There are no data from which valuable inference can be made regarding the population trend of *E. coloradense*. Baseline population size data are available for only four occurrences; monitoring data are essentially non-existant. Basic life history parameters need to be determined from which the viability of populations can be inferred.

Autecological research is also needed for *Eriogonum coloradense*. Information on the habitat of *E. coloradense* comes from disparate sources and is sparse. Detailed descriptions and quantitative ecological data would help tremendously in understanding and managing this species. Given the current paucity of information and the breadth of habitats in which *E. coloradense* occurs, it is difficult to determine with any degree of confidence where other occurrences might be found. Information on soil chemistry and nutrient relations might yield valuable insights into the ecological requirements of *E. coloradense*; this would facilitate effective conservation stewardship of this species. Physiological ecology studies will help to determine what substrate characteristics are required by *E. coloradense*. This will be valuable information in the event that an occurrence needs to be restored,

and it will help to model the potential distribution of the species.

Response to change

Rates of reproduction, dispersal, and establishment and the effects of environmental variation on these parameters have not been investigated in *Eriogonum coloradense*. Thus, the effects of various management options cannot be assessed during project planning.

Given the floral biology typical of the genus *Eriogonum*, some inferences can be cautiously made regarding its pollinators. However, as one of the few alpine species of *Eriogonum* in Colorado, it is well worth studying the relationship of *E. coloradense* with its pollinators.

The importance of herbivory in the ecology of *Eriogonum coloradense* is not understood. Observations made thus far do not suggest that it has a significant impact on biomass reduction and disturbance of the species, but this has not been assessed with any degree of rigor.

The presence of exotic species has been documented with *Eriogonum coloradense*, but no impacts were cited, nor were any likely under the circumstances. However, the issue of exotic species is a relevant consideration for all plant conservation efforts. No information is available for the low elevation occurrences of *E. coloradense*, where concerns of the impacts of exotics are most acute.

Metapopulation dynamics

Metapopulation dynamics are probably not important for the viability of *Eriogonum coloradense*, given its life history strategy and habitat. However, research on its population ecology has not been done to determine the importance of metapopulation structure and dynamics to the long-term persistence of *E. coloradense* at local or regional scales.

Demography

Basic information on population sizes of the known occurrences has not been documented. Growth, survival, and reproduction rates are also unknown. Our knowledge of the distribution of the species is incomplete. Therefore much work is needed in the field before local and range-wide persistence can be assessed with demographic modeling techniques. Short term demographic studies often provide misleading guidance for conservation purposes, so complementary information, such as historical data and experimental manipulations, should be included whenever possible (Lindborg and Ehrlén 2002).

Population trend monitoring methods

There has been no monitoring of occurrences of *Eriogonum coloradense*, but methods are available to begin a monitoring program and are discussed herein. Measuring transitions between life history stages can provide more reliable data for slow-growing, long-lived species such as *E. coloradense* (Schemske et al. 1994). U.S. Fish and Wildlife Service (1995) offers basic recommendations for monitoring populations of *E. ovalifolium* var. *williamsiae*.

Restoration methods

Because no attempts have been made to restore occurrences of *Eriogonum coloradense* or members of the genus *Eriogonum*, there is no applied research to draw from in developing a potential restoration program. If seed viability is low, as has been observed in studies of other *Eriogonum* species, then propagation of the species by seed may be difficult. Advice for handling the seed of *E. fasciculatum* is offered by Ratliff (1974), and this is probably relevant to *E. coloradense* as well. Clonal propagation is probably highly feasible in *E. coloradense*.

Research priorities for Region 2

Reveal (personal communication 2002) suggests that the highest priority for research on *Eriogonum coloradense* is an investigation of its taxonomic status, since conservation priority might decrease if it turns out to be conspecific with *E. lonchophyllum*. However, even as a subspecies or variety, *E. coloradense* is a unique element of the flora of the southern Rocky Mountains and will probably still warrant conservation action after its taxonomic status is resolved.

That so much of the basic information in this report was written by making inferences from other *Eriogonum* species is testament to the need for inventory work on *E. coloradense*. Species inventory work on *E. coloradense* would yield a great deal of valuable information for a minimal cost.

There are several priorities for inventory work. These include searching for the historic occurrences of *Eriogonum coloradense* that have not been reassessed in many years. More attempts to find the

historic occurrences in Park and Saguache counties are important because these occurrences are in such different habitats than the occurrences that have been recently documented. Obtaining data from the type location on Mt. Harvard in Chaffee County is also important. Revisiting the Gothic Earthflow and resampling Langenheim's plots, if possible, could also be particularly interesting and fruitful.

Searching for new occurrences of *Eriogonum coloradense* is another priority. Areas between the known occurrences offer the highest probability of finding new populations. Searching for high elevation occurrences in Park County (in the Mosquito and Ten Mile ranges) and low elevation occurrences in Gunnison County (in the vicinity of Crested Butte and Baldwin) will broaden the scope of the search. *Eriogonum coloradense* has not been found in several wilderness areas of central Colorado (Raggeds, Hunter-Frying Pan, Holy Cross, and Eagle's Nest) where searches of high elevation areas might be fruitful.

Assessing demographic status, identifying critical life history stages, and determining biological processes affecting these stages should be the primary focuses of studies intended to confer practical benefits to conservation efforts (Schemske et al. 1994). Studies of its floral biology, dispersal, germination requirements, and longevity would address some of these priorities. Identifying the pollinators for *Eriogonum coloradense* will help to identify appropriate conservation strategies, and will also contribute valuable scientific data on the floral biology of this species. Understanding the physiological ecology of *E. coloradense* will help to understand its peculiar distribution and mysterious substrate specificity (or lack thereof). Investigations of the genetic structure of populations will help to understand the degree of genetic isolation and diversity of occurrences of *E. coloradense* and may help to resolve the existing taxonomic questions. This will be important for stewardship and setting conservation priorities. Investigating the population biology of *E. coloradense* will also yield valuable data, such as recruitment rate and annual variation in recruitment. Studies of the autecology of *E. coloradense* will begin to reveal the interspecific relationships that affect it, and will help managers to predict the effects of human disturbance, weed invasion, and climate change. Evaluating the response of *E. coloradense* to disturbance and grazing will provide valuable data to stewards and managers.

Eriogonum coloradense is an ideal species for graduate students to consider when selecting a research project, given the abundant opportunities for discovery that it offers. The availability of information on other species of *Eriogonum* would serve well in almost any biological study of *E. coloradense*.

Additional research and data resources

A forthcoming volume of the Flora of North America will include a treatment of the genus *Eriogonum* by Dr. James Reveal that was not available for inclusion in this report.

Definitions

Achene — A small, dry, indehiscent fruit with a single locule and a single seed (Harris and Harris 1999). This fruit is typical of members of *Eriogonum*.

Allopolyploid — A polyploid formed from the union of genetically distinct chromosome sets, usually two different species (Allaby 1998).

Caespitose — Growing in dense tufts (Harris and Harris 1999).

Caudex — The persistent and often woody base of an herbaceous perennial (Harris and Harris 1999).

CSR (Competive/Stress-tolerant/ruderal) model — A model developed by J.P. Grime in 1977 in which plants are characterized as Competitive, Stress-tolerant, or Ruderal, based on their allocation of resources. Competitive species allocate resources primarily to growth, stress-tolerant species allocate resources primarily to maintenance, and ruderal species allocate resources primarily to reproduction. A suite of other adaptive patterns also characterize species under this model. Some species show characteristics of more than one strategy (Barbour et al. 1987).

Ecophene — The morphological response of a phenotypically plastic species to environmental variation (after Cole 1967).

Ecotype — The morphological expression of a unique genotype that is adapted to particular habitat attributes (after Allaby 1998).

Imperilment Rank — Used by Natural Heritage Programs, Natural Heritage Inventories, Natural Diversity Databases, and NatureServe. Global imperilment (G) ranks are based on the range-wide status of a species. State-province imperilment (S) ranks are based on the status of a species in an individual state or province. State-province and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character (NatureServe 2003a). These ranks should not be interpreted as legal designations.

Lanate — Wooly; densely covered in long tangled hairs (Harris and Harris 1999).

Lanceolate — Lance-shaped; much longer than wide, with the widest point below the middle (Harris and Harris 1999).

Marcescent — Withering but persistent, as in the leaves at the base of some plants (Harris and Harris 1999).

Ocrea — A sheath around the stem formed from the stipules that is common throughout most of the Polygonaceae, but absent in *Eriogonum* (Harris and Harris 1999).

Perianth — The calyx and corolla of a flower, collectively (Harris and Harris 1999).

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