Eriogonum exilifolium Reveal (dropleaf buckwheat): A Technical Conservation Assessment

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Cover Photo Credit

Eriogonum exilifolium (dropleaf buckwheat). Photograph by author.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ERIOGONUM EXILIFOLIUM*

Status

Eriogonum exilifolium (dropleaf buckwheat) is a regional endemic whose global distribution is limited to 26 occurrences in Carbon and Albany counties, Wyoming and Jackson, Grand, and Larimer counties, Colorado. Two of these occurrences are known from National Forest System lands on the Medicine Bow National Forest of Wyoming; an additional occurrence may be located on the Routt National Forest in Colorado. An occurrence reported on the Roosevelt National Forest in Larimer County, Colorado was later found to be located only on nearby private and Bureau of Land Management lands. Other occurrences are located on lands managed by the Bureau of Land Management, the State of Colorado, and on private property.

Eriogonum exilifolium is restricted to scattered small areas of specific habitats within a narrow global range. The total population size of *E. exilifolium* is unknown. Individual occurrences range in size from 30 plants to more than one million. The species is ranked globally vulnerable (G3) by NatureServe, and is considered imperiled (S2) in both Wyoming and Colorado by the Wyoming Natural Diversity Database and the Colorado Natural Heritage Program, respectively. The USDA Forest Service Region 2 considers *E. exilifolium* to be a sensitive species (USDA Forest Service 2003). It is not considered sensitive by the Bureau of Land Management in Colorado (Bureau of Land Management 2000a) or Wyoming (Bureau of Land Management 2001a). It is not included on the federal Endangered Species List, is not a candidate for listing and has not been petitioned for listing.

Primary Threats

Observations and quantitative data document several threats to the persistence of *Eriogonum exilifolium*. In order of decreasing priority, these include residential and commercial development, range improvements, off-road vehicle use, other recreational uses, grazing, energy development, reservoir creation, right-of-way management, coal mining, exotic species invasion, effects of small population size, disease, declining pollinators, fire, global climate change, and pollution. Some threats are more immediate at some sites than at others; thus the hierarchy of threats is different for each site.

Primary Conservation Elements, Management Implications and Considerations

Current data suggest that *Eriogonum exilifolium* is a regionally endemic species that is imperiled due to a limited global range, small number of occurrences, scattered distribution, limited habitat availability, and threats to its habitat. Conservation elements for *E. exilifolium* include the need for open, barren sites on soil types and geological formations known to support the species, a suitable disturbance regime, availability of pollinators, and an absence of competitors.

Parts of two occurrences of this species are located on the Medicine Bow National Forest in Wyoming; two other occurrences reported from the Routt and Roosevelt national forests in Colorado have not been confirmed. While these four occurrences benefit from *Eriogonum exilifolium*'s status as a USFS-designated sensitive species, off-road vehicle use, road maintenance, grazing, and possibly other impacts threaten these and other occurrences. Ten (possibly 11) occurrences are located at least partly on private land where they are threatened by residential development and other intensive uses. Including occurrences in Research Natural Areas (USFS) and Areas of Critical Environmental Concern (BLM), pursuing conservation easements on private properties, and other protective land status changes could help to achieve conservation goals for *E. exilifolium*. Surveys for *E. exilifolium* are a high priority as they are likely to locate new occurrences. Research is needed to investigate the population biology and autecology of *E. exilifolium* so that conservation actions can be most effective.

TABLE OF CONTENTS

EDITORS: Beth Burkhart, Kathy Roche, and Janet Coles, USDA Forest Service, Rocky Mountain Region

List of Tables and Figures

Tables:

Figures:

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 exilifolium* is the focus of an assessment because it is a USFS-designated sensitive species. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (FSM 2670.5(19)). A sensitive species requires special consideration in management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Eriogonum exilifolium* throughout its range in Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. 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 background upon which management must be based and focuses on the consequences of changes in the environment that result from management. Furthermore, it cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope of Assessment

This assessment examines the biology, ecology, conservations status, and management of *Eriogonum exilifolium* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. The reproductive behavior, population dynamics, and other characteristics of *E. exilifolium* are considered in the context of the current environment rather than under historical conditions.

In producing this assessment, the author reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. All known publications, reports, and element occurrence records for *Eriogonum exilifolium* are referenced in this assessment, and all of the experts on this species were consulted during its synthesis. Specimens of *E. exilifolium* were viewed to verify occurrences and to incorporate specimen label data. Herbaria searched for specimens include University of Colorado Herbarium (COLO), Colorado State University Herbarium (CS), Rocky Mountain Herbarium (RM), San Juan College Herbarium (SJMC), University of Northern Colorado Herbarium (GREE) Kalmbach Herbarium, Denver Botanic Gardens (KHD), New Mexico State University Range Science Herbarium (NMCR), and University of New Mexico Herbarium (UNM). Specimen data from other institutions were obtained via the internet and from Reveal (1967a). This assessment emphasizes refereed literature, but non-refereed publications, personal communications, and reports were used when information was otherwise unavailable. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of this species, and they contain the majority of the useful information known on *E. exilifolium*. However, these data require 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 and tested through experimentation. 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, observations, inference, good thinking, and models must be relied on to guide our understanding of ecological relations. These alternative approaches are accepted as sound methods to improve our understanding of the species. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations described when appropriate.

Overall, knowledge of *Eriogonum exilifolium* is sparse and incomplete. To the author's knowledge there have been no quantitative or qualitative studies of the autecology of *E. exilifolium*. The existing information is mostly from herbarium labels, field surveys, and anecdotal observations. The paucity of information for *E. exilifolium* forced the author to rely heavily on personal communications with botanists who have experience with the species, and to draw inferences from other members of the genus *Eriogonum* where possible.

Treatment of This Document as a Web Publication

To facilitate their use, species assessments in the Species Conservation Project 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

Species assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation employing 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 exilifolium is a sensitive species in Region 2 of the USDA Forest Service (USDA Forest Service 2003). Its merits as a sensitive species were evaluated in 2002 (Burkhart 2002, Handley and Laursen 2002). It was determined that *E. exilifolium* warrants sensitive species status because it is a regional endemic with relatively few occurrences that are at risk from management actions such as road building, weed spraying, and oil and gas development (Houston and Sidle 2002).

The Global Conservation Status rank for *Eriogonum exilifolium* is G3 (Colorado Natural Heritage Program 2005, NatureServe 2005). The global conservation (G) rank is based on the status of a taxon throughout its range. A rank of G3 is given to taxa that are at moderate risk of extinction due to a restricted range, few occurrences (80 or fewer), recent and widespread declines, or other factors. *Eriogonum exilifolium* is known from a total of 26 occurrences in parts of three Colorado counties and two Wyoming counties.

The subnational (S) rank is based on the status of a taxon in an individual state, using the same criteria as those used to determine the global rank. Within Region 2, *Eriogonum exilifolium* is known from Colorado and Wyoming. The subnational rank for *E. exilifolium* in both of these states is S2. This rank is applied to species that are generally known from 6 to 20 occurrences within a jurisdiction, and are considered to be at high risk of extinction due to very restricted range, steep declines, or other factors (NatureServe 2005). *Eriogonum exilifolium* has this rank in Colorado and Wyoming due to its limited range and number of occurrences in each state (14 in Colorado and 12 in Wyoming) (Colorado Natural Heritage Program 2005, Wyoming Natural Diversity Database 2005).

Eriogonum exilifolium has no status under the Endangered Species Act of 1973 (U.S.C. 1531-1536, 1538-1540). It is not listed as endangered or vulnerable by the International Union for Conservation of Nature and Natural Resources (Ayensu and DeFilipps 1978). No other federal or state laws or regulations are concerned with *E. exilifolium*.

Inclusion on the Region 2 sensitive species list affords some protection to occurrences of *Eriogonum exilifolium* on National Forest System lands. Species are designated as sensitive when they meet one or more of the following criteria: 1) The species is declining in numbers or occurrences, and evidence indicates that it could be proposed for federal listing as threatened or endangered under the Endangered Species Act if action is not taken to reverse or stop the downward trend, 2) the species' habitat is declining, and continued loss could result in population declines that lead to federal listing as threatened or endangered under the Endangered Species Act if action is not taken to reverse or stop the decline, or 3) the species' population or habitat is stable but limited (USDA Forest Service 2003). In the case of *E. exilifolium*, the third criterion is most applicable.

Two sites on the Medicine Bow National Forest in Wyoming thought to support *Eriogonum exilifolium* (Cedar Pass and Sheep Mountain) were proposed for establishment as Research Natural Areas (Jankovsky-

Jones et al. 1996, Jones and Fertig 1996). However, both areas were dropped from consideration in the forest's final Land and Resource Management Plan (Cables 2003). The proposed Cedar Pass Research Natural Area was dropped because it did not meet enough of the criteria for Research Natural Area status. Sheep Mountain is designated as a Special Interest Wildlife Area and is within an inventoried roadless area. A survey of the proposed Sheep Mountain Research Natural Area identified no occurrences of *E. exilifolium* (Jankovsky-Jones et al. 1996). Both areas are available for oil and gas leasing (Cables 2003).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Adequacy of current laws and regulations

Eriogonum exilifolium has no known enforceable protective designations, conservation agreements, or approved management plans that would prevent the destruction of habitat or individual plants. There is no known documentation of recovery or conservation planning for this species (Medicine Bow National Forest 2003). It is included on the USDA Forest Service Region 2 sensitive species list (USDA Forest Service 2003), which affords it some protection on National Forest System lands. The USDA Forest Service must maintain viable populations of sensitive species. For example, Special Forest/Rangelands Products Standard One, which allows the collection of plants or plant parts through a permitting process, does not allow the collection of sensitive species (Medicine Bow National Forest 2003). The USDA Forest Service can modify allotment management plans and projects or contracts on a discretionary basis to protect *E. exilifolium* (Medicine Bow National Forest 2003). Biological assessments and evaluations are conducted in response to applications for permits to drill, and impacts to sensitive species are mitigated. No proposed activities in the Medicine Bow National Forest Plan Revision will likely affect *E. exilifolium* occurrences or habitat (Medicine Bow National Forest 2003).

Because there are no laws in place that protect this species on private lands, current laws and regulations protecting this species are clearly inadequate to conserve the species throughout its range. Rapid population growth in Grand County, Colorado suggests that occurrences in Middle Park may be threatened by residential development. Although population growth is relatively slow in Albany County, Wyoming, some occurrences in the vicinity of Sheep Mountain and the city of Laramie are threatened by residential development.

The Rawlins Field Office of the Bureau of Land Management is in the process of writing a Resource Management Plan and Draft Environmental Impact Statement (Bureau of Land Management 2005). This document is unlikely to have explicit provisions for protecting *Eriogonum exilifolium* because the species is not considered to be sensitive by the Wyoming Bureau of Land Management. Similarly, the Kremmling Field Office's Resource Management Plan (Bureau of Land Management 1984) does not specify any management considerations for *E. exilifolium*.

The Medicine Bow National Forest Revised Land and Resource Management Plan, completed in December 2003, includes a discussion of the impacts of various alternatives under this plan on *Eriogonum exilifolium*. While all alternatives considered probably pose a low risk to *E. exilifolium* occurrences, the selected alternative (Alternative D) provides fewer protective measures for *E. exilifolium* than Alternative F, which included the fewest ground-disturbing activities.

Eriogonum exilifolium is a conservation target for ecoregional planning in the Southern Rocky Mountain Ecoregion (Neely et al. 2001). The Nature Conservancy has set a goal of protecting 20 occurrences of *E. exilifolium* throughout the Rocky Mountain Ecoregion (Neely et al. 2001).

Adequacy of current enforcement of laws and regulations

There have been no known cases in which an occurrence of *Eriogonum exilifolium* was extirpated due to the failure to enforce an existing regulation. However, this does not mean that current regulations or their enforcement are adequate for its protection. Human impacts to habitat, such as residential development and recreational use, may have diminished the abundance of this species. Current protections that apply to this species pertain only to occurrences on National Forest System lands. There are currently no enforceable laws or regulations that confer any protection to occurrences of this species on private, state, or federal lands administered by other agencies.

Enforcement of existing off-road vehicle use restrictions on public lands in the West presents challenges because of the vast areas administrated by federal agencies (Bureau of Land Management 2001b). Recreationists frequently pull down barriers

and breach fences to gain access to off-limits areas (Brekke personal communication 2004). Illegal trash dumping has occurred at California Gulch in North Park, a known location for *Eriogonum exilifolium* (Colorado Natural Heritage Program 2005). This activity is also very difficult to prevent (Brekke personal communication 2004).

Biology and Ecology

Classification and description

Eriogonum exilifolium is a member of the buckwheat family (Polygonaceae), a large family composed mainly of herbs that includes 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 Eudicot group, order Caryophyllales (Stevens 2001 onwards). *Eriogonum* is in the subfamily Eriogonoideae. **Table 1** summarizes the classification of *E. exilifolium*.

Frye and Kron (2003) used chloroplast DNA from the rbcL gene to construct a molecular phylogeny of the Polygonaceae. While the focus of this study was the genus *Polygonum*, two species of *Eriogonum* were included, and the family appears to be monophyletic. No comparable analysis has been done to investigate relationships throughout the genus *Eriogonum*.

The genus *Eriogonum* includes about 250 species, all but two of which are endemic to North America (Reveal 1981, Reveal 1985). The center of distribution for *Eriogonum* appears to be the Rocky Mountains and surrounding regions (Reveal 1967b). The combination of isolated mountain ranges and many unusual soil types in the Intermountain West has resulted in a high degree of adaptive radiation and endemism in this recently evolved genus (Shields and Reveal 1988, 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), and many of them are rare. The Colorado Natural Heritage Program tracks 16 species of *Eriogonum* as rare. One Colorado species, *E. pelinophilum*, is a federally listed endangered species (U.S. Fish and Wildlife Service 1983). As a regional endemic, *E. exilifolium* is a distinctive element of the flora of the Southern Rocky Mountains and is important in the taxonomic study of the genus. It is part of an interesting flora found on sparsely vegetated sites within its restricted range.

Eriogonum species have long been considered among the most difficult to resolve taxonomically

Table 1. Classification of *Eriogonum exilifolium* after USDA Natural Resource Conservation Service 2003, with sources (not necessarily the original source) of particular portions cited below. *The taxonomic level of the Eudicots group has not yet been determined (Stevens 2001 and onwards).

Kingdom	**Plantae (Plants)**
Subkingdom	Tracheobionta (Vascular Plants)
Superdivision	Spermatophyta (Seed Plants)
Division	Magnoliophyta (Flowering Plants)
Class*	Eudicots[3]
Subclass	Caryophyllidae
Order	Caryophyllales[3]
Family	Polygonaceae (Buckwheat Family)
Subfamily	Eriogonoideae[1]
Tribe	Eriogoneae[1]
Subtribe	Eriogoninae[1]
Genus	*Eriogonum* (buckwheat)
Subgenus	*Eucycla*[2]
Section	*Capitata*[2]
Subsection	*Epochthidia*[2]

1: Reveal 2000

2: Reveal 1969

3: Stevens 2001 onwards

(Reveal 2003). *Eriogonum exilifolium* is allied with *E. lonchophyllum* and *E. coloradense* (Reveal 1967a, Reveal 2003). There is nothing to suggest that the taxonomic validity of *E. exilifolium* is questionable, but it has been mistaken for *E. pauciflorum* on occasion (see discussion below).

History of knowledge

Eriogonum exilifolium was described by James Reveal, the current monographer of the genus (Reveal 1967a). In this paper, Reveal (p. 115) states that "This taxon has long been recognized as an excellent species, and the naming of it as such after so many years is simply due to the misapplication of the name *Eriogonum pauciflorum* for it." In this paper Reveal also offers an excellent summary of the history of the expedition that led to the first collection of *E. pauciflorum* by John Bradbury.

Prior to its formal description, *Eriogonum exilifolium* was collected numerous times and identified as *E. pauciflorum*. This is understandable since without a couplet that includes *E. exilifolium*, it would key out as *E. pauciflorum* in most dichotomous keys. The earliest known collection of *E. exilifolium* (#133 at CS) was made July 21, 1894 by Charles Crandall (Colorado EO#11 in **Table 2**). Crandall made numerous collections of Colorado's flora during his tenure as curator of the Colorado State Herbarium (Colorado State Herbarium 2004).

One example of the misapplication of *Eriogonum pauciflorum* described by Reveal (1967a) can be found in Harrington (1954, p. 192), where he notes that "our few records [of *E. pauciflorum*] are from north central and central Colorado." Clearly he is referring to *E. exilifolium* since *E. pauciflorum* is not known from this part of Colorado, and Harrington had access to several specimens of *E. exilifolium* that had then been labeled "*Eriogonum pauciflorum*."

Targeted surveys for *Eriogonum exilifolium* have been conducted in Wyoming, and records have been recently updated. Three assessments of potential Research Natural Areas for the Medicine Bow National Forest resulted in confirmation of historic occurrences of the species. Recent floristic studies in the Laramie basin by Ernie Nelson of the Rocky Mountain Herbarium resulted in the discovery of one new occurrence (Heidel personal communication 2004, Nelson personal communication 2004). An occurrence was located on private land in the Laramie Basin by Bonnie Heidel of the Wyoming Natural Diversity Database in 2002 (Wyoming EO#8 in **Table 2**; Heidel personal communication 2004, Wyoming Natural Diversity Database 2004). Work by John Proctor and Wendy Haas in 2002 enlarged the area known to support *E. exilifolium* at Big Creek Park (Medicine Bow National Forest 2003, Proctor personal communication 2004). Two more occurrences were located in 2004 and 2005 in Wyoming (Wyoming Natural Diversity Database 2005).

In the 1970s, an Energy Minerals Rehabilitation Inventory and Analysis (EMRIA) study site was established east of the town of Walden, Colorado at the McCallum Coal Area. The purpose of this study, conducted jointly by the U.S. Geological Survey and the Bureau of Land Management, was to identify methods of restoring areas damaged by coal exploration and strip mining, and to test various treatments (Bureau of Land Management 1981, U.S. Congress Office of Technology Assessment 1986, Cesar personal communication 2004). It is unclear whether *Eriogonum exilifolium* was involved in this study, but a voucher specimen collected at this site in 1979 (Colorado EO#13 in **Table 2**) was later identified as *E. exilifolium*. Unfortunately, *Eriogonum* species documented in the study report were not identified to species.

Two collections of *Eriogonum exilifolium* from Larimer County, Colorado created confusion about the range of this species. One is George E. Osterhout's collection (#1166 at RM) from "North Park, Larimer County" dated July 13, 1896. The other was made by Leslie Goodding (#1924 at COLO and elsewhere) on August 17, 1903. Jackson County was not split off from Laramie County until 1909; at the time of the collections North Park (today in Jackson County) was part of Laramie County. Zion (2002) offers a detailed treatment of changes in county boundaries, summarized here. North-central Colorado was very poorly surveyed when the county boundaries were first drawn in 1861. The western boundary of Larimer County was vaguely defined, leaving it uncertain whether it fell along the continental divide or the Medicine Bow Range. Thus, when minerals were discovered in North Park, three counties (Grand, Summit, and Larimer) claimed the area. This dispute was settled in 1886 by the Colorado Supreme Court who gave North Park to Larimer County. North Park remained part of Larimer County until 1909 when Jackson County was formed. Thus, herbarium specimens collected in North Park between 1886 and 1909 were within Larimer County as it was then defined. Most sources (e.g., Reveal 1967a, Fertig 2000a, Medicine Bow National Forest 2003, University of Colorado Herbarium 2004) included Larimer

Table 2. Summary of all known herbarium specimens of *Eriogonum exilifolium*. EO# is Colorado Natural Heritage Program and Wyoming Natural Diversity Database element occurrence number.

EO#	State	County	Location	Collection Date	Collector/ Observer	Herbarium[1]	Notes
1	CO	Larimer	West of Hohnholz Lake	24-Jul-2001	S. Nunn (#3404)	RM	
2	CO	Jackson	10 mi. west of Coalmont	22-Jul-1947	H.D. Harrington (#3605)	CS	Collected as *E. pauciflorum*; annotated as *E. exilifolium* by Reveal
3	CO	Larimer	Grace Creek Ranch/ Hohnholz Lake #3	2004	R. Scully (#15)	COLO	
	CO	Larimer	Grace Creek Ranch/ Hohnholz Lake #4	2004	R. Scully (#16)	RM	
	CO	Larimer	Grace Creek Ranch/ Hohnholz Lake #5	2004	R. Scully (#10)	RM, COLO	
4	CO	Larimer	Lower Bull Mountain Road	13-Aug-2004	R. Scully (#18)	COLO	
5	CO	Larimer	Laramie River/ Bull Mountain	2004	G. Doyle (#GD-04-30)	COLO	
	CO	Larimer	Laramie River/ Bull Mountain	2004	R. Scully (#17)	COLO	
7	CO	Grand	Middle Park near Granby	Jul-1990	D. Johnson (s.n.)	COLO	
	CO	Grand	Not specified	Unknown	C.C. Parry (s.n.)	GH, NEB, NY, US	
8	CO	Grand	Northwest of Tabernash	Unknown	Ripley and Barneby (#10489a)	CAS, NY	
9	CO	Grand	Hot Sulphur Springs	05-Aug-1928	Johnson (s.n.)	CS	Collected as *E. pauciflorum*; annotated as *E. exilifolium* by Reveal
10	CO	Jackson	California Gulch	02-Jul-1985	S. O'Kane (#2106)	COLO, CS	Collected as *E. coloradense*; annotated by W.A. Weber
	CO	Jackson	California Gulch	29-Jun-1989	K.D. Warren (#26)	RM	
11	CO	Jackson	North Fork Platte River	17-Aug-1903	L.N. Goodding (#1924)	COLO, NY, RM, UC, US	Collected as *E. pauciflorum*; annotated as *E. exilifolium* by Reveal; was in Larimer County when collected
	CO	Jackson	North Fork Platte River	09-Aug-1980	R. Wittmann (#1308)	COLO	
	CO	Jackson	North Park on North Fork	06-Aug-1914	G.E. Osterhout (#5169)	RM	Collected as *E. pauciflorum*; annotated as *E. exilifolium* by C.L. Porter
	CO	Jackson	North Park	13-Jul-1896	G.E. Osterhout (#1166)	CS, RM	Collected as *E. pauciflorum*; annotated as *E. exilifolium* by C.L. Porter; was in Larimer County when collected

Table 2 (cont.).

EO#	State	County	Location	Collection Date	Collector/ Observer	Herbarium[1]	Notes
	CO	Jackson	North Park	21-Jul-1894	Crandall (#133)	CS, GH, MO, NY	Collected as *E. pauciflorum*; annotated as *E. exilifolium* by Reveal
12	CO	Jackson	North end of Lake John	10-Sep-1983	W.A. Weber, H. Beck (#17072)	COLO	
	CO	Jackson	Lake John	24-Jul-1937	K.R. Johnson (#890)	COLO	Collected as *E. pauciflorum*; annotated as *E. exilifolium* by Reveal
	CO	Jackson	Lake John	Unknown	Ramaley and Johnson (#890)	CAS, COLO, MO	
13	CO	Jackson	East of Walden	08-Aug-1979	K. Wiley-Eberle (#465)	CS	
14	CO	Jackson	Beaver Creek	30-Jul-1981	S. Tabar (#488)	CS	
1	WY	Albany	Simpson Springs	24-Jul-1979	R.W. Lichvar (#2118)	RM	
	WY		Red Buttes		Greene (s.n.)	NY	
2	WY	Carbon	Sierra Madre Mountains, Trent Creek/ Big Creek Park	26-Jun-1977	B.E. Nelson and L. Nelson (#1472)	RM	
	WY	Carbon	2.5 mi. N. of State Line	13-Jul-1979	R.W. Lichvar (#2027)	RM	
	WY	Carbon		27-Aug-1977	B. Hammel and R. Hartman (#554)	RM	
3	WY	Albany	Laramie	19-Jul-1900	A. Nelson (#7636)	COLO, RM	Collected as *E. pauciflorum*; annotated as *E. exilifolium* by Reveal and others
	WY	Albany	Along U.S. Highway 287	24-Aug-1972	J.L. Reveal (#2940) and C.G. Reveal	COLO, RM	
	WY	Albany	Laramie Plains	14-Sep-1896	A. Nelson (#2794)	GH, MONT, NY, RM, US	Collected as *E. pauciflorum*; annotated as *E. exilifolium* by Reveal
	WY	Albany	Laramie	28-Jun-1913	J.F. Macbride (#2383)	RM	Collected as *E. pauciflorum*; annotated as *E. exilifolium* by B.E. Nelson
	WY	Albany	Not specified	21-Jul-1945	C.L. Porter (#3706)	DS, GH, MO, NY, RM, UC, US	Type specimen; collected as *E. pauciflorum*
	WY	Albany	Not specified	Unknown	A. Nelson (#7637)	BM, MO, NY, RM, US	
	WY	Albany	Not specified	29-May-1995	W. Fertig (#15689)	RM	

Table 2 (concluded).

EO#	State	County	Location	Collection Date	Collector/ Observer	Herbarium[1]	Notes
3	WY	Albany	Laramie River	15-Jul-1897	E. Nelson (#3385)	BM, MO, NY, RM, US	Collected as *E. pauciflorum*; annotated as *E. exilifolium* by C.L. Porter
	WY	Albany	Not specified	Unknown	Engelmann (s.n.)	GH, MO, NY	
4	WY	Albany	Centennial Valley	12-Jul-1976	M.L. Roberts (#4690)	RM	
	WY	Albany	Sheep Mountain	28-Jun-1996	W. Fertig (#16725)	RM	
	WY	Albany	Near Wyo. Hwy. 130	10-Aug-1968	W.E. Myers (#273)	RM	
5	WY	Carbon	Along State Route 487	03-Jul-1981	T.W. Nelson and J.P. Nelson (#6659)	RM	
6	WY	Carbon	Shirley Basin	21-Aug-1996	W. Fertig (#17184)	RM	
	WY	Carbon	Shirley Basin	03-Jul-1993	W. Fertig (#14014)	RM	
7	WY	Carbon	Cedar Pass Research Natural Area	25-Jun-1996	G.P. Jones (s.n.)	RM	
8	WY	Albany	Sensitive Data	21-Jun-2002	B. Heidel	N/A	
9	WY	Albany	Laramie Plains, Twin Buttes Lake	16-Jul-1998	K.K. Hughes (#971)	RM	
10	WY	Albany	Mule and Rogers creeks	13-Jul-1999	B.E. Nelson (#46515)	RM	
11	WY	Albany	Maggie Creek	01-Sep-2004	R. Scully (#24)	RM	
12	WY	Carbon	Elk Mountain	22-Jul-2005	E. Foley (#12286 & 12287)	RM	

[1]Herbariums: BM – The Natural History Museum, London; CAS – California Academy of Sciences, San Francisco; CS – Colorado State University; COLO – University of Colorado; GH – Gray Herbarium, Harvard University; MO – Missouri Botanical Garden, Saint Louis; MONT – Montana State University; NEB – Charles E; Bessey Herbarium, University of Nebraska; NY – New York Botanical Garden Herbarium; RM – Rocky Mountain Herbarium; UC – University of California, Berkeley; US – US National Herbarium.

County within the current distribution of *E. exilifolium*, probably because of these specimens.

In 2001, Sarah Nunn established the existence of *Eriogonum exilifolium* in modern Larimer County when she collected a specimen in the Upper Laramie River Valley (Nunn 2003). Subsequent surveys in 2004 by Richard Scully, Mary Jane Howell, Georgia Doyle, Janet Coles, and David Anderson identified occurrences in Larimer County containing thousands to more than 1,000,000 individuals (Doyle et al. 2005). Limited field surveys in Jackson County in 2004 by Richard Scully, Mary Jane Howell, Jill Handwerk, and David Anderson identified large occurrences of *E. exilifolium* at California Gulch and north of Lake John.

In 2005, the Colorado Natural Heritage Program conducted a biological survey of the uplands of Grand County, Colorado (Culver and Jones in prep). This survey resulted in the discovery of a new occurrence and relocation of an historic occurrence by Richard Scully, Mary Jane Howell, Denise Culver, and Jennifer Jones, confirming suspicions that *Eriogonum exilifolium* is locally abundant in Middle Park.

When the draft of this assessment was submitted in the spring of 2004, census data for all known occurrences of *Eriogonum exilifolium* totaled only 990 individuals although many records did not include plant counts or estimates. There had also never been any field surveys targeting *E. exilifolium*. The fieldwork conducted in 2004 and 2005 greatly improved our knowledge of the distribution and habitat of this species in Colorado, and the information from these projects has been incorporated into the final version of this assessment where relevant.

Non-technical description

The genus *Eriogonum* is distinguished from other members of the Polygonaceae in that its members lack an ocrea at the leaf base (Harrington 1954). The ocrea is a sheath around the stem formed from the stipules and is a common and distinguishing feature of the family (Harris and Harris 1999). Members of the genus *Eriogonum* also have wood anatomy distinct from other members of the Polygonaceae (Carlquist 2003).

The following description is from Fertig and Jones (1997) and Fertig (2000a) except where noted: *Eriogonum exilifolium* is a taprooted perennial herb forming dense mats 10 to 20 cm across (**Figure 1**, **Figure 2**, **Figure 3**, **Figure 4**, **Figure 5**, **Figure 6**). The epithet "exilifolium" refers to its narrow leaves (Reveal 1967a), which are diagnostic and distinguish *E. exilifolium* from congeners with which it might be found. Leaves are all basal with narrowly linear blades 1 to 2.5 mm wide and 3 to 6 cm long. Leaf blades are green and nearly glabrous above and densely white-woolly below with smooth, slightly inrolled margins. The inflorescence is a compact head of three to seven involucres borne on sparsely woolly stems 3 to 10 cm long. Each involucre is 2.5 to 3.5 mm long (Reveal 1967a, Reveal 1969, Dorn 1992, Fertig and Jones 1997).

As noted previously, *Eriogonum pauciflorum* has been confused with *E. exilifolium*. *Eriogonum pauciflorum* is relatively widely distributed through the northern high plains in seven states and four Canadian provinces (Reveal 1967a, Kartesz 1999). It is comprised of four varieties as circumscribed by Reveal (1967a). Two of these, var. *nebraskense* and var. *gnaphalodes*, are known to occur near occurrences of *E. exilifolium*, and var. *gnaphalodes* is sympatric with *E. exilifolium* at California Gulch (**Table 3**). *Eriogonum pauciflorum* can be readily distinguished from *E. exilifolium* by its wider leaves with grayish-white pubescence on the upper and lower surfaces and hairy perianth segments (Reveal 1967a, Dorn 1992, Weber and Wittmann 2001a, Fertig personal communication 2004). See Reveal 1967a for details on diagnosing these species.

Eriogonum exilifolium has involucres that are single or in heads or umbels at the tips of leafless stems. Only four other species east of the Rocky Mountains (*E. flavum*, *E. jamesii*, *E. lachnogynum*, and *E. pauciflorum*) share this characteristic (Rickett 1973). *Eriogonum ovalifolium* has broadly oval, gray-woolly leaf blades and typically has longer flowering stems (Dorn 1992). *Eriogonum exilifolium* bears many similarities to *E. coloradense*, to which it is closely related (Reveal 1967a). They differ primarily in leaf shape, size of parts, and ecological requirements (Reveal 1967a).

There have been no cytological investigations of *Eriogonum exilifolium*. It has been suggested that members of *Eriogonum* have a base chromosome number of ten, and that members whose base chromosome number is 20 or 40 are the descendents of an ancestral allopolyploid (Stokes 1936, Stokes and Stebbins 1955). *Eriogonum allenii* is n = 20 (Bellmer 1969) while *E. umbellatum* ssp. *polyanthum* is n = 40 (Reveal and Holmgren 1965). Chromosome numbers of 18, 22, 24, 32, and 34 have also been reported within the genus, suggesting some aneuploid events have also occurred in the evolution of the species (Stokes and Stebbins 1955).

Figure 1. *Eriogonum exilifolium* in the Upper Laramie River Valley, Larimer County, Colorado. Photograph by author.

Figure 2. *Eriogonum exilifolium* in the Upper Laramie River Valley. Photograph by Georgia Doyle, in Doyle et al. (2005). Used with permission.

Figure 3. *Eriogonum exilifolium* from Albany County, Wyoming. Photograph provided by James Reveal.

Figure 4. The inflorescences of *Eriogonum exilifolium*. Photograph by James Reveal.

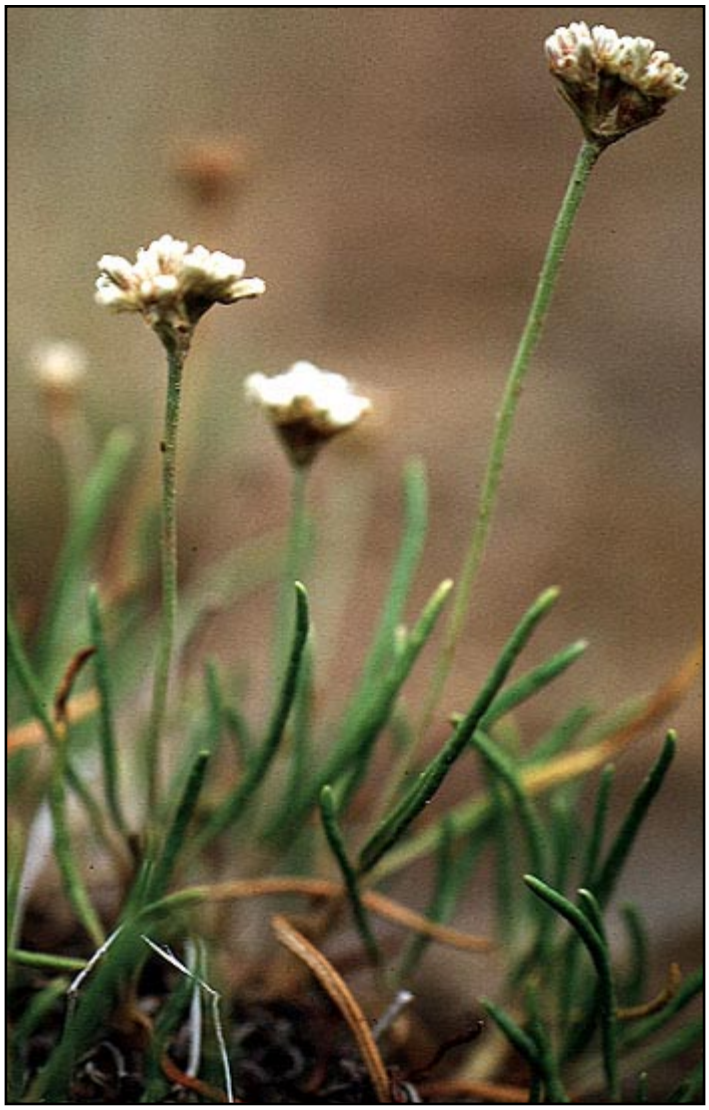

Figure 5. Detail of the habit of *Eriogonum exilifolium* from Reveal 2003. Used by permission of James Reveal.

Technical description (from Reveal (1969), p. 183):

> "Low pulvinate matted herbaceous perennials forming mats 1 to 2 dm across; leaves basal, the leaf-blades linear to linear-oblanceolate, (2) 3 to 5 (6) cm long, 1 to 2 (3) mm wide, white-tomentose below, less so to glabrous and green above, the margins entire, revolute, the petioles short, 5 to 10 mm long, tomentose; flowering stems scapose, 3 to 10 cm long, glabrous or sparsely tomentose; inflorescences compact cymose-umbellate, 1.5 to 3 cm long; bracts semifoliaceous, ternate, 3 to 5 mm long, 2 to 3 mm wide; peduncles short, stout, 1 to 4 mm long, glabrous; involucres solitary, turbinate-campanulate, rigid, 2.5 to 3.5 (4.5) mm long, 2 to 3 mm wide, glabrous except for small patches of cottony tomentum at the base of the lobes, five-lobed; flowers white, 2 to 3.5 mm long, glabrous, the tepals oblanceolate to elliptic; stamens exserted, 3 to 4 mm long, the filaments sparsely pilose basally, the anthers rose to red; achenes brown, 2.5 to 3.5 mm long."

Sources for photographs, illustrations, and descriptions

Reveal (1967a) and Reveal (1969) provide full technical descriptions of *Eriogonum exilifolium*. Weber and Wittmann (2001a) contains a key but no technical description. Fertig and Jones (1997) and Fertig (2000a) provide good non-technical descriptions. A brief description appears in Dorn (1992).

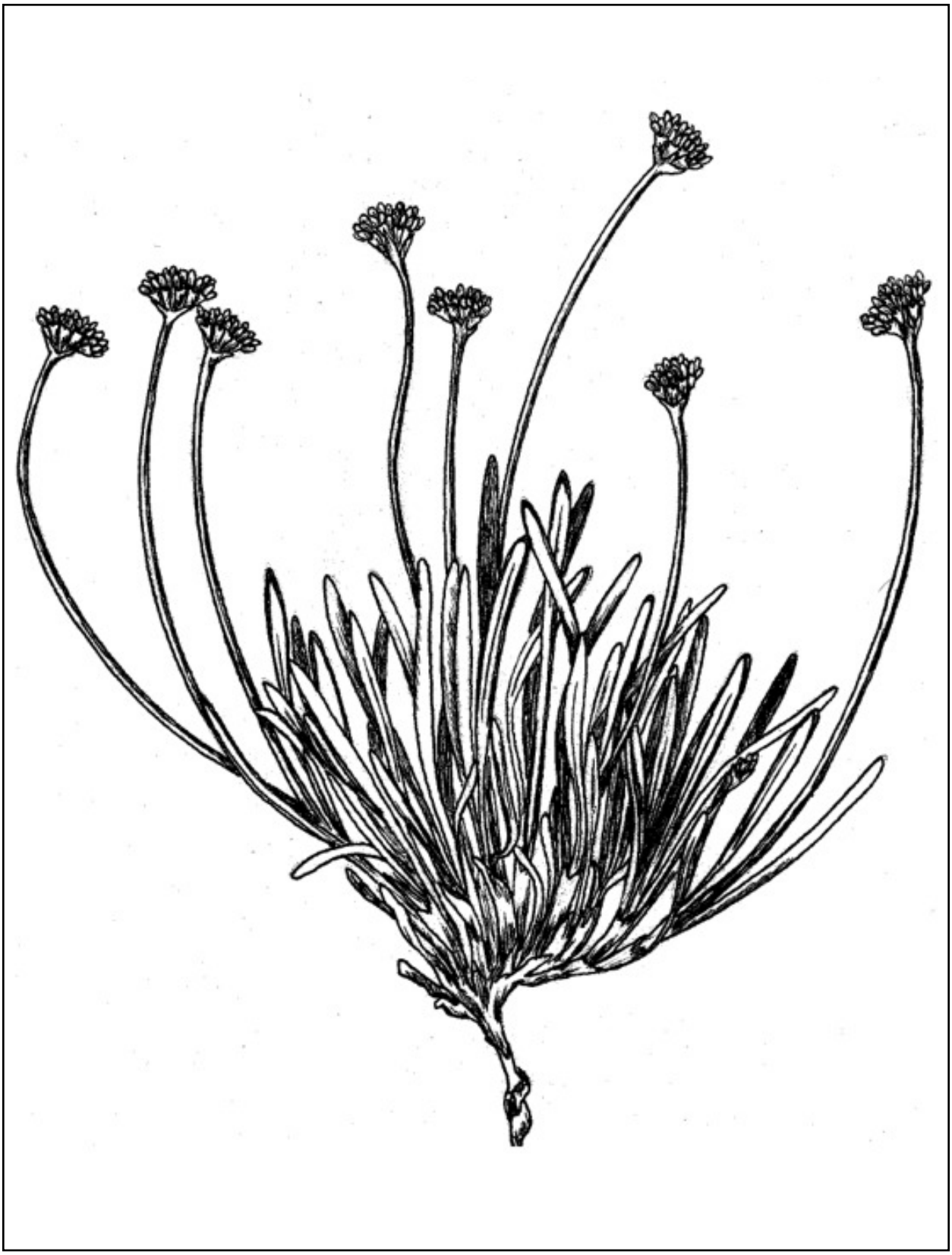

Figure 6. Illustration of *Eriogonum exilifolium* by Walt Fertig from Fertig and Jones 1997 and Fertig 2000a.

Table 3. Summary information for the known occurrences of *Eriogonum exilifolium*. EO# is Colorado Natural Heritage Program and Wyoming Natural Diversity Database element occurrence number. Precision is G (general, exact location unknown), M (minutes record, location known to within approximately one square mile), and S (seconds record, precise location known). National Forest System lands are in bold in the management column.

EO#	State	County	Location	Precision	Date of First Observation	Date of Last Observation	Elevation	Abundance	Management	Habitat and Habit
1	CO	Larimer	West of Hohnholz Lake	M	24-Jul-2001	24-Jul-2001	8,500 to 8,700 ft.	not reported	**USDA Forest Service Roosevelt National Forest**	Sagebrush and rabbitbrush hillsides with scattered aspen glens; west facing. *Eriogonum exilifolium* was not found at this location in 2004 after several hours of searching. The area is underlain by granite, and it appears that the location reported with this specimen is erroneous.
2	CO	Jackson	10 miles west of Coalmont	G	22-Jul-1947	22-Jul-1947	8,300 ft.	not reported	**Possibly USDA Forest Service Routt National Forest**	Dry, deeply eroded open slope.
3	CO	Larimer	Grace Creek Ranch/ Hohnholz Lake #3	S	08-Jul-2004	26-Aug-2004	7,800 to 8,000 ft.	greater than 1,000,000	Bureau of Land Management Kremmling Field Office, Private	*Eriogonum exilifolium* is most abundant in the sparsely vegetated areas but occurs sporadically within the sagebrush matrix community. Occurs on the eroded margins of uplands. Soil is calcareous, loamy and clayey. Soil on the shoulder slope of the bluff consists of a coating of small granite gravel on calcareous clay loam. The bluff appears to be mantled with old alluvium, but a fine-textured deposit of uncertain geologic age is exposed on the west-facing slope. Outcrops of Niobrara, Benton, and Lower Pierre Shale are present. Some portions of the occurrence are crossed by cattle trails along a fence line with no apparent ill effect. A two track road also runs through the occurrence.
4	CO	Larimer	Lower Bull Mountain Road	S	13-Aug-2004	13-Aug-2004	8,100 ft.	“thousands”	Bureau of Land Management Kremmling Field Office	In breaklands with sparse vegetative ground cover. Associated with *Chrysothamnus* sp., *Astragalus tenellus*, *Comandra umbellata*, and other species. Growing in moderately deep colluvial soil washed from the slope break above. Soil is calcareous clay loam with 40% shale fragments. Vegetative cover is denser in some areas due to the deeper soils in this area than other Larimer County sites. With *Penstemon laricifolius* ssp. *exilifolius* in some portions of the occurrence.

Table 3 (cont.).

EO#	State	County	Location	Precision	Date of First Observation	Date of Last Observation	Elevation	Abundance	Management	Habitat and Habit
5	CO	Larimer	Laramie River/ Bull Mountain	S	12-Aug-2004	08-Aug-2004	7,950 to 8,220 ft.	1,000	Private	On open hillsides along road on shaley knolls on seleniferous soils. Soils are on red beds consisting of calcareous heavy loam with 40% rock fragments, and in shale/gray clay. Parent material is shale of the Niobrara Formation and Triassic/ Permian red beds. With *Gutierrezia sarothrae*, *Artemisia frigida*, *A. tridentata*, *Penstemon laricifolius* ssp. *exilifolius*, and other species; *Eriogonum exilifolium* is a dominant species in some areas. Part of this occurrence is on a large roadcut.
6	CO	Grand	East of Willow Creek Reservoir	S	01-Sep-2005	01-Sep-2005	8,030 ft.	75	County road right-of-way; probably adjacent private	Barren hillside on exposures of the Troublesome Formation. Soils are light gray, calcareous clay loam. 40% vegetative, 15% in flower, 55% in fruit. Leaves had turned reddish-brown. *Eriogonum exilifolium* and *Penstemon caespitosa* are the dominant species. Occurrence is surrounded by residential development.
7	CO	Grand	Chalk Bluffs	S	Jul-1990	24-Jun-2005	8,045 ft.	"thousands"	Private	On steep, barren bluffs in highly erodable soils of the Troublesome Formation and Pierre Shale. *Eriogonum exilifolium* is the dominant species on the bluffs, but is sparser on the alluvial fan below the bluffs, where sagebrush is dominant. Associated species include *Artemisia frigida*, *Chrysothamnus viscidiflorus*, *Achnatherum hymenoides*, *Poa secunda*, *Phlox hoodii*, *Penstemon caespitosus*, *Pseudoroegneria spicata*. 5% vegetative, 90% in flower, 5% in fruit. No evidence of grazing, OHV trails, or exotic plants. Only a two-track road that does not pass through the occurrence. Adjacent to a rapidly growing subdivision and golf course; adjacent ranch with conservation easement.
8	CO	Grand	Northwest of Tabernash	G	Unknown	Unknown	unknown	unknown	Uncertain	(From Reveal 1967)
9	CO	Grand	Hot Sulphur Springs	G	05-Aug-1928	05-Aug-1928	7,655 ft.	not reported	Possibly Bureau of Land Management Kremmling Field Office	None reported.

Table 3 (cont.).

EO#	State	County	Location	Precision	Date of First Observation	Date of Last Observation	Elevation	Abundance	Management	Habitat and Habit
10	CO	Jackson	California Gulch	S	02-Jul-1985	26-Aug-2004	8,040 to 8,200 ft.	5,000	Bureau of Land Management Kremmling Field Office	On sandstone slopes of the Coalmont Formation above gulch. Distribution is patchy; in some areas it is the dominant species. Abundance is greatest on slopes where few other species are present. 25% Vegetative, 50% in flower, 25% in fruit. Found on barren slopes and in shrublands dominated by *Tetradymia canescens* and *Chrysothamnus viscidiflorus*. Other associated species include *Phacelia formosula*, *Oryzopsis hymenoides*, *Eriogonum* c.f. *umbellatum*, *E. pauciflorum* var. *gnaphalodes*, *E. cernuum*, *Artemisia frigida*, *Chaenactis douglasii*, *Astragalus kentrophyta*, *Opuntia polyacantha*, *Hymenoxys*, and *Comandra umbellata*. On west, south, and southwest exposures, 0-30 degree slopes. Rangeland in surrounding area; grazing and weeds not apparent within occurrence.
11	CO	Jackson	North Fork Platte River	S	13-Jul-1896	09-Aug-1980	7,875 ft.	not reported	Private, possibly Bureau of Land Management Kremmling Field Office	Gumbo swales and draws, sagebrush community; low sandy valleys.
12	CO	Jackson	North end of Lake John	S	240Jul-1937	03-Sep-2004	8,120 to 8300 ft.	“thousands”	Bureau of Land Management Kremmling Field Office, Lake John State Wildlife Area	Breaklands and rolling uplands among sagebrush-rabbitbrush benches and dry grassland. On lower Pierre Shale and Niobrara Formation in strongly calcareous clay loam and clay soil. *Eriogonum exilifolium* is abundant within the delineated populations, and is frequently a dominant species. Associated species include *Chrysothamnus* sp., *Tetradymia canescens*, *Adenolinum lewisii*, *Gutierrezia sarothrae, Artemisia frigida*, *Krascheninnikovia lanata*, *Stanleya pinnata*, and grasses. Surrounding areas have sagebrush, but sagebrush is generally absent from *E. exilifolium* occurrences. All potential habitat in this area was not surveyed.
13	CO	Jackson	McCallum Gulch	M	08-Aug-1979	08-Aug-1979	8,300 ft.	“infrequent”	Bureau of Land Management Kremmling Field Office	Eroded knoll in sandy soil with *Artemisia frigida* and *Oryzopsis hymenoides*.
14	CO	Jackson	Beaver Creek	M	30-Jul-1981	30-Jul-1981	8,300 ft.	not reported	Colorado State Land Board	Cliffs above Beaver Creek.

Table 3 (cont.).

EO#	State	County	Location	Precision	Date of First Observation	Date of Last Observation	Elevation	Abundance	Management	Habitat and Habit
1	WY	Albany	Simpson Springs	S	24-Jul-1979	24-Jul-1979	7,350 ft.	40	Private	On red sandstone knolls in dry reddish sandstone soil mixed with limestone. With *Arenaria hookeri*, *Astragalus spathulatus*, and *Potentilla arguta*.
2	WY	Carbon	Sierra Madre Mountains, Trent Creek/ Big Creek Park	S	26-Jun-1977	2003	8,400 to 8,500 ft.	225 to 300	**USDA Forest Service Medicine Bow National Forest**	Growing in sandy soil on sandstone-limestone outcrop with *Elymus smithii*, *Artemisia tridentata*, *Astragalus kentrophyta*, *Arenaria hookeri*, *Chrysothamnus nauseosus*, *Machaeranthera coloradensis*, *Artemisia tridentata* ssp. *vaseyana*, and *Lesquerella alpina*. Also growing on roadside banks and borrow pits. Some two-tracks in the area are a potential threat.
3	WY	Albany	Laramie	S	19-Jul-1900	29-May-1995	7,200 ft.	"locally abundant"	Private	Cushion plant community on outcrops of red sandstone of the Chugwater Formation and adjacent red sandy plains. With *Astragalus tridactylicus*, *Hymenoxys acaulis*, *Haplopappus nuttallii*, *Oryzopsis hymenoides*, *Eriogonum flavum*, and *Artemisia frigida*. Some habitat may have been lost to development.
4	WY	Albany	Centennial Valley/ Sheep Mountain	S	10-Aug-1968	2003	7,800 to 8,600 ft.	400 to 500	Private, highway right-of-way	Barren white shaley-gypsum west-facing slopes and gray, barren knoll of the Upper Niobrara formation. Soils seleniferous, dry. Cushion plant community with scattered shrubs (*Chrysothamnus nauseosus* and *Atriplex* sp.) and bunchgrasses with vegetative cover between 0 to 40%. Also on Red sandstone hogback. Occurs with *Oryzopsis hymenoides*, *Astragalus bisulcatus*, *Stanleya pinnata*, *Oenothera caespitosa*, and *Machaeranthera coloradoensis*.
5	WY	Carbon	Shirley Basin, Along State Route 487	M	03-Jul-1981	03-Jul-1981	6,900 ft.	not reported	Uncertain (not USDA Forest Service)	None reported.
6	WY	Carbon	Shirley Basin	S	03-Jul-1993	21-Aug-1996	7,180 to 7,200 ft.	75 to 100	Bureau of Land Management Rawlins Field Office	Seleniferous clay gumbo soil with low vegetative cover (ca 10-25% on average, but may be as high as 40% in some areas) in borrow pit at edge of dirt road. Surrounding flats dominated by sagebrush/ saltbush-bunchgrass communities. On a northeast slope. With *Haplopappus wardii*, *Stanleya pinnata*, *Cirsium pulcherrimum*, *Cryptantha celosioides*, *Gutierrezia sarothrae*, *Chrysothamnus viscidiflorus*, and *Eriogonum gordonii*.

Table 3 (concluded).

EO#	State	County	Location	Precision	Date of First Observation	Date of Last Observation	Elevation	Abundance	Management	Habitat and Habit
7	WY	Carbon	Cedar Pass Research Natural Area	S	25-Jun-1996	25-Jun-1996	8,120 ft.	not reported	**USDA Forest Service Medicine Bow National Forest**	Lower part of east-facing slope of pale shale outcrops in *Artemisia arbuscula* var. *longiloba* grassland community. With *Elymus smithii*, *E. spicatus*, *Pseudoroegneria spicata*, and *Poa* sp.
8	WY	Albany	Sensitive Data	S	21-Jun-2002	21-Jun-2002	7,100 ft.	not available	Private	Not available
9	WY	Albany	Laramie Plains, Twin Buttes Lake	M	16-Jul-1998	16-Jul-1998	7,250 to 7,280 ft.	not reported	Bureau of Land Management Rawlins Field Office	Along the shore of lake and hill above.
10	WY	Albany	Between Mule and Rogers creeks	M	13-Jul-1999	13-Jul-1999	6,090 to 7,050 ft.	30 to 50	Bureau of Land Management Rawlins Field Office and Private	White shaly knolls.
11	WY	Albany	Maggie Creek	S	01-Sep-2004	01-Sep-2004	8,000 ft.	“thousands”	BLM: Rawlins Field Office	On semi-barren uplands adjacent to and on moderately sloping sides of gullies (but not on the steep gully side slopes). Soil: Calcareous clay loam. Parent Material: Niobrara shale of the Colorado Group. With Bluebunch wheatgrass, *Chrysothamnus* sp., *Astragalus bisulcatus*, *Gutierrezia sarothrae, Comandra umbellata*, *Stanleya pinnata*, *Krascheninnikovia lanata*, *Artemisia frigida*.
12	WY	Carbon	Elk Mountain	S	22-Jul-2005	22-Jul-2005	7,700 to 8,140 ft.	~1000 or more	State of Wyoming and Private	Badlands along road.

The only known illustration of *Eriogonum exilifolium* was drawn by Walt Fertig and can be found in Fertig and Jones (1997) and Fertig (2000a); it is also included in this assessment (**Figure 6**). These sources are readily available via the internet from the Wyoming Natural Diversity Database website. Fertig (2000a) also contains a photograph of the species. Other photographs are available at James Reveal's website (Reveal 2003) and are included in this assessment (**Figure 3**, **Figure 4**, **Figure 5**). A photograph of the type specimen, housed at the New York Botanical Garden, is available on their website (New York Botanical Garden 2004).

Detailed investigations of the wood anatomy of members of the Polygonaceae, including *Eriogonum*, were done by Carlquist (2003) and include SEM photographs of the microstructure of several *Eriogonum* species (not *E. exilifolium*).

Distribution and abundance

The genus *Eriogonum* is of North American origin and is almost entirely limited to North America, with only two species found in South America (Stokes 1936, Reveal 1967b, Reveal 1969, Heywood 1993). The greatest diversity can be found in the western United States (Shields and Reveal 1988).

Eriogonum exilifolium is a regional endemic known from Wyoming and Colorado (**Figure 7**; Fertig 2000a, USDA Natural Resource Conservation Service). There are currently 26 documented occurrences, 12 in Wyoming and 14 in Colorado (**Table 3**, **Figure 8**). Occurrences of *E. exilifolium* are naturally small and isolated (Fertig personal communication 2004, Nelson personal communication 2004) although discoveries in Colorado in 2004 and 2005 show that *E. exilifolium* is

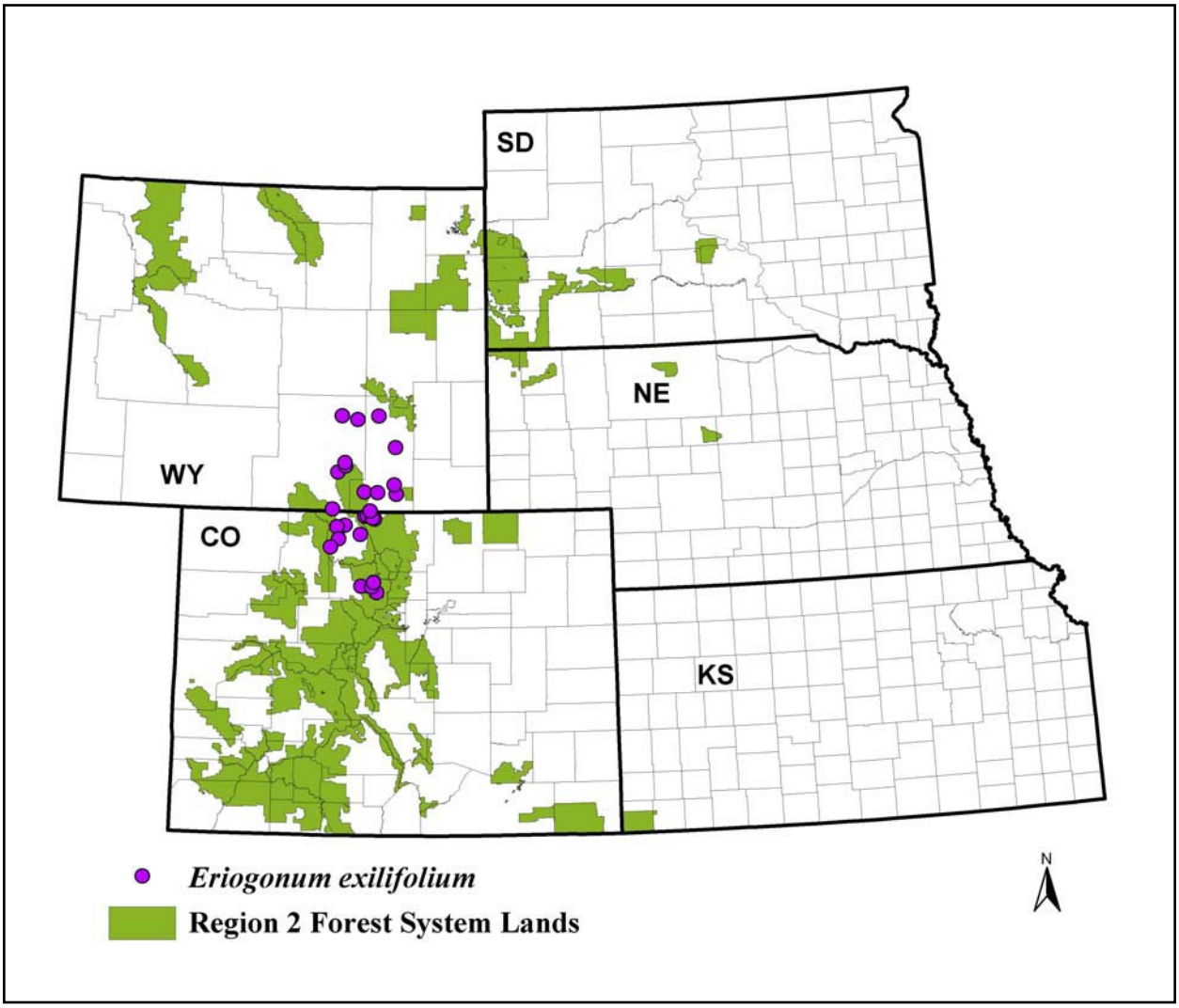

Figure 7. Distribution of *Eriogonum exilifolium* in the states of USDA Forest Service Region 2.

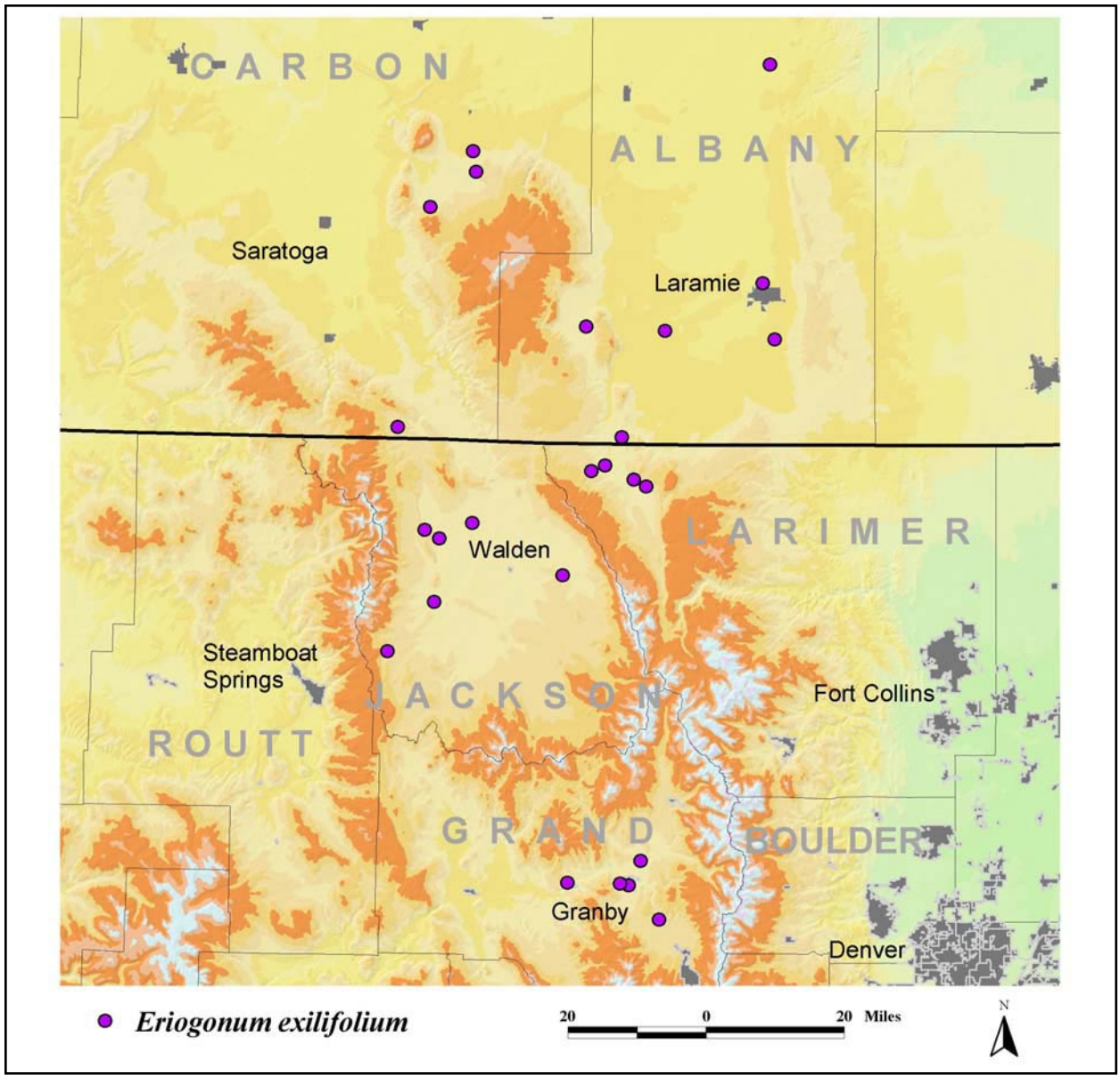

Figure 8. Distribution map of *Eriogonum exilifolium* showing physiographic features, municipalities, and county boundaries.

locally abundant where large tracts of suitable habitat are present, such as Middle Park, North Park, and the Upper Laramie River Valley of Colorado.

In Wyoming, *Eriogonum exilifolium* is restricted to the Laramie and Shirley basins and to the foothills of the Medicine Bow and Laramie ranges in Albany and Carbon counties (Fertig and Jones 1997, Fertig 2000a). The type specimen of *E. exilifolium* was collected on the Red Beds north of Laramie in Albany County (Reveal 1967a, Fertig personal communication 2004). Of the 12 Wyoming occurrences, all but two have been observed within the last 20 years.

Two occurrences in Wyoming are on the Medicine Bow National Forest (Medicine Bow National Forest 2003, Wyoming Natural Diversity Database 2004). One is in the rejected Cedar Pass Research Natural Area (Jones and Fertig 1996), and the other is in Big Creek Park (Medicine Bow National Forest 2003, Wyoming Natural Diversity Database 2004). A third occurrence is located in a county road right-of-way and private land just outside the Sheep Mountain Special Interest Wildlife Area, but efforts to find it within the area were not successful (Jankovsky-Jones et al. 1996). Other occurrences in Wyoming are known from Bureau of Land Management and private lands (**Table 4**).

Table 4. Land ownership for the 26 known occurrences of *Eriogonum exilifolium* within Region 2. Because some occurrences straddle property lines, the total is less than the sum of the rows in the table. See **Table 3** for ownership of specific occurrences.

Land Ownership Status	Number of Occurrences	Subtotals
USDA Forest Service	**~4**	
Medicine Bow National Forest		2
Routt National Forest		1?
Roosevelt National Forest		1
Bureau of Land Management	**9 (2)**	
Rawlins Field Office		4
Kremmling Field Office		5 (2)
State of Colorado	**2**	
State Land Board		1
Lake John State Wildlife Area		1
State of Wyoming	**1**	
Private	**10 (1)**	
Unknown	**2**	
TOTAL	**26**	

In Colorado, *Eriogonum exilifolium* is known from 14 occurrences in Middle Park (Grand County), North Park (Jackson County; Reveal 1967a), and the upper Laramie River Valley (Laramie County; Doyle et al. 2005). Six of the 14 occurrences in Colorado have not been seen in more than 20 years (**Table 3**). Occurrences in Colorado are known from lands managed by the Bureau of Land Management, State of Colorado, and private owners (**Table 4**, **Figure 9**). However, the reports of *E. exilifolium* on National Forest System lands in Colorado are suspect.

Questionable or erroneous reports

One occurrence in Colorado may be located on the Routt National Forest. H.D. Harrington reported a collection site as "10 miles west of Coalmont." It is assumed that in traveling west from Coalmont he followed the road to Buffalo Pass, which existed in 1947 when the collection was made. Measuring 10 miles west along this road places this site within the Routt National Forest by about one mile. It is not known how carefully Harrington measured the distance from Coalmont; if the actual distance is less than 10 miles, then this occurrence is probably on private land east of the USFS boundary. Exactly 10 miles west of Coalmont along the Buffalo Pass Road, the geology consists of unconsolidated Quaternary deposits that are atypical habitat for *Eriogonum exilifolium*; suitable geologic strata occur approximately one mile east on private land. Field surveys are needed to obtain better location information for this and other occurrences in Colorado.

Nunn (2003) reported *Eriogonum exilifolium* from the Roosevelt National Forest in the upper Laramie River Valley, Larimer County, Colorado. The area was searched for several hours by Richard Scully and Mary Jane Howell in 2004, but *E. exilifolium* was not found there. The area reported by Nunn is underlain by granite (**Table 5**), which is atypical for *E. exilifolium* and led Scully (personal communication 2004) to speculate that the location information of the specimen is incorrect. Scully and Howell found large colonies of *E. exilifolium* two miles east of Nunn's location outside the USFS boundary (Scully personal communication 2004, Doyle et al. 2005). Thus, it appears likely that this report for *E. exilifolium* on the Roosevelt National Forest is erroneous.

There is one questionable report of *Eriogonum exilifolium* from southern Colorado. A collection of *E. brandegeei* at the Colorado State University Herbarium (collected by E. Bethel in 1895, Accession number 6456) was annotated as *E. exilifolium* by Reveal, after being annotated as *E. pauciflorum* by Susan Stokes. Stokes wrote "slight variation" on her annotation label, and one plant on this sheet has leaves that are quite broad. This specimen was reportedly collected from "Southern Colorado." Reveal noted on the annotation label that this was unlikely to have been collected

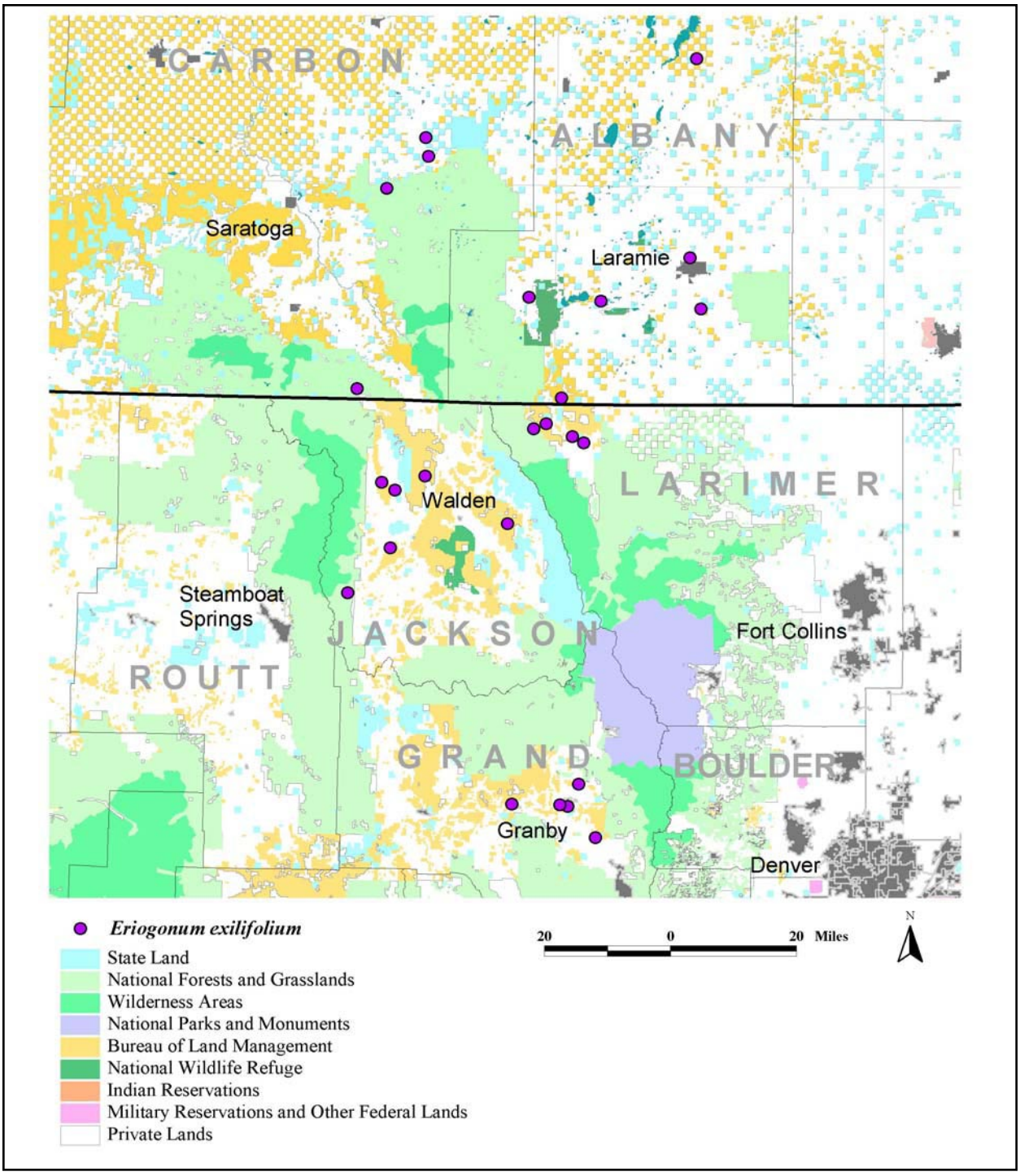

Figure 9. Distribution map of *Eriogonum exilifolium*, showing land ownership status, county boundaries, and municipalities.

Table 5. Intersection of element occurrence point locations with vegetation, geology, and soils. These data were generated using GIS layers for Vegetation, Bedrock Geology, and Soils. Vegetation data is from University of Wyoming (1996) and Colorado Division of Wildlife (1998) (at 1:100,000). Geology is from U.S. Geological Survey (1994) and Tweto (1979) (at 1:500,000). Soils are from USDA Soil Conservation Service (1994) (at 1:250,000) and Munn and Arneson (1999a and b) (at 1:100,000). Because these data are mapped at a coarse scale, fine scale variation is not accounted for; therefore there may be inaccuracies in these data. Precision is G (general, exact location unknown), M (minutes record, location known to within approximately one square mile), and S (seconds record, precise location known).

EO#	State	County	Location	Precision	Matrix Vegetation Type	Bedrock Geology	Soil
1	CO	Larimer	West of Hohnholz Lake	M	Rocky Mountain Lodgepole Pine Forest	Granite	Cryochrepts, loam
2	CO	Jackson	10 mi. west of Coalmont	G	Irrigated Agriculture	Quaternary Deposits (gravel, alluvium, and glacial drift) and granite	Cryoborall, loam
3	CO	Larimer	Grace Creek Ranch/ Hohnholz Lake #3	S	Intermountain Basin Big Sagebrush Shrubland	Tnp/ Kc Pierre and Niobrara Shale, some Benton Shale	Cryaquolls, loam
4	CO	Larimer	Lower Bull Mountain Road	S	Intermountain Basin Big Sagebrush Shrubland	Colorado Group (Niobrara Shale and Benton Shale or other Formations)	Cryoborall, sandy loam
5	CO	Larimer	Laramie River/ Bull Mountain	S	Intermountain Basin Big Sagebrush Shrubland	Colorado Group (Niobrara Shale and Benton Shale or other Formations)	Cryaquolls, loam
6	CO	Grand	East of Willow Creek Reservoir	S	Intermountain Basins Montane Sagebrush Steppe	Troublesome Formation	Cryorthent, clay
7	CO	Grand	Middle Park	S	Big Sagebrush	Troublesome Formation	Cryoboralf, loam
8	CO	Grand	Northwest of Tabernash	G	G	Troublesome Formation (possibly also metamorphic rocks or granite)	Cryoborall, gravelly sandy-loam
9	CO	Grand	Hot Sulphur Springs	G	Big Sagebrush	Coalmont Formation and numerous other Cretaceous and Tertiary strata	Cryoborall, loam
10	CO	Jackson	California Gulch	S	Big Sagebrush	Coalmont Formation	Cryoborall, sandy loam
11	CO	Jackson	North Fork Platte River	S	Irrigated Agriculture	Dakota, Morrison, and Sundance Formations	Cryorthent, clay
12	CO	Jackson	North end of Lake John	S	Big Sagebrush	Niobrara Formation	Cryoborall, gravelly sandy-loam
13	CO	Jackson	East of Walden	M	Big Sagebrush	Pierre Shale (Undivided)	Cryoborall, sandy loam
14	CO	Jackson	Beaver Creek	M	Big Sagebrush	Older Gravels and Alluviums	Cryoborall, gravelly sandy-loam

Table 5 (cont.).

EO#	State	County	Location	Precision	Matrix Vegetation Type	Bedrock Geology	Soil
1	WY	Albany	Simpson Springs	S	Mixed grass prairie	Forelle limestone and Satanka shale	Ustic Haplargids, fine-loamy, mixed, frigid; Ustic Haplocalcids, loamy, mixed, shallow, frigid; Ustic Haplocalcids, coarse-loamy, mixed, frigid
2	WY	Carbon	Sierra Madre Mountains, Trent Creek	S	Mountain big sagebrush	Miocene Rocks	Pachic Argicryolls, fine-loamy, mixed, Typic Argicryolls, fine, smectitic- Lithic Haplocryolls, loamy-skeletal, mixed
3	WY	Albany	Laramie	S	Mixed grass prairie	Chugwater formation or group	Ustic Lithic Haplocalcids, loamy-skeletal, mixed, frigid; Rock Outcrop; Ustic Haplargids, coarse-loamy, mixed, frigid
4	WY	Albany	Centennial Valley/ Sheep Mountain	S	Mountain big sagebrush	Niobrara Formation; Gravel, pediment, and fan deposits	Ustic Haplocalcids, loamy-skeletal, mixed, frigid; Aridic Argiustolls, fine-loamy, mixed, frigid; Ustic Haplargids, loamy-skeletal, mixed, frigid
5	WY	Carbon	Shirley Basin, Along State Route 487	M	Greasewood fans and flats	Niobrara formation	Ustic Haplargids, fine and fine-loamy, mixed, frigid- Ustic Haplocambids, fine-silty, mixed, shallow
6	WY	Carbon	Shirley Basin	S	Mixed grass prairie	Niobrara formation	Ustic Haplargids, fine and fine-loamy, mixed, frigid- Ustic Haplocambids, fine-silty, mixed, shallow
7	WY	Carbon	Cedar Pass Research Natural Area	S	Lodgepole pine	Hanna formation	Pachic Argicryolls, fine-loamy, mixed, Typic Argicryolls, fine, smectitic- Lithic Haplocryolls, loamy-skeletal, mixed
8	WY	Albany	Sensitive Data	S	Mixed grass prairie	Wagon Bed formation	Ustic Lithic Haplocalcids, loamy-skeletal, mixed, frigid; Rock Outcrop; Ustic Haplargids, coarse-loamy, mixed, frigid

Table 5 (concluded).

EO#	State	County	Location	Precision	Matrix Vegetation Type	Bedrock Geology	Soil
9	WY	Albany	Laramie Plains, Twin Buttes Lake	M	Basin exposed rock/soil	Alluvium and colluvium	Ustic Haplocambids, loamy-skeletal, mixed, frigid; Ustic Haplocambids, sandy-skeletal, mixed, frigid; Ustic Haplargids, fine-loamy, mixed, frigid
10	WY	Albany	Between Mule and Rogers creeks	M	Mixed grass prairie	Goose egg formation	Ustic Lithic Haplocalcids, loamy-skeletal, mixed, frigid; Rock Outcrop; Ustic Haplargids, coarse-loamy, mixed, frigid
11	WY	Albany	Maggie Creek	S	Mixed grass prairie	Upper Miocene Rocks	Typic Dystrocryepts, loamy-skeletal, mixed; Typic Haplocryalfs, loamy-skeletal, mixed; Lithic Cryorthents, sandy-skeletal, mixed
12	WY	Carbon	Elk Mountain	S	Wyoming big sagebrush, irrigated crops, and aspen forest	Niobrara formation and landslide deposits	Ustic Haplargids, fine and fine-loamy, mixed, frigid- Ustic Haplocambids, fine-silty, mixed, shallow. Also Typic Dystrocryepts, loamy-skeletal, mixed- Humic Dystrocryepts, loamy-skeletal, mixed. Histic Cryaquepts, fine-loamy over sandy or sandy-skeletal- Rock outcrop

from southern Colorado. Although Ewan and Ewan (1981) make note of Bethel's general reliability, Reveal (personal communication 2004) has noted a tendency for his specimens to be mislabeled and recommends ignoring it.

Eriogonum exilifolium is reported in Reveal (1967a) from "Grant" County instead of Grand County. This minor error is repeated in other documents including Fertig (2000a) and Medicine Bow National Forest (2003).

Microscale distribution patterns

Microscale distribution patterns of *Eriogonum exilifolium* are probably influenced by microtopography and other microhabitat attributes. Studies at Craters of the Moon National Monument in Idaho reported a positive association of *E. ovalifolium* var. *depressum* with itself. This association is probably the result of seed trapping by the prostrate canopy of *E. ovalifolium* var. *depressum* and more favorable conditions for seedling establishment under its canopy (Day and Wright 1989). Because *E. exilifolium* has a similar habit to *E. ovalifolium* var. *depressum*, such distribution patterns are plausible for *E. exilifolium* as well, but there have been no studies to confirm this. As a poor competitor, such a phenomenon would be deleterious to *E. exilifolium*.

Abundance

The total number of *Eriogonum exilifolium* plants in Region 2 is unknown (Wyoming Natural Diversity Database 2004). There are few data from which population estimates can be made. There have been no systematic counts of *E. exilifolium* plants in any occurrence; all known *E. exilifolium* population data were collated from rough ocular estimates. Some occurrences are small due primarily to the restricted size and patchy nature of the habitats they occupy (Medicine Bow National Forest 2003). Several sources note that *E. exilifolium* may be abundant where areas of suitable habitat are extensive (Fertig and Jones 1997, Fertig 2000a, NatureServe 2005), and field surveys in 2004 and 2005 located occurrences with many thousands to more than one million plants in the upper Laramie River Valley and in North Park in Colorado. *Eriogonum exilifolium* is under-inventoried, and it is possible that occurrences remain to be discovered. Fertig thought that *E. exilifolium* may warrant a change in status from S2 to S3 in Wyoming (personal communication 2004); this may ultimately be the case in Colorado as well.

Population trend

There are no repeat population counts or population monitoring data that could be used directly to infer a population trend for *Eriogonum exilifolium*. Because the species is a long-lived perennial, changes in population size may occur gradually and be difficult to detect.

There is evidence to suggest that *Eriogonum exilifolium* numbers are trending downward as the result of human activities and habitat loss. Reservoir filling may have destroyed large areas of *E. exilifolium* habitat and has affected at least one occurrence at Twin Buttes Lake (Wyoming EO#9 in **Table 2**). At this location, plants were reported along the water's edge, suggesting that the reservoir probably inundated part of this occurrence. Other impoundments in and near *E. exilifolium* occurrences in the Laramie Basin include Wheatland Reservoir, Lake Hattie Reservoir, and Cooper Lake. It is likely that some of these lakes inundated habitat and occurrences of *E. exilifolium*. Reservoirs in Colorado near *E. exilifolium* occurrences include Lake John, Walden Lake, Cowdrey Lake, MacFarlane Reservoir, Lake Granby, Willow Creek Reservoir, Williams Fork Reservoir, and other small impoundments in North Park. In particular, occurrences reported from the vicinity of Lake John (Colorado EO#12 in **Table 2**) and from Willow Creek Reservoir (Colorado EO#6 in **Table 2**) may also have been impacted by the creation of these reservoirs.

Residential development is also likely to have affected occurrences. Some habitat was certainly lost to subdivisions in the Laramie area (Fertig 2000a, Fertig personal communication 2004), near the Sheep Mountain Special Interest Wildlife Area (Jankovsky-Jones et al. 1996), and in Middle Park, where rapid population growth is occurring (US Census Bureau 2003).

Energy exploration and extraction occur throughout the range of *Eriogonum exilifolium* and very likely have impacted some occurrences. Coal exploration and strip mining have occurred in *E. exilifolium* habitat east of Walden, Colorado at the McCallum Coal Area, and oil and gas development is ongoing in North Park and Wyoming occurrences.

Development of transportation infrastructure has negatively affected some occurrences (Fertig personal communication 2004, Proctor personal communication 2004). Roads run through five occurrences in Wyoming

and three in Colorado. Construction of Interstate Highway 80 probably destroyed at least parts of several occurrences (Fertig personal communication 2004). While plants at some locations appear to be capable of colonizing road cuts, the presence of the road prevents the occupation of significant portions of these sites. There is evidence that off-road vehicle use is contributing to downward population trends locally (Proctor personal communication 2004).

Irrigated agriculture now occurs in areas in Wyoming and Colorado where there may have been *Eriogonum exilifolium*. This has probably reduced the abundance and distribution of *E. exilifolium*. While the soils where it occurs are typically clayey or sandy and poorly suited to agriculture, vegetation maps show many occurrences in close proximity to cultural vegetation (**Table 5**; University of Wyoming 1996, Colorado Division of Wildlife 1998).

Livestock grazing appears to have locally impacted occurrences. Livestock trailing has clearly resulted in the loss of some plants (Proctor personal communication 2004).

Habitat

General habitat description

The genus *Eriogonum* has shown a propensity for adaptive radiation and specialization throughout the Intermountain West. Many *Eriogonum* species, including *E. exilifolium*, are narrowly endemic to restricted habitat types. Other examples include *E. diatomaceum* (Reveal et al. 2002), *E. codium* (Reveal et al. 1995), *E. robustum* (Morefield 2000), *E. gypsophilum* (Limerick 1984), and *E. pelinophilum* (U.S. Fish and Wildlife Service 1983).

Eriogonum exilifolium occurs in the Temperate Steppe Division of the Dry Domain Ecoregion (Bailey 1995). Within the Temperate Steppe Division, it is found in the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province and the Temperate Desert Division in the Intermountain Semi-Desert Province (Bailey 1995). These provinces are referred to as the Southern Rocky Mountain Ecoregion and the Wyoming Basin Ecoregion respectively in Neely et al. (2001).

The climate of the basins in which *Eriogonum exilifolium* occurs is cool, dry, and windy. Temperature and precipitation are summarized from weather stations within the range of *E. exilifolium* at Centennial, Laramie, Walden, and Grand Lake (Western Regional Climate Center 2004). Average maximum summer temperatures in July range from 74.8 °F (at Grand Lake 6SSW) to 80 °F (at the Laramie Airport). At Walden, freezing temperatures are possible in July and become very likely by the end of August for a frost-free period of about 33 days (McKee et al. 1981). By flowering primarily during this frost-free period, *E. exilifolium* probably minimizes frost damage to its reproductive structures.

May, July, and August are the wettest months of a typical year throughout the range of *Eriogonum exilifolium*. Most of May's precipitation is delivered by late spring snowstorms. June is typically drier, but monsoonal thundershowers make July and August the wettest months. Average July precipitation ranges from 1.26 inches at Walden to 1.80 inches at Laramie. This pattern corresponds with the timing of peak flowering and fruit set for *E. exilifolium*.

Average annual precipitation ranges from 10.67 inches at Laramie to 14.20 inches at Centennial. Annual average precipitation is estimated to be as low as 5 inches at the McCallum EMRIA Study Area (McKee et al. 1981). Due to local wind patterns, much of the snow that falls on the exposed areas occupied by *Eriogonum exilifolium* is probably blown elsewhere (McKee et al. 1981).

Eriogonum exilifolium occurrences are located on sparsely vegetated habitat (**Figure 10** and **Figure 11**). Dorn (1977, 1992) describes the habitat simply as barren plains and hills. The habitat is distinct, patchy, and usually not extensive (Nelson personal communication 2004, Proctor personal communication 2004), but it may occur in tracts hundreds of acres in size. Habitat descriptions of all known occurrences of *E. exilifolium* are summarized in **Table 3**.

Eriogonum exilifolium occurs on a variety of soil types and geologic strata (**Table 5**). All verified occurrences are found on sites underlain by sedimentary rocks or alluvium. Soils reported from *E. exilifolium* occurrences vary greatly in their textural composition, with plants reported from clay, loam, and sandy soils. Reveal (1967a) noted a tendency for Wyoming occurrences to be found on finer-textured soils than in Colorado. It appears that *E. exilifolium* is found predominantly on clayey soils throughout its range, except in North Park where it occurs in sandy soils derived from the Coalmont Formation. Two occurrences in Wyoming are documented on seleniferous soils. In Larimer County, Colorado, *E. exilifolium* occurs with

Figure 10. *Eriogonum exilifolium* habitat at Big Creek Park, Wyoming (Medicine Bow National Forest). Photograph provided by John Proctor.

Figure 11. Shale outcrops in the Upper Laramie River Valley, Larimer County, Colorado. Photograph by Georgia Doyle in Doyle et al. (2005). Used with permission.

Stanleya pinnata, a species that is strongly associated with seleniferous soils.

Wyoming

In Wyoming, *Eriogonum exilifolium* has been reported from "semi-bare sandy-clay gumbo flats, white shaley-gypsum ridges, red clay hills, and limestone or limey sandstone outcrops in cushion plant-bunchgrass communities with low total plant cover" (Medicine Bow National Forest 2003 from Fertig and Jones 1997, Fertig 2000a). Most Wyoming occurrences of *E. exilifolium* have been reported from the Laramie Basin and the adjacent Shirley Basin. This area is underlain by a complex mosaic of geologic strata, consisting primarily of sedimentary rocks but also including granite, volcanics, and Quaternary alluvium.

In the Shirley Mountains, *Eriogonum exilifolium* is reported from seleniferous clay-gumbo soils in borrow pits and roadsides (Fertig and Jones 1997). At the north side of the rejected Cedar Pass Research Natural Area (Wyoming EO#7 in **Table 2**), *E. exilifolium* grows on clay barrens (Jones and Fertig 1996). On the west side of the Sheep Mountain Special Interest Wildlife Area, *E. exilifolium* grows on Niobrara Shale, which is highly fossiliferous and calcareous (Proctor personal communication 2004).

Colorado

As in Wyoming, occurrences in Colorado are underlain by sedimentary rocks (**Table 3**, **Table 5**). Reveal (1967a) noted that *Eriogonum exilifolium* is "often found on rolling granitic sand hills below 8,500 feet" in Colorado, but there is no other evidence that it occurs on granite anywhere in its range. One reported site (west of Hohnholz Lake on the Roosevelt National Forest) is underlain by granite, but unsuccessful efforts to find *E. exilifolium* at this location suggest that the report is in error.

North Park and Middle Park

North Park and Middle Park, Colorado are basins characterized by grasslands, barrens, and shrub-steppe vegetation surrounded by forested mountains. The floor of North Park ranges in elevation from 8,000 to 8,500 feet and is bounded by the Park Range to the west, the Medicine Bow Mountains to the east, and the Never Summer Mountains to the southeast. Middle Park is bounded by the Gore Range to the west, the Rabbit Ears Range to the north, the Indian Peaks to the east, and the Williams Fork Mountains and Blue Ridge to the south. The elevation of Middle Park is somewhat lower than that of North Park, between 7,300 and 8,000 feet. Both Middle Park and North Park are underlain by Mesozoic and Tertiary sedimentary rocks and Tertiary volcanic rocks. North Park is rich in oil, gas, and coal. Fluorspar was mined there in the past, but all mines are now closed. Abundant sand and gravel resources are available in North Park (Bureau of Land Management 2000b).

In North Park, *Eriogonum exilifolium* occurs on a variety of sedimentary deposits. It is grows on sandy soils derived from the Coalmont Formation, and on other rocks of Cretaceous and Jurassic age including Niobrara and Pierre shales, and possibly the Dakota, Morrison, and Sundance formations. In Middle Park *E. exilifolium* is reported most frequently on clay soils of the Troublesome Formation. It is also known from a location underlain by the Coalmont Formation and other Cretaceous and Tertiary strata at Hot Sulphur Springs.

Upper Laramie River Valley

The Laramie River flows north from its headwaters at Cameron Pass in western Larimer County. The upper Laramie River Valley is bounded on the east by the Laramie Mountains and on the west by the Medicine Bow Mountains. Within 15 miles of the Wyoming border, the valley widens where the Laramie River flows through sedimentary deposits. In this broad valley, *Eriogonum exilifolium* is found on calcareous clay loam soils derived from Niobrara, Lower Pierre, and Benton shales (Colorado Natural Heritage Program 2005, Doyle et al. 2005). Scully (personal communication 2004) noted good correspondence between *E. exilifolium* and the Kildor-Shale Outcrop Complex (Soil Map Unit 52 in USDA Soil Conservation Service 1980) in Larimer County. However, soils at most *E. exilifolium* sites differ from Kildor clay loam in being shallower and violently effervescent in reaction to 10 percent hydrochloric acid, versus very slightly effervescent in the typical Kildor profile. The strength of the effervescent reaction indicates how calcareous the soils are. All fine and coarse fragments were violently effervescent at three sites in the upper Laramie River Valley of Larimer County, Colorado. *Eriogonum exilifolium* is sometimes found in areas mapped as Miracle sandy loam 5 to 25 percent slopes (soil map unit 68 in USDA Soil Conservation Service 1980), but the plants occur on clayey soils that are not listed as inclusions in the map unit description due to the coarseness of the soil survey (Scully personal communication 2004).

Slope, aspect, and elevation

Eriogonum exilifolium typically grows on moderately sloping or flat sites. It has been reported from west, east, and northeast facing slopes. It has been reported from a wide range of geomorphologic settings including "dry, deeply eroded slopes," "low sandy valleys," "white shaley knoll," in gullies, and on hills. The elevation range of *E. exilifolium* is 6,090 to approximately 8,800 feet. See **Table 3** for elevation ranges of each occurrence.

Potential and unoccupied habitat

The habitat for *Eriogonum exilifolium* is conspicuous; at least one occurrence was discovered by searching barren areas with suitable soils and vegetation (Proctor personal communication 2004). However, other apparently suitable but unoccupied sites occur on the Medicine Bow National Forest. These areas include Cunningham Park, Holoroyd Park, Jerry Park, and Quimby Park. There is low potential for large tracts of suitable habitat on the Medicine Bow National Forest (Nelson personal communication 2004). Some potential habitat for *E. exilifolium* occurs on private lands, and accessing many of these sites is problematic (Fertig personal communication 2004, Nelson personal communication 2004). Much potential habitat in Colorado remains unsurveyed.

Reproductive biology and autecology

In the CSR (Competitive/Stress-Tolerant/Ruderal) model of Grime (2001), *Eriogonum exilifolium* most closely approximates a stress-tolerant species. Stress-tolerant attributes of *E. exilifolium* include adaptations to xeric conditions, tolerance of droughty and clayey soils, long lifespan, and low reproductive output. *Eriogonum exilifolium* often grows in sites with limited resources and consequently grows slowly, as is also typical of a stress-tolerator. Because it allocates relatively little biomass to producing seeds, the life history pattern of *E. exilifolium* is best classified as *K*-selected (using the classification scheme of MacArthur and Wilson 1967).

Although annual and some perennial *Eriogonum* species are competitive (and can be aggressive and ruderal), many perennial *Eriogonum* species are usually specialists that do well on a particular substrate but do not do well when competing with more aggressive species. The adaptations of *Eriogonum* species to difficult substrates allow them to persist where more competitive species are excluded (Reveal personal communication 2004). The patterns of distribution of *E. exilifolium* suggest that it is a species of barren sites without an affinity to a particular soil type or texture. It is possible that *E. exilifolium* avoids competition by tolerating stressful conditions in the poor, droughty soils that it inhabits.

The specific responses of *Eriogonum exilifolium* to disturbance are unknown, but the habitats in which it is found suggest that it may be tolerant of a low level of chronic disturbance. Fertig and Jones (1997) noted that *E. exilifolium* appears to be resilient to low levels of vehicle disturbance and also appears to tolerate some trampling by grazing livestock; however, concentrations of livestock on its loose substrate have been shown to dislodge plants and accelerate erosion (Medicine Bow National Forest 2003, Proctor personal communication 2004). The species has been documented on road cuts, in borrow pits, and on highly eroded slopes (**Table 3**). At Big Creek Park, *E. exilifolium* grows on either side of a cattle trail and on a road shoulder (**Figure 12**). However, these plants appear to be persisting rather than thriving. Conversely, plants appeared vigorous in 2004 at locations in Larimer County near cattle trails and along roads (Colorado Natural Heritage Program 2005). The road shoulder material may have come from a borrow pit upslope of the road (**Figure 13**; Proctor personal communication 2004). At Sheep Mountain, *E. exilifolium* is found on the toe slopes of a bank adjacent to a highway. Plants were also observed beyond the fence line on adjacent private land in more natural habitat (Proctor personal communication 2004).

At Sheep Mountain, *Eriogonum exilifolium* has colonized a road cut from adjacent undisturbed habitat (Heidel personal communication 2004, Proctor personal communication 2004). It has also been documented on a road shoulder and in an adjacent borrow pit at Big Creek Park (**Figure 13**) and at sites in Carbon and Larimer counties.

Regarding the response to disturbance of *Eriogonum lewisii*, Morefield (1996) wrote the following, which could also be true for *E. exilifolium*:

> "At several sites, *Eriogonum lewisii* has been observed to colonize and reproduce on recent, recovering disturbances such as road banks. I have observed this to be true of many, if not most, rare plant species in the arid west, and this is often interpreted by some to suggest that the species in question is not threatened by habitat disturbance, but instead is able to survive or even

Figure 12. Cattle trail (showing impacts of trailing on *Eriogonum exilifolium*) and road shoulder at Big Creek Park. Photograph provided by John Proctor.

thrive with continual disturbance. This is usually a misinterpretation of plant ecologic responses based on short-term observation. Most rare plant species are rare because they are adapted to and depend upon rare habitat types. Many of these habitat types impose harsh growing conditions that exclude most other plant species, thus creating relatively low-competition conditions for the few remaining species that are able to adapt. Disturbance also creates a temporary low competition situation of which rare species, already adapted to such conditions, frequently are able to take short-term, opportunistic advantage. Almost always, though, this is observed only if the disturbance occurs within or immediately adjacent to a source population occupying the rare soil or other habitat type that the species requires for long-term survival, and only when the disturbance is temporary and has begun to stabilize. Almost never has a rare plant species been observed to continue spreading onto disturbances farther outside its rare habitat type, or to persist where disturbance is severe and continuous. If rare species had the biologic and ecologic characteristics of invasive weeds, they would not now be rare. No plant population can withstand severe, uninterrupted disturbance of its habitat, and rare plants are no exception.

> Thus, while *Eriogonum lewisii* may be seen thriving for a few generations on disturbed sites, all my observations indicate that its long-term survival depends upon the continued availability of undisturbed or recovering [habitat]. *Eriogonum lewisii* has never been observed spreading off of such sites along disturbance corridors, and permanent loss of plants is evident where disturbance has been continuous and severe, such as on road beds bisecting the habitat."

Like *Eriogonum lewisii*, *E. exilifolium* is also sometimes found in anthropogenically modified areas. While this species is apparently capable of colonizing such sites, the overall impacts of this kind of disturbance are negative. The impacts from a road passing through an occurrence include loss of habitat, potential for the introduction invasive species, disruption of natural disturbance regimes, creation of a potential barrier to gene flow, and altered hydrology and other ecological processes. Some impacts are likely to be considerable although they may not become apparent for many years. Monitoring data would help to determine what levels and types of disturbances might benefit this species, and which are detrimental (Medicine Bow National Forest 2003).

Figure 13. Borrow pit at Big Creek Park colonized by *Eriogonum exilifolium*. Photograph provided by John Proctor.

There have been several investigations of the ecophysiology of *Eriogonum* species (e.g., Cole 1967, Mooney et al. 1983, Chapin and Bliss 1988), but no studies have been done on *E. exilifolium* to investigate its adaptations to its habitat. Mooney et al. (1983) observed rapid stomatal closure in response to decreased humidity in *E. latifolium*; this is an effective mechanism for maximizing water use efficiency. The tomentum on the abaxial leaf surfaces of *E. exilifolium* may serve to reduce water loss through open stomata during the day.

Reproduction

There has been no detailed investigation of the reproductive biology of *Eriogonum exilifolium*. Reveal (personal communication 2002) explains the sequence of maturation and floral biology typical of the genus *Eriogonum*: The anthers mature a day or two before the stigma is receptive. On the first day, a flower opens and six stamens shed pollen while the style and stigma remain coiled around the achene (fruit) within the flower. At this time, the flower is functionally male and cannot self-pollinate. The flower closes that night and opens again the next day. On the second day, the remaining three stamens shed pollen, and the stigma and style uncoil. At this time, the stigma is receptive and 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.

Most perennial members of the genus *Eriogonum* reproduce both vegetatively and sexually. The relative importance of these modes of reproduction varies within the genus. Clonal propagation may be the primary mode of reproduction in *Eriogonum ovalifolium* var. *williamsiae* (U.S. Fish and Wildlife Service 1995) while other species, particularly annuals, depend almost entirely on reproduction by seed. Clonal propagation does not appear to be an important mode of reproduction in *E. exilifolium*, and there are no difficulties in defining an individual plant (Fertig personal communication 2004). Many widespread species of *Eriogonum*, particularly low elevation species, tolerate fragmentation by the action of the hooves of herbivores. Like *E. exilifolium*, these species have a deep-seated, vertical taproot and an extensive system of lateral caudex branches. The caudex branches may produce adventitious roots, and if the branch is torn away from the main body of the plant, it can grow as a clone of the parent plant and produce a new taproot. It is not known if *E. exilifolium* tolerates this kind of

disturbance or if it can reproduce this way in the wild, but it can be propagated from cuttings (Slaby 2001).

Pollination ecology

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' because they utilize generalist pollinators as pollen vectors (Grant 1949, Bell 1971). Reliance on a broad suite of pollinators for pollination services buffers promiscuous plants from population swings of any one pollinator (Parenti et al. 1993). *Eriogonum ovalifolium* var. *williamsiae* individuals transplanted to containers at the Nevada Division of Forestry nursery successfully produced seed, suggesting that it does not depend on the services of a specialized pollinator (U.S. Fish and Wildlife Service 1995).

Eriogonum species offer a small amount of nectar at the base of the filaments and ovaries and are important nectar sources for many insects. This reward and pollen attract bees, flies, ants, and other insects (Reveal personal communication 2002).

Two insects, a syrphid fly (**Figure 14**) and a hymenopteran, were documented visiting the flowers of *Eriogonum exilifolium* at the Big Creek Park occurrence (Proctor personal communication 2004). Two species of bee flies in the family Bombylinidae were observed visiting the flowers of *E. exilifolium* in Larimer County, Colorado in 2004. One is in the genus *Poecilanthrax*, the other is unidentified (Doyle personal communication 2004). The importance of these insects in the pollination biology of *E. exilifolium* is unknown.

Phenology

Flowering occurs from mid-June to late August and September in *Eriogonum exilifolium* (Fertig and Jones 1997, Fertig 2000a, Colorado Natural Heritage Program 2005). Plants were in bud or vegetative on May 29. All specimens collected in mid to late June were in flower. Most herbarium collections were made in July and August, during the peak of flowering. Fruits mature in late August and September. Because the time of flowering was similar in two consecutive years, Johnston et al. (1981) suggest that flowering is probably controlled by day length in *E. brandegeei*. This may also be the case for *E. exilifolium*.

Fertility, seed viability, and seed dormancy

Eriogonum species produce numerous small flowers in umbels. One seed is produced per flower and is borne within an achene that dehisces from the plant when ripe. It is likely that the seeds of *E. exilifolium* are able to survive in the seed bank for several years.

Average seed viability exceeded 60 percent in a study of 10 native perennial *Eriogonum* species of Utah (Meyer and Paulsen 2000); two other *Eriogonum* species had very low viability. 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).

The germination requirements of *Eriogonum exilifolium* are unknown. In a study of *E. umbellatum*, seeds germinated without pre-treatment over a wide range of incubation temperatures, with the greatest success under widely fluctuating temperatures (Young 1989). This suggests that seeds germinate best near the soil surface. Seeds of an annual *Eriogonum* species (*E. abertianum*) from the Chihuahuan Desert were found to exhibit a pattern of conditional dormancy in the winter and non-dormancy in the summer; this is typical of annuals in unpredictable habitats. Temperature and soil moisture control germination in this annual species (Baskin et al. 1993). In a study of 10 species of native perennial *Eriogonum* species of Utah, Meyer and Paulsen (2000) determined that chilling is a primary regulator of dormancy in the species studied. Seeds of these species have no carryover mechanism to prevent germination in the first year following seed production, but it is possible that light requirements might cause buried seeds to persist in the seed bank. Dormancy in *Eriogonum* causes most seeds to germinate during the year following seed production, resulting in late winter germination and early spring emergence in most species. A few *Eriogonum* species are used as rock garden plants; these are generally easily germinated in well-drained soils (Reveal 1989a, Hickman 1993, Reveal 2003). Slaby (2001) recommends cultivation of *E. exilifolium* in a sunny site with a poor, sandy soil. It can be propagated by seed the in the spring, or by cuttings in late summer.

Dispersal mechanisms

The seeds of *Eriogonum* species are dispersed by wind, rain, streams, and animals (Stokes 1936). Due to

Figure 14. Syrphid fly visiting *Eriogonum exilifolium*. Photograph by John Proctor.

their high oil content, the seeds float and are readily moved by flowing and sheeting water during heavy rains. Stokes (1936) cites birds and vehicles as other likely dispersal vectors, especially for annual species of *Eriogonum*. Wind is a dispersal agent for many species of *Eriogonum* (Reveal personal communication 2004). *Eriogonum ovalifolium* var. *williamsiae* is a wind-dispersed species (U.S. Fish and Wildlife Service 1995), as is *E. scabrellum* (Reveal personal communication 2004). In some species of *Eriogonum* such as *E. brachypodum*, dispersal is thought to be similar to that of tumbleweeds. When inflorescences of *E. exilifolium* break off, they are blown along the surface where they disperse seeds as they go or deposit all seeds at a resting place (Reveal personal communication 2004). The high genetic diversity of some founder populations of *Eriogonum* suggests that they were dispersed this way, but deposition of the contents of a bird's crop would also transport numerous seeds to a site. Spatial studies of *E. fasciculatum* and *E. inflatum* suggest that most seeds fall close to the parent (Miriti et al. 1998). Seeds of *E. exilifolium* have been observed on the ground beneath the parent plant, suggesting that many do not disperse far (**Figure 15**).

Figure 15. *Eriogonum exilifolium* in Larimer County, Colorado in September. Achenes have fallen to the ground adjacent to the parent plant below center of photograph (see arrows). Photograph provided by Richard Scully. Used with permission.

Ants are particularly interesting dispersal agents for *Eriogonum exilifolium*. Many species of *Eriogonum* actively engage ants as dispersal agents by providing a reward in the form of abundant, oil-rich endosperm (Stokes 1936, Reveal personal communication 2002). Some *Eriogonum* species also have specialized structures on the seed called elaiosomes, which store oil and attract ants. However, elaiosomes have not been documented on the seeds of *E. exilifolium*. Ants will often carry seeds of *Eriogonum* underground where they may germinate if not consumed (Reveal personal communication 2002).

While ants may play an important role in seed dispersal, they may also negatively impact plant density. Ryti (1992) observed lower densities of *Eriogonum umbellatum* in a montane grassland in Montana where ants (*Formica altipetens*) tend aphids on this species. There has been no documentation of aphid or other insect utilization of *E. exilifolium*.

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 the more common *E. polycladon* (Spellenberg et al. 1988). *Eriogonum exilifolium* is not known to be morphologically or ecologically variable, and there are no indications that it is a rare phenotypic variant of another species.

Ecophenic variation occurs in several species of *Eriogonum* in California (Cole 1967). Two species with a prostrate, matted growth form in their native habitat produced a more erect habit when grown in a greenhouse. The prostrate growth form in coastal species of *Eriogonum* is a phenotypic response to strong wind and unstable soil, and these plants appear morphologically similar to inland species in the absence of these conditions. Other *Eriogonum* species of harsh habitats may demonstrate a similar ecophenic response, including *E. exilifolium*.

A morphological response to light intensity has been observed in *Eriogonum apricum*. Differences between an erect variety, which is found in more shaded sites, and a prostrate variety, which is found in open sites, were attributed to a growth response to

light (Myatt and Kaufman 1986). It is likely that *E. exilifolium* would exhibit a similar response by growing less prostrate in a shaded site.

Mycorrhizae

Roots of *Eriogonum exilifolium* have not been assayed for the presence of mycorrhizal symbionts, and its role as a mycorrhizal host has not been investigated. Arbuscular mycorrhizal (AM) fungi belong to a group of soil fungi (Glomales) that are difficult to identify because they seldom sporulate (Fernando and Currah 1996). They are the most abundant type of soil fungi (Harley 1991) and infect up to 90 percent of all angiosperms (Law 1985). AM fungi are generally thought to have low host specificity, but there is increasing evidence for some degree of specificity between at least a few taxa (Rosendahl et al. 1992, Sanders et al. 1996).

The effects of AM fungi on growth, reproduction, and survival of three plant species, including one species of *Eriogonum* (*E. parvifolium*), were studied at a dune restoration site in California (Holte 1994). Under controlled conditions, little or no colonization by AM fungi was observed in *E. parvifolium*, and inoculated plants showed no response in growth, reproduction, or survival. However, plants collected from wild populations were infected with vesicles and arbuscles.

Hybridization

Several stable hybrids have been documented in the genus *Eriogonum* (Stokes 1936). Welsh (1984) observed evidence of hybridization among four varieties of the *E. brevicaule* complex with *E. corymbosum*, *E. lonchophyllum*, *E. microthecum*, and possibly others.

There is no evidence of hybridization in *Eriogonum exilifolium*. It has been documented growing with five other species of *Eriogonum* (*E. gordonii*, *E. flavum*, *E. cernuum*, *E.* c.f. *umbellatum*, and *E. pauciflorum* var. *gnaphalodes*). There are no specimens or reports that suggest that hybridization or introgression are taking place where these species are sympatric.

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, and others listed in Reveal 1989b), there have been few studies of population genetics of *Eriogonum* species. Nonetheless, some meaningful inferences regarding the population genetics of *E. exilifolium* can be drawn from previous studies of rare *Eriogonum* species.

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). However, two studies of rare *Eriogonum* species found surprisingly high levels of genetic diversity. Populations of the extremely rare and federally listed *E. ovalifolium* var. *williamsiae* were shown to 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). The genetic variability of *E. ovalifolium* var. *williamsiae* exceeds that typically seen in a common, widespread taxon. These populations showed no evidence of inbreeding and were likely the result of random mating. 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 these studies suggest that conservation of *E. exilifolium* will require maintaining large populations to minimize inbreeding and to support pollinator communities that facilitate outcrossing. In subsequent studies, Neel and Cummings (2003) and Neel and Ellstrand (2003) showed that selecting occurrences for conservation using principles of ecological reserve selection (as reviewed by Noss et al. 1997 and Margueles and Pressey 2000) was not better than selecting occurrences randomly in terms of preserving genetic diversity in *E. ovalifolium* var. *vineum*. They concluded that preserving as many occurrences as possible is the best means of conserving genetic diversity. These studies underscore the importance of understanding a species' population genetics when planning its conservation (as described by Hamrick et al. 1979, Brown 1989, Hamrick and Godt 1989, and Loveless and Hamrick 1989).

The value of population genetic data for drawing inferences regarding *Eriogonum exilifolium* is unknown. Levels of genetic diversity tend to be highly correlated between rare and widespread congeners (Gitzendanner and Soltis 2000), suggesting that *E. exilifolium* may also exhibit high genetic diversity. It is likely that the distance between occurrences is a significant barrier to gene flow, suggesting that important genetic differences may exist between occurrences. The level of genetic variability in *E. exilifolium* has not been measured, but no readily observable effects of inbreeding depression have been documented.

In general, the density of seeds and other propagules decreases rapidly with increasing distance

from the source (Barbour et al. 1987). Long-distance dispersal events are therefore rare. Pollinator-mediated pollen dispersal is limited to the flight distances of pollinators (Kearns and Inouye 1993). Due to distances between occurrences, there is probably very little pollen or seed exchange among them, and therefore there is probably no gene flow between most occurrences of *Eriogonum exilifolium*. Areas of unsuitable habitat for *E. exilifolium* very likely act as sinks when seeds fall in these areas.

There has been no investigation of the life history characteristics of *Eriogonum exilifolium*. Large plants are likely to have taken many decades and perhaps more than 100 years to reach their size given their slow growth rate. Some shrubby *Eriogonum* species have been aged in California and these species commonly live more than 100 years (Reveal personal communication 2002). Individuals in the genus *Dedeckera*, a close relative of *Eriogonum*, have been aged using annual growth rings and can exceed 150 years in age (Reveal personal communication 2002). Perennial species of *Eriogonum* may be periodically disrupted by grazing or mass wasting of their substrate. This could result in fragmentation and clonal propagation of the species. Thus, a single product of a sexual reproduction event may persist for a very long period of time in some species of *Eriogonum* (Reveal personal communication 2002).

No Population Viability Analysis (PVA) has been performed for *Eriogonum exilifolium*, nor has there been a PVA of any member of the genus *Eriogonum* from which inferences could be drawn for this assessment.

Most occurrences of *Eriogonum exilifolium* appear small enough to warrant concern for the consequences of demographic, environmental, and genetic stochasticity. Demographic stochasticity results from chance variation in vital rates such as survival and reproduction, and it becomes a concern in populations of fewer than 50 individuals (Menges 1991). Genetic stochasticity includes founder effects, inbreeding depression, loss of genetic variation due to genetic drift, and the accumulation of deleterious mutations (Matthies et al. 2004). This factor generally becomes a concern in effective populations of fewer than 500 individuals. Inbreeding depression is a loss of fitness due to decreased heterozygosity resulting from repeated matings between closely related individuals. In isolated occurrences, matings occur between individuals that are more closely related than are two randomly chosen members from across the range of the species. In isolated occurrences, loss of genetic variation by drift is not balanced by immigration of seeds or pollen from other populations (Oostermeijer et al. 2003). Environmental stochasticity includes temporal variation in reproduction and survival as a consequence of environmental conditions and catastrophic local events, and it may lead to local extinction (Lande 1998, Oostermeijer et al. 2003). Environmental stochasticity can operate at many scales and thus may impact large or small occurrences. The minimum viable population thresholds outlined above vary considerably among species, depending on their reproductive biology and autecology. Maintaining the largest occurrences possible across the entire range of the species is most likely to reduce the effects of stochastic events.

Many life history parameters remain unknown in *Eriogonum exilifolium*. Of particular value would be information on seeds and recruitment. Quantifying seed production, longevity, and dormancy, as well as defining the variables controlling these parameters, would reveal much about the life history and the demography of *E. exilifolium*, including any potential bottlenecks.

There have been no observations of seedlings or successful recruitment in *Eriogonum exilifolium*, suggesting that recruitment events are rare (**Figure 16**; Fertig personal communication 2004, Proctor personal communication 2004). 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 one or more wet years during which plants can become established (Fertig personal communication 2004).

Community ecology

There has been no formal study of the community ecology and interspecific relationships of *Eriogonum exilifolium*. Available information is limited to surveys, herbarium specimens, observations, and inference from GIS data layers.

As a part of the EMRIA study conducted at the McCallum Coal Area east of Walden, Colorado, treated (nitrogen fertilizer and herbicide applied) and untreated plots were sampled and harvested, and the relative biomass of the component species or genera was measured. Because *Eriogonum* were not identified to species in this study, it is not known if *E. exilifolium* is included in the plot data. *Eriogonum* species were found only in untreated plots, where their biomass was only 0.2 to 0.3 pounds per acre (1 percent of total biomass). Cover of *Eriogonum* species was also low, ranging from 0.25 percent to 0.5 percent (**Table 6**; Bureau of Land

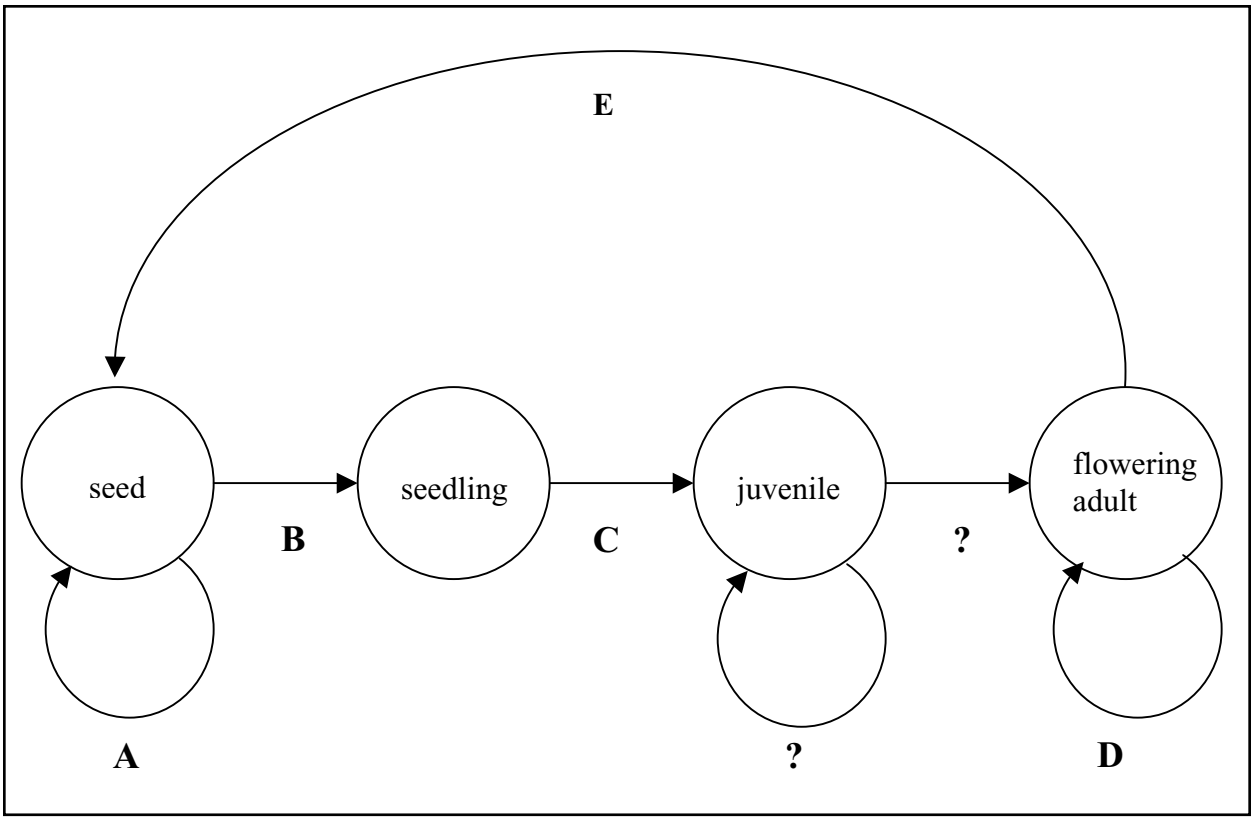

Figure 16. Hypothetical life cycle graph (after Caswell 2001) for *Eriogonum exilifolium*. There has been no investigation of the life history stages of this species. No transition probabilities are known for *E. exilifolium*, and there has been no demographic monitoring of other species of *Eriogonum* from which valuable inferences can be drawn. Studies of other perennial *Eriogonum* species showed no evidence of carryover mechanisms that would cause seeds to persist in the seed bank, so the value of A appears small (Meyer and Paulsen 2000). 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, but plants are capable of flowering. Given a probable slow growth rate and the radial size of some herbarium specimens, 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 (D). Fecundity of *E. exilifolium* is not known (E).

Table 6. Data for "*Eriogonum* spp." from Energy Minerals Rehabilitation Inventory and Analysis study site at the McCallum Coal Area near the Conrad Coal Mine (Bureau of Land Management 1981).

	Mountain Loam site	Dry Mountain Loam site
Dry weight (lbs./acre)	.3	.2
Percent cover	.25	.5
Frequency	15	20

Management 1981). The sampling protocols used in this study are unknown. See the History of knowledge section of this assessment under Classification and description for more information on this study.

Eriogonum exilifolium occurs in sparsely vegetated sites. In the Shirley Mountain area, *E. exilifolium* was observed in sites with average vegetative cover of 10 to 25 percent (Fertig and Jones 1997).

Associated species

Associated species documented with *Eriogonum exilifolium* are listed in **Table 3**. *Eriogonum exilifolium* most commonly occurs with *Oryzopsis hymenoides* (at five occurrences) and other grasses including *Pascopyrum smithii* and *Pseudoroegneria spicata* (three locations). Common associated species in Wyoming include *E. gordonii*, *Cirsium pulcherrimum*,

Gutierrezia sarothrae, *Chrysothamnus viscidiflorus*, and *Stanleya pinnata* (Fertig and Jones 1997, Fertig 2000a). *Eriogonum exilifolium* is often documented with shrubby plants, particularly *Artemisia tridentata* ssp. *vaseyana*.

Eriogonum exilifolium shares its habitat with at least four other species of rare plants. At Sheep Mountain and in the Shirley Basin in Wyoming, it grows with *Machaeranthera coloradoensis* var. *coloradoensis*, which is ranked globally as G2T2?, subnationally as S2 in Wyoming, and is designated as a Region 2 sensitive species (Fertig and Jones 1997, Fertig 2000a, Fertig 2000b, Wyoming Natural Diversity Database 2004). In the Shirley Basin, *E. exilifolium* grows with *Haplopappus wardii* (G2, S2 in Wyoming; Fertig and Jones 1997). In 2004, Georgia Doyle discovered *H. wardii* in Colorado, where it also occurs with *E. exilifolium* (Doyle et al. 2005). *Penstemon laricifolius* ssp. *exilifolius* (G4T2Q, S2 in Wyoming and Colorado) is locally abundant in the Upper Laramie River Valley, but it is infrequent on the barrens where *E. exilifolium* occurs. It is more common in sagebrush-dominated areas (Scully personal communication 2004, Heidel personal communication 2005).

North Park and Middle Park support occurrences of several narrow endemic plant species. *Phacelia formosula* is a federally listed endangered species known only from barren outcrops of the Coalmont Formation in North Park, Colorado (Wiley 1979, U.S. Fish and Wildlife Service 1986). *Astragalus osterhoutii* is also federally listed as endangered and is known only from exposures of the Troublesome Formation in Middle Park (Colorado Natural Heritage Program 2005).

Surveys in 2004 confirmed that *Eriogonum exilifolium* occurs with *Phacelia formosula* at California Gulch in North Park, Colorado (**Figure 17**). *Eriogonum exilifolium* was suspected to occur with *P. formosula* because both were collected at California Gulch although neither the specimen labels nor other sources described these species as occurring together. Plants tentatively identified as *P. formosula* were also found with *E. exilifolium* in the Upper Laramie River Valley in 2004

Figure 17. *Eriogonum exilifolium* at California Gulch with *Phacelia formosula*, a federally listed endangered species. Soils at this location are sandy, derived from the Coalmont Formation. Photograph by author.

(Doyle et al. 2004), which would represent a significant range extension for *P. formosula*. Expert confirmation of this material is pending. *Phacelia formosula* and *E. exilifolium* have similar habitat affinities although the ecological amplitude of *E. exilifolium* is much broader than that of *P. formosula*.

Vegetation

Eriogonum exilifolium has been documented from four broadly defined ecological systems. These are described below using the typology developed by Rondeau (2000a, 2000b, 2001, 2002) and Neely et al. (2001). Included within the description of each ecological system is a brief summary of human impacts on these systems. More detailed treatments of impacts appear in the references cited below.

The physiography and vegetation documented in several occurrences of *Eriogonum exilifolium* are similar to those described in the Shale-Siltstone Barrens System (Rondeau 2002). *Oryzopsis hymenoides*, *Artemisia tridentata* ssp. *vaseyana*, and *Gutierrezia sarothrae*, documented at many *E. exilifolium* occurrences, are characteristic of this system, as is the sedimentary substrate. This system is typically sparsely vegetated, with total plant cover often less than 10 percent. Although this system is subject to high levels of natural disturbance, it is susceptible to alterations in species composition when impacted by roads and drill pads (Rondeau 2002).

Eriogonum exilifolium occurs in two types of sagebrush-dominated systems. The most prevalent within its habitat is sagebrush steppe, which is dominated by smaller species of sagebrush (most commonly *Artemisia nova*, *A. bigelovii*, *A. arbuscula*, or *A. tripartita* with occasional component shrubs, e.g., *Chrysothamnus* spp. and *Krascheninnikovia lanata*). Dominant herbaceous species may include *Festuca idahoensis*, *Pseudoroegneria spicata*, *Hesperostipa comata*, *Pascopyrum smithii*, *Carex geyeri*, and *Bouteloua gracilis* (Rondeau 2000a). Large areas of North Park and Middle Park are dominated by sagebrush steppe, which tends to occupy poorly drained, poorly aerated soils. Sagebrush steppe is less susceptible to fire than taller *Artemisia*-dominated shrublands. In the Shirley Basin, *E. exilifolium* was documented in a birdfoot sagebrush/ Gardner saltbush sparse shrubland (*Artemisia pedatifida-Atriplex gardneri*; Fertig and Jones 1997).

Eriogonum exilifolium has also been documented in sagebrush shrublands. Sagebrush shrublands are widely distributed, occupying nearly 10 percent of the Southern Rocky Mountain Ecoregion (as circumscribed by Bailey 1995) (Rondeau 2000b). Sagebrush shrublands are widely distributed in the broad valleys and lower foothills of the Southern Rocky Mountains. Basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) and mountain big sagebrush (*A. tridentata* ssp. *vaseyana*) are the most common dominant species in these shrublands (Colorado Division of Wildlife 1998). Mountain big sagebrush is more prevalent in the intermountain parks and basins where *E. exilifolium* occurs than is basin big sagebrush. Although agriculture has greatly diminished the extent of sagebrush shrublands in the Great Basin (Cronquist et al. 1986), this has not occurred within the range of *E. exilifolium*. Invasion of sagebrush shrublands by *Bromus tectorum* (cheatgrass) increases the likelihood of fire, after which sagebrush regeneration occurs only slowly by seed. This can convert these shrublands to annual grasslands dominated by *B. tectorum* and other non-native species (Bunting et al. 1987). While *B. tectorum* has invaded many sagebrush-dominated areas in Colorado and Wyoming, its spread within the range of *E. exilifolium* appears limited at present.

Although *Eriogonum exilifolium* is often found in areas dominated by sagebrush, it usually grows in barren areas with little or no sagebrush that are surrounded by sagebrush or other shrublands. In Larimer County, *E. exilifolium* tends to occur near *Artemisia nova* and *A. bigelovii*, but little or no sagebrush occurs where the rare plants are found (Doyle et al. 2005). At many locations, *E. exilifolium* is the dominant species on barren sites.

Eriogonum exilifolium has also been documented from "dry grasslands" at Lake John, Colorado (Colorado EO#5 in **Table 2**), and in areas containing a mosaic of sagebrush shrublands and grasslands at the rejected Cedar Pass Research Natural Area (Wyoming EO#7 in **Table 2**) (Medicine Bow National Forest 2003). Montane grasslands typically occur in large patches within a matrix of lodgepole pine (*Pinus contorta*) or other forest type (Rondeau 2001). They are often species rich, and while grass species are dominant, they often contain a diverse flora of forbs as well (Mutel and Emerick 1992). They are susceptible to overgrazing, and the species composition of many montane grasslands has been altered by historic grazing practices (Turner 1975 as cited in Rondeau 2001).

Herbivores

Some species of *Eriogonum* are important in the diets of various herbivore species. *Eriogonum* species are important winter forage for desert bighorn sheep in Mexico, where they comprise up to eight percent of their fall and winter diet (Tarango et al. 2002). Bighorn sheep browsing resulted in the decline of *E. heracleoides* and *E. niveum* in British Columbia. Grazing pressure also reduced vigor and reproductive potential in these species (Wikeem and Pitt 1991). California bighorn sheep selected forage based primarily on availability, and they did not appear to seek out *E. niveum* and *E. heracleoides* as they did other species (Wikeem and Pitt 1992). *Eriogonum* species in Oregon are among the primary forbs consumed by sage grouse. Nutrient analyses of these species showed that they have high nutritional value (Barnett and Crawford 1994).

There are no observations suggesting that *Eriogonum exilifolium* is sought after by domestic or native herbivores for forage. No reports have made any reference to consumption of plants by herbivores, and no herbarium specimens appeared to have been browsed. Livestock grazing probably occurs at all occurrences of *E. exilifolium* (Proctor personal communication 2004), but Fertig and Jones (1997) state that *E. exilifolium* is not grazed by livestock.

Eriogonum exilifolium habitat is utilized by numerous native vertebrate species. Sage grouse and pronghorn utilize *E. exilifolium* habitat for forage. Sage grouse may also use *E. exilifolium* habitat for lekking, nesting sites, and winter habitat. Sagebrush steppe and sagebrush shrubland are important habitat for sage grouse and sage sparrow (Rondeau 2000a, Rondeau 2000b). Mule deer have been observed east of Walden (Colorado EO#6 in **Table 2**) using the area as transitional range. Raptors, rodents, and songbirds are also present in and adjacent to *E. exilifolium* habitat (Bureau of Land Management 1981).

Competitors

There is no information on competitors for biotic and abiotic resources with *Eriogonum exilifolium*. As a habitat specialist, *E. exilifolium* may be a poor competitor, and it may be vulnerable to negative impacts from introduced species. Some species of *Eriogonum* are competitive and respond positively to disturbance (Reveal personal communication 2002). Stress tolerant species sensu Grime (2001) do not typically need to be good competitors, since highly competitive species cannot tolerate the chronic stress to which stress tolerators are adapted. Thus, they typically do not share the same resource pool with species such as *E. exilifolium*. *Eriogonum exilifolium* is found in barren sites lacking highly competitive species.

Parasites and disease

Eriogonum species are commonly attacked by the rust *Uromyces intricatus* (Savile 1966). This species is divided into six varieties, all of which attack various members of the genus *Eriogonum* in western North America. Rust has been documented on several Colorado *Eriogonum* species, including *E. brandegeei*, a narrow endemic in the Arkansas River Valley of Colorado (Colorado Natural Heritage Program 2005). There are no reports of rust attack on *E. exilifolium*. Attacks of *Uromyces* are cyclical in nature and may be brought on by drought or other stress (Dawson personal communication 2004). Several occurrences of *E. brandegeei* have been severely affected by rust, but it is unknown whether rust epidemics resulted in mortality. While rust infections are visually dramatic, they do not typically do serious damage to the host. This rust typically causes the leaves to fall off, but it does not attack the plants systemically (Reveal personal communication 2004). While it is possible that *E. exilifolium* is susceptible to rust, there is currently no evidence suggesting that rust represents a threat. However, the combination of drought and increased erosion and disturbance by off-road vehicle use in its habitat may weaken plants and leave them more susceptible to rust attack. Under these conditions, it is possible that an attack may have long-term consequences for individuals or occurrences (Spackman-Panjabi personal communication 2004).

CONSERVATION

Threats

Numerous reports, observations, and opinions of experts document several threats to the persistence of *Eriogonum exilifolium*. In order of decreasing priority, these are residential and commercial development; range improvements; off-road vehicle use and other recreation; grazing and its secondary effects; oil, gas, and coalbed methane development; reservoir creation; right-of-way management; coal mining; exotic species invasion; effects of small population size; disease; impacts to pollinators; fire; global climate change; and pollution. Similar threats are identified for *Phacelia formosula* (U.S. Fish and Wildlife Service 1986, Medicine Bow National Forest 2003), which occurs with *E. exilifolium* in North Park and possibly the Upper

Laramie River Valley. These threats and their priority order are speculative; more complete information regarding the biology and ecology of this species may reveal other threats. Assessment of threats to this species will be an important component of inventory and monitoring studies.

The Medicine Bow National Forest (2003) lists trampling by livestock and/or humans, road construction and maintenance, illegal off-road all-terrain vehicle (ATV) and motorcycle traffic, and residential development as threats to *Eriogonum exilifolium*. Threats to *Phacelia formosula*, a federally listed endangered species that occurs with *E. exilifolium* at some sites in Colorado, include motorcycle and off-road vehicle activity, livestock grazing, trampling and trailing, coal development, oil and gas exploration and development, and range improvements (U.S. Fish and Wildlife Service 1986). It is possible that the observed response of *E. exilifolium* to some types of human disturbance (reviewed in Reproductive biology and autecology) may mean this is less of a threat (Fertig 2000a). In general, activities that concentrate use within occurrences are likely to threaten *E. exilifolium* (Fertig personal communication 2004). This includes road construction, by allowing access to a site by off-highway vehicles, installation of water sources for cattle, and energy development. The lack of information on this species, especially in Colorado, complicates the degree of threat because land management decisions often do not give consideration to its protection.

Influence of management activities or natural disturbances on habitat quality and individuals

Residential and commercial development

Residential development poses an increasing threat to the quality, availability, and connectivity of *Eriogonum exilifolium* habitat (Medicine Bow National Forest 2003). Urban growth is occurring rapidly in Grand County, Colorado, where the human population increased 56 percent between 1990 and 2000 (U.S. Census Bureau 2003). It is likely that most occurrences on private land in Grand County are threatened to some extent by residential development, and that some have already been impacted. Subdivision of surrounding private lands is occurring near the Sheep Mountain Special Interest Wildlife Area (Jankovsky-Jones et al. 1996). Residential development north of Laramie has already resulted in a decline in the amount of available habitat for *E. exilifolium* and has probably extirpated all or parts of occurrences on private land.

Range improvements and livestock grazing

Range improvements (modifications to rangeland intended to improve forage yield for livestock) are cited among the threats to *Phacelia formosula* (U.S. Fish and Wildlife Service 1986); they are also a threat to co-occurring *Eriogonum exilifolium*. At McCallum Gulch, herbicide was applied to reduce the cover of sagebrush and to reduce forb cover (Bureau of Land Management 1981). Although *E. exilifolium* was documented at this site, it is not known if it was subjected to herbicide treatments, as it was not identified at the time the report was written. "*Eriogonum* spp." were reported from untreated plots but not from treated plots. Given the known effects of selective herbicides, it is likely that this common, widespread type of range improvement is detrimental to *E. exilifolium*.

Although there is no evidence of heavy grazing of *Eriogonum* species, the impacts of grazing to the plant communities in which *E. exilifolium* occurs suggest that grazing may be a threat through habitat degradation. Observations at Big Creek Park, which is in an active allotment, suggest that trailing threatens portions of occurrences but is unlikely to extirpate an occurrence. Trampling by livestock is reported to be a threat to *E. exilifolium* (Medicine Bow National Forest 2003). The rejected Cedar Pass potential Research Natural Area is located within the active Pass Creek grazing allotment (Jones and Fertig 1996, Haas personal communication 2005). The reported location west of Hohnholz Lake on the Roosevelt National Forest is in the Grace Creek allotment, both of whose units are active. Range condition in this area is reportedly good despite several years of drought (LaFontaine personal communication 2005). The occurrence 10 miles west of Coalmont may fall on the Routt National Forest, where it would occur within the Sawmill C&H Allotment, where 300 cow-calf pairs are grazed for 670 head-months from July 26-September 30 (Alpe personal communication 2006).

Consideration of the impacts of grazing on *E. exilifolium* is important because most, if not all, occurrences are probably grazed by livestock (Proctor personal communication 2004). Although the habitat of *E. exilifolium* has low forage value, the barren sites it occupies might be deemed suitable locations for the placement of range improvements such as water tanks and salt blocks that would increase trailing, soil compaction, trampling, and excessive consumption of vegetation (Fertig personal communication 2004). At appropriate stocking rates, livestock probably avoid the barren areas occupied by *E. exilifolium* if there

are accessible areas nearby with higher forage value. Domestic horse grazing on ranchettes often leads to serious degradation and erosion from trampling and overgrazing, which could result in the extirpation of occurrences on private land.

Recreation

Recreational use of *Eriogonum exilifolium* habitat represents a major threat to the species (Medicine Bow National Forest 2003). Off-road travel is permitted within 300 feet of roads in the Medicine Bow National Forest (Medicine Bow National Forest 2003). Barren areas are frequently targeted by recreational operators of ATVs, four wheel drive trucks, motorcycles, and mountain bikes because of their challenging slopes and the lack of interference from vegetation (Bureau of Land Management 2001b, Lyon and Denslow 2001). The proximity of *E. exilifolium* habitats to Laramie, Walden, Granby, and other towns increases the threat from recreational use. Off-road vehicle use will increase as human populations grow. Impacts from off-road vehicle use have been documented at seven occurrences. Numerous roads cross the north end of the rejected Cedar Pass Research Natural Area where *E. exilifolium* occurs. The roads and gentle topography make it difficult to protect the resources in the area "against unwanted human intrusions" (Jones and Fertig 1996). Dirt roads within the Cedar Pass area may also receive substantial use during the hunting season. Motorized recreational use is increasing at the Sheep Mountain Special Wildlife Area due to the rising popularity of the area and its proximity to Laramie, Wyoming (Jankovsky-Jones et al. 1996). The impacts to habitat and individuals from off-road vehicle use are evident at Big Creek Park (**Figure 18**; Proctor personal communication 2004). Off-road vehicle use is a potential threat to occurrences at California Gulch and in Larimer County where access is unimpeded. Although recognized as a problem, enforcement of road and trail closures is nearly impossible (Brekke personal communication 2004).

Mining and energy resource development

Exploration and development of oil, gas, and coalbed methane pose a threat to occurrences of *Eriogonum exilifolium* across its range. There is interest

Figure 18. Off-road vehicle tracks at Big Creek Park, Medicine Bow National Forest, within a population of *Eriogonum exilifolium*. Photograph provided by John Proctor.

in exploring for coalbed methane in North Park, and four exploration wells may be installed on private land near the occurrence east of Walden (Colorado EO#6 in **Table 2**). Exploration for oil and gas resources is likely to occur in the near future on public lands in Jackson and Grand counties. Under the BLM's preferred alternative, most of the mineral estate in these two counties will be open to leasing under standard constraints or with minor stipulations (Bureau of Land Management 2005). If significant methane resources are found, wells could become permanent (Cesar personal communication 2004). There have been oil wells in North Park for many years (Cesar personal communication 2004). Plans for gas and coalbed methane development are also underway in Carbon County, Wyoming (Bureau of Land Management 2004). Because *E. exilifolium* is not a BLM sensitive species in Wyoming, leasing will probably take place on BLM lands without consideration of occurrences of this species.

At least one occurrence of *Eriogonum exilifolium* has been impacted by mining or exploration for coal. It is possible that undocumented occurrences were impacted by strip mining in North Park and in Wyoming. At least four coal strip mines have operated in North Park. One mine is near the town of Coalmont, and another, the Conrad Mine, is in the McCallum Gulch area. Coal exploration has also occurred in North Park. However, North Park is remote from major market and transportation costs are prohibitive; the probability of future coal mining is low given the economics of extraction (Cesar personal communication 2004). Reclamation is ongoing at the strip mines in North Park, but recovery of *E. exilifolium* is not a stated goal of these efforts.

Mining for coal, gold, silver, and copper is an important industry in Albany County, Wyoming, and mining and exploration are ongoing. Seventy-eight active and retired mines exist in the county (Bogue Technologies International 2002). There have been no documented impacts on *Eriogonum exilifolium* from mining in Wyoming.

Reservoir creation

The creation of reservoirs has probably reduced the amount of habitat for *Eriogonum exilifolium* and almost certainly impacted the occurrence at Twin Buttes Lake in Wyoming. Numerous impoundments have been created in North Park and the Laramie Basin (see the Population trend section of this assessment for details). While this continues to threaten occurrences of *E. exilifolium*, new reservoir construction has slowed in recent decades. Raising the levels of existing reservoirs is probably a greater threat than building and filling new reservoirs.

Road maintenance and construction

Occurrences within road rights-of-way are susceptible to maintenance activities such as mowing, spraying for weeds, and widening (Medicine Bow National Forest 2003). Threats to roadside occurrences are ongoing and will be difficult to ameliorate. In Colorado, plants within 23 feet of the pavement (or 15 feet, depending on the size of the mower) may be mowed repeatedly through the growing season (Powell personal communication 2003). Fertig and Jones (1997) note that the occurrence along the main access road to the Shirley Mountains does not appear to be affected by road maintenance. Mowing is minimal along USFS roads on the Medicine Bow National Forest (Roche 2004). Construction and periodic blading of the natural surface road may have created new habitat for *Eriogonum exilifolium* by reducing competition with nearby plants.

The proliferation and use of roads is likely to encourage the spread of invasive exotic weeds throughout the range of *Eriogonum exilifolium* (see the Exotic species section for details). The barrier effect of roads on pollinators and dispersers is known to have broad demographic and genetic consequences, which are reviewed in Forman and Alexander (1998).

Exotic species

Competition from non-native plants is a potential threat to *Eriogonum exilifolium* (Medicine Bow National Forest 2003). This document also notes that invasive species could arrive in *E. exilifolium* habitat as the result of livestock grazing, road maintenance or construction, recreational use, or timber harvest.

Musk thistle (*Carduus nutans*) has been documented with *Eriogonum exilifolium* at Big Creek Park (**Figure 19**) and is a threat to occurrences in natural and human-created habitat (Medicine Bow National Forest 2003, Proctor personal communication 2004). Musk thistle and Canada thistle (*Cirsium arvense*) were documented along the road that passes through the Sheep Mountain occurrence of E. exilifolium, but no weeds were observed within the occurrence (Proctor personal communication 2004). Canada thistle is unlikely to invade *E. exilifolium* habitat because the thistle prefers riparian and wetland soils. However, musk thistle has a broader ecological amplitude and can

Figure 19. Musk thistle (*Carduus nutans*) at Big Creek Park. Thistle is the large plant adjacent to the road at bottom center. Photograph provided by John Proctor.

invade upland ecosystems. Both species are included on the Colorado Noxious Weed List (Colorado Weed Management Association 2005).

Use of herbicides for right-of-way management threatens *Eriogonum exilifolium* where it occurs on roadcuts or roadsides. Care must be taken with the application of herbicides in *E. exilifolium* habitat, and use of herbicides within known occurrences should be limited to hand application to the target species. Use of herbicides for range enhancement (such as sagebrush control) may also threaten *E. exilifolium*.

Cheatgrass (*Bromus tectorum*) is an aggressive invader of natural communities following even mild disturbance, and its spread throughout the Intermountain West is well documented (Young and Blank 1995). Cheatgrass replaces native bunchgrasses, resulting in increased erosion (West and Young 2000). The dramatic changes invoked by cheatgrass on the fire ecology of shrubland ecosystems are also a cause for concern if it becomes widespread in *E. exilifolium* occurrences.

Yellow starthistle (*Centaurea solstitialis*) is present on Colorado's western slope (Dillon 1999), and a population was identified and eradicated on the Colorado Front Range. It poses a potential threat to *Eriogonum exilifolium* and many other native plant species if efforts to contain it fail. It has a broad ecological amplitude and the potential to spread widely in Colorado. It currently infests 10 million acres in California (Colorado Weed Management Association 2005).

Other exotic species of concern for *Eriogonum exilifolium* include saltlover (*Halogeton glomeratus*) and Medusa head (*Taeniatherum caput-medusae*). These species have not yet been documented with *E. exilifolium*, but they are aggressive species that have invaded large areas of upland native plant habitat throughout the West.

Disease

Rust attack has been cited by numerous observers as a threat to some *Eriogonum* species, although it has not been documented in occurrences of *E. exilifolium*. It appears that the rust does not usually kill its host or cause long-term damage. Periodic outbreaks of this rust are probably part of the natural cycle of *Eriogonum* species; there is no evidence that it causes widespread mortality. 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.

Pollinator community

Activities that decrease the size or change the composition of pollinator populations may impact *Eriogonum exilifolium* if pollen exchange declines as a result. Maintenance of genetic diversity by outcrossing is important in other species of *Eriogonum*, and may be for *E. exilifolium* as well. Surface disturbance or soil compaction is a potential threat to ground nesting-pollinators, many of which are generalists that may visit *E. exilifolium*. Further study is needed to determine whether sufficient pollinator resources exist for *E. exilifolium*, and if ongoing impacts to *E. exilifolium* occurrences are also affecting its pollinators.

Fire

Several studies have addressed the response of *Eriogonum* species to fire, including summer burning regimes (Rickard 1989) and postfire succession (Malanson 1982). The role of fire in maintaining population viability of *E. longifolium* var. *gnaphalifolium* has been demonstrated (Satterthwaite et al. 2002). Fire probably plays a minor role in maintaining the barren habitat of *E. exilifolium*, and it is unlikely that *E. exilifolium* is adapted to fire. The sparse communities in which *E. exilifolium* is usually found would probably not carry fire (Rondeau 2000a, Rondeau 2002, Medicine Bow National Forest 2003).

Climate change

Global climate change is likely to have wide-ranging effects in the future. However, the direction of projected trends is yet to be determined, and predictions vary based on the environmental parameters used in predictive models. For example, Manabe and Wetherald (1986) model future conditions based on current atmospheric CO_2 trends and suggest that average temperatures will increase while precipitation will decrease in the West. However, Giorgi et al. (1998) showed that both temperature and precipitation increased under simulated doubling of atmospheric carbon dioxide levels. Either scenario could have significant effects on the distribution of *Eriogonum exilifolium* habitat. Temperature increase, predicted by both models, could cause vegetation zones to climb 350 feet in elevation for every degree F of warming (U.S. Environmental Protection Agency 1997). Because the habitat for *E. exilifolium* is already xeric, lower soil moistures in the growing season induced by decreased precipitation could have serious impacts. On the other hand, an increase in precipitation would promote the growth of perennial species with which *E. exilifolium* cannot compete.

Experimentally elevated CO_2 levels increased rates of biomass accumulation and reduced stomatal conductance in *Eriogonum* inflatum, a widespread desert annual, but did not change its seasonal pattern of net photosynthesis. *Eriogonum inflatum* retained the traits needed to persist in its desert habitat (Huxman and Smith 2001). The consequences for the perennial species *E. exilifolium* are difficult to predict.

Pollution

Atmospheric nitrogen deposition is one of the most important agents of vegetation change in densely populated regions (Köchy and Wilson 2001). Nitrogen loading and vegetation change are greatest near large metropolitan areas (Schwartz and Brigham 2003). Measurable impacts from nitrogen pollution might therefore be expected within the range of *Eriogonum exilifolium*. Nitrogen enrichment experiments show that nitrogen is limited in undisturbed habitats (Gross et al. 2000). An increase in soil nitrogen is likely to cause a few species to increase in abundance while many others decline (Schwartz and Brigham 2003). The degree to which nitrogen pollution has resulted in vegetation change in the habitats of *E. exilifolium* is unknown. Acid deposition, which has increased markedly in Colorado through the 20th century, may have already changed soil chemistry and affected habitat quality for *E. exilifolium* locally or regionally, although many sites are buffered by the high pH of their residual soils. High elevation watersheds of the Front Range have reached an advanced stage of nitrogen saturation (Burns 2002).

Threats from over-utilization

While there are no known commercial uses for *Eriogonum exilifolium*, there is potential for over-utilization of *Eriogonum* species if they become popular in the herb trade. Members of the genus *Eriogonum* are reputed to be good for honey production (Lovell 1969, Hickman 1993). Native Americans used the roots of some *Eriogonum* species for medicinal purposes (Kearney and Peebles 1960), including the treatment of colds, tuberculosis, bladder problems, skin cuts, open sores, and itching (Train et al. 1957, Ayer et al. 1989). Extracts of *E. brevicaule* have medicinal potential, but exhibited some lethality in mice (Abdel-Kader and Stermitz 1996). There are no reports of any toxicity

concerns to humans of *Eriogonum* (Burrows and Tyrl 2001). Numerous species of *Eriogonum* are sought after for the horticulture trade (Reveal 1989a, Hickman 1993, Reveal 2003). *Eriogonum exilifolium* is an attractive species and is of horticultural interest (Slaby 2001, Reveal 2003). In collecting plants for scientific purposes, care should be taken by collectors not to remove plants from small occurrences (Wagner 1991, Pavlovic et al. 1992).

Conservation Status of Eriogonum exilifolium in Region 2

Do habitats vary in their capacity to support this species?

It is likely that habitats vary in their capacity to support *Eriogonum exilifolium*, but critical habitat variables are not known. Research is needed to clarify the relationships between *E. exilifolium* and its habitat. An abundance of apparently suitable but unoccupied habitat suggests that either these sites are not yet colonized, or may be unsuitable in ways we do not understand. The key environmental variables that determine the capacity of habitats to support occurrences of *E. exilifolium* could include soil texture, parent material, slope and aspect, disturbance regime, geochemistry and soil chemistry, pollinator availability, associated species, or combinations of these variables. There is some understanding of *E. exilifolium*'s ecology gleaned through rare notations of its natural history, but the its tolerance limits with respect to environmental variables have not been measured, and its ecological amplitude is not known. Clearly, edaphic factors are important, but we do not know the habitat variables to which *E. exilifolium* responds most strongly. Improved nutrient or water availability would probably lead to dominance by more competitive species and the exclusion of *E. exilifolium*.

Vulnerability due to life history and ecology

Eriogonum exilifolium's small global range, narrow habitat specificity, and the human uses of its limited habitat are the primary reasons for its vulnerability. A restricted suite of edaphic requirements appears to limit it to specific soil types found in a few geological strata. The proximity of suitable habitats to roads and to a growing human population, their fragility, isolation and small size, potential commercial value of the mineral estate underneath them, and suitability for off-road vehicle use leaves them vulnerable to human impacts.

While some perennial *Eriogonum* species are somewhat tolerant of damage resulting from low intensity off-road vehicle or herbivore trampling, it is unknown to what extent *E. exilifolium* can withstand these impacts. The instability of the substrate and the species' slow growth rate probably mean a long recovery time. *Eriogonum exilifolium* may lack specific adaptations to mechanical disturbance and herbivore damage if it has not historically been subject to grazing pressure.

All occurrences of *Eriogonum exilifolium* for which plant counts or estimates exist are small by conventional measures of population viability. The minimum viable population size is not known for *E. exilifolium*, but even populations falling below the 50/500 thresholds of Soulé (1980) may be viable and have conservation value. The Colorado Natural Heritage Program currently considers occurrences of *E. exilifolium* containing ten or more plants to be viable (Colorado Natural Heritage Program 2005).

The degree to which its life history and ecology increase the vulnerability of *Eriogonum exilifolium* is difficult to determine because of the paucity of information available. As a long-lived, stress-tolerant perennial, it is adapted to some degree to the effects of environmental stochasticity such as drought. Because it may have effective mechanisms for selfing, it may also be buffered from a loss of pollinator diversity. Preventing the buildup of homozygous loci in the population requires frequent outcrossing, which would be augmented by the presence of appropriate pollinators and sufficiently large population sizes (Neel et al. 2001). If this is also true for *E. exilifolium*, then it is vulnerable to inbreeding depression and pollinator decline.

Evidence of populations in Region 2 at risk

Eriogonum exilifolium's habitat specificity, limited range, small number of occurrences, disjunct distribution, and susceptibility to human impacts suggest that occurrences of *E. exilifolium* are at risk. Population growth is pressuring some occurrences of *E. exilifolium*. Residential development threatens the type locality and occurrences at Sheep Mountain near Laramie. Grand County, Colorado grew 56 percent between 1990 and 2000 (U.S. Census Bureau 2003); the occurrence near Granby is likely at risk. On the other hand, the populations of Carbon County, Wyoming and Jackson County, Colorado decreased between 1990 and 2000 (U.S. Census Bureau 2003).

All occurrences of *Eriogonum exilifolium* in Wyoming are located on private land or public land managed for multiple uses (Fertig 2000a). One occurrence in Colorado is located on the Lake John State Wildlife Area, but protection of *E. exilifolium* and its habitat is not a goal for this area, which is managed primarily for recreation. Use of *E. exilifolium* habitat for recreation, especially by off-road vehicles, places some occurrences at risk. Some occurrences of this species are close to roads where off-road vehicle use is likely to be greatest (Fertig personal communication 2004).

The potential value of natural resources in *Eriogonum exilifolium* habitat places plants at risk when extraction of these resources begins. Resource exploration and extraction has already occurred near some *E. exilifolium* occurrences. The potential direct and ancillary impacts of resource extraction are great. The risk of losing *E. exilifolium* occurrences to these activities is correlated with economics and the market value of these resources, which could change greatly in coming years. Oil and gas exploration and development are likely to increase in North Park, and there is interest in exploring for coalbed methane. Four coalbed methane exploration wells are planned in the vicinity of the McCallum Gulch occurrence. Other exploration for coalbed methane is occurring in North Park on private land (Cesar personal communication 2004). Gas and coalbed methane development is also planned for areas of Carbon County (Bureau of Land Management 2004).

The autecology of *Eriogonum exilifolium* is poorly understood; conservation actions are less effective when basic information regarding a species' tolerances and needs is missing. The small size of many *E. exilifolium* occurrences suggests that they may be at risk of going through a genetic bottleneck. Reduced gene flow between occurrences resulting from human impacts may lead to smaller effective population sizes and increase the risk of inbreeding depression. Habitat fragmentation may reduce the movement of pollinators and create additional barriers to geneflow. Parts of some *E. exilifolium* occurrences are in sites that were created or are maintained by an anthropogenic disturbance, especially roadcuts. These occurrences are at risk from routine road maintenance such as mowing and herbicide use. They are also at risk from road widening projects, as are plants in adjacent natural habitat.

Management of <u>Eriogonum exilifolium</u> in Region 2

Implications and potential conservation elements

The most current data suggest that *Eriogonum exilifolium* is a regionally endemic species that is imperiled due to a limited global range, a small number of isolated occurrences, limited habitat availability, and threats to its habitat. Conservation elements for *E. exilifolium* include the need for open, barren sites that correlate with specific soil types and geological formations; a suitable disturbance regime, the nature of which is unknown; availability of pollinators; and lack of competitors.

Desired environmental conditions for *Eriogonum exilifolium* include sufficiently large areas where the natural ecosystem processes upon which this species depends can occur, permitting it to persist unimpeded by human activities and their secondary effects, such as weeds. This includes a degree of ecological connectivity between occurrences to provide corridors and nectar resources for pollinators. It is possible that most or all of the ecosystem processes upon which *E. exilifolium* depends are functioning properly at many or most of the occurrences of this species.

Protection of known occurrences, Area of Critical Environmental Concern (ACEC) or Research Natural Area designation, acquisition by federal agencies through land exchange, conservation easements, public education, and development of effective management strategies and protective regulations offer the best chance for the conservation of this species. Restoration policies will need to address the condition of native plant communities, grazing regimes, human and natural disturbance regimes, and pollinator resources. See the Beneficial management actions section of this assessment for information on mitigating threats resulting from management.

Tools and practices

Species and habitat inventory

Much suitable habitat remains unsurveyed throughout the range of *Eriogonum exilifoliumi*. Surveying potential habitat is a high research priority.

Areas with the highest probability of new occurrences are those with geologic and edaphic attributes similar to those of known occurrences. The habitat for *E. exilifolium* is highly conspicuous and can be identified readily on aerial photographs (Proctor personal communication 2004). Areas likely to support *E. exilifolium* can be predicted using soil map units defined by the USDA Soil Conservation Service (1980) (discussed in the Distribution and Abundance section of this assessment). Doyle et al. (2005) observed that rare plants, including *E. exilifolium*, were often found on the Bare Soil mapping unit identified by the Colorado Division of Wildlife (2003).

Better data on population size, habitat, spatial extent, threats, and other natural history observations are needed at many known *Eriogonum exilifolium* occurrences. The occurrences reported from National Forest System lands in Colorado are questionable, and searches are needed to determine whether the species is present at these locations. Comprehensive surveys of potential habitat have not been completed anywhere within the range of *E. exilifolium*. Recent reports of *E. exilifolium* in North Park and Middle Park note the presence of additional habitat in the vicinity that was not searched due to time constraints or difficulty of access. For example, suitable habitat continued for at least one mile beyond the surveyed area at California Gulch, but it was not visited in 2004 due to time constraints (**Figure 20**).

A good strategy for surveying for this species is to start with known occurrences and extend the search around them into unsurveyed suitable habitats. Many areas within the known range of *Eriogonum exilifolium* have not been searched because of they are located on private land. If private landowners are willing, their property should be surveyed for the species. The Arapaho National Wildlife Refuge in North Park may contain suitable habitat for *E. exilifolium* and also needs to be surveyed (Proctor personal communication 2004).

Eriogonum exilifolium could benefit from using Global Positioning System equipment to mark precise occurrence boundaries. This would provide

Figure 20. Unsurveyed *Eriogonum exilifolium* habitat northwest of California Gulch in Jackson County, Colorado (foreground). Although this species is present at the photo point and beyond, this area was not surveyed in 2004 due to time constraints. Further surveys are needed in much of the range of this species. Photograph by author.

land managers with data for land use planning and permitting. The best time to conduct surveys for *E. exilifolium* is from July to mid-August at the peak of flowering. September may also be a good time for surveys of this species because the leaves turn reddish-brown, and the plant is easy to see (Colorado Natural Heritage Program 2005).

Searches for *Eriogonum exilifolium* could be aided by predictive distribution modeling using deductive and inductive techniques. The availability of fine-scale GIS data with high predictive value for *E. exilifolium* (e.g., Colorado Division of Wildlife 2003) suggests that these techniques generate useful models for guiding and focusing future surveys. Species distribution modeling is an effective means of determining the extent of suitable habitat on USFS lands. Techniques for predicting species distributions are reviewed by Scott et al. (2002). Habitat modeling has been done for other sensitive plant species in Wyoming (Fertig and Thurston 2003) and Colorado (Decker et al. 2005), and these methods could apply to *E. exilifolium* as well.

Better population estimates or counts of *Eriogonum exilifolium* occurrences are needed to obtain a better determination of the total population size. The cost and human resources required to conduct a census vary and depend on the occurrence size, plant distribution, and methods used. For some species, such as *E. ovalifolium* var. *williamsiae*, a census is difficult because the plant proliferates via fragmentation, and determining genetic individuals is nearly impossible (Reveal personal communication 2004). The use of quantitative census techniques, as described by Bullock (1996), would help to develop a better understanding of the rarity or abundance of this species.

Population monitoring

A monitoring program that addresses recruitment, seed production, seed and plant longevity, population variability, and pollinators would generate data useful to managers and scientists. Population monitoring can detect population trends under different management and use scenarios, by comparing occurrences in disturbed and undisturbed sites. Monitoring sites under a variety of land use scenarios will help to identify appropriate management practices for *Eriogonum exilifolium* and will help to understand its population dynamics and structure.

The most sensitive measure of population change may come from tracking recruitment success. Suitable methods for monitoring pollinators are discussed in Kearns and Inouye (1993). It will be important to define *a priori* the changes that the sampling regime intends to detect and the management actions put into place based on the results (Schemske et al. 1994, Elzinga et al. 1998). On steep slopes or unstable soils, consideration may be needed to minimize impacts and degradation resulting from the monitoring. Marking and tracking individuals may also be difficult on steep slopes and mobile substrate.

Resampling monitoring plots annually will be necessary at first to understand the baseline dynamics of *Eriogonum exilifolium*. Since *E. exilifolium* is a slow growing, long-lived perennial, it may be determined that monitoring at longer intervals is sufficient. However, this may result in missing a major recruitment event. To document important demographic events (e.g., seedling establishment and fruit set), two trips per growing season may be required, one in early spring and one in late August or early September. Because *E. exilifolium* is a non-rhizomatous perennial reproducing entirely by seed, the methods of Lesica (1987) would be suitable for population monitoring. Standard monitoring methods generally employ the use of randomly arrayed systematic sampling units (quadrats). Within each quadrat, plants are marked and tracked using an aluminum tag or other field marker. During annual visits, data are gathered for each marked plant. Ideally, this would include a measure of size (for *E. exilifolium*, two perpendicular measurements can be taken across the basal portion of the plant and the formula for an ellipse used as a measure of size), life history stage, fecundity (the number of fruits or some other measure of reproductive output), and mortality. Recruitment within each quadrat 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. Elzinga et al. (1998) offers additional suggestions regarding this demographic sampling techniques.

Seed viability and longevity can be estimated using small buried bags containing known numbers of live seeds that are collected and tested periodically using tetrazolium chloride and germination trials on subsets of each bag. Data from several years of monitoring could provide insight into the rate of change among the life history stages of seeds, seedlings, juveniles, and reproductive individuals and could be used in calculating transition probabilities. Data would also yield insight into the longevity, fecundity, seed bank dynamics, annual growth rate, and recruitment rates of *Eriogonum exilifolium*, and permit the use of modeling to determine life

history stages, minimum viable population size, and probability of long-term persistence.

Several methods of monumentation are recommended in Elzinga et al. (1998), depending on the site physiography and frequency of human visitation to the site. This is an important consideration with long-term benefits if done at the outset of the monitoring program. Monumentation will be somewhat challenging given the unstable substrates where occurrences of *Eriogonum exilifolium* tend to be found.

Estimating cover and/or abundance of associated species within permanent monitoring plots will permit the investigation of interspecific relationships through ordination or related techniques. In very sparsely vegetated plots this can be difficult, but it can be done accurately using appropriate cover classes or subdivided quadrat frames. Understanding environmental constraints on *Eriogonum exilifolium* would facilitate the development of beneficial management practices for this species. Gathering data on slope, aspect, and edaphic characteristics (particularly moisture and texture) from monitoring plots would permit the analysis of species-environment relationships. These data would facilitate hypothesis generation for studies of *E. exilifolium* ecology.

Adding a photo point component to a monitoring regime, as recommended by Elzinga et al. (1998), could facilitate the tracking of individuals. A handbook on photo point monitoring (Hall 2002) is available with detailed instructions on establishing photo point monitoring plots. Monitoring sites should be selected carefully, and a sufficient number of sites should be selected if the data are intended to detect population trends.

Habitat monitoring

Habitat monitoring could be conducted on sites lacking *Eriogonum exilifolium* plants but within the species' known distribution with similar soils, geologic substrate, and vegetation. For sites occupied by *E. exilifolium*, habitat monitoring should be conducted concurrently with population monitoring. Documenting habitat attributes, evidence of disturbance, and associated species can be a part of population monitoring designs and will improve understanding of the species' habitat requirements and management needs. If carefully selected environmental variables are measured during monitoring, they may help to explain observed population changes. Evidence of current land use practices is also important to document while monitoring occurrences. Habitat monitoring within occurrences will alert managers of new impacts such as weed infestations and damage from human disturbance or grazing. Change in environmental variables might not cause observable demographic effects for years, so resampling may help to identify underlying causes of population trends. Observer bias can introduce errors in habitat monitoring (Elzinga et al. 1998); this type of monitoring is usually better at identifying new impacts than tracking changes in existing impacts. Using broad abundance classes to estimate the extent of weed infestations may reduce the effects of observer bias. To assess trampling impacts, using photographs of impacts to train field crews will help them to consistently rate the severity of the impact.

Beneficial management actions

Surveys and monitoring would be highly beneficial to *Eriogonum exilifolium*. Identifying the highest-quality occurrences in terms of population size, condition, and the landscape context will help managers prioritize conservation efforts. A better understanding of the species' distribution will help develop regional management protocols that favor the persistence of *E. exilifolium*.

Baseline inventories in potential *Eriogonum exilifolium* habitat prior to changing management would help alleviate threats to this species from human impacts. Complete and detailed surveys are needed wherever there is the potential for impact to *E. exilifolium*. This will help to identify new occurrences and to avoid impacts to known occurrences.

Current information suggests that *Eriogonum exilifolium* qualifies for addition to the BLM sensitive species lists in Wyoming and Colorado. It meets two of the four criteria for consideration for BLM sensitive species status, by having "typically small or widely dispersed populations" and by "inhabiting ecological refugia or other specialized or unique habitats" (Bureau of Land Management 2000a). Sensitive species status would ensure that consideration is given to occurrences and habitat of *E. exilifolium* in land management decisions, and would prioritize its habitat in conservation work (Bureau of Land Management 2000a).

Eriogonum exilifolium will be given consideration in the fire management plan being developed for the Medicine Bow National Forest (Medicine Bow National Forest 2003). Among the recovery steps for the federally listed species *Phacelia formosula* are implementing conservation strategies to protect the

species' habitat and developing habitat management plans (U.S. Fish and Wildlife Service 1986). Because *E. exilifolium* occurs with *P. formosula*, these efforts may benefit *E. exilifolium*.

Due to unstable soils and the proximity of its habitat to human developments, *Eriogonum exilifolium* is vulnerable to recreational uses. Management actions that limit recreational impacts are likely to confer benefits to this species. Assessment of the susceptibility and impacts to all occurrences from off-road vehicle use is needed. Road closures, gates, and fences may warrant consideration. Plans to barricade areas that have been used for illegal off-road vehicle use at Big Creek Park (Proctor personal communication 2004) will help to mitigate impacts from this activity.

The establishment of protected areas managed for the conservation of *Eriogonum exilifolium* is an important conservation strategy for this species. Research Natural Area or Special Interest Botanical Area status for Sheep Mountain, Cedar Pass, and possibly Big Creek Park on the Medicine Bow National Forest, with *E. exilifolium* specified as a management target, could help to ensure the protection of this species on USFS lands. These areas are no longer under consideration for Research Natural Area status and are not included in the Record of Decision for the Medicine Bow National Forest (Cables 2003). Area of Critical Environmental Concern designation of occupied areas was among the recommendations for the recovery of *E. gypsophilum* (Limerick 1984), and this may also be appropriate for high quality *E. exilifolium* occurrences on BLM-managed public land. Bringing sites on private land into public ownership through land exchange or purchase could protect occurrences from residential development. Conversely, land exchanges involving occurrences on public land being transferred to private ownership would not be beneficial to *E. exilifolium*. Conservation easements and other land trust activities would be a useful conservation tool to protect occurrences on private land. Land exchange and purchase of easements by The Nature Conservancy are listed among the recovery steps for *Phacelia formosula* (U.S. Fish and Wildlife Service 1986). Purchase of land or conservation easements by land trusts would also be a useful conservation tool. Purchasing conservation easements of any size may confer significant benefits to *E. exilifolium* since occurrences and habitat are naturally insular and limited in size. The conservation of *E. exilifolium* would be an appropriate goal to include in county and city planning efforts, particularly the municipalities of Laramie and Granby.

Given the potential threats to *Eriogonum exilifolium* and its habitat from exotic species, aggressive management of weeds in and near *E. exilifolium* occurrences is a high priority. Management strategies designed to prevent weed infestation of *E. exilifolium* occurrences are likely to confer the greatest benefits. The weed-free-hay policy enforced by the Medicine Bow National Forest (Medicine Bow National Forest 2003) is a policy aimed to prevent the spread of weeds. Management to reduce the prevalence of cheatgrass will help to maintain high quality habitat and to ensure a natural fire regime (Rondeau 2000a, 2000b).

Although mowing and weed control have the potential to affect portions of occurrences of *Eriogonum exilifolium*, there is potential for right-of-way management practices to be modified to mitigate these impacts. Hand-pulling weeds whenever possible is beneficial for *E. exilifolium*. Limiting the use of herbicides within occurrences of *E. exilifolium* to direct application to target species will decrease the effects of overspray and indiscriminate application. Also, avoiding right-of-way mowing in *E. exilifolium* occurrences from June until late August or September (after fruit has dried and seeds are released) would also be beneficial. Surveys by someone who is familiar with *E. exilifolium* will help to prevent impacts to occurrences during road projects such as utility line installation or road maintenance.

Management practices that reduce impacts from grazing are likely to contribute to achieving conservation goals for *Eriogonum exilifolium*, but research is needed to identify grazing regimes that are compatible with this species. The best approach to determining the impacts of 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). Allotment management plans that include recommendations such as the construction of exclosures and adjustments of stocking rates to reduce impacts to *E. exilifolium* will be beneficial to the species. The use of exclosures to protect plants from livestock would probably have little impact on grazing animals since the barren sites where *E. exilifolium* occurs typically have very little forage. Maintaining livestock stocking rates at suitable levels will help prevent grazing of *E. exilifolium*. Because of the poor forage of *E. exilifolium* occurrences, livestock are unlikely to venture far into occurrences unless stocking rates are so high as to force animals onto less productive range.

The establishment of a monitoring program (as recommended for the recovery of *Eriogonum gypsophilum* by Limerick (1984) and *Phacelia formosula* by U.S. Fish and Wildlife Service (1986)) would help protect *E. exilifolium* by providing information on its population dynamics and biology to be used to develop beneficial management protocols and conservation priorities. Studying the species' population genetics and autecology would have similar benefits and provide valuable scientific data.

Seed banking

No seeds or genetic material are currently in storage for *Eriogonum exilifolium* at the National Center for Genetic Resource Preservation (Miller personal communication 2004). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2003). Collection of seeds for long-term storage will be useful if restoration is necessary.

Information Needs

Distribution

Species inventory is the most important information need for *Eriogonum exilifolium*. Determining the species' distribution and abundance will help to determine conservation priorities. Relocating Harrington's collection from "10 miles west of Coalmont" is a priority for the Routt National Forest, and surveys are needed to verify the presence or absence of *E. exilifolium* on the Roosevelt National Forest west of Hohnholz Lake. Surveys of private land are a priority throughout the Laramie Basin (Nelson personal communication 2004) and in Middle Park, where residential development is proceeding rapidly. Bureau of Land Management land likely supports additional occurrences in Wyoming and Colorado. Determining the number of plants in known occurrences of *E. exilifolium* is important for assessing conservation needs and priorities.

Life cycle, habitat, and population trend

Research is needed to understand the population ecology of *Eriogonum exilifolium*. Although inferences can be made from other taxa, they cannot take the place of studies of *E. exilifolium*. Information on recruitment, safe sites, longevity, seed viability and dormancy, reproductive effort, and seed germinability on different substrates would help to establish basic life history parameters and would be useful in population models and restoration.

Although some descriptive information is available for *Eriogonum exilifolium* habitat at some locations, more detailed information is needed. A better understanding of the ecological tolerances of this species with respect to soil texture, soil moisture, nutrient levels, and disturbance would be useful to scientists and land managers, and is needed to understand the species-environment relationships. Investigating spatial correlations with other species may reveal underlying ecosystem processes. Autecological research is needed to refine the definition of appropriate habitat and facilitate effective habitat monitoring and conservation stewardship of this species.

The population trend of *Eriogonum exilifolium* is unknown, and it may be difficult to quantify given the species' long lifespan and episodic recruitment. Because *E. exilifolium* is a long-lived perennial, population responses to environmental changes may be slow. Lack of access to occurrences on private land may complicate this research.

Response to change

Understanding the response of *Eriogonum exilifolium* to disturbance is important for determining compatible land management practices. The response of this species to grazing is unknown, but some observations suggest that it will tolerate a low level of livestock trampling (Medicine Bow National Forest 2003). The potential for exotic species to impact *E. exilifolium* is also unknown since no significant infestations of occurrences have been observed. Musk thistle is the only noxious weed to have been observed in an occurrence of *E. exilifolium*, and the degree to which it poses a threat to occurrences of *E. exilifolium* is not known. Determining threats from weeds will help managers assign appropriate priority levels to weed management efforts.

Metapopulation dynamics

To date, there has been no research to determine the importance of metapopulation structure and dynamics to the long-term persistence of *Eriogonum exilifolium* at local or regional scales. Emigration, immigration, and extinction rates are unknown for *E. exilifolium*; population dynamics and viability must first be assessed.

Demography

At present, only the broadest generalizations can be made regarding the demography of *Eriogonum exilifolium*. Our knowledge of the species' distribution is incomplete, and abundance has not been rigorously determined at any occurrence. Reproductive output, recruitment, longevity, and other demographic parameters are not known. Additional fieldwork is needed 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). The value of demographic data for conservation planning and species management cannot be overstated.

Population trend monitoring methods

There has been no population monitoring of *Eriogonum exilifolium*, but methods are available to begin a monitoring program. Lesica (1987) described a technique for monitoring occurrences of non-rhizomatous perennial plant species that would apply to *E. exilifolium* (see the Population monitoring section of this assessment for details). Selection of monitoring sites from a variety of physiognomic and geological settings and land use scenarios will be necessary to monitor overall population trends.

Restoration methods

There are no known attempts to restore occurrences of *Eriogonum exilifolium*, but some efforts have been made to restore its habitat. Natural revegetation of mined sites in western coal regions occurs slowly due to the harsh climate, short growing season, and poor soils (U.S. Congress Office of Technology Assessment 1986). Since the passage of the Surface Mining Control and Reclamation Act in 1977, mining companies are required to meet environmental performance standards in restoring disturbed land (U.S. Congress Office of Technology Assessment 1986). The science of restoration ecology has flourished as a result of this and other environmental laws. While much progress has been made in the ability to re-grow native vegetation, it is difficult and expensive to restore some vegetation types. Irrigation of dry reclamation sites sometimes has little effect. Methods for restoring mining sites are reviewed in U.S. Congress Office of Technology Assessment (1986). While there has been some effort to restore *E. exilifolium* habitat following coal strip mining, there is not enough information to determine if the methods employed are effective for restoring the species, and it is not known to what extent activities at these sites impacted *E. exilifolium*. McKee et al. (1981) offers suggestions for seed application and surface treatment based on climatological observations, but these recommendations are not specific to *E. exilifolium*.

Some observations suggest that restoration of *Eriogonum exilifolium* occurrences may not be difficult. These include the fact that the species colonizes borrow pits, road shoulders, and road cuts. These observations suggest that this species could be restored or re-introduced by seeding onto exposed surfaces with little effort to ameliorate the site. However, as noted by Morefield (1996) for *E. lewisii*, such occurrences may not contribute greatly to the long-term viability of the species, and the preservation of unaltered habitat is the best practice for ensuring long-term viability.

Numerous members of the subgenus *Eucycla*, to which *Eriogonum exilifolium* belongs, are noted for their virtues as rock garden plants, and most are readily grown from seeds (Reveal 2003). Slaby (2001) and Reveal (2003) offer some advice for their cultivation that might be useful in efforts to restore occurrences of *E. exilifolium*. Introduced occurrences are of lesser conservation value than occurrences in their known range (Given 1994).

Research priorities for Region 2

The highest research priority in Region 2 is a better understanding of the abundance and distribution of *Eriogonum exilifolium*. Determination of total population size and range is fundamental in understanding the species' rarity and prioritizing its conservation needs. Conservation actions cannot act effectively on behalf of undiscovered occurrences.

Reaching a better understanding of the influence of human activities, including grazing, on individuals and the habitat of *Eriogonum exilifolium* will confer practical benefits on land managers and planners. Medicine Bow National Forest (2003, p. I-261) notes, "There are no quantitative monitoring data to indicate what levels and types of disturbances might benefit this species, and which are detrimental." Identifying life history and phenological stages that are less sensitive to grazing would help with developing grazing practices that are compatible with *E. exilifolium*. Exploring the effects of exclosures, stocking rates, timing of grazing, and pasture rotation is likely to yield valuable information.

Monitoring the impact of non-native species on *Eriogonum exilifolium* will help to ensure that occurrences are not invaded and degraded by weeds. It will also help to assess the importance of weed management for the conservation for this species.

Studies of the habitat requirements and autecology of *Eriogonum exilifolium* are needed. Information gleaned from studies of the physiological and community ecology of *E. exilifolium* will be valuable in the event that an occurrence needs to be restored, and it will help to determine biotic and abiotic factors that contribute to its survival.

Understanding plant-environment relationships for *Eriogonum exilifolium* may reveal the coping strategies employed by this species and will help to model its potential distribution and understand the causes of its rarity. Testing hypotheses regarding the causes of endemism and rarity in *E. exilifolium* will improve our understanding of management, locations for inventory, and potential reintroduction sites. An understanding of the degree to which *E. exilifolium* tolerates a variety of human and natural disturbance regimes will assist with developing conservation strategies and management plans.

Demographic studies are needed for *Eriogonum exilifolium*. Demographic data are more helpful in assessing status and developing recovery efforts than is genetic information (Schemske et al. 1994). Determining the critical life history stages of *E. exilifolium* will allow managers to focus efforts on implementing management protocols that benefit those stages. A monitoring program that determines the effective population size and investigates the growth, survival, and reproduction of individuals within occurrences will help to determine the conservation status of *E. exilifolium*. An investigation of the population genetics of *E. exilifolium* would also be a valuable tool for its conservation. The determination of the species' genetic diversity and whether there are genetic differences among occurrences is an important question. Understanding the role of pollinators in the population biology of *E. exilifolium* will clarify the relative importance of floral visitors in pollen transfer.

Additional research and data resources

A forthcoming volume of the Flora of North America will include a treatment of *Eriogonum* by Dr. James Reveal that was not available for inclusion in this report. The Rawlins Field Office BLM is currently drafting a Revised Resource Management Plan (Bureau of Land Management 2005) that will have implications for the management and viability of *E. exilifolium*. The Medicine Bow National Forest is drafting an Allotment Management Plan that may or may not include protective measures for *E. exilifolium* at the two occurrences found on that forest.

DEFINITIONS

Abaxial – the lower surface of a leaf (away from the axis) (Harris and Harris 1999).

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

Conservation Status Rank – the Global (G) Conservation Status (Rank) of a species or ecological community is based on the *range-wide* status of that species or community. The rank is regularly reviewed and updated by experts, and takes into account such factors as number and quality/condition of occurrences, population size, range of distribution, population trends, protection status, and fragility. A subnational (S) rank is determined based on the same criteria applied within a subnation (state or province). The definitions of these ranks, which are not to be interpreted as legal designations, are as follows:

GX Presumed Extinct: Not located despite intensive searches and virtually no likelihood of rediscovery.

GH Possibly Extinct: Missing; known only from historical occurrences but still some hope of rediscovery.

G1 Critically Imperiled: At high risk of extinction due to extreme rarity (often 5 or fewer occurrences), very steep declines, or other factors.

G2 Imperiled: At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.

G3 Vulnerable: At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.

G4 Apparently Secure: Uncommon but not rare; some cause for long-term concern due to declines or other factors.

G5 Secure: Common; widespread and abundant.

Competive/Stress-tolerant/Ruderal (CSR) 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 mophological expression of a unique genotype that is adapted to particular habitat attributes (after Allaby 1998)

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).

Stomata (plural for Stomate) – a pore or aperature, surrounded by two guard cells, which allows gaseous exchange (Harris and Harris 1999).

Tomentum – a covering of short, soft, matted, wooly hairs (Harris and Harris 1999).

References

Abdel-Kader, M.S. and F.R. Stermitz. 1996. Cytotoxic phenolic glucosides from flowers of *Eriogonum brevicaule*. Planta Medica 62:383.

Allaby, M. 1998. A Dictionary of Plant Sciences. Oxford University Press, New York, NY.

Alpe, M. 2006. Personal communication with Rangeland Management Specialist with the Medicine-Bow/Routt National Forest regarding *Eriogonum exilifolium*.

Archibald, J.K., P.G. Wolf, V.J. Tepedino, and J. Bair. 2001. Genetic relationships and population structure of the endangered steamboat buckwheat, *Eriogonum ovalifolium* var. *williamsiae* (Polygonaceae). American Journal of Botany 88:608-615.

Ayensu, E.S. and R.A. DeFilipps. 1978. Endangered and Threatened Plants of the United States. Smithsonian Institution and World Wildlife Fund, Inc., Washington, D.C.

Ayer, W.A., L.M. Browne, and G.C. Kasitu. 1989. Metabolites of *Eriogonum umbellatum*. Planta Medica 56:336.

Bailey, R.G. 1995. Description of the Ecoregions of the United States. Second edition. Misc. Publ. No. 1391. USDA Forest Service, Washington, D.C.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial Plant Ecology. Benjamin/Cummings Publishing Company, Inc., Menlo Park, CA.

Barnett, J.K. and J.A. Crawford. 1994. Pre-laying nutrition of sage grouse hens in Oregon. Journal of Range Management 47:114-118.

Baskin, C.C., P.L. Chesson, and J.M. Baskin. 1993. Annual seed dormancy cycles in two desert winter annuals. Journal of Ecology 81:551-556.

Bell, C.R. 1971. Breeding systems and floral biology of the Umbelliferae, or evidence for specialization in unspecialized flowers. Pages 93-107 *in* V.H. Heywood, editor. The Biology and Chemistry of the Umbelliferae. Botanical Journal of the Linnean Society 64, Supplement 1.

Bellmer, E.H. 1969. Distribution, Variation, and Chromosome Number in the Appalachian Shale Barren endemic *Eriogonum allenii* Watson (dissertation). Catholic University of America, Washington, D.C.

Bogue Technologies International. 2002. Wyoming Mine Locations. Accessed via the internet at http://www.trainweb.org/wyomingrails/wymining/wymines.html.

Brekke, E. 2004. Personal communication with Bureau of Land Management Wildlife Biologist regarding *Eriogonum brandegeei*.

Brown, A.H.D. 1989. Genetic characterization of plant mating systems. Pages 145-162 *in* A.H.D. Brown, M.T. Clegg, A.L. Kahler, and B.S. Weir, editors. Plant Population Genetics, Breeding, and Genetic Resources. Sinauer Associates, Inc., Sunderland, MA.

Bullock, J. 1996. Plants. Chapter 3 *in* W.J. Sutherland, editor. Ecological Census Techniques: A Handbook. Cambridge University Press, Cambridge, UK.

Bunting, S.C., B.M. Kilgore, and C.L. Bushey. 1987. Guidelines for Prescribed Burning Sagebrush-Grass Rangelands in the Northern Great Basin. General Technical Report INT-231. USDA Forest Service Intermountain Research Station, Ogden, UT.

Bureau of Land Management. 1981. McCallum Coal Area EMRIA Study Site Description, Jackson County, Colorado. Bureau of Land Management Kremmling Field Office, Kremmling, CO.

Bureau of Land Management. 1984. Kremmling Resource Area, Resource Management Plan and Record of Decision. Bureau of Land Management Kremmling Field Office, Kremmling, CO.

Bureau of Land Management. 2000a. Colorado BLM State Director's Sensitive Species List. Accessed via the internet at http://www.co.blm.gov/botany/sens_species.htm.

Bureau of Land Management. 2000b. Kremmling Field Office Decisions Record and Resource Management Plan Amendment- Land Acquisition Land Use Priorities. Bureau of Land Management Kremmling Field Office, Kremmling, CO.

Bureau of Land Management. 2001a. BLM Wyoming Sensitive Species Policy and List. Accessed via the internet at http://www.wy.blm.gov/.

Bureau of Land Management. 2001b. National Management Strategy for Motorized Off-Highway Vehicle Use on Public Lands. U.S. Department of Interior, Bureau of Land Management, Washington, D.C.

Bureau of Land Management. 2004. Rawlins Resource Management Plan. Accessed via the Web at http://www.rawlinsrmp.com. Wyoming.

Burkhart, B. 2002. Region 2 Sensitive Species Evaluation Form for *Eriogonum exilifolium*. USDA Forest Service Region 2, Lakewood, CO.

Burns, D.A. 2002. The Effects of Atmospheric Nitrogen Deposition in the Rocky Mountains of Colorado and Southern Wyoming- a Synthesis and Critical Assessment of Published Results. U.S. Geological Survey Water Resources Investigations Report 02-4066.

Burrows, G.E. and R.J. Tyrl. 2001. Toxic Plants of North America. Iowa State University Press, Ames, IA.

Cables, R. 2003. Final Environmental Impact Statement and Revised Land and Resource Management Plan- Medicine Bow National Forest. USDA Forest Service, Rocky Mountain Region, Lakewood, CO.

Carlquist, S. 2003. Wood anatomy of polygonaceae: analysis of a family with exceptional wood diversity. Botanical Journal of the Linnean Society 141:25-51.

Caswell, H. 2001. Matrix Population Models. Second Edition. Sinauer Associates, Inc., Sunderland, MA.

Center for Plant Conservation. 2003. National Collection of Endangered Plants. Accessed via the internet at: http://ridgwaydb.mobot.org/cpcweb/CPC_NCList_Find.asp. Missouri Botanical Garden.

Cesar, C. 2004. Personal communication with Bureau of Land Management Wildlife Biologist for the Kremmling Field Office regarding *Eriogonum exilifolium*.

Chapin, D.M. and L.C. Bliss. 1988. Soil-plant water relations of two subalpine herbs from Mount St. Helens. Canadian Journal of Botany 66:809-818.

Cole, N.H.A. 1967. Comparative Physiological Ecology of Genus *Eriogonum* in Santa Monica Mountains Southern California. Ecological Monographs 37:1-96.

Colorado Division of Wildlife. 1998. Colorado GAP Analysis Land Cover Map. Denver, CO: Colorado Division of Wildlife.

Colorado Division of Wildlife. 2003. Basinwide vegetation mapping, Colorado Vegetation Classification Project, data available from www.ndis.nrel.colostate.edu.

Colorado Natural Heritage Program. 2005. Biodiversity Tracking and Conservation System. Colorado State University, Fort Collins, CO.

Colorado State Herbarium. 2004. History [of the Herbarium]. Accessed via the internet at http://herbarium.biology.colostate.edu/history.htm. Colorado State University, Fort Collins, CO.

Colorado Weed Management Association. 2005. Colorado's Weed List. Accessed via the Web at http://www.cwma.org/.

Cronquist, A., A.H. Holmgren, N.H. Holmgren, and J.L. Reveal. 1986. Intermountain Flora-Vascular Plants of the Intermountain West, U.S.A. Volume 1. The New York Botanical Garden, New York, NY.

Culver, D. and J. Jones. In prep. Survey of Critical Biological Resources: Grand County, CO.

Dawson, C. 2004. Personal communication with Bureau of Land Management Botanist regarding *Eriogonum brandegeei*.

Day, T.A. and R.G. Wright. 1989. Positive plant spatial association with *Eriogonum ovalifolium* in primary succession on cinder cones: seed-trapping nurse plants. Vegetatio 80:37-45.

Decker, K., A. Lavender, and D.G. Anderson. 2005. Modeling the Potential Distribution of *Phacelia scopulina* var. *submutica* (Debeque Phacelia) and *Astragalus debequaeus* (Debeque Milkvetch) in Western Colorado. Prepared by the Colorado Natural Heritage Program for U.S. Fish and Wildlife Service and Colorado State Parks.

Dillon, B. 1999. Yellow Starthistle Threatens Local Rangeland, Livestock. Newspaper article published August 12, 1999. Montrose Daily Press, Montrose, CO.

Dorn, R.D. 1977. Manual of the Vascular Plants of Wyoming. Garland Publishing, Inc., New York, NY.

Dorn, R.D. 1992. Vascular Plants of Wyoming. Second edition. Mountain West Publishing, Cheyenne, WY.

Doyle, G. 2004. Personal communication with Colorado Natural Heritage Program botanist/ ecologist regarding *Eriogonum exilifolium*.

Doyle, G., S.L. Neid, and R. Rondeau. 2005. Survey of Critical Biological Resources: Larimer County, Colorado, 2004. Report prepared for Larimer County Parks and Open Lands, City of Fort Collins Natural Areas Program, Loveland Natural Areas Program, and Larimer County Planning Department by the Colorado Natural Heritage Program.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM Technical Reference 1730-1. USDI Bureau of Land Management, Denver, CO.

Ewan, J. and N.D. Ewan. 1981. Biographical Dictionary of Rocky Mountain Naturalists. Dr. W. Junk, Publishers, Boston, MA.

Fernando, A.A. and R.S. Currah. 1996. A comparative study of the effects of the root endophytes *Leptodontidium orchidicola* and *Phialocephala fortinii* (fungi imperfecti) on the growth of some subalpine plants in culture. Canadian Journal of Botany 74:1071-1078.

Fertig, W. 2000a. State Species Abstract for *Eriogonum exilifolium*- Slender-leaved Buckwheat. Wyoming Natural Diversity Database, Laramie, WY.

Fertig, W. 2000b. State Species Abstract for *Machaeranthera coloradoensis* var. *coloradoensis*. Wyoming Natural Diversity Database, Laramie, WY.

Fertig, W. 2004. Personal communication with former Wyoming Natural Diversity Database Botanist regarding *Eriogonum exilifolium*.

Fertig, W. and G. Jones. 1997. Plant species of special concern and plant associations of the Shirley Mountains ecosystem Carbon County, Wyoming. Unpublished report prepared for the Bureau of Land Management Wyoming State Office by the Wyoming Natural Diversity Database, Laramie, WY.

Fertig, W. and R. Thurston. 2003. Modeling the Potential Distribution of BLM sensitive and USFWS Threatened and Endangered Plant Species. Wyoming Natural Diversity Database, Laramie, WY.

Forman, R.T.T. and L.E. Alexander. 1998. Roads and their major ecological effects. Annual Reviews of Ecological Systems 29:207-231.

Frye, A.S.L. and K.A. Kron. 2003. Phylogeny and Character Evolution in Polygonaceae. Systematic Botany 28:326-332.

Giorgi, F., L.O. Mearns, C. Shields, and L. McDaniel. 1998. Regional nested model simulations of present day and 2 x CO_2 climate over the central plains of the U.S. Climatic Change 40:457-493.

Gitzendanner, M.A. and P.S. Soltis. 2000. Patterns of genetic variation in rare and widespread plant congeners. American Journal of Botany 87:783-792.

Grant, V. 1949. Pollination systems as isolating mechanisms in Angiosperms. Evolution 3:82-97.

Grime, J.P. 2001. Plant Strategies, Vegetation Processes, and Ecosystem Properties. Second edition. John Wiley & Sons, Chichester, West Sussex, England.

Gross, K.L., M.R. Willig, and R. Gough. 2000. Patterns of species density and productivity at different spatial scales in herbaceous plant communities. Oikos 89:417-427.

Haas, W. 2005. Personal communication with Medicine Bow National Forest Range and Wildlife Specialist regarding grazing allotment status.

Hall, F.C. 2002. Photo Point Monitoring Handbook- Parts A and B. General Technical Report PNW-GTR 526. USDA Forest Service Pacific Northwest Research Station, Portland, OR.

Hamrick, J.L. and M.J.W. Godt. 1989. Allozyme diversity in plant species. Pages 44-64 *in* A.H.D. Brown, M.T. Clegg, A.L. Kahler, and B.S. Weir, editors. Population Genetics and Germplasm Resources in Crop Improvement. Sinauer Associates, Inc., Sunderland, MA.

Hamrick, J.L., Y.B. Linhart, and J.B. Mitton. 1979. Relationship between life history characteristics and electrophoretically detectable genetic variation in plants. Annual Review of Ecology and Systematics 10:173-200.

Handley, J. and S. Laursen. 2002. Region 2 Sensitive Species Evaluation Form for *Eriogonum exilifolium*. USDA Forest Service Region 2.

Harley, J.L. 1991. Introduction: The state of the art. Pages 1-24 *in* J.R. Norris, D.J. Read, and A.K. Varma, editors. Methods in Microbiology, Vol. 23. Academic Press, London, England.

Harrington, H.D. 1954. Manual of the Plants of Colorado. Sage Books, Denver, CO.

Harris, J.G. and M.W. Harris. 1999. Plant Identification Terminology- an Illustrated Glossary. Spring Lake Publishing, Spring Lake, UT.

Heidel, B. 2004. Personal communication with Wyoming Natural Diversity Database Botanist regarding *Eriogonum exilifolium*.

Heidel, B. 2005. Personal communication with Wyoming Natural Diversity Database Botanist regarding *Penstemon laricifolius* ssp. *exilifolius*.

Heywood, V.H. 1993. Flowering Plants of the World. Oxford University Press, New York, NY.

Hickman, J.C. 1993. The Jepson Manual- Higher Plants of California. University of California Press, Berkeley, CA.

Holte, J.E. 1994. Effects of vesicular-arbuscular mycorrhizae on growth, reproduction and survival in three plant species in a sand dune restoration site in Monterey, California (Master's Thesis). San Jose University, San Jose, CA.

Houston, S. and M. Sidle. 2002. Region 2 Individual Species Recommendations for *Eriogonum exilifolium* (Revised by A. Kratz and N. Warren). USDA Forest Service Region 2.

Huxman, T.E. and S.D. Smith. 2001. Photosynthesis in an invasive grass and native forb at elevated CO_2 during an El Nino year in the Mojave Desert. Oecologia 128:193-201.

Inoue, K. and T. Kawahara. 1990. Allozyme differentiation and genetic structure in island and mainland Japanese populations of *Campanula punctata* (Campanulaceae). American Journal of Botany 77:1440-1448.

Jankovsky-Jones, M., G.P. Jones, and W. Fertig. 1996. Ecological evaluation of the potential Sheep Mountain Research Natural Area within the Medicine Bow National Forest, Albany County, Wyoming. Laramie, WY: unpublished report prepared for the Medicine Bow National Forest by the Wyoming Natural Diversity Database.

Johnston, B.C., J.S. Peterson, and W. Harmon. 1981. Status Report for *Eriogonum brandegeei* Rydb. Colorado Natural Areas Program, Denver, CO.

Jones, G.P. and W. Fertig. 1996. Ecological evaluation of the potential Cedar Pass Research Natural Area within the Medicine Bow National Forest, Carbon County, Wyoming. Unpublished report prepared for the Medicine Bow National Forest by the Wyoming Natural Diversity Database, Laramie, WY.

Karron, J.D. 1991. Patterns of genetic variation and breeding systems in rare plant species. Pages 87-98 *in* D. Falk and K. Holsinger. Genetics and Conservation of Rare Plants. Oxford Press, Oxford, England.

Kartesz, J.T. 1999. A Synonymized Checklist and Atlas with Biological Attributes for the Vascular Flora of the United States, Canada, and Greenland. First Edition. *In*: J.T. Kartesz and C.A. Meacham. Synthesis of the North American Flora [computer program]. Version 1.0. North Carolina Botanical Garden, Chapel Hill, NC.

Kearney, T.H. and R.H. Peebles. 1960. Arizona Flora. Second edition. University of California Press, Berkeley, CA.

Kearns, C.A. and D.W. Inouye. 1993. Techniques for Pollination Biologists. University Press of Colorado, Niwot, CO.

Köchy, M. and S.D. Wilson. 2001. Nitrogen deposition and forest expansion in the northern Great Plains. The Journal of Ecology 89:807-817.

Kuyper, K.F., U. Yandell, and R.S. Nowak. 1997. On the taxonomic status of *Eriogonum robustum* (Polygonaceae), a rare endemic in western Nevada. Great Basin Naturalist 57:1-10.

LaFontaine, V. 2005. Personal communication with Roosevelt National Forest Range and Wildlife specialist regarding grazing allotment status.

Lande, R. 1998. Anthropogenic, ecological and genetic factors in extinction and conservation. Researches on Population Ecology 40:259-269.

Law, R. 1985. Evolution in a mutualistic environment. Pages 145-170 *in* D.H. Boucher, editor. The Biology of Mutualism, Ecology and Evolution. Oxford University Press, New York, NY.

Lesica, P. 1987. A technique for monitoring nonrhizomatous, perennial plant species in permanent belt transects. Natural Areas Journal 7:65-68.

Limerick, S. 1984. Recovery Plan for Gypsum Wild Buckwheat (*Eriogonum gypsophilum* Wooton and Standley). Office of Endangered Species, U.S. Fish and Wildlife Service, Albuquerque, NM.

Lindborg, R. and J. Ehrlén. 2002. Evaluating the extinction risk of a perennial herb: demographic data versus historical records. Conservation Biology 16:683-690.

Loveless, M.D. and J.L. Hamrick. 1989. Ecological determinants of genetic structure in plant populations. Annual Review of Ecology and Systematics 15:65-95.

Lovell, H.B. 1969. Lets Talk About Honey Plants - *Eriogonum* - Wild Buckwheat. Gleanings in Bee Culture 97:611-612.

Lyon, P. and M. Denslow. 2001. Gunnison Gorge Natural Conservation Area Survey of Impacts on Rare Plants. Unpublished report prepared for the Bureau of Land Management, Montrose, CO by the Colorado Natural Heritage Program.

MacArthur, R.H. and E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton, NJ.

Malanson, G.P. 1982. Modeling postfire succession in coastal sage scrub. Page 616 *in* C.E. Conrad and W.C. Oechel, technical coordinators. Proceedings of the symposium on dynamics and management of Mediterranean- type ecosystems. Pacific Southwest Forest and Range Experiment Station General technical report PSW-58, Berkeley, CA.

Manabe, S. and R.T. Wetherald. 1986. Reduction in summer soil wetness induced by an increase in atmospheric carbon dioxide. Science 232:626-628.

Margueles, C.R. and R.L. Pressey. 2000. Systematic conservation planning. Nature 405:243-253.

Matthies, D., I. Bräuer, W. Maibom, and T. Tscharntke. 2004. Population size and the risk of local extinction: empirical evidence from rare plants. Oikos 105:481-488.

McKee, T.B., N.J. Doesken, F.M. Smith, and J.D. Kleist. 1981. Climate Profile for the McCallum EMRIA Study Area. Colorado Climate Center, Colorado State University, Fort Collins, CO.

Medicine Bow National Forest. 2003. Revised Land and Resource Management Plan and Final Environmental Impact Statement. USDA Forest Service Region 2, Lakewood, CO.

Menges, E.S. 1991. Predicting the future of rare plants: demographic monitoring and modeling. Natural Areas Journal 6:13-25.

Meyer, S.E. and A. Paulsen. 2000. Chilling requirements for seed germination of 10 Utah species of perennial wild buckwheat (*Eriogonum* Michx. (Polygonaceae)). Native Plants Journal 1(1):18-24.

Miller, A. 2004. Personal communication with National Center for Genetic Resource Preservation Seed Analyst regarding *Eriogonum exilifolium*.

Miriti, M.N., H.F. Howe, and S.J. Wright. 1998. Spatial patterns of mortality in a Colorado desert plant community. Plant Ecology 136:41-51.

Mooney, H.A., C. Field, W.E. Williams, J.A. Berry, and O. Bjorkman. 1983. Photosynthetic characteristics of plants of a Californian cool coastal environment. Oecologia 57:38-42.

Morefield, J.D. 1996. Current Knowledge and Conservation Status of *Eriogonum lewisii* Reveal (Polygonaceae), the Lewis Buckwheat. Nevada Natural Heritage Program, Carson City, NV.

Morefield, J.D. 2000. Current Knowledge and Conservation Status of *Eriogonum robustum* E. Greene (Polygonaceae), the Altered Andesite Buckwheat. Nevada Natural Heritage Program, Carson City, NV.

Munn, L.C. and C.S. Arneson. 1999a. Draft 1:100,000-Scale Digital Soils Map of Albany County. University of Wyoming Agricultural Experiment Station. Laramie, WY.

Munn, L.C. and C.S. Arneson. 1999b. Draft 1:100,000-Scale Digital Soils Map of Carbon County. University of Wyoming Agricultural Experiment Station. Laramie, WY.

Mutel, C.F. and J.C. Emerick. 1992. From Grassland to Glacier- the Natural History of Colorado and the Surrounding Region. Johnson Books, Boulder, CO.

Myatt, R.G. and S. Kaufman. 1986. Comparative anatomy of erect versus prostrate flowering stems in *Eriogonum* Michx. American Journal of Botany 73:776-777.

NatureServe. 2005. NatureServe Explorer: an Online Encyclopedia of Life. Accessed via the Web at: http://www.natureserve.org/explorer.

Neel, M.C. and M.P. Cummings. 2003. Genetic consequences of ecological reserve design guidelines: An empirical investigation. Conservation Genetics 4:427-439.

Neel, M.C. and N.C. Ellstrand. 2003. Conservation of genetic diversity in the endangered plant *Eriogonum ovalifolium* var. *vineum*. Conservation Genetics 4:337-352.

Neel, M.C., J. Ross-Ibarra, and N.C. Ellstrand. 2001. Implications of Mating Patterns for Conservation of the Endangered Plant *Eriogonum ovalifolium* var. *vineum* (Polygonaceae). American Journal of Botany 88:1214-1222.

Neely, B., P. Comer, C. Moritz, M. Lammert, R. Rondeau, C. Pague, G. Bell, H. Copeland, J. Humke, S. Spackman, T. Schulz, D. Theobald, and L. Valutis. 2001. Southern Rocky Mountains: An Ecoregional Assessment and Conservation Blueprint. Prepared by the Nature Conservancy with support from the USDA Forest Service, Rocky Mountain Region, Colorado Division of Wildlife, and Bureau of Land Management.

Nelson, B.E. 2004. Personal communication with Botanist/ Assistant Curator of the Rocky Mountain Herbarium regarding *Eriogonum exilifolium*.

New York Botanical Garden. 2004. Vascular Plant Type Catalog. Image of *Eriogonum exilifolium* type specimen. Accessed via the Web at http://www.nybg.org/bsci/hcol/vasc/.

Noss, R.F., M.A. O'Connell, and D. Murphy. 1997. The Science of Conservation Planning: Habitat Conservation under the Endangered Species Act. Island Press, Covello, CA.

Nunn, S.C. 2003. A Vascular Flora of the Canyon Lakes Ranger District of Roosevelt National Forest, Larimer County, and Adjacent Areas, Colorado (Master's Thesis). University of Arkansas.

Oostermeijer, J.G.B., S.H. Luijten, and J.C.M. den Nijs. 2003. Integrating demographic and genetic approaches in plant conservation. Biological Conservation 113:389-398.

Parenti, R.L., Jr., A.F. Robinson, and J. Kagan. 1993. Bradshaw's Lomatium Recovery Plan. Unpublished report prepared for the U.S. Fish and Wildlife Service, Portland, OR.

Pavlovic, N.B., M. DeMauro, and M. Bowles. 1992. Perspectives on plant competition- Plant collection rate should be positively correlated with plant population size. Plant Science Bulletin 38:8.

Perez, C.J., S.S. Waller, L.W. Moser, J.L. Stubbendieck, and A.A. Steuter. 1998. Seedbank characteristics of a Nebraska sandhills prairie. Journal of Range Management 51:55-62.

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Powell, J. 2003. Personal communication with Colorado Department of Transportation threatened and endangered species specialist regarding management of roadside plant populations.

Proctor, J. 2004. Personal communication with Medicine Bow-Routt National Forest Botanist regarding *Eriogonum exilifolium*.

Reveal, J.L. 1967a. Notes on Eriogonum III on the Status of *Eriogonum pauciflorum* Pursh. The Great Basin Naturalist 27(2):114-117.

Reveal, J.L. 1967b. Subgeneric Concept in *Eriogonum* (Polygonaceae). American Journal of Botany 54:630.

Reveal, J.L. 1969. A revision of the genus *Eriogonum* (Polygonaceae). Unpublished doctoral dissertation. University Library, Brigham Young University.

Reveal, J.L. 1981. Notes on endangered buckwheats (*Eriogonum*, Polygonaceae) with 3 newly described from the western United-States. Brittonia 33:441-448.

Reveal, J.L. 1985. New Nevada entities and combinations in *Eriogonum* (Polygonaceae). Great Basin Naturalist 45: 276-280.

Reveal, J.L. 1989a. The Eriogonoid flora of California (Polygonaceae: Eriogonoideae). Phytologia 66:295-414.

Reveal, J.L. 1989b. A checklist of the Eriogonoideae (Polygoneace). Phytologia 66:266-294.

Reveal, J.L. 2002. Personal communication with expert on *Eriogonum* regarding *E. coloradense*.

Reveal, J.L. 2003. *Eriogonum* as a Rock Garden Plant. accessed via Web at: www.life.umd.edu/emeritus/reveal/pbio/eriog/eriogarden.html. University of Maryland.

Reveal, J.L. 2004. Personal communications with expert on *Eriogonum* regarding *E. brandegeei* and *E. exilifolium*.

Reveal, J.L., F. Caplow, and K. Beck. 1995. *Eriogonum codium* (Polygonaceae: Eriogonoideae), A new species from southcentral Washington. Rhodora 97:350-356.

Reveal, J.L. and A.H. Holmgren. 1965. Documented chromosome numbers. Madrono 18:124.

Reveal, J.L., J. Reynolds, and J. Picciani. 2002. *Eriogonum diatomaceum* (Polygonaceae: Eriogonoideae), a new species from western Nevada, U.S.A. Novon 12:87-89.

Rickard, W.H. 1989. Response of round-headed buckwheat to summer burning. Northwest Science 63:144-145.

Rickett, H.W. 1973. Wildflowers of the United States. Volume 6, Part 1. McGraw-Hill Book Company, New York, NY.

Roche, K. 2004. Letter of instruction for revision of: *Eriogonum exilifolium* Reveal (dropleaf buckwheat): A Technical Conservation Assessment (Draft). Submitted for peer review by D.G. Anderson, Colorado Natural Heritage Program. Fort Collins, CO.

Rondeau, R. 2000a. Sagebrush Shrubland- Matrix. Community Characterization Abstract produced for the Colorado Natural Heritage Program and the Nature Conservancy.

Rondeau, R. 2000b. Sagebrush Steppe- Matrix. Community Characterization Abstract produced for the Colorado Natural Heritage Program and the Nature Conservancy, Fort Collins, CO.

Rondeau, R. 2001. Montane/Subalpine Grassland. Colorado Natural Heritage Program, Fort Collins, CO.

Rondeau, R. 2002. Shale-Siltstone Barrens System. Colorado Natural Heritage Program, Fort Collins, CO.

Rosendahl, S., C.N. Rosendahl, and U. Sochting. 1992. Distribution of VA mycorrhizal endophytes amongst plants from a Danish grassland community. Agric Ecosystem and Environment 29:329-335.

Ryti, R.T. 1992. Relationship between Density of Aphid Host Plants and an Associated Aphid-tending Ant (*Formica altipetens*). The American Midland Naturalist 127:190-197.

Satterthwaite, W.H., E.S. Menges, and P.F. Quintana-Ascencio. 2002. Assessing scrub Buckwheat population viability in relation to fire using multiple modeling techniques. Ecological Applications 12:1672-1687.

Savile, D.B.O. 1966. The rusts of *Eriogonum*, *Chorizanthe*, and *Oxytheca*. Canadian Journal of Botany 44:1151-1170.

Schemske, D.W., B.C. Husband, M.H. Ruckelshaus, C. Goodwillie, I.M. Parker, and J.G. Bishop. 1994. Evaluating approaches to the conservation of rare and endangered plants. Ecology 75:584-606.

Schwartz, M.W. and C.A. Brigham. 2003. Why plant population viability assessment? Chapter 1 *in* C.A. Brigham and M.W. Schwartz, editors. Population Viability in Plants. Springer-Verlag, Berlin.

Scott, M.J., P.J. Heglund, M.L. Morrison, J.B. Haufler, M.G. Raphael, W.A. Wall, and F.B. Samson. 2002. Predicting Species Occurrences- Issues of Accuracy and Scale. Island Press, Washington, D.C.

Scully, R. 2004. Personal communication with Colorado Native Plant Society botanist regarding *Eriogonum exilifolium*.

Shields, O. and J.L. Reveal. 1988. Sequential evolution of *Euphilotes* (Lycaenidae: Scolitantidini) on their plant host *Eriogonum* (Polygonaceae: Eriogonoideae). Biological Journal of the Linnean Society 33:51-93.

Slaby, P. 2001. *Eriogonum exilifolium*. Accessed via the Web at: http://web.kadel.cz. Rock Garden Database.

Small, J.K. 1906. Studies in North American Polygonaceae II. Bulletin of the Torrey Botanical Club 33:51-57.

Soule, M.E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-169 *in* M.E. Soule and B.A. Wilcox, editor. Conservation Biology: an Evolutionary Perspective Sinauer Associates, Inc., Sunderland, MA.

Spackman-Panjabi, S. 2004. Personal communication with Colorado Natural Heritage Program Botanist regarding *Eriogonum brandegeei*.

Spellenberg, R., C. Leiva, and E.P. Lessa. 1988. An Evaluation of *Eriogonum densum* (Polygonaceae). Southwestern Naturalist 33:71-80.

Stevens, P.F. 2001 onwards. Angiosperm Phylogeny Website. Version 6, May 2005 [and more or less continuously updated since] http://www.mobot.org/MOBOT/research/APweb/.

Stokes, S.G. 1936. The Genus *Eriogonum*, a Preliminary Study Based on Geographic Distribution. J.H. Neblett Pressroom, San Francisco, CA.

Stokes, S.G. and L. Stebbins. 1955. Chromosome numbers in the genus *Eriogonum*. Leaflets of Western Botany 7: 228-233.

Tarango, L.A., P.R. Krausman, R. Valdez, and R.M. Kattnig. 2002. Research observation: desert bighorn sheep diets in northwestern Sonora, Mexico. Journal of Range Management 55:530-534.

Tepedino, V. 2002. Pollination biology research in relationship to rare plants. Presentation to the Colorado Native Plant Society's Annual Meeting on September 21, 2002.

The Nature Conservancy and the Association for Biodiversity Information. 2000. Precious Heritage. B. Stein, L. Kutner, and J. Adams, editors. Oxford University Press, Inc., New York, NY.

Train, P., J.R. Henrichs, and W.A. Archer. 1957. Medicinal Uses of Plants by Indian Tribes of Nevada. Quarterman Publications, Lawrence, MA.

Turner, G.T. 1975. Mountain Grassland Ecosystem. USDA Forest Service Research Paper RM-161. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Tweto, O. 1979. Geologic Map of Colorado. Compiled by the U.S. Geological Survey with technical assistance by the Colorado Geological Survey.

U.S. Census Bureau. 2003. 1990 and 2000 census data for Fremont and Pueblo Counties. Accessed via the internet at www.census.gov.

U.S. Congress Office of Technology Assessment. 1986. Western Surface Mine Permitting and Reclamation, OTA-E-279. U.S. Government Printing Office, Washington, D.C.

USDA Forest Service Region 2. 2003. Forest Service Manual Rocky Mountain Region. Chapter 2670: Threatened, Endangered, and Sensitive Plants and Animals. Lakewood, CO. Forest Service Region 2.

USDA Natural Resource Conservation Service. The PLANTS Database. Accessed via the Web at: http://plants.usda.gov. 2003. National Plant Data Center, Baton Rouge, LA.

USDA Soil Conservation Service. 1980. Larimer County Soil Survey. Colorado Agricultural Experimental Station, Fort Collins, CO.

USDA Soil Conservation Service. 1994. State Soil Geographic (STATSGO) database for Colorado. USDA Soil Conservation Service, Fort Worth, TX.

U.S. Environmental Protection Agency. 1997. Climate Change and Colorado. EPA 230-F-97-008f. Office of Policy, Planning, and Evaluation, Climate and Policy Assessment Division, Washington, D.C.

U.S. Fish and Wildlife Service. 1983. A Colorado wild-buckwheat proposed with critical habitat. Endangered Species Technical Bulletin 8:3-5.

U.S. Fish and Wildlife Service. 1986. North Park Phacelia (*Phacelia formosula*) Recovery Plan. U.S. Fish and Wildlife Service, Denver, CO.

U.S. Fish and Wildlife Service. 1995. Steamboat Buckwheat (*Eriogonum ovalifolium* var. *williamsiae*) Recovery Plan. Portland, OR. 32 pages plus appendices.

U.S. Geological Survey. 1994. Bedrock Geology of Wyoming. U.S. Geological Survey, Denver, CO.

University of Colorado Herbarium. 2004. Vascular Plants by County. Accessed via the internet at http://cumuseum.colorado.edu/Research/Botany/botany_databases.html. University of Colorado, Boulder, CO.

University of Wyoming. 1996. Land Cover for Wyoming. Second edition. Spatial Data and Visualization, University of Wyoming, Laramie, WY.

Wagner, D.H. 1991. The 1 in 20 rule for plant collectors. Plant Science Bulletin 37:11.

Weber, W.A. and R.C. Wittmann. 2000. Catalog of the Colorado Flora: A Biodiversity Baseline. Electronic version, revised March 11, 2000. University of Colorado Museum, Boulder, CO.

Weber, W.A. and R.C. Wittmann. 2001a. Colorado Flora: Eastern Slope. Third edition. University Press of Colorado, Boulder, CO.

Weber, W.A. and R.C. Wittmann. 2001b. Colorado Flora: Western Slope. Third edition. University Press of Colorado, Boulder, CO.

Welsh, S.L. 1984. Utah Flora: Polygonaceae. Great Basin Naturalist 44:519-557.

West, N.E. and J.A. Young. 2000. Intermountain valleys and lower mountain slopes. *In*: M.G. Barbour and W.D. Billings, editors. North American Terrestrial Vegetation. Second Edition. Cambridge University Press, New York, NY.

Western Regional Climate Center. 2003. Climate Summaries. Accessed via the internet at http://www.wrcc.dri.edu/summary/.

Wikeem, B.M. and M.D. Pitt. 1991. Grazing effects and range trend assessment on California bighorn sheep range. Journal of Range Management 44:466-470.

Wikeem, B.M. and M.D. Pitt. 1992. Diet of California bighorn sheep, *Ovis canadensis californiana*, in British Columbia: Assessing optimal foraging habitat. The Canadian Field-Naturalist 106:327-335.

Wiley, K.L. 1979. Status Report on *Phacelia formosula* Osterhout. U.S. Fish and Wildlife Service, Denver, CO.

Wyoming Natural Diversity Database. 2005. Element occurrence records and ancillary data for *Eriogonum exilifolium*. Wyoming Natural Diversity Database. Laramie, WY.

Young, J.A. 1989. Germination of seeds of sulfur flower (*Eriogonum umbellatum* Torr). Journal of Seed Technology 13:31-38.

Young, J.A. and R.R. Blank. 1995. Cheatgrass and wildfires in the Intermountain West. California Exotic Pest Plant Council Symposium Proceedings 1-3.

Zion, L. 2002. Larimer County Border Disputed. Accessed via the Web at http://www.rootsweb.com.

Zomlefer, W. 1994. Guide to Flowering Plant Families. University of North Carolina Press, Chapel Hill, NC.