Draba graminea Greene (Rocky Mountain draba): A Technical Conservation Assessment

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

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Lynn Moore[1] and Sandy Friedley[2]
[1]Windom Floristics
361 South Camino Del Rio #222
Durango, CO 81303

[2]Ecosphere Environmental Services
2257 Main Avenue
Durango, CO 81301

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AUTHORS' BIOGRAPHIES

Lynn Moore Botanist/Owner Windom Floristics. Lynn graduated from Fort Lewis College with a Bachelor of Science in Biology in 1992 and continued her graduate work at the University of Wyoming, where she finished a Masters of Science degree in Botany in 1998. Lynn has worked in the private sector independently contracting services in the Four Corners area since 1997. She has experience in threatened and endangered species surveys, noxious weed surveys, environmental assessments, wetland delineations, and floristic surveys. Lynn is currently working on the treatments of three families, the Geraniaceae, Fumariaceae, and the Papaveraceae for the Flora of the San Juan Basin project. She actively researches the flora of the San Juan Mountains and adjacent areas through funding provided by small grants for floristic studies.

Sandy Friedley Botanist/Ecosphere Environmental Services. Sandy graduated from the University of Colorado with Bachelor of Arts in Environmental Biology and continued her graduate work at Western State College, where she received a Master of Arts degree in Environmental Biology. Sandy worked for the San Juan National Forest in the evaluation and transfer of vegetation cover and management data into GIS/ARC-INFO coverages. She assisted in the development of an identification guide for sensitive plant species for the San Juan National Forest, including researching plant distribution and habitat descriptors. Sandy has worked with Ecosphere since 1999, as a field coordinator and assistant project manager for environmental consulting services in areas of botanical investigations, due diligence environmental site assessments, NEPA, biological assessments, wetlands delineations, stormwater management, and regulatory compliance and permitting.

COVER PHOTO CREDIT

Draba graminea (Rocky Mountain draba). Photograph by Peggy Lyon (San Juan County, 2002), used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *DRABA GRAMINEA*

This species assessment for *Draba graminea* (Rocky Mountain draba) is produced as a part of the Species Conservation Project for the USDA Forest Service (USFS), Region 2. *Draba graminea* is considered a regional endemic of southwestern Colorado. Within Region 2 and the state of Colorado, *D. graminea* can be characterized as narrowly endemic because it restricted to a small area surrounding the continental divide in southern and southcentral Colorado. It is not federally listed or a candidate for listing under the Endangered Species Act (U.S.C. 1531-1536, 1538-1540). The species is not designated a sensitive species USFS lands in Region 2. The global heritage status rank for the species is G2 (imperiled globally because of rarity), and the national heritage status rank is N2 (imperiled nationally because of rarity). The Colorado Natural Heritage Program ranks *D. graminea* as S2 (imperiled in the state because of rarity).

Draba graminea is a plant of the high mountains of southwestern Colorado. It exhibits a more or less discontinuous distribution, occupying suitable habitat in the high mountains surrounding the continental divide in southwestern Colorado. It is typically located in the alpine, and less often in subalpine areas, occupying crevices of rock outcrops, talus slopes, late snowmelt areas, and alpine tundra along the continental divide and in the greater San Juan Mountains area. The Colorado Natural Heritage Program reports 21 Element Occurrence Records for *D. graminea* located in San Juan, San Miguel, Ouray, La Plata, Hinsdale, and Montezuma counties. Eight additional occurrences (one unconfirmed) have been identified in La Plata, Gunnison, Hinsdale, Mineral, Dolores, and Ouray counties during surveys conducted in 2003 and 2004 (information from one of the authors, Lynn Moore; Heil personal communication 2003 and Lyon personal communication 2003).

Abundance data are scarce for this species, and the data that do exist are based upon casual field estimates. Based on the available EOR and herbarium label data, it is estimated that approximately 4,000 or more individuals make up the known abundance of this species. This number is based on general field observations and not on actual counts. The precision of the estimate may over or underestimate the actual population number by thousands. No population trend data or inferences of population trend are known.

No federally protected areas have been designated that include the conservation of this species or its habitat as an explicit goal. All of the 29 known occurrences are located on public land, with 28 of the occurrences located on lands administered by the USFS Region 2. There are documented occurrences of *Draba graminea* on lands managed by the San Juan National Forest (16 occurrences, seven of which are in the Weminuche Wilderness Area and one of which is in the Lizard Head Wilderness Area), the Rio Grande National Forest (two occurrences), and the Grand Mesa, Uncompahgre, and Gunnison National Forest (ten occurrences, one of which is in the Lizard Head Wilderness Area). One occurrence is located on Bureau of Land Management land within the San Juan Resource Area in southwest Colorado.

Current threats to *Draba graminea* are difficult to discern due to the remoteness of the occurrences. The concern for the viability of the species is based on its limited abundance and restricted global distribution. In Colorado, past threats that have been observed include erosion from nearby jeep trails (EOR 003*CO) and sheep grazing (Heil personal communication 2003). Of the activities that typically occur or are planned for the San Juan, the Rio Grande, or the Grand Mesa, Gunnison, Uncompahgre national forests, livestock grazing, mining, and recreation are likely to be the most influential activities with regards to *D. graminea* occurrences. Other potential threats to the species include extreme weather conditions, global warming, herbivory by native fauna (e.g. deer, elk, rodents, insects), competition from invasive species, and air pollution. Existing laws, regulations, management, and enforcement do not adequately protect occurrences of this species. The remote locations of the occurrences provide some protection. However, land managers may be unaware of occurrences and thus would be unable to make informed decisions concerning management activities.

Priorities for determining conservation elements include surveying for new occurrences; gathering current population census information on known occurrences; collecting data on community structure and composition to provide a baseline for future habitat monitoring; evaluating reproductive and ecological characteristics (e.g., pollination mechanisms, seed germination, seedling establishment, herbivory, flowering/fruiting, dispersal vectors); gathering information on demographics (e.g., life history stages, population structure, longevity, mortality); and determining impacts to population viability from management activities and natural disturbances.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Draba graminea* (Rocky Mountain draba) is the focus of an assessment because it is a species whose population viability is identified as a concern based on its limited global distribution. This species may require special management; therefore, knowledge of its biology and ecology is critical. This assessment addresses the biology of *D. graminea* throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologist, 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 (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere, and when management recommendations have been implemented, the assessment examines their success.

Scope

This assessment examines the biology, ecology, conservation status, and management of *Draba graminea* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. This assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *D. graminea* in the context of the current environment. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, the authors reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Most refereed publications on *Draba graminea* are referenced in the assessment, but not all are considered equally reliable. Inferences were made where the authors deemed a comparison was sufficiently supported. The assessment emphasizes refereed literature because this is the accepted standard in science. This assessment consulted eight taxonomic references; not all of these were specific to *D. graminea*. The most specific to *D. graminea* are the mustard monograph by Rollins (1993) and Hitchcock's revision of western North American *Drabas* (1941). Non-refereed publications or reports were used when information was unavailable elsewhere, but these were regarded with greater skepticism. Unpublished data (e.g. state natural heritage program records) were important in estimating the geographic distribution and abundance of the species. These data required special attention because of the diversity of persons and methods used in collection.

Data for the species assessment was obtained by secondary sources through state natural heritage programs including the Colorado Natural Heritage Program (CNHP), herbarium specimen label data, scientific literature, and knowledgeable individuals. Fifty-three herbaria within Region 2 and surrounding states were contacted. Six responded with pertinent data: Rocky Mountain Herbarium (RM), Kathryn Kalmbach Herbarium (KHD), San Juan College Herbarium (SJNM), University of Northern Colorado Herbarium (GREE), Fort Lewis College Herbarium (FLD), and University of Colorado Museum (COLO). Literature of closely related taxa was reviewed, and inferences were drawn where reasonable and when a basis could be established for application to *Draba graminea*. The authors present no empirical data.

Treatment of Uncertainty

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

Publication of Assessment on the World Wide Web

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

Peer Review

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

Management Status and Natural History

Management Status

Within Region 2 and the state of Colorado, *Draba graminea* can be characterized as narrowly endemic, as it is known to occur only in a small area surrounding the continental divide in southern and southcentral Colorado. It is not federally listed or a candidate for listing under the Endangered Species Act. The species is not designated a sensitive species on USFS lands in Region 2, nor is it listed as a Bureau of Land Management (BLM) Special Status Species. The global heritage status rank for the species is G2 (imperiled globally because of rarity [6 to 20 occurrences]), and the national heritage status rank is N2 (imperiled nationally because of rarity [6 to 20 occurrences]). In Colorado, *D. graminea* is ranked S2 (imperiled in the state because of rarity [6 to 100 occurrences]).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Documented locations of *Draba graminea* occur in San Juan, Hinsdale, Dolores, San Miguel, Ouray, La Plata, Montezuma, Mineral, and Gunnison counties. All of the 29 known occurrences are located on public land. One occurrence is located on Bureau of Land Management land within the San Juan Resource Area, and the other 28 are on lands administered by the USFS Region 2. Specifically, *D. graminea* occurs on lands managed by the San Juan National Forest (16 occurrences, seven of which are in the Weminuche Wilderness Area and one of which is in the Lizard Head Wilderness Area), the Rio Grande National Forest (two occurrences), and the Grand Mesa, Uncompahgre, and Gunnison National Forest (10 occurrences, one of which is in the Lizard Head Wilderness Area).

The San Juan National Forest Land and Resource Management Plan, as amended 1992 (USDA Forest Service 1992), the Revised Rio Grande National Land and Resource Management Plan (USDA Forest Service 1996), and the Grand Mesa, Uncompahgre, Gunnison National Forest Land and Resource Management Plan (USDA Forest Service 1991) provide guidelines for management of each individual forest. Although *Draba graminea* is not considered a sensitive species on the forests in which it occurs, the National Forest Management Act (1976) and its rules require the USFS to sustain habitats that support healthy populations of existing plant and animal species on the national forests and grasslands. Project-specific National Environmental Policy Act compliance does not require evaluation of project alternatives with respect to *D. graminea* occurrences. No specific management or conservation plan is in place for protection of this species on National Forest System lands. Management on BLM lands is accomplished according to the 1985 San Juan-San Miguel Resource Management Plan and Final Environmental Impact Statement (U. S. Bureau of Land Management 1985). Existing laws, regulations, management, and their enforcement may not adequately protect species occurrences on federal lands due to the fact that no species-specific protective mechanisms are in place.

Biology and Ecology

Systematics and general species descriptions

The Mustard family (Brassicaceae) is an important agricultural and ornamental family. This family consists of approximately 376 genera and 3200 species, primarily in cold and temperate regions of the Northern Hemisphere. Centers of diversity are thought to occur in the Mediterranean and in southwestern and central Asia (Zomlefer 1994). North American representatives include some 99 genera and 778 species. Although the North American Brassicaceae element is relatively less diverse than the Mediterranean and Asian elements, Rollins (1993) believes that a center of diversity also exists on the North American continent. Thirty-nine of the North American genera are wholly endemic, and most of the 677 native taxa are endemic. The largest genus is *Draba*, with more than 350 species (104 of which occur in North America; Rollins 1993). The focus of this assessment is *D. graminea*, one of several narrowly endemic, poorly understood members of the genus. Other Colorado endemic members include *D. exunguiculata* (Schulz) Hitchcock, *D. weberi* Price & Rollins, and *D. smithii* Gilg *ex* Schulz. All of these taxa occur in high-elevation, relatively isolated habitats in the Colorado Rocky Mountains.

The earliest collection of *Draba graminea* was made by F. Tweedy in 1894 near Telluride, Colorado (*Tweedy 142* NY). This was followed by a collection made by C. F. Baker in 1901 near Carson, Colorado (*Baker 296* NY, US). The Baker collection was designated as the type specimen for *D. graminea* in the formal description prepared that same year by E.L. Greene (Hitchcock 1941). The Tweedy collection was originally identified as *D. graminea*, apparently after the 1901 description. It was annotated 1927 by O.E. Schulz as *D. chrysantha* var. *hirticaulis* Schulz. Hitchcock (1941) later revised the genus *Draba* and annotated the specimen as *D. graminea*. This would make the Tweedy specimen the first documented collection. **Table 1** summarizes the current classification of *D. graminea*.

The dicotyledonous family Brassicaceae, formerly known as the Cruciferae, is considered a natural family. It is clearly related to the Capparaceae, and it is thought that the two families are derived from a common ancestor no longer in existence (Rollins 1993). It is currently proposed to combine these two families (Heil personal communication 2003). *Draba* is a large genus, and sectional classification has been highly controversial. Recent molecular data suggest that North American members of *Draba* are relatively young taxa when compared to European *Draba* (Koch and Al-Shebaz 2002). The genus is considered a polyploid complex; it is not surprising that differentiation between *Draba* is difficult at an intra-continental and intercontinental level. Further morphological and molecular research is needed to resolve the phylogeny of *Draba* (Koch and Al-Shebaz 2002).

There are three synonyms associated with *Draba graminea*: *D. chrysantha* var. *graminea* (Greene) Schulz, *D. chrysantha* var. *hirticaulis* Schulz, and *Braya graminea* (Greene) M.E. Jones (Rollins 1993). Rollins (1993) does not recognize these synonyms as viable species, and specimens bearing these names have been annotated as *D. graminea*.

Draba graminea is a caespitose perennial herb, 1 to 5 cm tall. Stems are caulescent with slender unbranched hairs. Leaves are linear to linear-oblanceolate, glabrous except for long ciliate hairs on the lower half. These hairs are simple or sometimes forked. Cauline leaves are mostly absent, and if present they number between one and six and are reduced. The inflorescence is a raceme with three to 15 flowers subtended by leaf-like bracts. The petals are yellow and 4 to 5 mm long. The siliques are 5 to 10 mm long and 2 to 4 mm wide, elliptic-ovate, thick, and glabrous (Hitchcock 1941, Harrington 1954, Rollins 1993).

Table 1. Classification of *Draba graminea*.

Draba graminea Greene
Family: Brassicaceae (Cruciferae)
Genus: *Draba*
Species: *Draba graminea*
Citation: E.L. Greene. 1901. Pl. Baker. 3:5-6 (Greene 1901)
Synonyms: *Draba chrysantha* var. *graminea* (Greene) Schulz, *D. chrysantha* var. *hirticaulis* Schulz, *Braya graminea* (Greene) M.E. Jones
Vernacular Name: Rocky Mountain draba
Type: United States, Colorado. Hinsdale Co. Region of the Gunnison watershed, Carson, 12500 ft. 21 July 1901. Baker 296 (GH, MO, NY, US)

There are morphological similarities in some Rocky Mountain members of *Draba*. Look-alike species include *D. crassifolia* R. Graham, *D. spectabilis* Greene, and *D. exunguiculata* (Schulz) Hitchcock. *Draba graminea* can be distinguished from the others by the ciliate linear, basal leaves, the lack of cauline leaves, and the leaf-like bracts subtending the flowers. **Figure 1** is a photograph of *D. graminea*, and **Figure 2** is a representative line drawing of the silique and basal leaves of this species.

Figure 1. Photograph of *Draba graminea* by Peggy Lyon (San Juan County, 2002), used with permission.

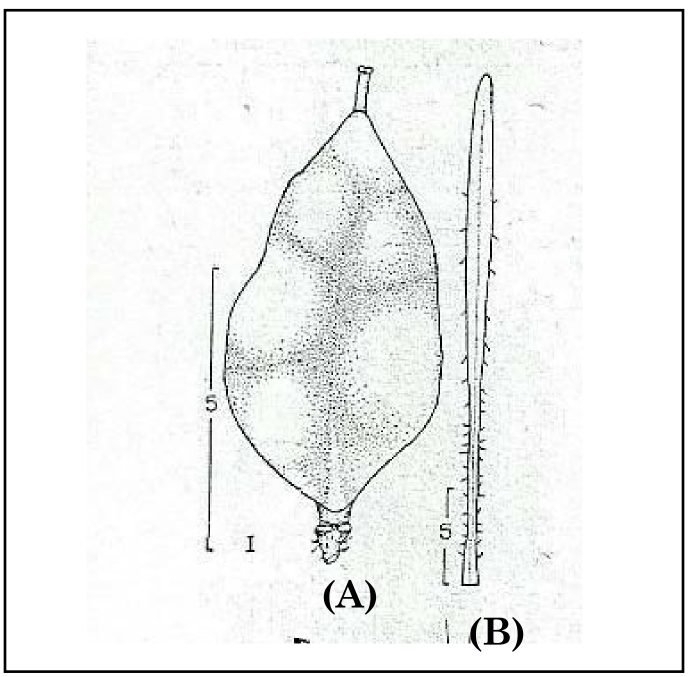

Figure 2. Line drawing of *Draba graminea* silique (A) and basal leaf (B) from Hitchcock (1941). Scale is in millimeters (5 mm).

Distribution and abundance

The historic and current global distribution of *Draba graminea* is restricted to the floristic region defined by Takhtajan (1986) as the Rocky Mountain Province of the Holarctic Kingdom. It is limited to one geographic area within Region 2 and appears to be restricted to Colorado. Historically, this species was first discovered in the 1890s in San Miguel and Hinsdale counties, Colorado. Documented locations occur in San Juan, Hinsdale, Dolores, San Miguel, Ouray, La Plata, Montezuma, Mineral, and Gunnison counties. All of the 29 known occurrences are located on public land, and 28 of those are located on lands administered by the USFS Region 2. Specifically, *D. graminea* has documented occurrences on lands managed by the San Juan National Forest (16 occurrences, seven of which are in the Weminuche Wilderness Area and one of which is in the Lizard Head Wilderness Area), the Rio Grande National Forest (two occurrences), and the Grand Mesa, Uncompahgre, and Gunnison National Forest (10 occurrences, one of which is in the Lizard Head Wilderness Area). One occurrence is located on BLM land within the San Juan Resource Area in southwest Colorado (**Figure 3**).

Draba graminea is considered a narrow endemic of southern and southcentral Colorado. It exhibits a more or less discontinuous distribution, occupying suitable habitat in the high mountains surrounding the continental divide in southwestern Colorado. Its distribution also exhibits two peripheral occurrences. One is located on the San Juan National Forest in Montezuma County in the La Plata Mountains (an independently-formed, small mountain group) approximately 40 km southwest of the main population cluster. The other peripheral occurrence is located on the San Juan National Forest in Mineral County, along the continental divide, approximately 40 km east of the main population cluster. The Colorado Natural Heritage Program (CNHP) reports 21 Element Occurrence Records (EORs) for *D. graminea* located in San Juan, San Miguel, Ouray, La Plata, Hinsdale, and Montezuma counties. Five locations in Gunnison and Mineral counties were documented through herbarium

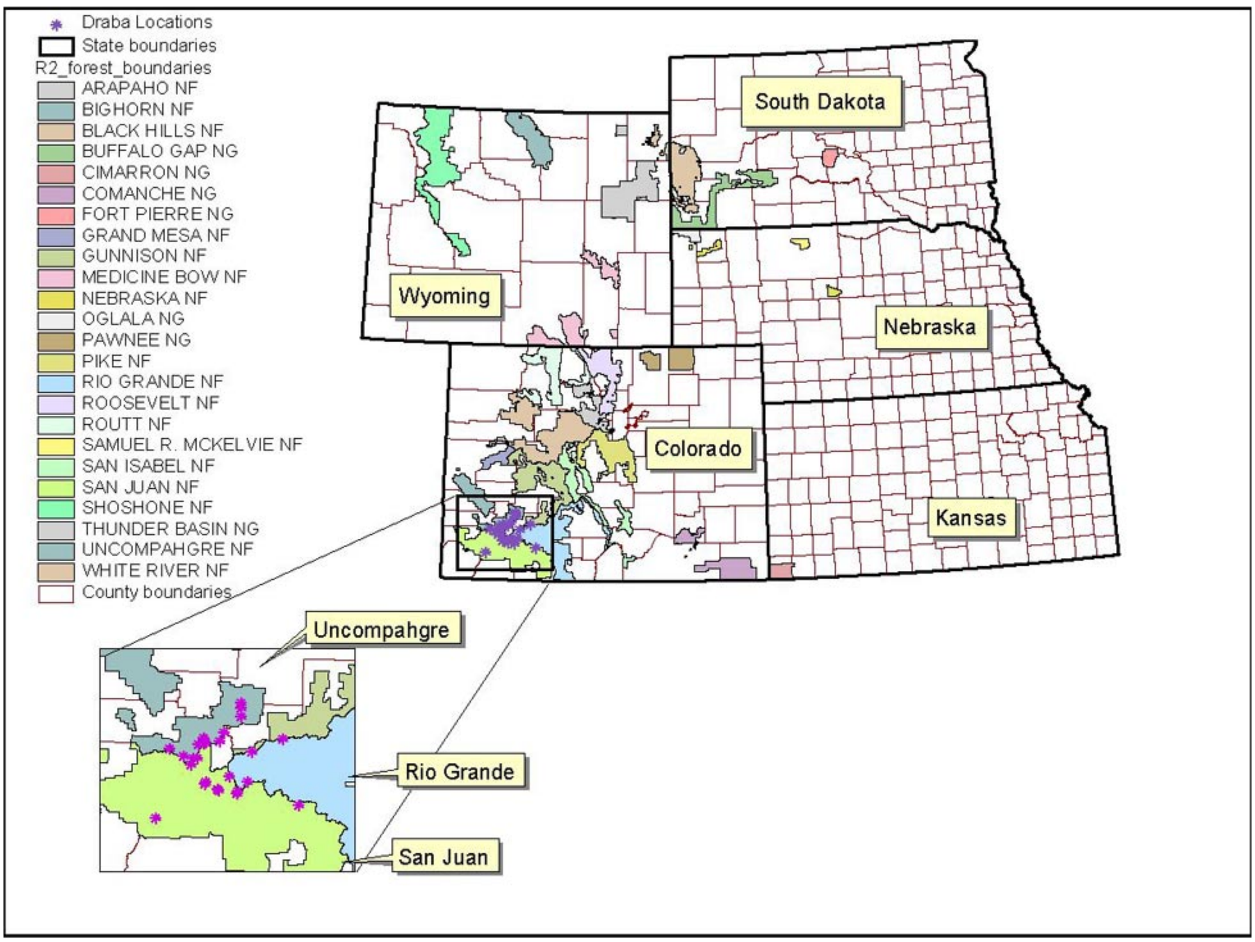

Figure 3. General location of *Draba graminea* occurrences on the San Juan and Grand Mesa, Uncompahgre and Gunnison national forests (not including 2003-2004 surveys).

specimens and will be included in the discussion of this species. Three additional locations were reported during surveys of the San Juan Mountains conducted in 2003 and 2004 (Lyon personal communication 2003) for a total of 29 occurrences. Twelve of the CNHP occurrences and all five of the locations documented through herbarium specimens are represented by voucher specimens deposited in various herbaria, including the New York Botanic Garden (NY), Gray Herbarium (GH), United States National Herbarium (US), Missouri Botanic Garden (MO), Rocky Mountain Herbarium (RM), Kathryn Kalmbach Herbarium (KHD), San Juan College Herbarium (SJNM), University of Northern Colorado Herbarium (GREE), Fort Lewis College Herbarium (FLD), and University of Colorado Museum (COLO).

Abundance data are scarce for this species, and the data that do exist are based upon casual field estimates. An accurate estimation of ecological density in the strict sense is not possible given the available data. Eleven of the 21 EORs report no abundance data, nor do the data for the five locations documented by herbarium specimens. Based on the available EOR and herbarium label data summarized in **Table 2**, it is estimated that approximately 4,000 or more individuals make up the known abundance of this species. In all likelihood, this estimate is low (Heil personal communication 2003).

Population trend

According to the CNHP, there are 21 reported EORs for *Draba graminea*. Five locations were discovered over the course of this assessment and were reported to CNHP in 2004 by one of the authors (Lynn Moore) and others (Heil personal communication 2003). Three additional locations were reported during surveys of the San Juan Mountains conducted in 2003 and 2004 (Lyon personal communication 2003). Ten of the CNHP occurrences have not been observed in over 20 years; all of these are on USFS lands. Individual populations range in size from 5 to 1,000 or more plants. For EOR 019*CO, 25 plants were recorded in an area less than 0.404 ha. Area was not recorded for the remaining known locations. Therefore, even rough estimates of density cannot be determined, and no conclusions concerning trends in population density can be made. Due to the limited number of site revisits, it is unclear whether any occurrences have been extirpated. Due to the lack of data, no inferences can be made concerning the temporal pattern of abundance at any spatial extent.

Habitat

Draba graminea is a plant of the high mountains of southwestern Colorado. It is typically located in the alpine, and less often in subalpine areas. It occupies the crevices of rock outcrops, talus slopes, late snowmelt areas, and alpine tundra along the continental divide and the greater San Juan Mountains area. **Table 3** summarizes habitat information from EOR and herbarium label data, including vegetation, elevation, substrate, slope, and aspect. **Figure 4** and **Figure 5** provide photographs of the habitat of *D. graminea*.

Draba graminea occurs in the South Central Highlands section of the Southern Rocky Mountain Province (McNab and Avers 1994). Based on the CNHP EOR occurrence data, herbarium label data, and personal observations by one of the authors (Lynn Moore in 1998), the most common community for this taxon is the alpine tundra. It is associated with a cushion/rosette physiognomy. Alpine communities vary according to aspect, substrate, dominant species, and moisture regime.

According to the ecosystem descriptions generated by the CNHP (Rondeau 2001), EOR habitat data, and herbarium label data, three alpine community types provide potential habitat for *Draba graminea*: the alpine tundra dry meadow, the alpine tundra fell-field community, and the alpine dwarf shrubland.

The alpine tundra dry meadow typically occurs between 3,048 and 4,267 m in elevation, on gentle to moderate slopes, flat ridges, valleys, and in basins where soil is relatively stable and the water supply is more or less constant. It is co-dominated by various species of *Carex* and *Geum rossii* var. *turbinatum* (Rydb.) C.L. Hitchc. (R.Br.) Ser. (Rondeau 2001). *Draba graminea* occurrences in the alpine tundra dry meadow are typically located in rocks and crevices within the mosaic.

The alpine tundra fell-field community can be found between 3,353 and 4,267 m in elevation, on gentle to steep slopes with varying aspects. Soils are generally immature and stable and consist of gravels and sands. Dominant species include matted or cushioned plants such as *Silene acaulis* (L.) Jacq. var. *subacaulescens* (F.N. Wms.) Fern & St. John and *Minuartia obtusiloba* (Rydb.) House (Rondeau 2001). *Draba graminea* is not

Table 2. Summary of abundance data for known occurrences of *Draba graminea*. Taken from Colorado Natural Heritage Program Element Occurrence Records and herbarium label data. A "?" next to the number of populations indicates unstated number of populations, so assumed to be 1. "N/A" indicates that information was not available.

EOR/ Collector Number	County	Area (hectare)	No. of Populations	Total # Plants	Land Ownership
001*CO	Hinsdale	N/A	1?	N/A	Uncompahgre National Forest
003*CO	Hinsdale and Ouray	N/A	1?	200+	Uncompahgre National Forest
004*CO	Hinsdale	N/A	1?	400+	Rio Grande National Forest
005*CO	Hinsdale	N/A	1?	N/A	San Juan National Forest
010*CO	Ouray	N/A	1?	N/A	Uncompahgre National Forest
011*CO	La Plata	N/A	1?	N/A	San Juan National Forest, Weminuche Wilderness Area
012*CO	San Juan	N/A	1?	N/A	San Juan National Forest
013*CO	La Plata	N/A	1?	N/A	San Juan National Forest, Weminuche Wilderness Area
014*CO	San Miguel	N/A	1?	N/A	Uncompahgre National Forest
015*CO	San Juan	N/A	1?	N/A	San Juan National Forest
016*CO	San Juan	N/A	1	83 to 200+	San Juan National Forest
017*CO	San Juan	N/A	1	1,000+	San Juan National Forest
018*CO	Hinsdale	N/A	1?	N/A	Rio Grande National Forest
019*CO	San Juan	<0.404	1?	25	San Juan National Forest, Weminuche Wilderness Area
020*CO	Montezuma	N/A	1	N/A	San Juan National Forest
021*CO	San Miguel	N/A	1	5	Uncompahgre National Forest
022*CO	San Miguel	N/A	1	400+	Uncompahgre National Forest, Lizard Head Wilderness Area
023*CO	Ouray and San Miguel	N/A	2	500 to 1,000+	Uncompahgre National Forest
024*CO	San Juan	N/A	1	32	San Juan National Forest
025*CO	San Juan	N/A	2	50 to 500+	Bureau of Land Management, San Juan Resource Area
026*CO	San Juan	N/A	1	10+	San Juan National Forest
027*CO	La Plata	N/A	1	200+	San Juan National Forest, Weminuche Wilderness Area
MA6019	Gunnison	N/A	1?	N/A	Gunnison National Forest
MA6126	Hinsdale	N/A	1?	N/A	Gunnison National Forest
LM9834	Hinsdale	N/A	1?	N/A	San Juan National Forest, Weminuche Wilderness Area
LM10114	Hinsdale	N/A	N/A	N/A	San Juan National Forest, Weminuche Wilderness Area
HEIL	Mineral	N/A	N/A	N/A	San Juan National Forest, Weminuche Wilderness Area
Lyon, 2004	Ouray	N/A	N/A	Several hundred	Uncompahgre National Forest
Lyon, 2004 Unconfirmed	Dolores	N/A	N/A	N/A	San Juan National Forest

Table 3. Summary of habitat data for known occurrences of *Draba graminea*. Taken from Colorado Natural Heritage Program Element Occurrence Records, herbarium specimen labels, and USGS 7.5 minute topographic maps. N/A indicates that information was not available.

EOR/ Collector Number	Elevation (meters)	Aspect	Substrate	Vegetation Cover (%)	Habitat Characteristics and Association
001*CO	4,115	SE	Ash-flow tuff, yellow rocky soil	N/A	Among rocks.
003*CO	3,901 to 3,962	SE	Intra-ash flow andesitic lavas	N/A	Talus slope.
004*CO	3,718	N	Andesitic lavas, breccians, tuffs, and conglomerates	N/A	Talus slope.
005*CO	4,053	N/A	Intra-ash flow quartz latitic lavas, ash-flow tuff, basaltic intrusive	N/A	N/A
010*CO	N/A	N/A	Ash-flow tuff	N/A	N/A
011*CO	3,596 to 4,023	N/A	Granitic rocks 1,400 M.Y.	N/A	Narrow rock ledges, rock cracks, crevices and shelves.
012*CO	3,048 to 3,352	N/A	Cutler Formation, andesitic lavas, breccians, tuffs, and conglomerates, Eocene prevolcanic sedimentary rocks, Morrison, Wanakah, and Entrada Formations	N/A	Gravel bars in stream of upper basin.
013*CO	3,901	N/A	Granitic rocks 1,400 M.Y.	N/A	Wet rock crevices and in gravel above and around lake. Cold, moist gravel.
014*CO	3,657	N/A	Mancos shale, glacial drift	N/A	Among rocks.
015*CO	3,657 to 3,688	N/A	Middle Tertiary intrusives, shallow rocky clay loam	N/A	Alpine rocks.
016*CO	3,523	N/A	Felsic and hornblendic gneiss	N/A	At base and in crevices of rock outcrops. Spruce fir-forest.
017*CO	3,657 to 3,810	N/A	Andesitic lavas, breccians, tuffs, and conglomerates, ash-flow tuff, gravelly areas	N/A	Alpine tundra, along rock outcrop at base, talus slopes.
018*CO	3,621	N	Ash-flow tuff, glacial drift, loose soil.	N/A	Growing in patches of loose soil on rocky slope.
019*CO	3,877	N/A	Uncompahgre Formation, gravelly wet	Tree = 0 Shrub = 0 Forb = 50 Moss/lichen = 20 Bare ground = 20	Alpine tundra on crest in wet mossy patches of gravelly soil.
020*CO	3,645	N/A	Uncompahgre Formation	N/A	Alpine meadow in alpine cirque basin with poorly developed vegetation.
021*CO	3,596	N	Andesitic lavas, breccians, tuffs, and conglomerates	N/A	Rocky, alpine tundra community.
022*CO	3,657 to 3,718	N/A	Middle Tertiary intrusives	N/A	Alpine tundra community in high basin, late snowmelt, 6 to 24 m from edge of snow.
023*CO	3,803 to 3,962	N/A	Ash-flow tuff, andesitic lavas, breccians, tuffs, and conglomerates, loose gravelly soil	N/A	Loose gravels and scree 6 to 24 m from edge of late snowmelt.

Table 3 (concluded).

EOR/ Collector Number	Elevation (meters)	Aspect	Substrate	Vegetation Cover (%)	Habitat Characteristics and Association
024*CO	3,852	S	Ash-flow tuff, intra-ash flow andesitic lavas	Sparse	Tundra at base of late snowmelt.
025*CO	3,487 to 3,864	N	Intra-ash flow andesitic lavas, middle Tertiary intrusives	N/A	Late snowmelt and talus slope in drainage upstream from lake. Alpine tundra.
026*CO	3,840	N	Felsic and hornblendic gneiss	N/A	Rock outcrops in pristine alpine area.
027*CO	3,840 to 3,900	W	N/A	N/A	Steep scree slope.
MA6019	3,779 to 4,013	N/A	Andesitic lavas, breccians, tuffs, and conglomerates	N/A	Alpine tundra.
MA6126	3,779 to 4,169	N/A	Andesitic lavas, breccians, tuffs, and conglomerates	N/A	Alpine tundra.
LM9834	3,690	N	Uncompahgre Formation	N/A	Alpine tundra on soil ledges of granitic rock. Mesic dwarfed willow thickets surrounding late snowmelt. Some krummholz on exposed outcrops
LM10114	3,598	SSW	Uncompahgre Formation	N/A	Alpine tundra; mosaic of scattered patches of unstabilized talus slopes, rocky ledges, and alpine turf.
HEIL	3,403	N/A	Intra-ash flow andesitic lavas	N/A	Alpine and subalpine.
Lyon, 2004	3,785	NE	N/A	N/A	Rock crevices.
Lyon, 2004 Unconfirmed	3,733	N/A	N/A	N/A	Alpine.

Figure 4. Generalized alpine habitat of *Draba graminea*. Photograph by Lynn Moore (Hinsdale County, San Juan National Forest, 1998), used with permission.

Figure 5. Alpine habitat of *Draba graminea*. *Draba graminea* is found in the cracks of the rock outcrops. Photograph by Lynn Moore (Hinsdale County, San Juan National Forest, 1998), used with permission.

frequently found in the typical fell-field community, but rather in crevices of rocks embedded within the fell-field. Talus slopes have characteristics of a fell-field, but the stability of their substrates differs. *Draba graminea* is frequently found on more or less stabilized talus slopes.

The third alpine community that provides habitat for *Draba graminea* is the alpine dwarf shrubland. This association generally occurs above 3,658 m, on gentle slopes and in depressions where snow lingers. The soils are more or less stabilized, and the water supply is constant (Rondeau 2001). Dominant species include *Salix arctica* var. *petraea* Anderss. Pall., *S. reticulata* var. *nana* Anderss. L., and *Geum rossii* var. *turbinatum* (Rydb.) C.L. Hitchc. (R.Br.) Ser. (Rondeau 2001). *Draba graminea* is frequently found in these late snowmelt areas, typically forming a band 6 to 25 m from the edge of the snowmelt.

These three alpine communities do not necessarily form distinct, separate associations. Rather, a complex mosaic of these communities ranging in elevation, aspect, soil stability, and moisture regime is typically the norm (Billings 1988, Knight 1994). *Draba graminea* is frequently found with *Ranunculus macauleyi* Gray, *Poa alpina* L., *Festuca brachyphylla* ssp. *coloradensis* Frederiksen Schult. & Schult., *Geum rossii* var. *turbinatum* (Rydb.) C.L. Hitchc. (R.Br.) Ser., and *Silene acaulis* (L.) Jacq. var. *subacaulescens* (F.N. Wms.) Fern & St. John. Other taxa associated with the *D. graminea* habitat documented by EOR records and herbarium labels are listed in **Table 4**.

According to the EOR and herbarium label data, three records casually estimated vegetation cover. Total vegetation cover varied from 1 to 70 percent and was verbally characterized as sparse (**Table 3**). No other data exists to adequately determine the typical total vegetation cover for *Draba graminea*.

Based upon available location data, the surface geology of occupied *Draba graminea* habitat suggests a marked preference for volcanic substrates (Tweto 1979, Green 1992). The San Juan Mountains were formed as a result of several uplifts and erosion cycles, but for our purposes it was the cataclysmic volcanic eruptions that occurred during the Tertiary and the following Cenozoic and Pleistocene glaciations that formed the substrates in which *D. graminea* occurs (Baars 1992). The most common substrates are various forms of ash-tuffs and andesitic and latitic lavas (**Table 3**). Other substrates include the Uncompahgre Formation (quartzite), felsic and hornblendic gneiss, and Mancos Shale. There are no empirical data to infer that *D. graminea* is restricted to volcanic substrates. It may be that temperature and moisture factors determine the alpine habitat preference for this species, and that substrate is a secondary consequence of location in a high-elevation, volcanically-formed mountain range.

Table 4. Associated taxa documented to co-occur with *Draba graminea*. Taken from EOR data forms and herbarium specimen labels (CNHP 2003).

Associated Species	Vernacular name
Agoseris glauca (Pursh) Raf. var. *laciniata* (D.C. Eat.) Smiley	false agoseris
Agrostis idahoensis Nash	Idaho bentgrass
Angelica grayi (Coult. & Rose) Coult. & Rose	Gray's angelica
Aquilegia caerulea James var. *caerulea*	Colorado blue columbine
Arenaria fendleri Gray var. *fendleri*	Fendler's sandwort
Arnica mollis Hook.	hairy arnica
Artemisia scopulorum Gray	alpine sagebrush
Bromus ciliatus L.	fringed brome
Campanula rotundifolia L.	bluebell bellflower
Carex albonigra Mack.	blackandwhite sedge
Carex arapahoensis Clokey	Arapaho sedge
Carex heteroneura W. Boott var. *chalciolepis* (Holm) F.J. Herm.	Holm sedge
Carex bella Bailey	southwestern showy sedge
Carex egglestonii Mack.	Eggleston's sedge
Carex haydeniana Olney	cloud sedge
Carex illota Bailey	sheep sedge
Carex nelsonii Mack.	Nelson's sedge
Carex nigricans C.A. Mey.	black alpine sedge
Carex norvegica Retz. var. *stevenii* (Holm) E. Murr	Steven's sedge
Carex nova Bailey var. *nova*	black sedge
Carex scirpoidea Michx. var. *pseudoscirpoidea* (Rydb.) Cronq.	western singlespike sedge
Carex scopulorum Holm var. *scopulorum*	mountain sedge
Castilleja occidentalis Torr.	western Indian paintbrush
Castilleja rhexifolia Rydb.	splitleaf Indian paintbrush
Chionophila jamesii Benth.	Rocky Mountain snowlover
Cystopteris fragilis (L.) Bernh.	brittle bladderfern
Danthonia intermedia Vasey	timber oatgrass
Deschampsia cespitosa (L.) Beauv.	tufted hairgrass
Draba aurea Vahl ex Hornem.	golden draba
Draba crassa Rydb.	thickleaf draba
Elymus glaucus Buckl. ssp. *glaucus*	blue wildrye
Elymus scribneri (Vasey) Jones	spreading wheatgrass
Erigeron leiomerus Gray	rockslide yellow fleabane
Erigeron melanocephalus (A. Nels.) A. Nels.	blackhead fleabane
Erigeron pinnatisectus (Gray) A. Nels.	featherleaf fleabane
Festuca brachyphylla J.A. Schultes ex J.A. & J.H. Schultes ssp. *coloradensis* Frederiksen	Colorado fescue
Gentiana algida Pall.	whitish gentian
Gentiana parryi Engelm.	Parry's gentian
Gentianella amarella (L.) Borner var. *heterosepala* (Engelm.) Dorn	autumn dwarf gentian
Geum rossii (R. Br.) Ser. var. *turbinatum* (Rydb.) C.L. Hitchc.	Ross' avens
Haplopappus pygmaeus (T. & G.) Gray	pygmy goldenweed
Hieracium gracile Hook. var. *gracile*	slender hawkweed

Table 4 (concluded).

Associated Species	Vernacular name
Hymenoxys grandiflora (T. & G. ex Gray) Parker	graylocks four-nerve daisy
Juncus drummondii E. Mey.	Drummond's rush
Juncus ensifolius Wikstr. var. *montanus* (Engelm.) C.L. Hitchc.	swordleaf rush
Lewisia pygmaea (Gray) B.L. Robins.	alpine lewisia
Ligusticum porteri Coult. & Rose var. *porteri*	Porter's licorice-root
Luzula spicata (L.) DC.	spiked woodrush
Mimulus guttatus DC.	seep monkeyflower
Minuartia obtusiloba (Rydb.) House	twinflower sandwort
Packera dimorphophylla (Greene) W.A. Weber & A. Löve ssp. *dimorphophylla*	splitleaf groundsel
Parnassia fimbriata Koenig var. *fimbriata*	fringed grass of Parnassus
Pedicularis groenlandica Retz.	elephanthead lousewort
Pedicularis parryi Gray var. *parryi*	Parry's lousewort
Phleum alpinum L.	alpine timothy
Poa alpina L.	alpine bluegrass
Podistera eastwoodiae (Coult. & Rose) Math. & Const.	Eastwood's podistera
Polygonum bistortoides Pursh	American bistort
Polygonum ramosissimum Michx.	bushy knotweed
Sagina saginoides (L.) Karst.	arctic pearlwort
Salix arctica Pallas ssp. *petraea* (Anderss.) A.& D. Löve & Kapoor	alpine willow
Salix glauca L. ssp. *glauca* var. *villosa* (D. Don ex Hook.) Anderss.	grayleaf willow
Salix reticulata L. var. *nana* (Hook.) Anderss.	snow willow
Saxifraga flagellaris Willd. ex Sternb. var. *crandallii* (Gand.) Dorn	Crandall's saxifrage
Saxifraga rhomboidea Greene	diamondleaf saxifrage
Saxifraga rivularis L. var. *debilis* (Engelm. ex Gray) Dorn	weak saxifrage
Senecio amplectens Gray var. *amplectens*	showy alpine ragwort
Senecio bigelovii Gray var. *hallii* Gray	Hall's ragwort
Senecio crassulus Gray	thickleaf ragwort
Senecio triangularis Hook.	arrowleaf ragwort
Sibbaldia procumbens L.	creeping sibbaldia
Silene acaulis (L.) Jacq.	moss campion
Solidago simplex Kunth	Mt. Albert goldenrod
Thlaspi montanum L. var. *montanum*	alpine pennycress
Trifolium nanum Torr.	dwarf clover
Trisetum spicatum (L.) Richt.	spike trisetum
Veronica wormskjoldii Roemer & J.A. Schultes	American alpine speedwell

However, the presence of volcanic substrates would provide a clue for closer inspection by field botanists during reconnaissance surveys.

One of the many interesting things about alpine habitats is the variation that occurs within the alpine environment. These variations have been studied extensively. Geographic gradients are influenced primarily by latitude and longitude (macrogradients), but the factors influenced by topography (mesogradients) and those occurring at a smaller scale within the topography, sometimes termed microgradients, are relevant to *Draba graminea* habitat (Billings 1973, 1974). It has been shown that the alpine environment varies greatly with topographic position, for example, ridgelines, depressions, and leeward versus windward slopes (Billings 1973). Aspect can greatly affect temperature, moisture, and exposure particularly in the alpine environment (Billings 1973, 1974, 1988, Knight 1994). Temperature is the overriding environmental factor influencing alpine habitats. A few centimeters change in elevation caused by a hummock or depression can change the temperature by several degrees, and a rock or tussock (a compact tuft, especially of grass or sedge) may have a distinct north slope-south slope temperature regime (Thilenius 1975). Based upon the available EOR and herbarium label data, *D. graminea* tends to occur more often on north-facing slopes than on other aspects (six out of 12 EORs for which aspect was recorded). This species has also been documented as occurring along the edges of late snowmelts. Typically, snow lingers on the lee side of slopes and on north-facing sites (Billings 1973). At the microscale, *D. graminea* appears to prefer sites found in the cracks, crevices, and edges of rock outcrops. In general, a field botanist should successfully find this plant frequently on north-facing slopes, tucked in protected, cool, more-or-less moist crevices located along rocky benches, ledges, and outcrops.

Draba graminea exhibits a range in elevation from 3,048 to 4,169 (**Figure 6**). Timberline in the San Juan Mountains is typically between 3,535 m and 3,600 m, and krummholz rarely occurs above 3,660 m (Carrara et al. 1991). One of the lower-elevation populations of *D. graminea* (EOR 025*CO) was found in rocky outcrops on a north-facing slope, along a late snowmelt. Most likely occurrences at these lower sites are located in microhabitats providing the same kind of cool, protected sites found at elevations above 3,657 m.

It is difficult to determine if alpine cushion plant communities ever develop a stable climax ecosystem (Knight 1994). However, some ecologists have identified clear succession in alpine ecosystems (Churchill and Hanson 1958). Stable alpine ecosystems can occur in areas with very little soil water and consequently little cryoturbation, such as boulder fields and some fellfields (Knight 1994). There are not enough data to determine in which stage of succession *Draba graminea* is most likely to occur.

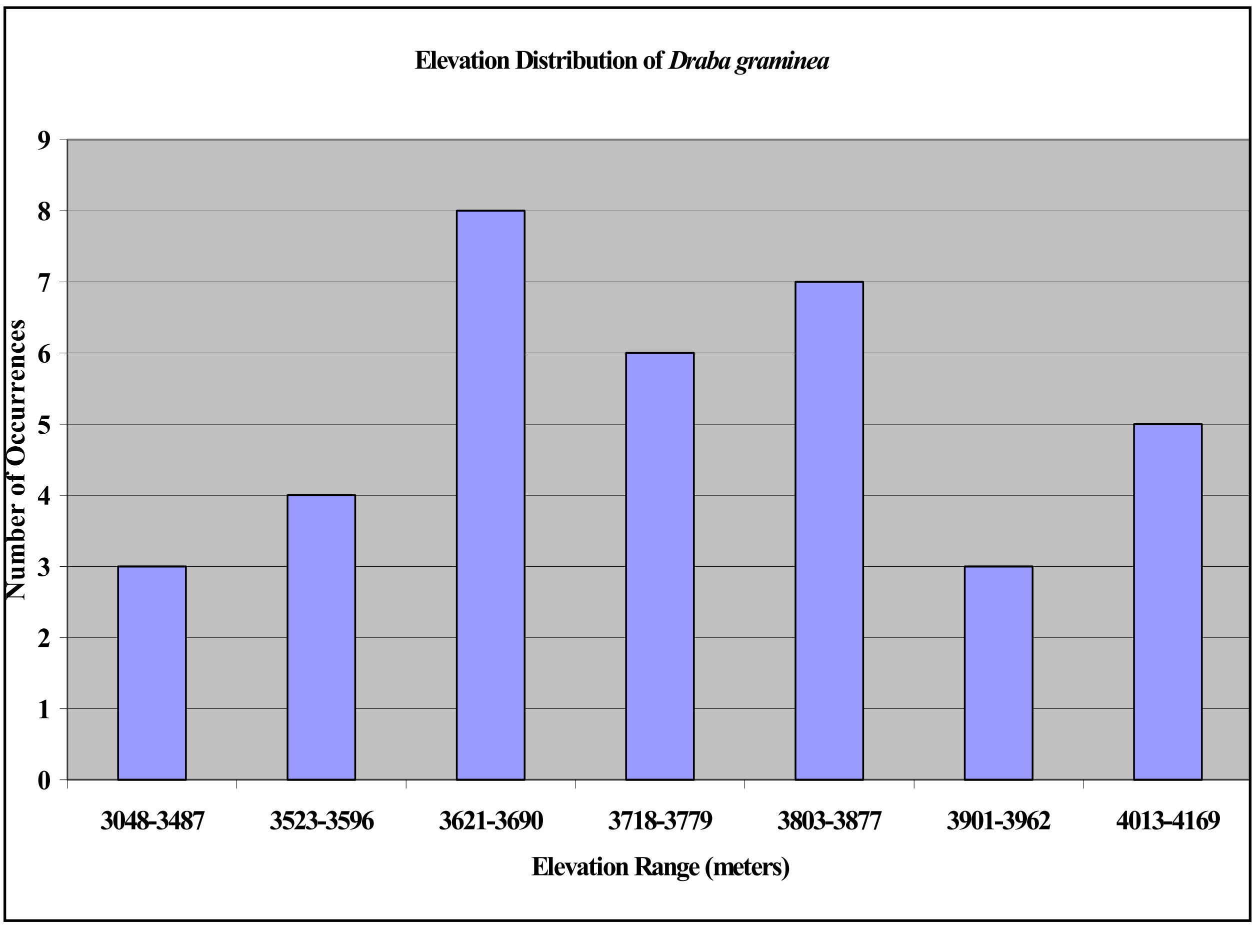

Figure 6. Distribution of *Draba graminea* occurrences, according to elevation.

Reproductive biology and autecology

An extensive literature search resulted in no empirical data describing the ecological strategies for *Draba graminea*. However, much has been written about the adaptations of alpine plants in general, and the harshness of the alpine habitat presents the same challenges to all vascular plants. Alpine plants are typically dwarfed and perennial. Most, but not all, alpine plants have relatively large underground root systems. By far the most important adaptation is the response to the short growing season and low temperatures (Billings 1974). Alpine plants generally survive the short growing season by growing very rapidly. This rapid growth is primarily due to a plant's ability to undergo physiological processes at low temperatures (Billings 1974). Low temperatures are also overcome through the diminutive stature of the plants; temperatures closer to the ground may be relatively warmer than the temperatures of the air 1 m aboveground. In addition, the physiognomy of the plant can create a phytomicroclimate where the temperature within the confines of the plant itself may be several degrees warmer than the surrounding environment (Billings 1974, Thilenius 1975). Another strategy for surviving low temperatures is the presence of relatively high osmotic concentrations of plant fluids that may prevent the plant from freezing during the nocturnal temperature drops (Thilenius 1975). It is not known if *D. graminea* has high osmotic concentrations in its plant fluids. It is a dwarfed hemicryptophyte with a relatively large, thickened root system, and this morphology is often associated with species that are well-adapted to surviving stressful environments as the perennating bud is protected during the harsh winter and short growing season (Grime 1979, Barbour et al. 1987).

It is not known if *Draba graminea* is a long-lived plant. *Draba graminea* appears to flower annually. It is not known how long fruits remain on the plant (Rollins 1993), nor is it known if this species flowers consistently year after year, or what the annual production of seeds is. According to Grime (1979), a persistent seed bank is one in which at least some of the seeds are at least one year old. Billings (1974) observed that the seeds of alpine plants are produced late in the year and do not germinate until the following year, if then. We can only assume that *D. graminea* produces viable seed to some extent. No seedlings have been observed, nor is there any indication that recruitment has taken place. This is not to say that recruitment is not occurring; rather, none of the known occurrences have ever been revisited to determine if recruitment is happening. *Draba graminea* also reproduces vegetatively by growth and development of the perennating bud. There is no evidence that this species exhibits clonal growth (Hitchcock 1941, Rollins 1993). Palatability of this species has not been documented. The only thing known about the physiology of this species is the location of its photosynthate storage system in the root crown (Hitchcock 1941, Rollins 1993).

Grime (1979) developed a useful conceptual model for classifying autecological strategies for individual species. This model is helpful in determining where in the broader picture an individual species can be placed by classifying plant strategies. His system is based on three basic stress responses: competitor, stress-tolerant, and ruderal. In reality, species can take on any combination of characteristics of these responses. There are not enough data to classify *Draba graminea* definitively. Given the harsh alpine environment, this taxon is more likely stress-tolerant than either a competitor or a ruderal. Natural processes, such drought and talus slides, may negatively impact the ability of *D. graminea* to reproduce or survive.

Draba graminea is monecious, reproducing sexually by seed. The inflorescence is a raceme, comprised of showy yellow (petals 4 to 5 mm long) flowers. *Draba graminea* flowers from July through August, with undispersed fruits present at least through August (Rollins 1993). In almost all alpine plants, flower primordia are formed at least one year before flowering. These preformed flower buds ensure that there is no delay in anthesis; flowering in many alpine species can occur from 10 to 20 days after snowmelt (Billings 1974). *Draba graminea* has been observed flowering in late snowmelt areas. This would indicate that this species likely forms flower primordia.

The genus *Draba* is a large polyploid complex typically occupying arctic and alpine habitats (Koch and Al-Shebaz 2002). Several breeding systems have been identified within the genus including outcrossing, selfing, and apomixis (usually agamospermy). Not all species in this genus have been cytotaxonomically studied. Base chromosome numbers in some *Draba* species vary from n = 8 in Eurasian species to n =5, n =6, n =10, n =12 to n =16 in North and South American species (Mulligan 1971, Windham 2000). The chromosome number of *D. graminea* is unknown. Chromosome numbers are important in *Draba*, because this great variation indicates a propensity to outcross (Grant 1981). However, this genus also has members that are apomictic, primarily in the mountains of western North America (Mulligan 1971, Brochmann et al. 1992). Mulligan (1971) experimentally showed that the large-flowered species *D. ruaxes* Payson & St. John (petals yellow, 4 to 5 mm long) is an obligate outcrosser. *Draba graminea* also has showy yellow flowers which are similar in size. This morphology is speculated to be associated with several outcrossing *Draba* species (Mulligan and Findlay 1970). Mulligan and Findlay (1970) also suggest that outcrossing is more prevalent in alpine *Draba* species located in the southern Rocky Mountains compared with wide-spread selfing *Draba* species in the arctic. It is not possible to characterize the breeding system of *D. graminea*; it is entirely possible that this species could exhibit outcrossing, selfing, apomixis, or characteristics of all three systems.

There have been no empirical studies to show that *Draba graminea* is either self-compatible, apomictic, or an obligate outcosser. If *D. graminea* were self-fertilizing, then a mechanism to overcome a lack of pollinators would exist, giving this species a reproductive advantage in the short term, in the event pollination vectors are absent. On the other hand, in the long term, selfing may promote homozygosity and possibly reduce fitness and its ability to adapt to changing environmental conditions (inbreeding depression) (Menges 1991, Weller 1994). If *D. graminea* is an outcrosser, then it would also have a long-term reproductive advantage by maintaining higher heterozygosity. In the short term, any loss of pollination vectors could theoretically reduce seed set (Weller 1994). Mulligan and Findlay (1970) propose that some species of *Draba* are selfing, but they will outcross if weather conditions favor pollinator activity. Primarily outcrossing *Draba* species may also occasionally self-fertilize (Mulligan 1976). Packer (1974) suggests that most of the Rocky Mountain *Draba* species appear to be autogamous.

There are currently no known examples of hybridization between *Draba graminea* and any other species of *Draba*. The genus *Draba* is known to have both diploid (autopolyploid) and allopolyploid species. Given the polyploid nature of the genus, it is possible that unidentified hybrids exist. Allopolyploidy is a type of permanent hybridity; it allows a hybrid to circumvent the sterility barrier and to maintain the hybrid genotype (Grant 1981). It is impossible to make inferences about the ability of *D. graminea* to hybridize without, at the very least, a base chromosome number. It has been shown that interploidal hybrids do exist in the genus *Draba*, contributing to the complexity of the polyploid complex (Brochmann et al. 1992). Brochman and others (1992) propose that arctic-alpine *Draba* grow in sparsely vegetated, environmentally stressed sites and that these sites may facilitate the formation of hybrids. Grant (1981) proposed that the existence of a diploid parental species, the ability to undergo natural hybridization, and a long-lived perennial growth habit are primary factors facilitating an allopolyploid system. Secondary factors include disturbed and stressful habitats and small chromosome sizes (Grant 1981). These conditions have been met by many *Draba* species. We do not know where *D. graminea* can be placed within the *Draba* polyploid complex. While it is not known if *D. graminea* readily undergoes hybridization, it is highly possible that it does. If *D. graminea* does form hybrids, any introduction of compatible species could facilitate the formation of hybrids and possibly affect the viability of *D. graminea*.

No formal investigations have been developed to characterize the pollination mechanisms for this species. As discussed above, this genus may be self-fertilizing, apomictic, or out-crossing. The Brassicaceae family possesses a mechanism for species specificity through expression of the *Brassica S* product of the pollen-signaling *S*-gene. If the pollen is compatible, the pollen tube will hydrate and fertilization will follow; if the pollen is incompatible, the pollen tube will not hydrate (Heizmann et al. 2000). In alpine habitats, entomophily as well as anemophily is likely (Packer 1974, Gómez and Zamora 1996). Most showy alpine flowers are insect pollinated. Price (1979) suggested that flies are likely the most common pollinators of alpine *Draba* species, though pollinator visits were few compared to other alpine species. Members of the Syrphidae, Muscidae, and Anthmyiidae were observed pollinating alpine *Draba* species, with the Syrphidae effecting pollination more often (Price 1979). No other reproductive mutualisms for this species have been identified.

No information is available about the physiology of germination or establishment of seedlings for *Draba graminea*. Moreover, no experimental data exist concerning the fertility or viability of the seeds of *D. graminea*. In general, Billings (1974) suggests that alpine seed germination and seedling establishment are occasional. He concluded that alpine seed germination is under environmental control, and the optimal combination of suitable temperature and moisture conditions may only occur occasionally.

Seedling growth in the alpine is slow, with most production going into establishing a root system to ensure a carbohydrate bank to survive the harsh conditions. Several years may pass before a young plant is firmly established (Billings 1974). No investigations into seed dispersal have been accomplished for this species. No observations have been made concerning seed predation of *Draba graminea* fruits. It is assumed that *D. graminea* maintains a persistent seed bank. How long the seeds are viable is not known. There are no other known cryptic phases in the *D. graminea* life history.

Phenotypic plasticity is defined as marked variation in the phenotype as a result of environmental influences on the genotype during development (Lincoln et al. 1982). There is no empirical evidence to suggest the presence of ecotypes in *Draba graminea*. An investigation using transplant experiments would perhaps answer the question of phenotypic plasticity in *D. graminea*. No evidence from collected specimens identified any variation in mortality.

Current literature indicates that relationships commonly exist between most higher plants and mycorrhizal fungi (Barbour et al. 1987). These relationships are poorly known, and in fact, this is a growing area of scientific study. It is not surprising, then, that there are no documented or observed mycorrhizal associations for *Draba graminea*. A study of vesicular-arbuscular mycorrhizae root associations in alpine plants on soils derived from crystalline or calcareous parent materials found *zero* infections of *D. oligosperma* on crystalline soils (Lesica and Antibus 1986). This study did not document an association with *D. oligosperma*; therefore, no inferences can be made concerning the relationship between *D. graminea* and vesicular-arbuscular mycorrhizae associations.

The relationship between rarity and genetic variation is a subject of increasing interest, and the past notion that rare species have a low level of genetic variation has been questioned (Linhart and Premoli 1993, Gitzendanner and Soltis 2000). There is no doubt that low genetic diversity does affect the ability of some rare plants to reproduce and survive (Fenster and Dudash 1994, Weller 1994). Genetic factors such as inbreeding depression and outbreeding depression should be considered in analyzing the genetic fitness of a species. *Draba graminea* may be capable of self-pollination and outcrossing, both of which may facilitate inbreeding depression and outbreeding depression, respectively. There is no evidence that *D. graminea* readily undergoes natural hybridization. Therefore, no conclusions can be drawn concerning the effect of outbreeding depression on this species. Given the lack of evidence and understanding, no inferences can be made by the authors concerning genetic issues possibly associated with *D. graminea*.

Demography

The life history of *Draba graminea* remains uninvestigated at this time. No information concerning vital rates, recruitment, survival, reproductive age, generation time, or lifespan have been documented. Estimates of the proportion of populations reproducing are not available. Observations by field botanists note that populations were flowering and fruiting, indicating that the populations were reproducing.

A demographic projection matrix provides valuable information about the vital rates of a species and is determined by tracking the fate of individuals over time. There are no established demographic monitoring sites for *Draba graminea*. Therefore, no data exist from which a population projection matrix can be constructed or a generalized life cycle diagram as per Caswell (2001). Nevertheless, a simple lifecycle diagram is presented in **Figure 7**. It is not known if immature stages exist. If there is a juvenile stage, it is unknown if juveniles must attain a certain size or stage before becoming reproductive. It is also unknown if reproductive adults revert to a vegetative state. Seed bank dynamics (i.e., recruitment rates, seed longevity, abundance) are unknown, but this is represented in the diagram by a question mark between seed bank and seed. No information is available on germination rate or seedling survival, depicted in the diagram by a question mark between seed and seedling. Reproductively mature individuals of *D. graminea* have been observed to undergo silique fill, or fruiting (Hitchcock 1941).

A Population Viability Analysis (PVA) is a rigorous quantitative analysis that uses demographic data to predict the future status of a given species. A literature search for PVA models for this species was performed. It is the minimum viable population (MVP), or the minimum population size necessary to have an acceptably low extinction probability that can provide useful information for management purposes. It has been suggested that demography is of more immediate importance than genetics in determining the MVP of a plant population (Landes 1988, Menges 1991). Menges (1991) suggests that if a plant population is able to buffer environmental stochasticity, then the population will be sufficient to protect its genetic integrity. No PVA has been accomplished or MVP has been determined for *Draba graminea* at this time.

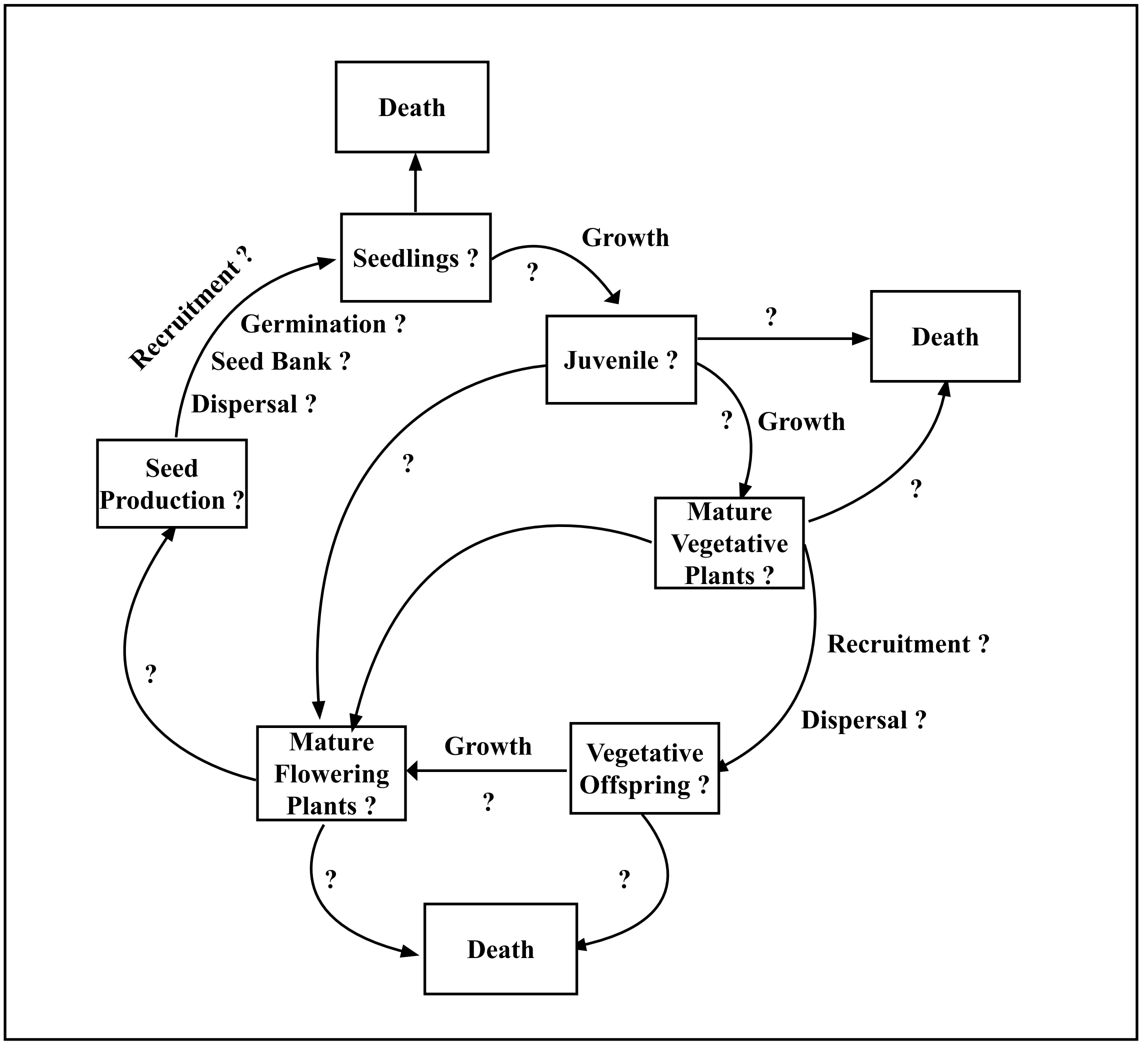

Figure 7. Generalized life cycle diagram for *Draba graminea*. Question marks reflect our lack of understanding of the mechanisms between stages. Vegetative and reproductive stages are assumed to be adult.

Information concerning the demographic spatial characteristics for this species is limited. Less than one half of all known locations have abundance estimates (**Table 2**). It is conceivable that sources and sinks could be identified if all of the EORs reported quantifiable data and genetic information had been obtained. However, at this point in time, there are not enough quantifiable abundance or genetic data to identify sources and sinks of *Draba graminea* populations.

Few factors limiting the population growth of *Draba graminea* have been identified. Possible factors include low germination, low seedling survivorship, and the inability of *D. graminea* to disperse. Herbivores have not been investigated nor has grazing pressure been observed at any of the known populations. Currently, no empirical data exist examining other population growth-limiting factors, such as seed predation, competition, habitat destruction or fragmentation.

Community ecology

Draba graminea is generally located in inaccessible areas. The topographic location of this species' habitat has provided it a degree of isolation from interactions with invasive species. No invasive species have been reported within the known occurrences of *D. graminea*. It is unknown whether interactions with native species have any effect on the distribution or abundance of *D. graminea*. Interactions between species along an elevation gradient may have an influence on alpine plant distribution. A study done in the French

Alps showed that facilitation appeared to allow species from lower elevations to move up the gradient, whereas competition at lower elevations prevented species from moving down the gradient (Choler et al. 2001).

There have been no recorded observations of interactions between *Draba graminea* and herbivores. Observations of habitat preferences and the autecology of *D. graminea* lead us to conclude that this species is stress-tolerant. It tends to colonize a specific habitat where there is less competition to overcome (see above discussion on habitat and autecology). No information is available regarding the competitive ability of *D. graminea* relative to invasive species. Based upon the principals set forth by Grime (1979), the authors speculate that this species is adapted to a non-competitive, stress-tolerant strategy, and as such it would most likely not successfully establish itself in microhabitats with greater species diversity.

There are no studies investigating parasites or diseases that may affect *Draba graminea*, nor have there been any investigations of symbiotic or mutualistic interactions.

An envirogram is a useful tool for evaluating the relationship between the environment and a single species. It traces the environmental factors that affect a species from the most indirect (distal) interactions to factors that have a direct (proximal) effect (Andrewartha and Birch 1984). Traditionally, it is most often applied to animal/environment interactions. An example of an envirogram constructed for *Pinus lambertiana* Douglas (sugar pine) showed that the same principles used to construct one for animals could be equally applied to plants (Lake Tahoe Watershed Assessment public communication 2000). The envirogram is a series of webs that converge upon a centrum. The centrum consists of the basic components of environment that cause an increase, a decrease, or no change in the expectation of fecundity and survivorship of a species. It is the most proximal level of the envirogram, and directly affects the target species (Andrewartha and Birch 1984). For plants, the centrum consists of resources (light, soil moisture, and nutrients), reproduction (flowering/fruiting, growth and development, and seedling establishment), and malentities (human interactions, extreme weather, and herbivory).

The envirogram is constructed as a modified dendrogram, with the centrum placed at the most proximal level to the species. From each of the centrum components a web is constructed distally, illustrating factors that affect the centrum component, termed Web 1. Web 2 consists of factors that affect Web 1; Web 3 consists of factors that affect Web 2; and so on. Two of the primary functions of an envirogram are to identify areas of research and to propose hypotheses (Andrewartha and Birch 1984). As with all analytical tools, the best envirogram is based upon a complete data set. An envirogram was constructed for *Draba graminea*, despite the lack of ecological and environmental data. Entries with a question mark denote areas in need of further research, such as pollination mechanisms, herbivory, flowering/fruiting, the effect of disturbance, and dispersal vectors. **Figure 8**, **Figure 9**, and **Figure 10** illustrate a preliminary envirogram for *D. graminea*. To conserve space, occasionally second- and third-level webs are referred to a more complete web rooted in Web 1. Web 4 levels and above (Web *n*) generally identify areas beyond the ecological and biological scope of the species.

The resources centrum for *Draba graminea* is made up three proximal factors: soil moisture, light, and nutrients. Soil moisture is affected by precipitation, soil porosity (permeability), soil water retention, and runoff. Moisture is generally modified through natural processes. However, cloud seeding activities may increase the soil moisture of an area. Light can be affected by community structure, rocks, and geology, while substrate parent material and the addition of organic materials can affect the nutrient centrum.

The reproduction centrum consists of factors affecting flowering and fruiting (pollination, weather, dispersal), seedling establishment (possible safe sites, substrate, protection), and growth and development (weather, light, substrate).

The malentities centrum identifies factors that may negatively affect *Draba graminea*, such as extreme weather conditions, herbivory, competition from invasives, recreational activity, and air pollution. Drought or unusually cold weather during the flowering and fruiting season can affect reproduction. Herbivory may cause damage through trampling, seed predation, or leaf damage. This may result from either domesticated livestock or native fauna, including insects and mammals, such as pikas or marmots. Competition from invasive species, introduced through grazing or recreational hikers may have a negative effect upon the ability of *D. graminea* to occupy available habitat. In addition, trampling from recreational hikers may threaten *D. graminea*. Air pollution, including acid rain, silver residue from cloud seeding, and the development of greenhouse gases, may also have a negative effect upon the alpine community, including *D. graminea*.

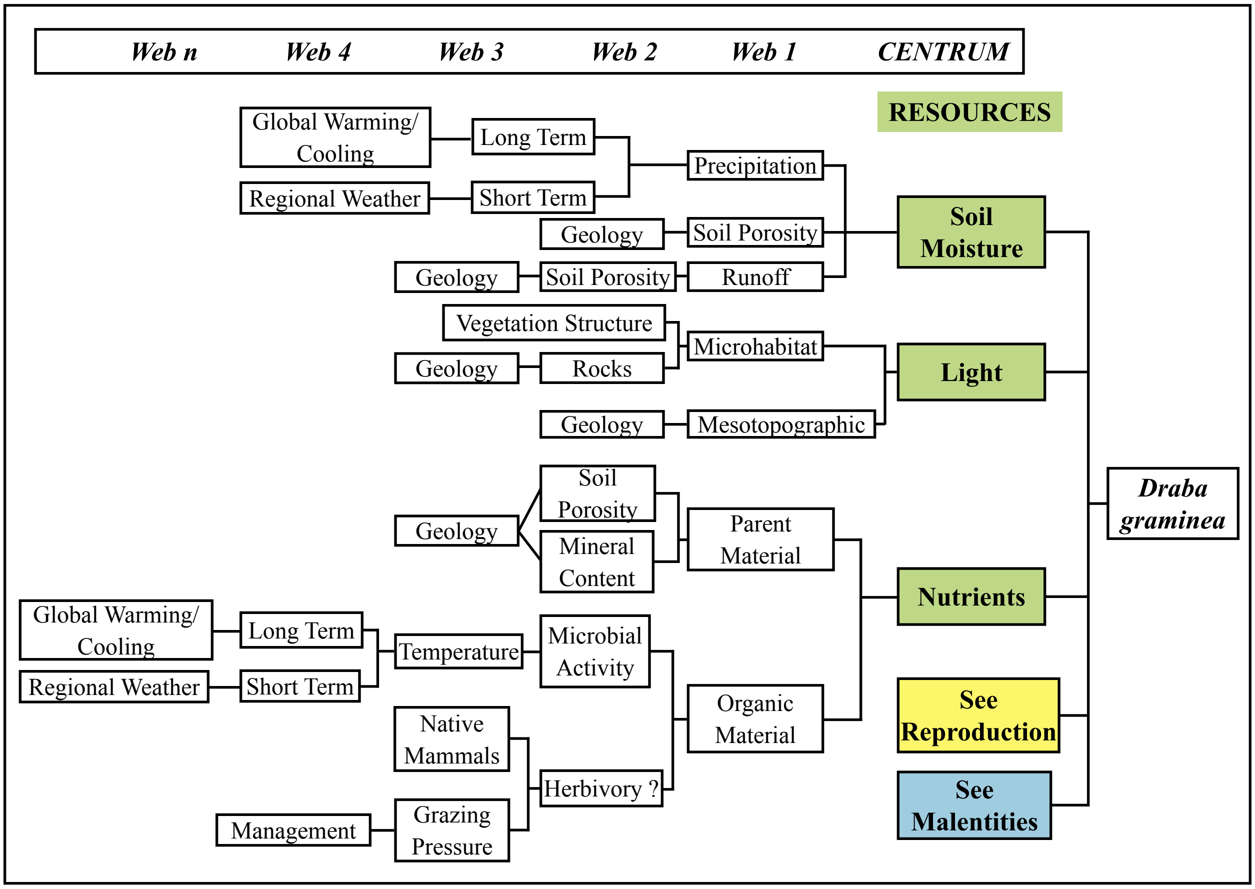

Figure 8. Envirogram for *Draba graminea*, Resources centrum.

Conservation

Threats

Current threats to *Draba graminea* are difficult to identify due to the remoteness of occurrences. The only threat that has been specifically identified for this species in Colorado was erosion from nearby jeep trails (EOR 003*CO). The remote location of this species may provide it some protection. However, land managers who are unaware of occurrences would be unable to make informed decisions concerning management activities and their impacts on *D. graminea*. The concern for the viability of this species reflects its limited abundance and restricted global distribution; population numbers are small to locally abundant. Viability considerations for *D. graminea* include possible loss of occurrences due to management activities that impact the habitats or populations. Of the activities that typically occur on or are planned for the San Juan, the Rio Grande, or the Grand Mesa, Uncompahgre, and Gunnison national forests, livestock grazing, recreation, and mining are likely to be the most influential with regards to *D. graminea*.

Palatability of this species has not been documented, but the plant's low stature and sparse habitat may provide some protection from herbivory (Johnston personal communication 2003). Secondary grazing impacts, including soil compaction, erosion, and spread of noxious weeds, may still be important. Both cattle and sheep grazing occur in areas where *Draba graminea* occurs. On the Grand Mesa, Uncompahgre and Gunnison National Forest, the species occurs in seven different allotments. Three of these allotments are vacant, two allotments are closed, one allotment is utilized for cattle, and one allotment is currently utilized for sheep grazing. On the San Juan National Forest, *D. graminea* occurs in five different allotments. Three of these are active sheep allotments, and two are vacant. On the Rio Grande National Forest, *D. graminea* occurs in 2 different allotments. The authores were not able to determine whether these allotments are active or not. Potential impacts of sheep grazing that have been observed include trampling and soil compaction (Heil personal observation). In general, however, the rugged topography and isolation from water sources of this habitat minimize direct threats of grazing to *D. graminea*.

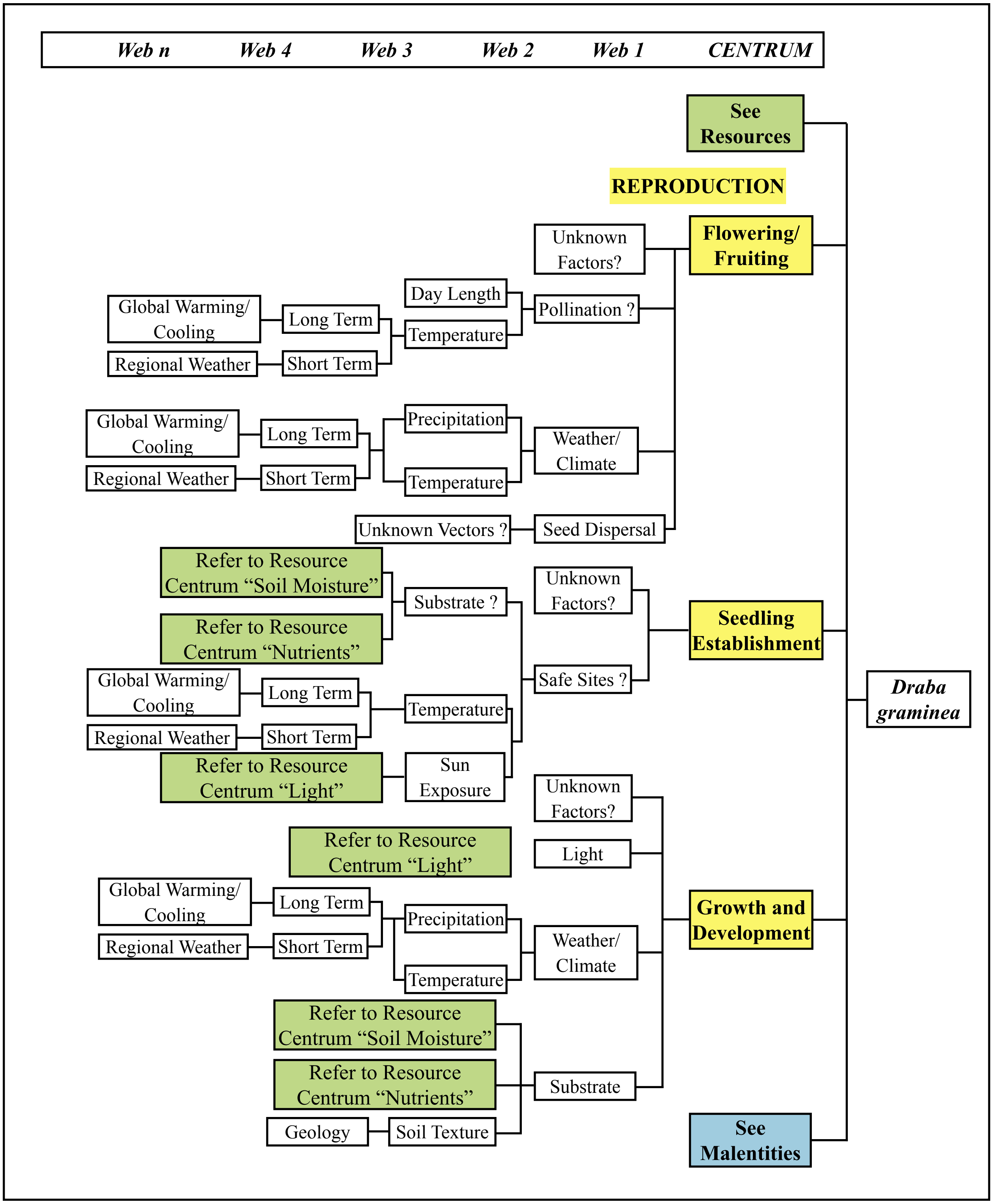

Figure 9. Envirogram for *Draba graminea*, Reproduction centrum.

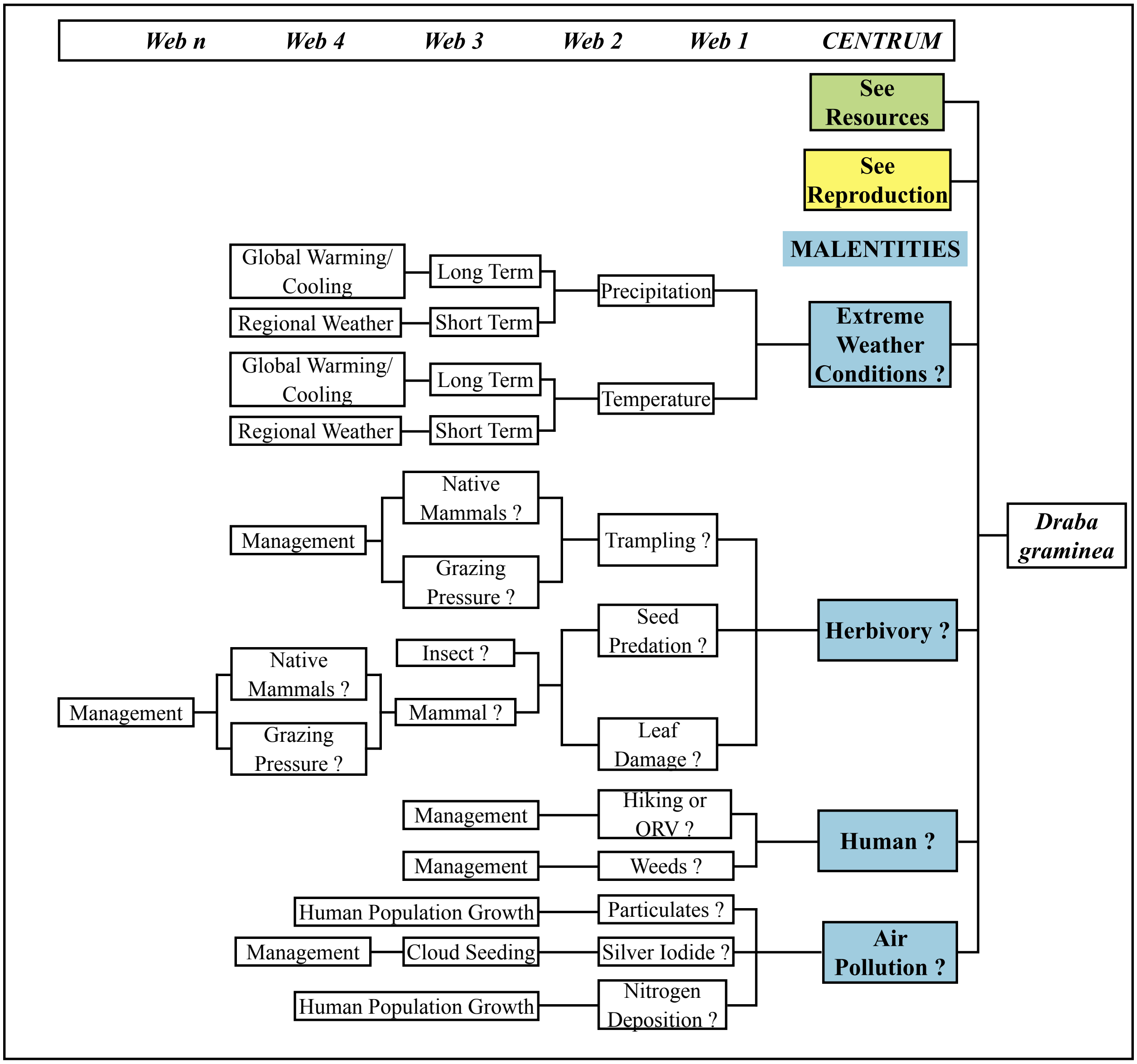

Figure 10. Envirogram for *Draba graminea*, Malentities centrum.

Recreation use in the proximity of occurrences primarily consists of 4-wheel drive vehicle use and hiking. Nine of the 29 populations are located in wilderness areas where both motorized and non-motorized vehicle use are prohibited. Impacts from vehicle use include habitat fragmentation, increased erosion, and direct damage to individual plants from trampling.

No reports of direct impacts from mining have been reported. Patented mining claims could occur on or near populations of *Draba graminea*. No evaluation of locations of *D. graminea* populations with respect to ownership of mining claims on BLM or USFS lands has been conducted. Mining impacts could include habitat fragmentation, alteration of hydrology, increased erosion, and direct damage to individual plants from construction and operation of roads and mines.

Other potential threats to the species include extreme weather conditions, herbivory by native fauna, competition from invasive species, cloud seeding, global warming, and air pollution. Extreme drought may impact late snowmelt habitats. Unusually cold springs may delay reproduction and subsequently seed set. Herbivory may occur from native fauna, including insects and mammals, such as pikas or marmots. Native herbivory could result in seed predation or leaf damage. No invasive species have been reported within the known occurrences of *Draba graminea*. The topographic location of some occurrences probably provides a degree of isolation from interactions with invasive plant species. Potential for introduction of invasive species may occur as a result of livestock grazing and/or recreational hikers, thereby reducing the ability of *D. graminea* to occupy available habitat.

The effectiveness of cloud seeding is still in debate, and it may be harmful to flora, fauna, and water through introduction of silver iodide or alteration of precipitation regimes in ecosystems (Irwin et al. 1998). It has been speculated that cloud seeding a west to east moving storm in one area may decrease the precipitation that a given storm produces in areas east of the seeded region. A majority of occurrences are within a 50-kilometer radius of known cloud seeding efforts (Durango Mountain Resort and the Telluride ski area). It is highly unlikely that cloud seeding will have any measurable effect upon *Draba graminea*.

Global warming has been identified as a potential threat to alpine communities. In Colorado, both lower elevation and alpine snow covers are very sensitive to changes in climate. Theoretically, Colorado's snow cover could be reduced in extent, duration, and depth with global warming. This could, in turn, result in an alteration of timberlines encroaching on alpine habitats and possibly alter phenology (Colorado Department of Public Health and Environment 1998, Inouye et al. 2003). Nitrogen emissions from fixed, mobile, and agricultural sources have increased dramatically along the Front Range of Colorado (Baron et al. 2000). A study of nutrient availability, plant abundance, and species diversity in alpine tundra communities determined that the addition of nitrogen resulted in an increase in species diversity in a dry meadow (Theodose and Bowman 1997). Increased nitrogen may provide a potential threat to *Draba graminea*.

Conservation Status of the Species in Region 2

As stated above, the concern for the viability of *Draba graminea* reflects its limited abundance and restricted global distribution. There are no established demographic monitoring sites for this species, nor have records been maintained noting changes in population size at any of the known occurrences. No inferences about population trend for the species at the scale of individual populations or range wide can be made. Due to the lack of data, no inferences can be made concerning the temporal pattern of abundance at any spatial extent. *Draba graminea* occurs in small occurrences ranging in size from 5 to 1,000 or more individuals.Our knowledge concerning the habitat capability and ecology of *D. graminea* is limited. Known occurrences occupy alpine habitat types. No empirical data are available describing ecological strategies for *D. graminea* (see Reproductive biology and autecology section).

Occurrences of *Draba graminea* may be at risk from environmental or demographic stochasticity due to small neighborhood size of populations. Factors increasing the risk include geographically isolated populations and *possible* inbreeding depression. Seedling recruitment may be a factor limiting population growth, particularly in the alpine. There are no identified specific mutualisms including mycorrhizal partners, pollinators, or dispersers. However, no investigations have been conducted concerning these mutualisms. The possible selfing and/or outcrossing breeding system may buffer against loss of heterozygosity, but the species may be affected in the short term by dependence upon pollinators or other mutualisms that have not been identified at this time (Menges 1991).

There is little direct evidence to indicate whether or not specific occurrences of *Draba graminea* in Region 2 are at risk. The discussion in the preceding paragraphs indicates that perhaps several potential threats may impact *D. graminea*. Evaluation of effects of management on species fitness has not been conducted.

Potential Management of the Species in Region 2

Implications and potential conservation elements

Detailed biological and ecological studies of *Draba graminea* and associated habitat have not been conducted. No specific information is available documenting impacts of management on the species. Based on this lack of information, the authors can only speculate as to the species' response to natural and anthopogenic disturbances.

Due to the fragile nature of alpine habitats, any alteration of soils, moisture, temperature regimes, or community composition may limit reproduction, growth, and vigor of *Draba graminea*. Activities potentially occurring on USFS lands that may threaten individuals or occurrences of *D. graminea* include grazing, mining, and recreation and competition from invasive species. The consequences of management actions may include habitat fragmentation, soil compaction, erosion, trampling of individuals, loss of fitness, or alteration of habitat. No experimental data are available on the response of this species to management actions.

Tools and practices

Few historical abundance data were available before the Colorado Natural Heritage program began tracking this species. Continued efforts in the location of other occurrences by the use of presence/absence surveys may provide additional information concerning distribution and abundance of the species. Conducting county-wide biological surveys is an integral part of the CNHP, and as a result of these surveys, new occurrences of many different species are discovered periodically. Documentation of new occurrences is time and resource intensive. This difficulty is magnified by the fact that *Draba graminea* is found in areas that are highly inaccessible. Due to the rough topography and inherent inaccessibility of many sites, estimating potential habitat for *D. graminea* requires taking into consideration the possibility of populations remaining undiscovered. It is likely that future documentation of new occurrences lies in chance discovery by enthusiastic plant lovers and botanists hiking the high country of the San Juan Mountains.

Potential habitat exists throughout the higher elevations of the San Juan Mountains, particularly in the areas close to and surrounding the continental divide. Eight new occurrences were identified by surveyors in 2003 and 2004. Potential habitat is present in the Rio Grande National Forest and the Gunnison National Forest. Alpine areas located at the headwaters of the Gunnison, Piedra, and San Juan rivers could also harbor *Draba graminea*. In addition, isolated mountain groups adjacent to the greater San Juan Mountains, such as the Rico Mountains and the Wilson Mountains may have occurrences of *D. graminea*. Specific information concerning population numbers, reproduction, and assessment of impacts to populations should be recorded.

Population monitoring should be designed to ascertain parameters of the species' life history, including generation time, net reproductive rate, age distribution, and potential reproductive output lost to abortion and predation. Periodic estimates of population size alone may not provide adequate information for management decisions (Elzinga et al. 1998). Factors affecting seedling establishment need to be determined, as this is a critical life stage for any alpine species. The establishment and remeasurement of permanent transects may yield information to determine reproduction, trends, disease, predation, mortality, and threats (Elzinga et al. 1998). Utilization of photo plots would provide a snapshot of plant vigor and distribution at the time of sampling. Random population sampling may not be adequate, given the patchy, clumpy distribution of individuals (Lyon personal communication 2003).

No evidence was identified that suggested that *Draba graminea* naturally hybridizes. However, it is likely based on the propensity of the genus to undergo hybridization even across ploidal levels. Should this be the case, a metapopulation study including DNA and/or isozyme analysis will need to be conducted to define the populations. Hybrid populations may reduce the vigor of the species and blur the boundaries of known populations.

Additional quantitative data that document the condition of the communities where *Draba graminea* occurs, including the composition, structure, and function of the plant community, would be useful in making future inferences of existing conditions, should an increase or decrease in occurrences take place. This information may also provide "clues" as to possible factors that limit or control the distribution of the species. Common variables to be measured include cover or density of all plant species; demographic parameters of important species; soil surface conditions, including rock type and size; and microhabitat observations, including slope, aspect, and geologic substrate. Soil temperature information may provide valuable insight to seed germination requirements and possible safe sites. Measurement and scheduled remeasurement, would provide a long-term ecological study to document rates and types of change that can occur in response to natural process such as succession and disturbance (Elzinga et al. 1998).

Habitat monitoring describes how well an activity meets the objectives or management standards for the habitat (Elzinga et al. 1998). Habitat monitoring is most effective when research has shown a clear link between a habitat parameter and the condition of a species (Elzinga et al. 1998). Without additional knowledge of specific factors that control the growth and distribution of *Draba graminea*, it would be difficult to establish a habitat monitoring program at this time.

The mission of the Center for Plant Conservation is to conserve and to restore the rare native plants of the United States. No plant material of *Draba graminea* has been stored with the Center for Plant Conservation.

Information Needs

The remoteness of *Draba graminea* occurrences suggests that other occurrences may exist as identified in the Tools and Practices section. The species' limited abundance and restricted global distribution could be attributed to the limited amount of habitat available, its reproductive strategy, and the short growing season in which it lives. Continued efforts in the location of other occurrences by use of presence/absence surveys may provide additional information concerning distribution, habitat attributes, and abundance of the species. This would assist in the formulation of conservation strategies for Region 2. Monitoring previously identified sites is essential to provide trend information and the level of threat that natural or anthropogenic activities pose.

In addition to surveying for new occurrences, the following information could prove invaluable in identifying parameters controlling the distribution, reproduction, and population trends of *Draba graminea*:

- ❖ Collection of quantitative data, including habitat attributes relevant to community structure and composition of high quality occurrences. This would provide a baseline for use of habitat monitoring in the future.

- ❖ Evaluation of the reproductive and ecological characteristics of the species, including pollination mechanisms, seed germination, seedling establishment, herbivory, flowering/fruiting, and dispersal vectors. This would provide a basis to assess the factors controlling the growth of *D. graminea*.

- ❖ Evaluation of demographic parameters (vital rates, recruitment, survival, reproductive age, lifespan, proportion of populations reproducing, seed viability, seed bank dynamics, longevity).

- ❖ Cytological investigation to determine ploidy and test hypotheses for an allopolyploidal origin of *D. graminea*, which might also identify possible ancestry. Determine if *D. graminea* reproduces sexually, or by apogamy or pseudogamy.

- ❖ Should baseline inventories identify impacts to the species or community from management activities or natural disturbances, development of impact assessments to generate information of value in determining effective conservation practices for the species.

Definitions

Agamospermy: Apomixis in which embryos and seeds are formed asexually, but not including vegetative reproduction (Lincoln et al. 1982).

Alleles: Any of the different forms of a gene occupying the same locus (Lincoln et al. 1982).

Allopolyploidy: A polyploid containing separate sets of nonhomologous chromosomes, the product of chromosome doubling in a species hybrid (Grant 1981).

Anemophily: Dispersed or pollinated by wind (Lincoln et al. 1982).

Apomixis: Reproduction without fertilization, in which meiosis and fusion of the gametes are partially or totally suppressed (Lincoln et al. 1982).

Autogamous: Self fertilizing (Lincoln et al. 1982).

Autopolyploid: A polyploid containing three or more sets of homologous chromosomes derived by doubling or adding the chromosome sets of a structural homozygote (Grant 1981).

Cryoturbation: The physical mixing of soil materials by the alternation of freezing and thawing (Lincoln et al. 1982).

Entomophily: Pollination by or dispersed by the agent of insects (Lincoln et al. 1982).

Environmental stochasticity: Variation over time in the populations operational environment (Menges 1991).

Generation time: The mean period of time between reproduction of the parent generation and reproduction of the first filial generation (Lincoln et al. 1982).

Heterozygosity: Having two different alleles at a given locus of a chromosome pair (Lincoln et al. 1982).

Homozygosity: Having identical alleles at a given locus of a chromosome pair (Lincoln et al. 1982).

Inbreeding: Mating or crossing of individuals more closely related than average pairs in the population (Lincoln et al. 1982).

Inbreeding depression: Reduction of fitness and vigor by increased homozygosity as a result of inbreeding in a normally outbreeding population (Lincoln et al. 1982).

Locus: The position of a given gene on a chromosome (Lincoln et al. 1982).

Longevity: The average life span of the individuals of a population under a given set of conditions (Lincoln et al. 1982).

Krummholz: A discontinuous belt of stunted forest or scrub typical of windswept alpine regions close to the tree line (Lincoln et al. 1982).

Phytomicroclimate: The environment created within the confines of a plant body, and within the various parts of the plant body, such as leaf or stem (Thilenius 1975).

Polyploid: Having more than two sets of homologous chromosomes (Lincoln et al. 1982).

Polyploid Complex: The result of continued polyploidization in unions of different lineages (Grant 1981).

Outbreeding depression: Reduction of fitness and vigor in the progeny when individuals mate from distant source populations (Lincoln et al. 1982).

Outcrossing: Mating or crossing of individuals that are either less closely related than average pairs in the population, or from different populations (Lincoln et al. 1982).

Self-compatible: Used of a plant that can self-fertilize (Lincoln et al. 1982).

Selfing: Self-fertilizing or self pollinating (Lincoln et al. 1982).

Silique: A dry, dehiscent fruit of the Brassicaceae family, typically more than twice as long as wide, with two valves separating from the persistent placentae and septum (replum) (Harris and Harris 1994).

Vital rates: The class-specific annual rates of survival, growth, and fecundity (Morris et al. 1999).

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