Draba grayana (Rydb.) C.L. Hitchcock (Gray's draba): A Technical Conservation Assessment

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

July 28, 2004

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Peer Review Administered by
Society for Conservation Biology

Ladyman, J.A.R. (2004, July 28). *Draba grayana* (Rydb.) C.L. Hitchcock (Gray's draba): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/drabagrayana.pdf [date of access].

ACKNOWLEDGEMENTS

The time spent and help given by all the people and institutions mentioned in the reference section are gratefully acknowledged. I would also like to thank the Colorado Natural Heritage Program, in particular Susan Spackman and David Anderson, and the Colorado Natural Areas Program, in particular Ron West, for their generosity in making their files and records available. I also appreciate access to the files and assistance given to me by Chuck Davis, U.S. Fish and Wildlife Service, Lakewood, Colorado. The conversations with and information sent from Teresa Prendusi, USDA Forest Service Region 4, Barry Johnston, USDA Forest Service Gunnison National Forest, Jennifer Rowens, Colorado State University Herbarium, and Nan Lederer and Tim Hogan, University of Colorado, were all very valuable. I appreciate the thoughtful reviews of Beth Burkhart, David Anderson, and Dr. David Inouye and thank them for their time.

AUTHOR'S BIOGRAPHY

Juanita A. R. Ladyman received her B.Sc. degree (with First-class honors) in Biochemistry from London University, England. Her first professional position was as plant pathology laboratory technician and, later, as greenhouse research supervisor with the Arid Lands Research Center on Sadiyat Island in the United Arab Emirates. She obtained her Ph.D. degree in Botany and Plant Pathology from Michigan State University where she was also a research assistant with the D.O.E. Plant Research Laboratory. She worked as a plant physiological ecologist and plant scientist for Shell Development Company conducting research on the physiology, ecology, and reproductive biology of economically important plant species and their wild relatives. She then worked for a plant biotechnology company in their Genetic Transformation and Plant Tissue Culture Division. For the last 11 years she has worked in the area of conservation, particularly on rare, endemic, and sensitive plant species in the southwest United States. For three years of that time, she was the botanist with the New Mexico Natural Heritage Program. She has conducted research and monitoring programs on both non-vascular and vascular species. She currently is a partner in *JnJ Associates*, an environmental consulting company in Colorado.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *DRABA GRAYANA*

Status

The NatureServe Global[1] rank for *Draba grayana* (Gray's draba or Gray's Peak whitlow-grass) is imperiled (G2), and it is designated imperiled (S2) by the Colorado Natural Heritage Program. It is designated a sensitive species by the USDA Forest Service, Region 2. It has no federal status at the current time under the Endangered Species Act of 1973 (U.S.C.1531-1536, 1538 -1540).

Primary Threats

Recreational use of habitat, such as foot traffic, poses a threat to some occurrences, particularly those on land managed by the USDA Forest Service. The impacts may become substantially more significant as the human population grows in areas within easy access to *Draba grayana* habitat and as recreational use increases. Mining activities are not perceived a threat to any of the currently known occurrences although individual occurrences may have been impacted in the past. Mountain goats have a negative impact on the habitat for this species in some parts of its range. Invasive weeds may pose an additional risk to its long-term sustainability. Wet nitrogen deposition (acid rain) poses a substantial risk to forb communities in alpine tundra in some regions of the Rocky Mountains, especially along the Front Range of Colorado. Global warming is a potential threat to all species currently restricted to sub-alpine and alpine-tundra zones.

Primary Conservation Elements, Management Implications and Considerations

Draba grayana is a rare mustard species that is endemic to the Rocky Mountains of central Colorado. It is restricted to elevations above 3,500 m. Relative to other areas where it has been observed, it appears to remain most abundant in the Gray's Peak area where it was originally found. Unfortunately, recreation activities and mountain goats are significantly impacting this area. The majority (25 of 28) of known occurrences are on land managed by the USDA Forest Service Region 2 on the Arapaho, Pike, San Isabel, and Rio Grande national forests. The information currently available suggests that several occurrences are relatively secure because they are located in areas that are afforded protection either by land use designation, for example USDA Forest Service wilderness area, State of Colorado natural area, and national park, or by their remote, relatively inaccessible location. There are no management plans directly concerning *D. grayana*. It appears to be a naturally uncommon species that is well-adapted to its fragile alpine habitat.

[1] For definitions of G and S ranking see "Rank" in the "Definitions section" at the end of this document.

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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 grayana* (Gray's draba or Gray's Peak whitlow-grass) is the focus of an assessment because it is a rare species endemic to the Rocky Mountains in Colorado and is designated a sensitive species by the Regional Forester of the USFS Region 2 (USDA Forest Service 2003). Within the National Forest System, a sensitive species is a plant or and animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or in habitat capability that would reduce its distribution (FSM 2670.5 (19)). A sensitive species may require special management so knowledge of its biology and ecology is critical. This assessment addresses the biology of *D. grayana* throughout its range, which is limited to Colorado. 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 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 an outline of information needs. This assessment does not 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 these have been implemented, the assessment examines their successes.

Scope

This assessment examines the biology, ecology, conservation status, and management of *Draba grayana* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although some of the literature relevant to the species may originate from field investigations on related species outside the region, this document places that literature in the ecological and social contexts of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *D. grayana* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting this synthesis, but it is placed in a current context.

In producing this assessment, the refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. Not all publications on *Draba grayana* may have been referenced in the assessment, but an effort was made to consider all relevant documents. This assessment tried to emphasize the refereed literature because this is the accepted standard in science. In some cases, non-refereed publications and reports were used because information was otherwise unavailable, but these were regarded with greater skepticism. Many reports or non-refereed publications on rare plants are often 'works-in-progress' or isolated observations on phenology or reproductive biology. For example, demographic data may have been obtained during only one year when monitoring plots were first established. Insufficient funding or manpower may have prevented work in subsequent years. One year of data is generally considered inadequate for publication in a refereed journal, but it still provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (for example, natural heritage program and herbarium records) were especially important in estimating the geographic distribution and population sizes. These data required special attention because of the diversity of persons and methods used in their collection. Records that were associated with locations at which herbarium specimens had been collected at some point in time were weighted with more significance than observations only.

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 critical experiments in the ecological relations. Therefore, while well-executed experiments represent the strongest approach to developing knowledge, alternative methods, such as observations, inference, good thinking, and models must be relied on to guide the understanding of features of biology. 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 their use in the Species Conservation Project, species assessments 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 their 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

The NatureServe Global Rank for *Draba grayana* is imperiled (G2), and the National Heritage Status Rank is also imperiled (N2) (NatureServe 2002). It is designated imperiled (S2) by the Colorado Natural Heritage Program (Spackman et al. 1997). It is designated sensitive by the USDA Forest Service, Region 2 (USDA Forest Service 2003). The Colorado Natural Areas Program (2004) considers it a rare species worthy of conservation. It currently has no federal status under the Endangered Species Act of 1973 (U.S.C.1531-1536, 1538 -1540).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies.

Draba grayana has been reported to be on land managed by the USFS and the National Park Service. While there are no specific management or conservation plans for this species, its sensitive designation within the USFS requires that a biological evaluation be conducted prior to the initiation of any project that may impact *D. grayana*. It is included by name in the document outlining general management strategy for selected plant species in the Grand Mesa, Uncompahgre, Gunnison, San Juan, Rio Grande, Pike, and San Isabel national forests published by Region 2 of the Forest Service (USDA Forest Service 1999).

Draba grayana is described in the field guide that was compiled for the Pike and San Isabel National Forest to assist field staff in identifying rare and sensitive species (Kettler et al. 1993). Prior to its formal sensitive designation, it was considered during the project that repaired and relocated the Mt. Goliath trail and trailhead (USDA Forest Service 1998). Disturbance of the plants was considered to be unacceptable, and the USFS planned to have a botanist available during the trail layout to ensure that plants would be avoided. *Draba grayana* was also located during a biological survey for rare or sensitive species before the construction of a Continental Divide Trail project (Yeatts 1999). Flags were placed so that the trail would avoid the plants, but the outcome of this effort is unclear (Yeatts 1999, Yeatts personal communication 2002). In addition, *D. grayana* is considered a sensitive species by the National Park Service and is considered in park planning (for example, National Park Service 2001, National Park Service and the Natural Resources Conservation Service 2002).

Draba grayana is recognized to be a rare species by the Colorado Natural Areas Program, which has designated the Mount Goliath Natural Area worthy of conservation partially because of its unique vegetation that includes *D. grayana* (West personal communication 2002). Designated state natural areas preserve a wide variety of Colorado's ecological and geological diversity on both public and private lands. The Colorado Natural Areas Program does not purchase property, but instead it works with local, state, and federal agencies to develop voluntary agreements protecting these areas (West personal communication 2002).

Biology and Ecology

Classification and description

Systematics and synonymy

Draba is the largest genus of the family Brassicaceae or Cruciferae, also commonly known as the mustard family. *Draba* species are found almost worldwide in relatively cool habitats, at either high elevation or high latitude. There are approximately 350 species worldwide and 104 through Central and North America (Rollins 1993). High elevation sites can be likened to virtual islands and are recognized for rapid speciation in sedentary species, such as plants.

Draba grayana (Rydberg) C.L. Hitchcock is synonymous with *D. streptocarpa Grayana* Rydberg (Rydberg 1904), *D. chrysantha* Wats. var. *hirticaulis* Schulz forma *perhumilis* Schulz (Hitchcock 1941), and *D. alpicola* Osterhout (Osterhout 1923). However, it is not synonymous with the *D. alpicola* described by Klotzsch in 1862 (Hitchcock 1941). *Draba oreades* Schrenk is synonymous with *D. alpicola* Klotzsch and is restricted to the Sinohimalayan region of western China (Schulz 1927, Slabý 2002).

Hitchcock (1941) reported that *Draba grayana* is most closely related to *D. aurea*, but it is definitely a distinct taxon rather than an alpine form of *D. aurea*. He noted that the pubescence, leaf size, fruit morphology, and general growth habit are all significantly different. Similarly, Hitchcock (1941) also listed clear distinctions between *D. grayana* and *D. streptocarpa*. These included different types and levels of hairiness on the vegetation and fruits and longer styles in the latter species. In addition, *D. grayana* is matted and caespitose while *D. streptocarpa* is tufted. Some distinguishing features of the closely sympatric species *D. grayana*, *D. streptocarpa*, *D. exunguiculata*, and *D. crassa* are listed in **Table 1**.

Table 1. Distinguishing features of *Draba grayana*, *Draba streptocarpa*, *Draba exunguiculata*, and *Draba crassa* (after Hitchcock 1941).

Characteristic	***D. grayana***	***D. streptocarpa***	***D. exunguiculata***	***D. crassa***
Root	Not thick.	Not thick.	Thick only at top.	Thick and fleshy (3 to 5 mm thick).
Basal leaves	5 to 15 mm long x 1 to 1.72 mm wide, long ciliate and sparsely hairy with short, simple or forked hairs.	10 to 35 mm long x 2 to 6 mm broad, quite densely hairy with often long (1 to 2 mm) simple and forked hairs.	10 to 25 mm long x 1 to 5 mm wide, ciliate, sparsely hairy with short, soft hairs and with few long simple hairs.	Fleshy, 20 to 80 mm long x 5 to 10 mm wide; hairless except for a few thick hairs on the margins (cilia).
Stems	2 to 5 cm tall, densely hairy with short simple or branched hairs.	2 to 30 cm tall, quite densely hairy like the leaves.	2 to 7 cm tall, hairless or with very sparse long hairs.	5 to 15 cm tall, quite hairy with short, soft simple or branched hairs.
Pedicel (stalk of individual flower)	2 to 5 mm long, densely hairy with short simple or branched hairs.	Usually slightly shorter than the fruits, quite densely hairy.	1 to 5 mm long, hairless or with few simple straight hairs.	5 to 10 mm long, usually quite hairy with short, soft simple or branched hairs.
Petals	3 to 4.5 mm long, with claws. Yellow color.	5 to 8 mm long. Yellow color.	3 to 5 mm long, clawless. Yellow color.	4 to 8 mm long. Yellow color.
Fruit	4 to 8 mm long x 2 to 3 mm broad.	8 to 15 (rarely 17) mm long x 1.5 to 2.5 mm broad; twisted.	5 to 14 mm long x 2 to 3 mm broad.	10 to 14 mm long x 3 to 4 mm broad.

History of species

Apparently the first collection of *Draba grayana* was made in 1880 by T. S. Brandegee while he was making a study of conifers in the Sawatch Range (Schulz 1927, Hitchcock 1941, Ewan and Ewan 1981). Just over a decade later a collection was made at the type location, on Gray's Peak Trail by Charles S. Crandall on July 18 in 1892 (Colorado State University herbarium specimen ID 12546). The holotype specimen was collected in 1895 on Gray's Peak by P. A. Rydberg (New York Botanical Garden herbarium specimen ID 185352 – see Internet site address in Reference section). This holotype specimen was initially described by Rydberg (1904) as *D. streptocarpa Grayana* (*D. streptocarpa* var. *grayana*). It was also briefly recognized as *D. alpicola* Osterhout (annotation of New York Botanical Garden herbarium specimen sheet by C. L. Hitchcock 1939). In 1941, it was formally described as the unique taxon, *D. grayana* (Hitchcock 1941). The epithet "grayana" may be derived from the renowned botanist Asa Gray who described *D. streptocarpa*. However, the name is particularly appropriate as it can also refer to the type location and center of its area of endemism, which is also named after Asa Gray (Colorado Native Plant Society 1997, Weber and Wittmann 2001a, 2001b).

Non-technical description

Draba grayana is a diminutive, compact, densely tufted perennial. The caudex is usually closely branched, only rarely unbranched, and the branches are thickened with old leaves and leaf bases. Each individual has several, often numerous, short stems that terminate in a cluster of flowers. The stems are 2 to 5 cm tall and may be erect or decumbent (laying down). Conspicuously dense hairs, which are both simple (straight without branches) and forked, cover the stems. The basal leaves are 0.5 to 1.5 cm long and noticeably ciliate, or hairy, at the margins. The lower surfaces are hairy while the upper surfaces are hairless or with only a few simple hairs. There are one to three, rarely four, leaves on the stem. These are much smaller than, but otherwise similar to, the basal leaves. There are five to 15 flowers per inflorescence (flower cluster). The petals are clawed, bright yellow, often described as lemon-yellow, and there are four per flower. The silicles (fruits or pods) are on 2 to 5 mm long stalks and are elongated-oblong, hairless, usually not twisted, 2 to 3 mm broad, and 4 to 8 mm long. The styles are 0.5 to 1 mm long, and the seeds are approximately 1 mm long. This description is taken largely from Hitchcock (1941) and Rollins (1993). It is important that both leaves and fruit are available when making identifications. Hair morphology is a particularly important characteristic among *Draba* species (Rollins 1993). An illustration of *D. grayana* is provided in **Figure 1**.

Figure 1. Illustration of *Draba grayana*. The illustrator is Dr. Janet Wingate and the illustration is used with permission.

Technical descriptions, photographs, line drawings and herbarium specimens

A comprehensive technical description is published in Rollins (1993). Technical descriptions are also in Weber and Wittmann (2001a, 2001b) and Schulz (1927), where it is described as *Draba streptocarpa* ssp. *grayana*. A detailed technical description and line drawings showing the leaf and fruit characters are in Hitchcock (1941). A description, photograph and line drawing are published in Spackman et al. (1997) and on the Colorado Natural Heritage Program Web site (2002). A photograph of the holotype herbarium specimen (P. A. Rydberg, August 1895) is on the New York Botanical Garden Web page (2003) under *D. streptocarpa* A. Gray var. *grayana* Rydb. See References section for internet site addresses.

Distribution and abundance

Draba grayana is one of the several *Draba* species found in the alpine tundra zone of the Rocky Mountains. It is endemic to Colorado. *Draba grayana* has been reported from approximately 28 locations in nine counties: Chaffee, Clear Creek, Gilpin, Grand, Huerfano, Larimer, Park, Saguache, and Summit (**Figure 2**). One occurrence was reported from Pitkin County, but this needs further verification (see arbitrary occurrence 28 in **Table 2**). The majority of occurrences are within 4 miles of Gray's Peak, the type location. Nineteen of the 28 occurrences were observed within the last 20 years. Occurrence data has been compiled from the Colorado Natural Heritage Program, and specimens at the University of Colorado Herbarium, Colorado State University Herbarium, the Kathryn Kalmbach Herbarium at Denver Botanic Gardens, and from the literature (Schultz 1927, Hitchcock 1941, Rollins 1993, Taylor 1999, Elliott and Hartman 2000). It must be noted that many, particularly older, records do not have precise location information and that errors have likely been made in determining the exact number of occurrences. In some cases a site may have been revisited and designated a new occurrence, or discrete populations in the same general vicinity may have been estimated to be the same site.

Occurrence and population size is variable but typically small. Although the species has been described as "relatively locally common," plants are more usually reported as "occasional" or "uncommon". Between 10 and 30 plants is a common occurrence size although plants grow in "clumps" and therefore the number of individuals is difficult to define. Although one clump is likely derived from one individual, in some cases two or more individuals may be represented in a clump. The clumps may have from eight to approximately 70 individual stems. Populations can be composed of plants that are distributed over areas that range from an isolated length of approximately 5 m (such as arbitrary occurrence number 21 in **Table 2**) to over one-quarter mile (such as arbitrary occurrence number 17, **Table 2**). One population of approximately 25 plants (or clumps) was counted in an area of approximately 1,115 m^2 (arbitrary occurrence number 22 in **Table 2**). Sixteen clumps with 70 individual stems in an area of 1 m^2 were also reported to be on a boulder, which appears to be a unique habitat type (Fayette 1997 in Colorado Natural Heritage Program element occurrence records). Price (1980) stated that "the taxon was fairly well dispersed along the Continental Divide in north central Colorado" and estimated that there were likely 5,000 individuals in the Mt. Evans area in Clear Creek County. He did not describe the method that was used to derive this estimation.

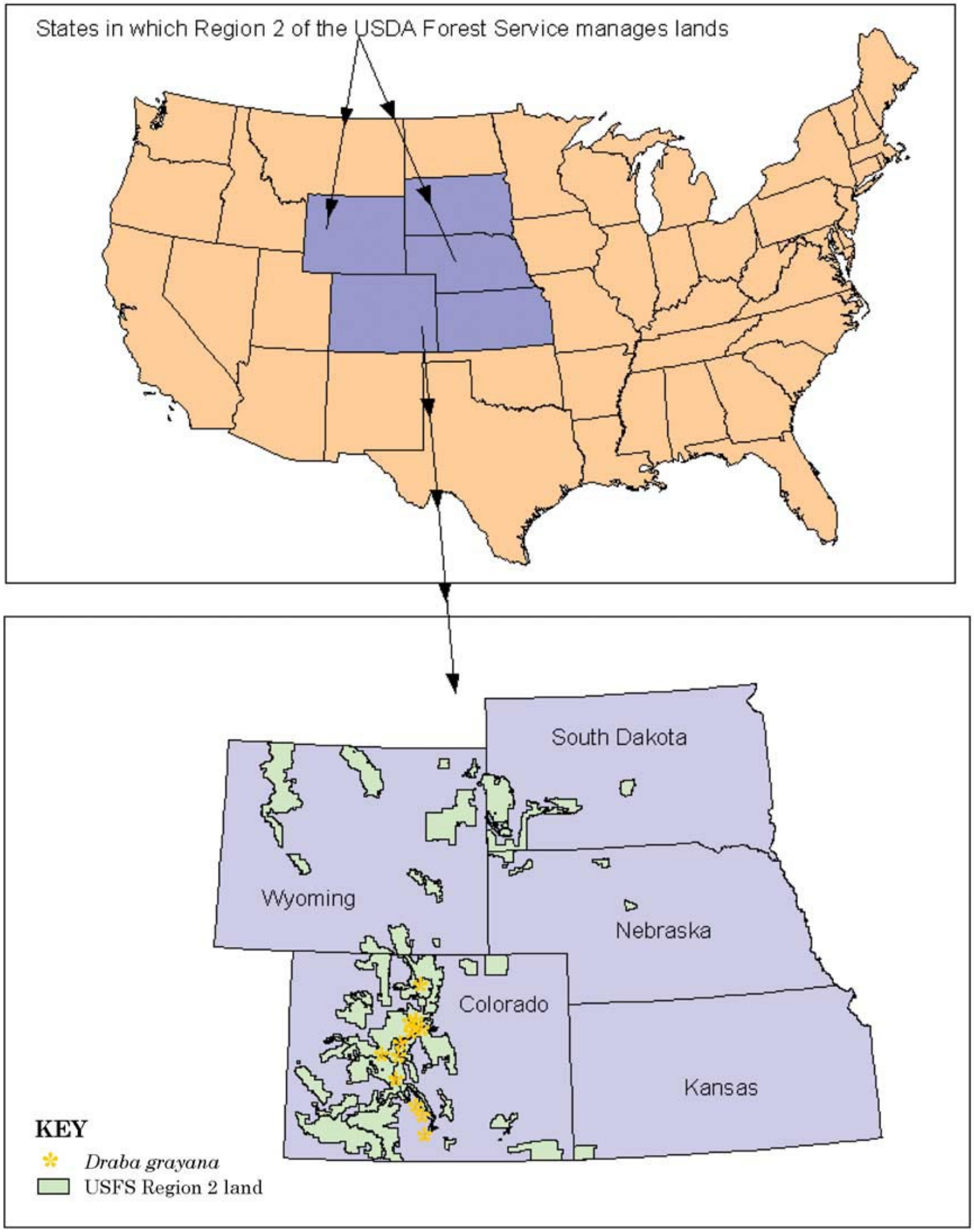


Figure 2. Distribution of *Draba grayana* in Region 2.

Table 2. Information on 28 *Draba grayana* occurrences in Colorado (USFS Region 2). Includes county, dates observed, location, land management context, habitat characteristics, estimated abundance, and collector.

Arbitrary occurrence no.	County	Dates observed	Location	Area management	Habitat	Abundance and comments	Collector
1	Park, Summit	7/19/1946; 8/8/1951; 7/7/1959	Mosquito Range. 1946: Ridge 1951: Hoosier Ridge, about 2 miles east of Hoosier. 1959: Summit of Hoosier Pass	Arapaho National Forest (possibly extends to private land)	1951: Open knoll.	1951: Original identification was *Draba exunguiculata*	Colorado Natural Heritage Program element occurrence records (G. Richard, 26 1959 CS). D Walter 26 1959 CS. R. C. Rollins 51293 with W. A. Weber 1951 COLO
2	Park	7/16/1985	Horseshoe Gulch, approximately 1.5 mi east of Horseshoe Mountain, Mosquito Range	Pike National Forest	North-facing slope, Mississippian Rocks; scattered willow.	No information	Colorado Natural Heritage Program element occurrence records, B. E. Neely & B. Johnston 3109 1985 CS
3	Park	7/22/1995; 7/12/1998	Mosquito Range, Peak 12,917 ft., approximately 0.5 mi west of Buffalo Peak, USGS 7.5' Harvard Lakes	San Isabel National Forest, Buffalo Peaks Wilderness Area	1995: Precambrian quartz monzonite, adamellite, quartz substrate. Common and near timberline. Steep west-facing alpine slope in gritty soil. With dominants: *Mertensia lanceolata*, *Acomastylis rossii*, *Trifolium nanum*, *Ligularia* spp., *Artemisia* spp. With tufts of *Carex elynoides*, *Festuca brachyphylla*, *Eremogone fendleri*. 1998: West-facing slope. Gravelly alpine tundra, abundant mat-former here.	1995: Flowers bright yellow. 1998: Flowers yellow	T. Hogan 2694 and L. Yeatts. 1995 KHD, COLO Rea Orthner s.n. 1998. KHD
4	Huerfano	7/7/1989	In the vicinity of Lilly Lake	San Isabel National Forest (possibly extends into Rio Grande National Forest and private land)	On northwest summit ridge in fellfield talus crevice at 13,800 feet.	Only a few plants locally. Flowers bright yellow	Colorado Natural Heritage Program element occurrence records, L. Yeatts 2168. 1989. COLO, KHD
5	Clear Creek	7/1/1978	Colorado Mines Peak, approximately 0.5 miles east of Berthoud Pass summit. Population apparently extends over portions of 6 sections. Likely includes arbitrary occurrence 6	Arapaho National Forest	Fellfields and disturbed areas along roadway (with *Draba aurea* and *D. cana*).	No information	Colorado Natural Heritage Program element occurrence records. R. A. Price 174 1978 COLO, CS

Arbitrary occurrence no.	County	Dates observed	Location	Area management	Habitat	Abundance and comments	Collector
6	Grand, Clear Creek	7/14/1997	West slope of Mt. Flora; West slope of Mt. Flora above saddle from Colorado Mines Peak. Probably a suboccurrence of arbitrary occurrence 5	Arapaho-Roosevelt National Forest	Occasional, rare. On upper rocky slope in alpine tundra. Dry sandy loam soil that is seasonally wet with spring run-off on high alpine slope with a few large boulders and cobbly soils; moderate surface rock and gravels derived from granite. Growing sheltered in rocks, with seasonal rocks available. Associated plant community: *Trifolium nanum/Lidia biflora* (cushion plants), *Silene acaulis* ssp. *acaulescens*, *Eritrichium aretioides*, *Paronychia pulvinata*, *Oreoxis alpina*, *Carex rupestris*, *Draba exunguiculata*. Total tree and shrub cover 0%; total forb cover 40%; total graminoid cover 10%; total moss/lichen cover 5%; total bare rock cover 40%. West to northwest aspect. 10 to 30 % slope. Summer sun is early morning until dusk, winter sun later morning until dusk.	25+ plants were counted in an area about 40 across and 300 feet upslope. All plants were in bloom and approximately 25% started to be in fruit. The population is on a slope extending to the summit	Colorado Natural Heritage Program element occurrence records. A. Petterson s.n. CSU (2 specimens)
7	Grand, Clear Creek	7/21/1997	On the upper slope of a summit near the Continental Divide along the National Scenic Trail	Arapaho-Roosevelt National Forest	On high alpine, steep (20 to 35%,) convex-shaped slope with south-aspect with large boulders and cushion plants. Associated with: *Lidia obtusiloba*, *Carex rupestris* spp. *drummondii*, *Silene acaulis*, *Oreoxis alpina*, *Paronychia pulvinata*, *Festuca brachyphylla* and *Eremogone fendleri*. Total: tree and shrub cover 0%, forb cover 50%, graminoid cover 5%, moss/lichen cover 0%, bare rock cover 45%. Summer sun is early morning until early dusk, winter sun early until mid afternoon. Soil was dry but is seasonally wet. The soil is rocky with pockets of topsoil.	21 plants were counted. All plants in bloom and starting to form fruits. This area seems to have a small isolated population. The size of the population [may have been] dictated by limited habitat. All plants growing beside cushion plants	Colorado Natural Heritage Program element occurrence records.
8	Saguache	8/19/1942	Wild Cherry Lake	San Isabel National Forest	"Gravelly and rocky soil, alpine, slope southwest 50%."	Common, low forage [value]. Light use	Colorado Natural Heritage Program element occurrence records. R.K. Gierisch 1417 CS
9	Saguache	6/24/2000	Sangre de Cristo Range, Mt. Owen	Rio Grande National Forest	Lower member of Sangre de Cristo formation (red arkose sandstone conglomerate siltstone and shale) Alpine fellfield summit and ridge near summit on steeply tipped slabs with ~ 50% vegetation cover.	Associated with *Phlox condensata*, *Eritrichium aretioides*, *Acomastylis rossii*, *Lidia obtusiloba*, *Festuca brachyphylla*. Small, hard, taprooted mats. Flowers bright yellow, locally common in gravel and rock crevices	L. Yeatts 4438 T. Hogan, D. Yeatts KHD
10	Saguache	7/25/1985	Sangre de Cristo Range. Final saddle on north ridge below summit of Milwaukee Peak. Crestone Peak 7.5' quad	Rio Grande National Forest	Below summit against boulders in conglomerated scree. With *Eritrichium aretioides*. Elevation: 13,320 ft.	Occasional. Corolla yellow	Colorado Natural Heritage Program element occurrence records, L. Yeatts 2091 1985 KHD

Arbitrary occurrence no.	County	Dates observed	Location	Area management	Habitat	Abundance and comments	Collector
11	Saguache	7/31/1994	Sangre de Cristo range, Crestone Peak, Cottonwood Lake drainage	Rio Grande National Forest	Substrate of permian-Pennsylvanian Sangre de Cristo formation, Crestone conglomerate member. 14000 ft. Crevices on southeast-facing barren rock face of west summit of Crestone Peak.	Closest associates include *Draba fladnizensis*, *Muscaria deliculata*. Plants inconspicuous occasional, near summit	L. Yeatts 3608 KHD
12	Chaffee	8/8/1995	Vicinity of Mt. Shavano (population may extend into private land)	San Isabel National Forest	Dry. Rocky alpine meadow, south facing slope. 50% bareground. Dominant species: *Geum rossii*, *Rydbergia grandiflora*, *Potentilla* spp., *Artemisia* spp., *Phlox* spp., *Trifolium dasyphyllum*, *Heuchera parviflora*. Soils gravelly at elevation 13,000 to 13,600 ft.	Uncommon and widely scattered on slope to the saddle. About 10 individuals observed	Colorado Natural Heritage Program element occurrence records
13	Chaffee	7/30/1983	West-facing slope of Mt. Antero above timberline	San Isabel National Forest	West-facing slope above timberline on well developed tundra.	No information	Colorado Natural Heritage Program element occurrence records, L. Yeatts 761 1983 KHD, Denver Museum of Natural History.
14	Clear Creek	7/15/1961; 9/27/1963	1961: Trailside within 50 yards of a portion of the upper third of the "Alpine Garden trail", Mt Goliath, above timber line 1963: above the treeline on the short "loop trail" of the Alpine Garden Trail, Mt. Goliath	Arapaho National Forest, Mount Goliath Natural Area	1961: "at about 12,100 feet altitude". Trailside above timberline; open ground. 1963: Above timberline at elevation about 12,000 feet. Growing unshaded, in very rocky soil.	1961: Not abundant. Brunquist specimen: Original identification *Draba streptocarpa* var. *streptocarpa*. Annotated in Price's writing (likely Price, no name) that it's *D. grayana*. Mayes specimen: Originally determined by HD Harrington as *D. exunguiculata*, annotated *D. grayana* by Price 1989 1963: Petals yellow	Colorado Natural Heritage Program element occurrence records. Brunquist, E.H. 1963 MG-118 KHD; Claude H. Mayes. 1961 MG-72 at KHD
15	Summit, Clear Creek	7/11/1950; 7/18/1978; 8/19/1992	1950: Rocky tundra slopes along trail from Stevens Mine to summit of Gray's Peak. TOPOTYPE! 1978: Saddle between Gray's and Torrey's Peaks, south- to southwest- facing slope; fellfield	Arapaho National Forest	1950: Rocky tundra slopes. 1978: Fellfield w/*Artemisia scopulorum*, *Geum rossii*, *Trifolium nanum*, *Primula angustifolia*. 1992: Very rocky area with patches of mossy, wet tundra and drier more wind swept patches. Associated taxa: *Muscaria deliculata*, *Polemonium viscosum*, *Hirculus serpyllifolius*. Also *Draba fladnizensis*.	1992: "Trampling by hikers evident. Also possibly by mountain goats that may browse." Colorado Natural Heritage Program (1992) commented that at a minimum, signs should be placed stating that the area has several rare alpine species that are susceptible to trampling e.g. "Please stay on the trail"	Colorado Natural Heritage Program element occurrence records. W.A. Weber 5616 1950 COLO; R.A. Price 242 1978 COLO.

Arbitrary occurrence no.	County	Dates observed	Location	Area management	Habitat	Abundance and comments	Collector
16	Clear Creek or Summit	7/18/1892	Gray's Peak Trail	Arapaho National Forest	No information.	No information	Colorado Natural Heritage Program element occurrence records. C. Crandall 634 CS
17	Summit, Clear Creek	8/22/1997	Between Argentine Pass and Mount Edwards	Arapaho National Forest	Plants occur close to ridgeline of the Continental Divide in the alpine tundra on cobbly soil between various sized boulders. Parent material was granite. Total tree and shrub cover 0%, total graminoid cover 15%, total forb cover 35%, total moss/lichen cover 10%, total bare rock cover 40%. Associated plant community: *Carex rupestris/Lidia obutsiloba*. With *Silene acaulis*, *Acomastylis rossii*, *Trifolium nanum*, *Luzula spicata*, *Artemisia scopulorum*, *Festuca brachyphylla*, *Draba exunguiculata*. South to southwest aspect on 10 to 25% concaved-shaped slope. Soil was dry.	The population is scattered in saddle, covers a minimum area of a quarter mile	Colorado Natural Heritage Program element occurrence records.
18	Larimer	7/15/1987	Front Range, Mummy Mountain Summit at 13,425 feet	Rocky Mountain National Park	In granite scree crevices on well-developed tundra with *Muscaria deliculata*, *Thlaspi montana*, *Oreon alpina*, *Trifolium nanum*.	Relatively common on northeast facing slope near summit. Flowers bright lemon yellow	Colorado Natural Heritage Program element occurrence records. L. Yeatts # 15111 1987. KHD
19	Larimer	7/31/1992	Mummy Range, Rowe Mountain at 13,000 feet	Rocky Mountain National Park	Schist and gneis substrate. Near summit in barren gravelly soil and talus with *Saxifraga cernua*, *Draba lonchocarpa*, *Salix arctica*, *Polemonium viscosum* at elevation 13,000 ft.	Relatively common locally and occasionally downslope to Flint Pass	Colorado Natural Heritage Program element occurrence records. L. Yeatts # 3416 1992. COLO, KHD
20	Summit	7/31/1997	South of the Mohawk Mine in the vicinity of Teller Mountain	Arapaho National Forest	In a rock garden at the top of a steep north-west facing cliff at elevation 12,600 ft.	Small number of individuals in pristine habitat	Colorado Natural Heritage Program element occurrence records
21	Summit	8/8/1997	Southwest of Keystone Mountain, west of the Erickson Mine and east of Keystone Gulch	Arapaho National Forest	In the alpine tundra on cobbly soil between various sized boulders. Parent material was granite. Total tree and shrub cover 0%; total forb cover 70%; total graminoid cover 15%; total moss/lichen cover 0%; total bare rock cover 15%. Associated plant community: *Paronychia pulvinata/Lidia obutisiloba*. Additional plant species include: *Silene acaulis*, *Eritrichium aretioides*, *Phlox siberica*, *Trifolium nanum*, *Poa artica*, *Carex rupestris*, *Luzula spicata*, *Festuca baffinensis*, *Polemonium viscosum*, *Draba streptobrachia*. On north-northwest aspect 10 to 25% concave-shaped slope. Summer sun is early morning until late afternoon, winter sun is mid-morning until late afternoon (generally snow-free winter). Plant population is close to ridgeline.	"The population covers an area of 5 meters staying in the cushion plant community. Population size: 10+ plants were inventoried. All plants in fruit, with clumps of 10 to over 30 individuals flowers."	Colorado Natural Heritage Program element occurrence records

Arbitrary occurrence no.	County	Dates observed	Location	Area management	Habitat	Abundance and comments	Collector
22	Summit	8/6/1997	Just west of Lower Mohawk Lake	Arapaho National Forest	On a boulder with *Erigeron* spp., *Carex* spp., chickweed, and *Potentilla* spp.. The boulder is surrounded by wet alpine habitat including *Salix* spp./*Ligusticum tenuifolium* on the shore of the lake, small patches of *Carex* meadows and very small, scattered ponds.	70 flowering stalks in 16 clumps in a very small area (3 ft. x 3 ft.) on a boulder	Colorado Natural Heritage Program element occurrence records
23	Clear Creek	7/14/1953; 7/24/1955; 7/27/1966; 7/26/1970	1953: On southeast shore of Summit Lake, Mount Evans 1955: Summit Lake 1966: Summit Lake, Mount Evans 1970: Summit Lake on Mount Evans	Arapaho National Forest and possibly on state of Colorado land	On level sandy ground, lakeshore. 12,700 ft (3,871 m).	No information	W.A. Weber 8538. With G.N. Jones. 1953 COLO; W.A. Conley 1955 CS; L. Synder 11106 1966 COLO; B. Anderson 267 KHD
24	Clear Creek	7/21/1962; 8/21/1964	1962: Below summit of Mount Evans 1964: Mount Evans	Pike National Forest	1962: Tundra. 1964: South exposure. Sandy soil, 10 to 20% slope. Occasional. Alpine vegetation.	No information	Colorado Natural Heritage Program element occurrence records. R.K. Gierisch 2897 CS. G.N. Jones 33754 1962 CS
25	Clear Creek	8/14/1965	About 150 feet below the summit of Mount Evans	Unknown	Alpine tundra. 14,100 ft. (4,297 m).	No information	Peter J. Salamun 2275 COLO
26	Clear Creek/ Grand	7/13/1999	Front Range, Continental divide. On west slope of north ridge of Bobtail Peak. Byers Peak 7.5' quad	Arapaho National Forest	Precambrian granite; on talus , occasional in area fellfields. With *Draba fladnizensis*, *Muscaria delicula*, *Sibbaldia procumbens*.	Flowers yellow (bight lemon)	L. Yeatts 4273, P. Francis KHD
27	Gilpin	7/4/1972	Slope of the cirque on north east side of James Peak	Roosevelt National Forest	No information.	Flowering	V. Komarkova s.n. COLO
28	Pitkin	7/23/1990	Southwest of Blue Lake and north of Independence Pass	White River National Forest/ San Isabel National Forest boundary	Mostly south and west facing alpine slopes near and at mountain summits, granite substrates.	In 1997 survey team from Colorado Natural Heritage Program were not able to relocate this occurrence (7/20/1997). *Draba crassa*, *D. streptobrachia*, and *D. fladnizensis* were found	Colorado Natural Heritage Program element occurrence records, R.E. Brooks, 20431 1990 RM

Twenty-five of the 28 occurrences are located on national forests in Region 2, specifically on the Arapaho, Pike, San Isabel, and Rio Grand national forests (**Table 2**). One of the occurrences in the San Isabel National Forest is in the Buffalo Peaks Wilderness Area. Two occurrences possibly extend from USFS land onto adjacent private land (one on the Arapaho National Forest and one on the San Isabel National Forest), and one may extend from the Arapaho National Forest onto adjacent State of Colorado lands.

Population trend

There are insufficient data in the literature, associated with herbarium specimens, or at the state natural heritage program to determine the long-term trends. Specific populations have not been monitored, and revisits to the same general areas have typically not reported abundance, only presence, over the years. Anecdotal evidence suggests some populations may have suffered a decline in abundance. An observation was made that the abundance of many *Draba* species, including *D. grayana*, has declined in the Gray's Peak area within the last decade, possibly due to the concomitant increase in mountain goats and human hikers (Yeatts personal communication 2002). However, there is no reason to believe that populations in less accessible habitats are either more or less abundant than in the past. The only occurrence in Pitkin County was reported in 1990 (see arbitrary occurrence number 28 in **Table 2**). This occurrence could not be relocated in 1997 although several other species of *Draba* (*D. crassa*, *D. streptobrachia*, and *D. fladnizensis*) were found. Possible reasons to explain the apparent absence of plants seven years after the initial report were not given.

Habitat

Draba grayana grows in the alpine tundra and less commonly in sub-alpine zones at elevations between approximately 3,535 and 4,300 m, with the majority of occurrences located between 3,800 and 4,000 m (**Figure 3**). Where a range was given for an occurrence, the lowest and highest elevations reported were included in the analysis. *Draba grayana* often occurs in narrow sympatry with another rare, endemic *Draba* species, *D. exunguiculata*.

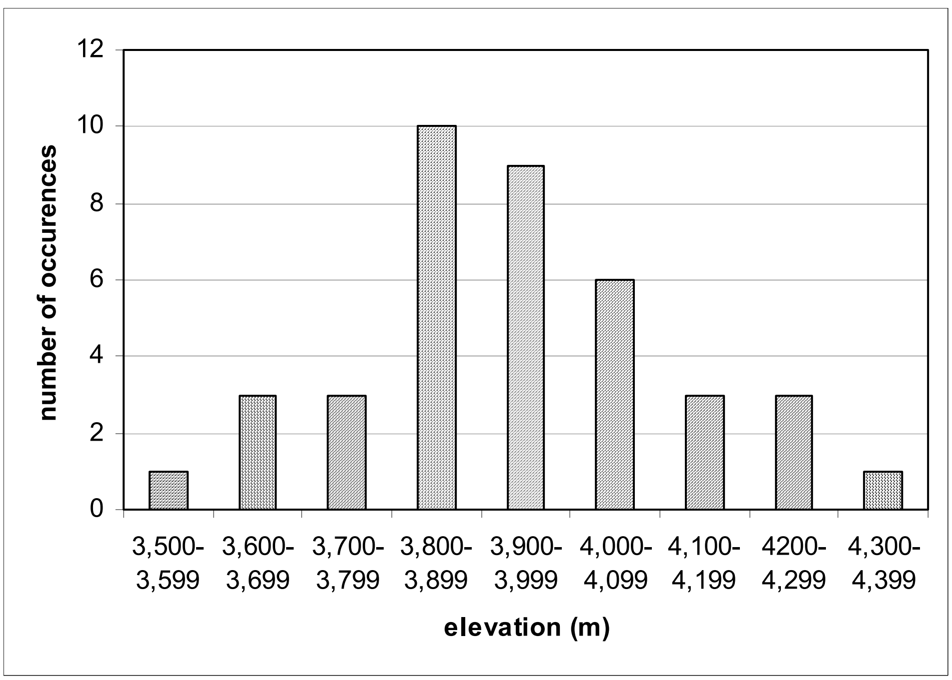


Figure 3. Range in elevations reported for the occurrences of *Draba grayana*. Where a range was given for an occurrence, the lowest and highest elevations reported were included in the analysis.

When habitat is described, *Draba grayana* is usually associated with talus or abundant gravels (Colorado Natural Heritage Program element occurrence records 2002). Plants have been reported on rocky, gravel soils derived from granite, among granitic-gneiss boulders, on fellfields, and on talus slopes (Colorado Natural Heritage Program element occurrence data 2002). Fellfields have significant amounts of fine material for soil formation but have features such as exposure to strong winds, little snow cover in winter, and extremes of temperature and moisture, that make them relatively dry with little vegetation cover (Willard 1979). The extremely ground-hugging growth habit of *D. grayana* likely makes it well-adapted to such adverse environmental conditions. Price (1979) reported that *D. grayana* generally grows on acidic soils (pH 6.3 to 7.0), but some of the associated plant species suggest that *D. grayana* can tolerate a range of substrate pH values. While some associates, *Luzula spicata* and *Sibbaldia procumbens*, are considered acidophilous, others, namely *Heuchera parvifolia*, *Polemonium viscosum*, and *Eritrichum aretioides*, are considered calciophilous in some parts of their range (Komárková 1979).

Draba grayana has most frequently been reported on slopes of a 10 to 35 percent incline, but plants have also been observed on slopes of more than 50 percent and in crevices on steep barren rock faces. Crevice-dwelling plants, or chasmophytes, need a certain amount of humus and fine earth in the crevice in order to become established. This prerequisite will limit suitable habitat on an otherwise expansive rock face. Rock crevices and niches among rocks and boulders can also provide a favorable microclimate. For example, because solid rocks have a high heat capacity, they will remain at a higher temperature than the surrounding air throughout the night in open, irradiated habitats (Ellenberg 1988). It may be that human accessibility accounts for the more gentle slopes and low ridges being reported as the most common habitat. Most, if not all, of the areas where *D. grayana* occurs, or may potentially occur, are in a relatively undisturbed condition. Plants have been reported to grow at sites with southern, northern and western aspects. They have been reported in both dry and seasonally moist sites and grow in sites with low competition from other species. Estimates of bare ground at the colonized sites range from 35 to 50 percent. Brief habitat summaries and comments associated with each occurrence are listed in **Table 3**.

Table 3. Plants species that have been reported to be associated with *Draba grayana*. This is not an exhaustive list and represents only the observations that were made on herbarium sheets and in occurrence records.

Species	Species
Draba crassa	*Phlox condensata*
Draba exunguiculata	*Phlox sibirica*
Draba fladnizensis	*Phlox* spp.
Draba streptocarpa	*Poa arctica*
Eremogone fendleri	*Polemonium viscosum*
Erigeron spp.	*Potentilla* spp.
Eritrichum aretioides	*Primula angustifolia*
Festuca baffinensis	*Rydbergia grandiflora*
Festuca brachyphylla	*Salix arctica*
Geum rossii	*Saxifraga cernua*
Heuchera parvifolia	*Sibbaldia procumbens*
Hirculus serpyllifolius	*Silene acaulis*
Lidia obtusiloba (*Lidia biflora*)[1]	*Silene acaulis* ssp. *acaulescens*
Ligularia spp.	*Smelowskia calycina*
Luzula spicata	*Stellaria* spp. (reported as chickweed)
Mertensia lanceolata	*Thlaspi montana*
Muscaria delicatula	*Trifolium dasyphyllum*
Oreoxis alpina	*Trifolium nanum*
Paronychia pulvinata	

[1]Both species have been reported as associates but in Colorado, *Lidia obtusiloba* exhibits floral dimorphism that is not justification to separate the taxon into two species and *Lidia biflora* is a Eurasian species (Weber and Wittmann 2001b).

Draba grayana is associated with cushion plant communities (for example, fellfield/cushion plants physiognomic type described by USDA Forest Service 1996). The low-growing species that compose this vegetation type generally have their highest woody, perennial parts flat on the soil surface and are described as hemicryptophytes according to Raunkiaer's life form system (Raunkiaer 1934). Plant species that have been reported to be associated with *D grayana* are listed in **Table 3**. *Festuca brachyphylla*, *Trifolium nanum*, *Lidia obtusiloba*, and *Muscaria delicatula* are particularly common associates of *D. grayana*. *Festuca ovina* has also been reported an associate, but this name was likely mistakenly applied to *F. brachyphylla* ssp. *coloradensis* plants (Weber and Wittman 2001b). *Festuca ovina* is a European species that is only cultivated in America (Weber and Wittman 2001b). In addition, *Arenaria obtusiloba*, which is synonymous with *Lidia obtusifolia*, was listed as an associate. Several other *Draba* species, namely *D. aurea*, *D. cana*, *D. crassa*, *D. exunguiculata*, *D. fladnizensis*, *D. lonchocarpa*, and *D. streptocarpa*, grow in the vicinity of *D. grayana*. In particular, *D. streptocarpa* has been reported growing within 10 cm, *D. exunguiculata* within 50 cm, and *D. crassa* within 1 m of *D. grayana* (Price 1979). This list of associated species is likely incomplete as comprehensive lists have not been made and the information mostly relies on casual observations.

Reproductive biology and autecology

Draba grayana is a perennial species. It flowers from June into at least late August (Rollins 1993, Colorado Heritage Program element occurrence records 2002, herbarium specimens at the Kathryn Kalmbach Denver Botanic Garden, University of Colorado, and Colorado State University). *Draba* is a reproductively-interesting genus because examples of self-fertilization, self-incompatibility, and apomixis have all been reported (Mulligan and Findlay 1970, Mulligan 1971, Brochmann et al. 1992, Brochmann 1993). *Draba grayana* reproduces by apomixis, specifically agamospermy. Apomixis, or "reproduction without fertilization," is relatively common among vascular plants (Grant 1981), and one of the main forms of apomixis is agamospermy, which is seed formation without fertilization. Gametophytic agamospermy, where a morphological gametophyte is present but unreduced, is most common in plants of northern and colder regions and is likely exhibited by *D. grayana*. In the alternative form of apomixis, adventitious embryony, there is no gametophyte stage and the embryo is derived from a somatic cell of the ovule. In an experiment studying the reproductive biology of several populations of *D. grayana*, no fruit were set on emasculated flowers, while fruit and seed set were normal on a plant that was only bagged (Price 1979). The emasculation treatment of other agamous *Draba* species in the same experiment had no such effect, and one conclusion may be that pseudogamy was operative. In pseudogamy, the species is still apomictic with no sexual reproduction occurring, but pollen is required to provide a stimulus to start embryo development (Grant 1981). However, because the anthers of *D. grayana* frequently do not dehisce, Price (1979) concluded that disturbance of the flowers caused the lack of reproduction by the emasculated flowers.

Apomixis in *Draba* is reportedly associated with polyploidy (Mulligan 1976). Apomictic species are often triploid, and their pollen fails to mature normally because the three sets of chromosomes are unable to align effectively during meiosis (Grant 1981). *Draba grayana* is apparently hexaploid with a base number of 8 (Price 1979). The gametophytic chromosome count was approximately 24, but meiosis was particularly difficult to study due to the frequent abortion of entire anthers (Price 1979). One accepted consequence of polyploid speciation has been that the polyploid will be reproductively inaccessible from its progenitor species because of a chromosome number barrier (Grant 1981). However, unlike many genera, ploidy differences may not preclude successful hybridization between *D. grayana* and other species of alpine *Draba*. More recently, Brochman et al. (1992) demonstrated that interspecific hybridization across ploidy levels in *Draba* can result in re-establishment of fertility and probably euploid chromosome numbers. Brochman et al. (1992) suggest that it is more likely that hybridization will occur between polyploids rather than between a diploid and a polyploid. Mulligan (1976) concluded that interspecific hybridization in *Draba* was rare in nature and appeared to result in sterile first-generation hybrids. However, he reported that although pollen fertility was generally very low (25 percent or less), it was not zero and that some hybrids did produce some poorly formed seed even though most fruits were aborted. This indicates that sexual reproduction was not impossible but probably unlikely.

The rate of seed recruitment to the seed bank, seed longevity in the soil, and the extent of seed predation are all unknown. Relative to other species, *Draba* seeds generally are less abundant in the tundra seed bank (McGraw and Vavrek 1989). *Draba grayana* is cultivated and propagated by seed (Slabý 2002, Rocky Mountain Rare Plants Seed Company 2003). Germination apparently requires light and occurs at

70 °F (Slabý 2002, Rocky Mountain Rare Plants Seed Company 2003). Seed is best planted in the spring. The benefit of pretreatment has not been specifically reported for *D. grayana*. Untreated seeds of arctic-alpine *Draba* are reported to germinate very poorly in general, and pretreatments such as scarification and/or gibberellic acid increase germination considerably (Brochmann et al. 1992). *Draba grayana* can also be propagated by rosette cuttings that should be taken in the late summer (Slabý 2002). Significant resources may be put into new rosette development because, although flowering and fruit initiation appears to be substantial, mature seed production appears to be quite low in some populations (**Figure 4**). Natural seed dispersal mechanisms are not known. In alpine tundra regions, wind may effectively disperse seed, but wind-dispersed seeds frequently may move only short distances (Silvertown 1987, Ellenberg 1988). In addition, snow pack and precipitation may also be involved in seed dispersal.

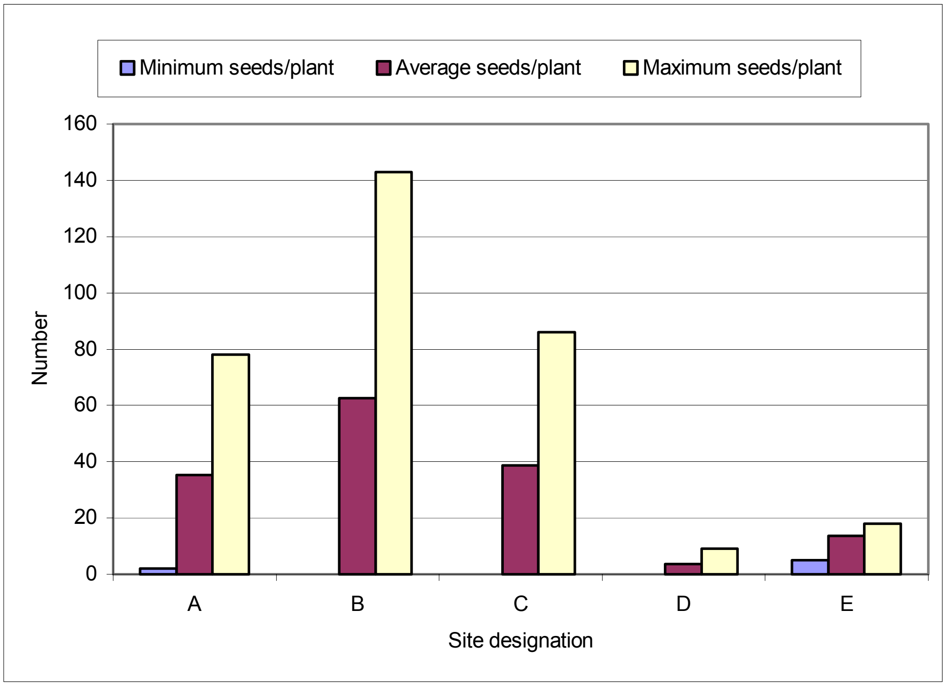
Medve (1983) reported that mycorrhizal associations with the roots of Brassicaceae are at best weak and facultative. No mycorrhizal associations have been reported on the roots of *Draba* species. No observations on the presence or absence of diseases or parasites on *D. grayana* have been reported.

Demography

Draba grayana is a perennial that reproduces by seed. No demographic studies have been undertaken, and transition probabilities between the different stages, from seed production to the flowering adult, are unknown. Because *D. grayana* grows at very high elevations with considerable year-to-year variability in the length of the growing season and the weather conditions, the numbers of seeds per plant can be expected to vary considerably depending upon the year. Seed production also appears to be very variable both within and between populations. Price (1979) counted the number of seeds per plant and the number of seeds per fruit for three to seven individual plants in each of five locations in Colorado (A to E in **Figure 4**) separated by approximately 5.5 to 37.5 km respectively. At some locations, mature, viable seeds per fruit averaged less than one, and the number of seeds per plant was very low (locations D and E in **Figure 4**).

Draba grayana populations appear to be largely comprised of adults. Information associated with herbarium specimens and element occurrence records provided by the Colorado Natural Heritage Program report individuals were either in fruit or flower, indicating that seedlings were few or particularly inconspicuous. The latter is likely because even the mature adults are apparently easy to overlook. Seed germination and seedling establishment are very sensitive to environmental conditions. The high elevation environment of *D. grayana* is highly variable within and between years, so seed germination will likely reflect this variability. However, evidence suggests that at some locations, or in some years, low seed production may be the cause of the apparent absence of *D. grayana* seedlings (**Figure 4**; Price 1979). In long-lived perennials, seed production may be low, and the most important life cycle components are growth and survival of the adult plants (Silverton et al. 1993). In this case, assets are allocated to favor the survival of the adult. In some instances this may be the strategy employed by *D. grayana*. However, at sites where seed production is abundant, the absence of seedlings may be due to poor seed germination or a high mortality rate. Experimental evidence indicates that for many alpine species with high seed production and good seed germination rates, few seedlings are able to develop and mature because there is a paucity of sites suitable for plant establishment even on expansive scree and gravelly slopes (Ellenberg 1988; also see Habitat section).

(A)



(B)

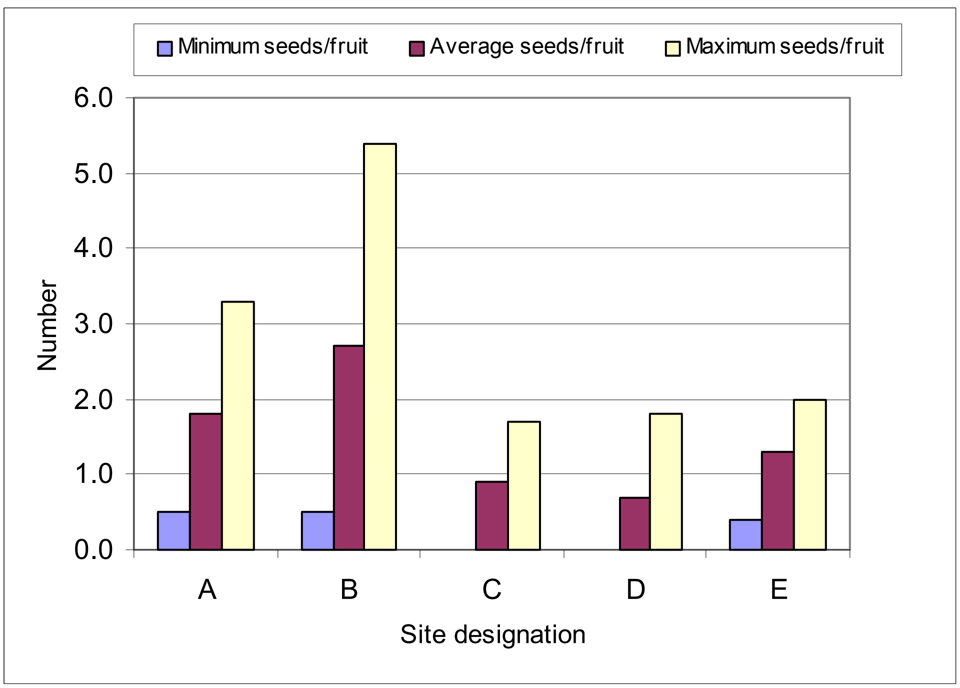


Figure 4. The number of seeds per plant (A) and seeds per fruit (B) at each of five locations (data from Price 1979).

A three-year demographic study was made on a perennial rock-dwelling *Draba*, *D. trichocarpa*, in Idaho (Moseley and Mancuso 1991, 1992, 1993). This species grows at somewhat lower elevations (approximately 6,200 feet) and is not a close relative to *D. grayana*. Despite the differences, the results of this demographic study may be useful to consider. *Draba trichocarpa* expended a considerable proportion of energy towards abundant seed production, but few seedlings were observed. Moseley and Mancuso (1993) concluded that mature *D. trichocarpa* plants are relatively long-lived, but poor seedling recruitment, caused by a 73 percent mortality rate, poses significant limitations to population growth and longevity. *Draba grayana* populations also appear to be skewed in favor of reproductive adults at all occurrence sites and possibly face the same limitations depending upon the year and location. There are obviously serious management implications if this is correct, as it implies that replacement of individuals is a slow process.

Unfortunately, there are few facts available pertaining to the life cycle of this species, and speculation is accepted as a poor substitute for facts. A simple life cycle model of *Draba grayana* can be described in diagrammatic terms (**Figure 5**). Heavy arrows indicate the phases in the life cycle that are more evident, and lighter weight arrows indicate the phases that are more uncertain. The steps that particularly need to be clarified are noted by a "?" at the appropriate arrow. More information is needed to define which of the life history stages have the greatest effect on population growth and survival. It is not known whether plants flowering one year revert to vegetative plants in subsequent years or whether size reflects the age of the plant. It is likely that environmental conditions, for example moisture, have a primary effect on plant size. Limits to population growth are not well defined. At the present time, it would appear that growth is restricted to some extent by available habitat niches and edaphic conditions such as adequate soil and moisture.

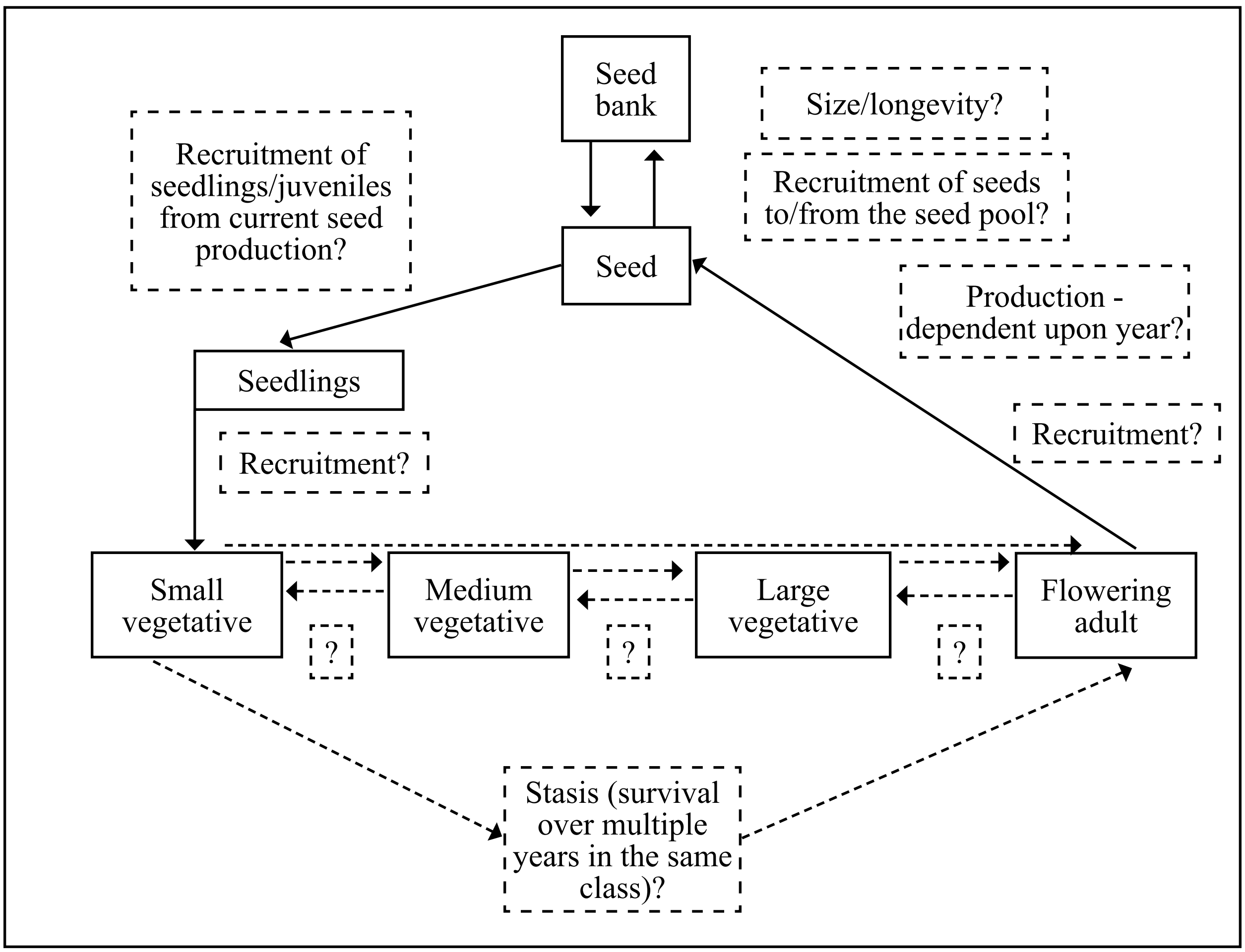


Figure 5. Life cycle diagram for *Draba grayana*. Heavy arrows indicate the phases in the life cycle that are more evident, and lighter weight arrows indicate the phases that are more uncertain. The steps that particularly need to be clarified are noted by a "?" at the appropriate arrow. The size referred to is relative.

In summary, the current evidence suggests that *Draba grayana* is a perennial species that is maintained in established, small populations and corresponds to the profile of a K-selected species (MacArthur and Wilson 1967). Grime et al. (1988) developed a simple dichotomous key to the strategies employed by herbaceous plants, and *D. grayana* appears to best fit the S, or stress-tolerant, life strategy

Population viability analyses for this species have not been undertaken. Apomictic taxa may be thought to be at an evolutionary disadvantage, but many purely asexual taxa, for example *Taraxacum officianalis* (common dandelions), have proven to be very successful for fairly long periods of time (Grant 1981, Menges 1991). The ecological consequences of the complicated reproductive systems and the complexity of polyploidy in *Draba* are not well defined. Brochmann (1993) hypothesizes that allopolyploidy, which may be exhibited in *D. grayana*, prevents genetic depauperation in the arctic *Draba*. In the case of *D. grayana*, short-term analyses of population viability that emphasize demography rather than genetics may be most rewarding (Landes 1988, Menges 1991). Studying the genetics of just a few populations may not represent the species in total and may lead to misconceptions. Metapopulation analyses based on the proportion of occupied suitable microsites may be an effective method of understanding population viability of this species at the management level (Menges 1991).

It appears that *Draba grayana* often exists in patches, or rather as a subdivided population. It is unknown if there is a balance of frequent local extirpations and colonizations within a colonized area or whether, once established, microsites are occupied for long periods of time. The instability of the talus and scree slopes of its habitat suggests that this species can deal with a certain amount of disturbance. Certainly it must be well-adapted to the freeze-thaw perturbations that occur (Johnston and Huckaby 2001). In addition, there is a constant slide associated with talus slopes. In one study in Colorado, the mean displacement of talus (downslope slide) over a 25-year period was 14.7 m. This is equivalent to an average rate of 0.59 m per year. However, this average rate is highly variable as it was five times the rate calculated for the site in 1967. This variation is likely due to the fact that the 25-year period was marked by several high-intensity storms, including a 100-year precipitation event (52 mm in 8 hr). In addition, the dispersion patterns and travel distances were found to be highly variable within and between sections of the same talus deposits (Davinroy 1993). The shape of talus also affected movement. As one would expect, displacement distance increases as particle shape approximated a sphere. Therefore the shape of the rocks and gravels and their propensity for movement may contribute to the patchy nature of *D. grayana* distribution. The species may well grow in microsites that are relatively stable in an otherwise unstable environment.

A consequence of an agamospermous lineage with intermittent sexual episodes is that new adaptive hybrids can reproduce themselves by successive cycles of agamospermy, and thus genotypes specifically adapted to local conditions can become established (Grant 1981). Because populations of *Draba grayana* are often separated by several miles of inappropriate habitat, local selection pressures may have led to increased fitness to local conditions, for example specific edaphic conditions, and transplantation of individuals from distant locations may be unsuccessful.

Community ecology

The reported occurrence size of *Draba grayana* is usually relatively small. The reported order of magnitude ranges from fewer than ten to "more than 30" individuals. The causes for the relatively small number of plants, in general, and for the differences in occurrence size are unknown. It appears that *D. grayana* does not flourish in highly competitive communities and favors more environmentally harsh and sparsely vegetated sites, such as fellfields. There are, however, frequent observations that boulders and rocks provide localized protection for plants, suggesting a limited number of niches with a favorable microclimate.

Interactions with the fauna of its associated community, for example the role of arthropods in potential seed dispersal or seed predation, have not been documented. Flies (Diptera) are common visitors and likely pollinators of alpine flowers (Shaw and Taylor 1986, Kearns and Inouye 1994). Two species of fly have been observed to visit the flowers of *Draba grayana*. They were a species of *Cheilosia* of the family Syrphidae, which are very like bees in appearance, and a species of *Helina* of the family Muscidae, which are generally similar to the house fly. Because *D. grayana* appears to be apomictic, these flies are unlikely to be important pollinators. However, if *D. grayana* proves to be pseudogamous (see Reproduction biology and autecology section), then these arthropod visitors may play a vital role in its reproduction especially because anther dehiscence is unreliable. One may speculate that insect visitation contributed to variability in seed production between locations (**Figure 4**; Price 1979).

Although *Draba grayana* is cited to be part of a cushion plant community and has been reported as particularly associated with those species (arbitrary occurrence numbers 7 and 21 in **Table 2**), the amount of bare ground associated with the plants is typically high. This suggests that this species has not evolved to be particularly competitive and may not be able to tolerate invasive weedy, non-native species. Although several species of noxious weeds have been reported above the treeline in that area, invasive weed species have not been specifically reported at any of the recorded occurrences (Ray 2001).

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used especially to describe the conditions of animals (Andrewartha and Birch 1984), but they may also be applied to describe the condition of plant species. Those components that directly impact *Draba grayana* make up the centrum, and the indirectly acting components comprise the web (**Figure 6** and **Figure 7**). Factors in the web are causally related to the factor in the centrum and are indicated as such by n = 1, 2, *ad infinitum*. Unfortunately, as mentioned previously, much of the information to make a comprehensive envirogram for *D. grayana* is unavailable. The envirograms in **Figure 5** and **Figure 6** are constructed to outline some of the major components known to impact the species directly and also include some more speculative factors that can be tested in the field by observation or management manipulation. Dotted boxes indicate resources or malentities that are either likely but not proven, or are of a regional nature.

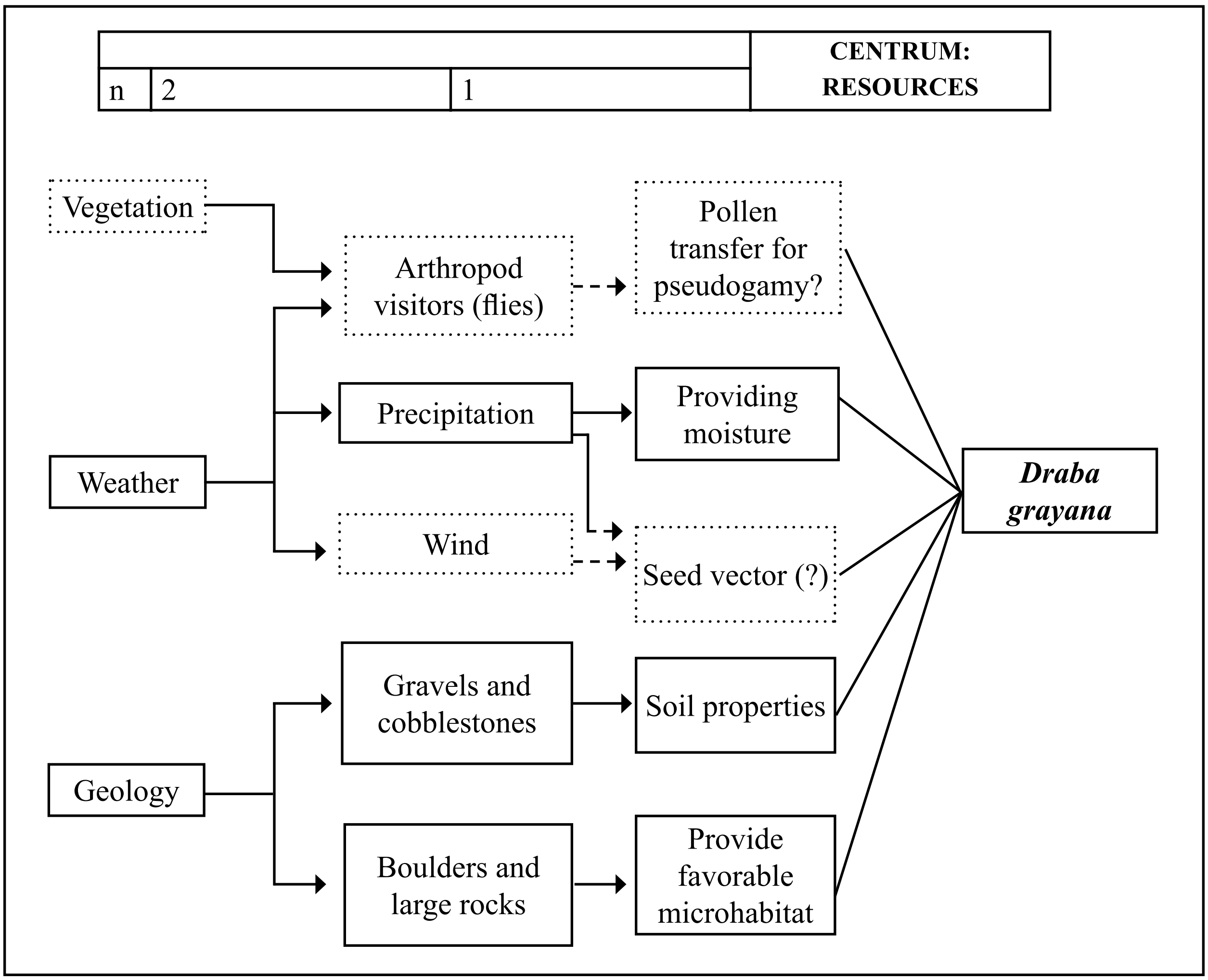


Figure 6. Envirogram of the resources of *Draba grayana*. A dotted line indicates the factor is a speculative resource. Factors in the web are indicated as related to the factor in the centrum by n = 1, 2, *ad infinitum*.

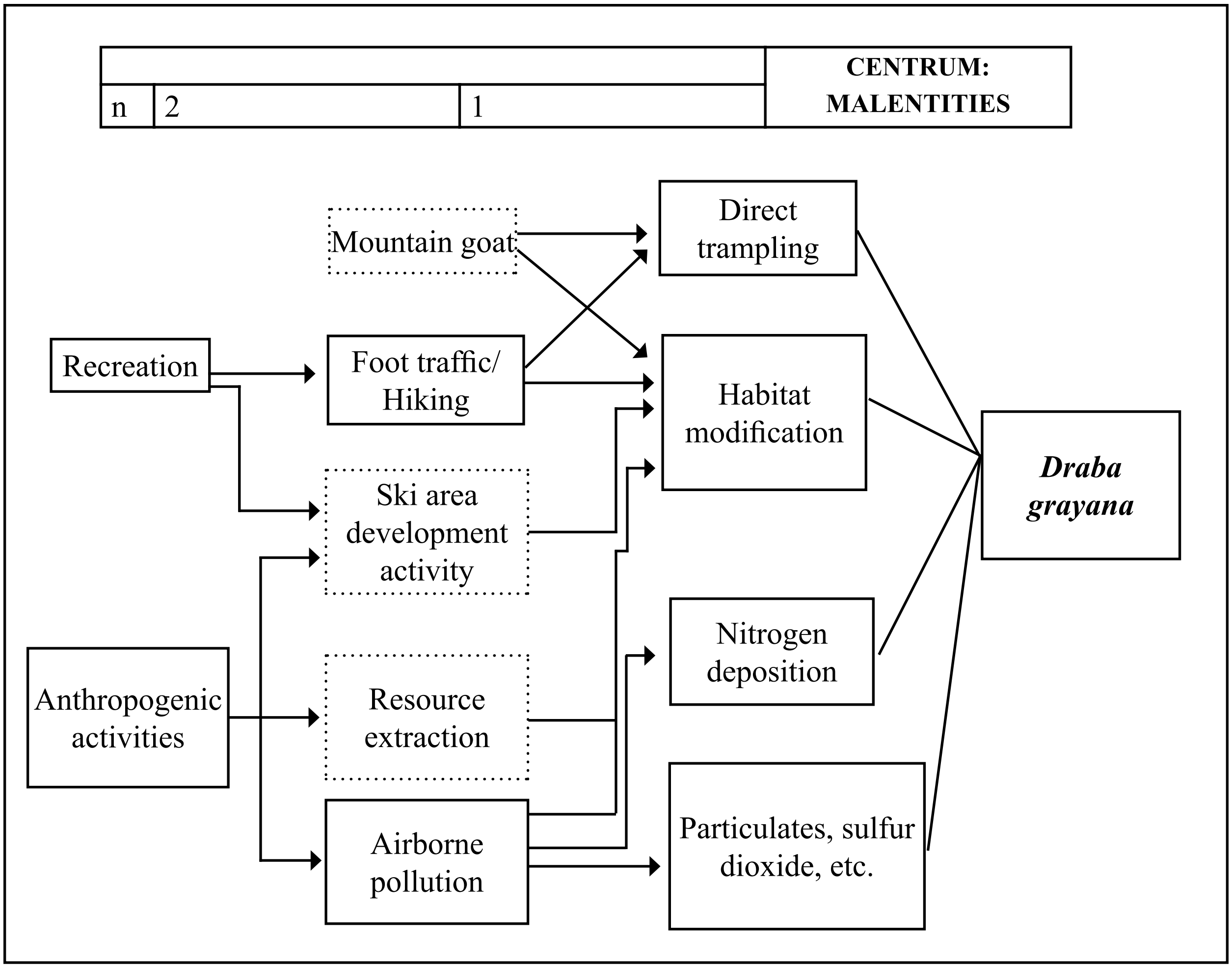


Figure 7. Envirogram outlining the malentities to *Draba grayana*. A dotted line indicates that the factor is not a well-documented malentity. Factors in the web are indicated as related to the factor in the centrum by n = 1, 2, *ad infinitum*.

Resources have been listed as gravel soils and talus substrates providing a suitable edaphic environment, and soil moisture for adequate growth. Pollinators for pseudogamous reproduction have been included in faint dotted lines to indicate the tenuous and speculative nature of the proposed resource. Disturbance in the form of slides from snow pack and precipitation, especially on the talus slopes, may aid dispersal of seeds but there is no evidence, other than habitat niche, to support this supposition. The lack of direct studies on this species leads to stretching the significance of observations and forming opinions from inference rather than fact. Inferences must be tested before predicting responses to management decisions.

At the current time malentities tend to be of local, rather than universal, importance and are indicated as such in the diagram by dotted lines. Trampling, either by hikers or mountain goats, is deleterious. Such disturbance contributes to soil erosion and habitat destruction as well as directly impacting the plants. Air pollution has been included in the envirogram as it is a significant problem, particularly in the Front Range of the Rocky Mountains (Baron 2001). Invasive plant species are potential malentities because they may become direct competitors for resources such as water, nutrients, and light. The extent and duration of malentities are important factors and need further study.

Conservation

Threats

There are impacts to populations from stochasticities as well as threats associated directly or indirectly with human activities. Frankel et al. (1995) replaced the term stochasticity by uncertainty, which may be easier to conceptualize. These stochasticities, which are typically addressed in population viability analyses, include elements of environmental stochasticity, demographic stochasticity, genetic stochasticity, and natural catastrophes (Shaffer 1981). Environmental stochasticity or uncertainty lies in random, unpredictable changes in weather patterns or in biotic members of the community (Frankel et al. 1995). Demographic uncertainty relates to the random variation in survival and fecundity of individuals within a fixed population. Genetic uncertainties are associated with random changes, such as inbreeding and founder effects, in the genetic structure of populations. The extent of the impact from such events on a species' sustainability decreases as both the number of populations and the population sizes increase.

Natural catastrophes, such as avalanches, and environmental stochasticity are likely the primary threats to *Draba grayana* at the range-wide scale. Few comments can be made on the influence of demographic stochasticity on individual populations because there is no information on the survival probability of individuals at any given life stage or age (see Demography section). Where occurrences are small, perhaps less than 50 individuals, demographic uncertainties may well be of significance (Pollard 1966, Keiding 1975). That is, chance events independent of the environment may affect the reproductive success and survival of individuals that, in very small populations, have an important influence on the survival of the whole population.

Small populations are often considered genetically depauperate as a result of changes in gene frequencies due to inbreeding or founder effects (Menges 1991), and locally endemic species tend to exhibit reduced levels of polymorphism (Karron 1991). These concerns associated with small populations may not be applicable because *Draba grayana* is polyploid and apomictic. In this case, genetic variation may be essentially stored and deleterious recessive genes masked (Grant 1981). If *D. grayana* reproduces solely by agamospermy, hybridization with sympatric species is not an issue.

It is generally assumed that there are few threats to the species because of its largely inaccessible habitat. However, at the level of individual occurrences, several specific threats have been identified. Although areas where *Draba grayana* occurs tend to be remote, many may be affected by anthropogenic activities. Several occurrences may be subjected to pressures imposed by human recreation. Foot traffic is a significant threat in many areas. Although there is an effort to restrict visitors to paths and trails, the openness of the area leads to a significant amount of trampling off the designated routes (Delmatier personal communication 2002). Known occurrences are in areas, such as Gray's Peak and Mount Evans in the Arapaho National Forest, where there is considerable use by hikers (Johnston personal communication 2002). *Draba grayana* also occurs at points along the Continental Divide Trail from Jones Pass to Vasquez Pass where there is the possibility for off-trail hiking and significant disturbance of the fragile alpine habitat (arbitrary occurrence number 7 in **Table 2**). Mountain bicycles may also impact some populations, for example at Mt. Evans. Ski areas are established throughout the range and habitat of *D. grayana*, but the impacts of skiing and related maintenance and construction activities are not documented. The alpine tundra takes a very long time to recover from disturbance. For example, a two-track trail remained clearly defined and without vegetation at least 40 years after disuse (Willard 1979). This is an example of large area disturbance, but it is likely that microsite compaction caused by the repetitive foot falls of trampling will be just as slow to recover.

Mining activities may have affected some occurrences because *Draba grayana* grows in areas that have been exploited for their rich mineral deposits, but there are no confirmed instances where mining has directly impacted populations and it is unknown what the consequence of past mining activities has been to the overall abundance of the species. Mining at the current levels appears to present no problems as there are large tracts of suitable habitat that should be unaffected by current mining activities.

Another potential threat, especially in areas within easy reach of urban centers, is over-collection of desirable rock garden species, such as *Draba*, by amateur and professional gardeners (Williams et al. 1986, USDA Forest Service 2001). In some years, seeds of *D. grayana* can be bought from seed supply companies. It is unknown whether the variation in offering from year to year reflects the variability in native seed production. For example, seeds were offered for sale in 2001/2002 but not in 1999 or in 2003 by the Rocky Mountain Rare Plant Seed Company (2003). A similar situation existed for the B&T World of Seeds Seed Company (2003). It is likely that some *D. grayana* seeds are wildcrafted (collected from non-cultivated plants) while others are collected from cultivated plants, depending upon the seed company.

Mountain goats have been reported to be a threat to some populations of *Draba grayana* (Colorado Heritage Program element occurrence records 2002, Yeatts personal communication 2002). Trampling by the mountain goats, rather than browsing or grazing, is cited as the particular problem. In recent years, the number of mountain goats killed by hunters has increased significantly, which suggests that mountain goat populations are increasing in size (Colorado Division of Wildlife 2001). It may be a concern that one of the areas in which the increases were most noticeable was Gray's Peak, which is under the management of the Arapaho National Forest. *Draba grayana* apparently evolved with another large mammal, bighorn sheep, whose numbers were kept in check by predators. However, mountain goats were likely introduced into the Rocky Mountains of Colorado in the 1940s. The long-term consequences of interaction between them and rare native plant species are difficult to assess. The absolute number and range of mammal species and *D. grayana* are important considerations, and mutually sustainable population sizes cannot be estimated without further information.

Invasive weeds have not been reported growing with *Draba grayana* although invasive species such as *Linaria vulgaris* (yellow toadflax), *Centaurea biebersteinii* (spotted knapweed), and *Matricaria perforata* (scentless chamomile) have all been reported at or above the treeline and are potential threats to endemic alpine species (Ray 2001). When considering community types over a wide region, high elevation sites can be likened to virtual islands (see Systematics and synonymy section). Unfortunately, one important difference between true islands, those surrounded by large expanses of water, and high elevation habitats is that the latter are separated by lands that are inhabited by a multitude of potential competitors that may have many opportunities for colonization (MacArthur and Wilson 1967).

A significant threat to alpine tundra plants is global climate change. Warming could affect alpine areas, causing tree lines to rise roughly 350 feet for 1 °F of warming. Mountain ecosystems, such as those found in the Rocky Mountains, could shift upslope, reducing habitat for many subalpine and alpine tundra species (U.S. Environmental Protection Agency 1997). In the last one hundred years the average temperature in Fort Collins, Colorado, has increased 4.1 °F, and precipitation has decreased by up to 20 percent in many parts of the state (U.S. Environmental Protection Agency 1997). Based on projections made by the Intergovernmental Panel on Climate Change and on results from the United Kingdom Hadley Centre's climate model (HadCM2), a model that accounts for both greenhouse gases and aerosols, by 2100 temperatures in Colorado could increase by 3 to 4 °F in spring and fall, with a range of 1 to 8 °F, and 5 to 6 °F in summer and winter, with a range of 2 to 12 °F (U.S. Environmental Protection Agency 1997).

Atmospheric deposition of nitrogen oxides and ammonium is increasing throughout the world. The western United States has been less affected than the east, but there are hotspots of elevated wet nitrogen (acid rain) deposition in Southern California and along the Colorado Front Range when compared with the rest of the West (Baron 2001). Wet nitrogen deposition occurring in the high mountain areas of the Colorado Front Range is high enough to cause chemical and ecological change (Baron et al. 2000, Baron 2001, Rueth and Baron 2002). Experiments have indicated that nitrogen additions in alpine tundra influence the species composition of the community (Bowman et al. 1993, Theodose and Bowman 1997). In dry meadows, grasses particularly increased in abundance in response to additional nitrogen, at the expense of other species. Therefore, there is the potential that an increase in nitrogen deposition will have a detrimental impact on *Draba grayana*. Given the remote locations of most occurrences, other forms of pollution are an unlikely threat. However, a study sponsored by the Colorado School of Mines, the National Park Service, and the Public Counsel of the Rockies analyzed the chemical content of snow near a snowmobile route (Skid Marks Newsletter 2000, Ray 2001). It reported that "an unnatural level of pollution" and at least 20 hydrocarbon compounds, some toxic and carcinogenic, were located 50 feet above the snowmobile route. The significance of this finding to the sustainability of plant populations that are located near such routes cannot be evaluated without further information.

In summary, the threats to *Draba grayana*, including those related to global climate change, are likely largely dependent upon the extent and intensity. At the present time, all threats appear to be at relatively low and manageable levels. However, the emphasis is "at the present time". Impacts from recreational pressures are becoming increasingly apparent. For example, thousands of people are estimated to walk in the alpine tundra regions in Colorado each weekend during the spring, summer, and autumn (Morrow 2002). On one walking trail alone, 250 people were counted on one weekend day, and hiking trails have become 12 to 15 feet wide in some areas as people have walked at the sides of established trails that become slippery (Morrow

2002). In addition, Morrow (2002) reported that some people were so averse to following designated trails that they destroyed trail markers. Alpine tundra systems are relatively fragile and are not able to recover rapidly from destructive forces. The potential colonization by invasive and competitive plant species that will be exacerbated by anthropogenic disturbances and warming temperatures also should not be underestimated.

Conservation Status of the Species in Region 2

There is no evidence that the distribution or abundance of this species is changing within its range. The majority (25 of 28) of known occurrences of *Draba grayana* occur on land managed by the USFS, specifically the Arapaho, Pike, San Isabel, and Rio Grande national forests (**Table 2**).

At the present time there appear to be several occurrences that, because of specific designation of land management unit, for example Colorado Natural Area (Mt. Goliath Colorado Natural Area; arbitrary occurrence number 14 in **Table 2**) and national park status (Rocky Mountain National Park; arbitrary occurrence numbers 18 and 19, **Table 2**), are relatively secure. One site is designated a Colorado Natural Area by the State of Colorado in order to preserve it for the benefit of present and future generations (Colorado State Parks 2004). A volunteer steward, who is appointed to each natural area, monitors natural resources of note, such as *Draba grayana*. Natural area designation is a conservation vehicle by which the state partners with private individuals, federal agencies (including the USFS), and other organizations to preserve natural areas. National parks are managed by the National Park Service for their scenic or historical significance and are more geared to human recreation than national forests or wilderness areas. Logging, mining, and other activities such as plant collection that may be allowed in national forests are prohibited in national parks (Environmental Media Services. 2001).

On land managed by USFS Region 2, one occurrence of *Draba grayana* is in the Buffalo Peaks Wilderness Area (arbitrary occurrence number 3 in **Table 2**). Congress passed the 1964 Wilderness Act to protect pristine public lands by designating them as wilderness. Wilderness is defined in the law as "an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions..." (Environmental Media Services 2001). In general, the Wilderness Act prohibits commercial activities, motorized access, roads, bicycles, structures, and facilities although Congress has granted exemptions (Environmental Media Services 2001). In the Buffalo Peaks Wilderness Area, all groups of 10 or more are required to obtain a special use permit through the local ranger district office in advance of their trip, and group size is limited to 15. The Buffalo Peaks Wilderness Area is a patchwork of conifer and aspen forests and rolling meadows and is primarily valued for providing habitat to a diverse assortment of wildlife, including one of Colorado's largest herds of bighorn sheep (USDA Forest Service 1984, National Wilderness Preservation System. 2004). Vegetation is often managed to maintain wildlife habitat in the Buffalo Peaks Wilderness Area (USDA Forest Service 1984) and therefore may not necessarily be managed to maintain *D. grayana* populations.

Management of the Species in Region 2

Implications and potential conservation elements.

Draba grayana is endemic to the high elevation mountains of north-central Colorado, and its entire range is within Colorado. Management plans have not specifically addressed this species. *Draba grayana* apparently relies on relatively long-lived mature individuals, and thus management practices that increase either the frequency or intensity of natural perturbations, or provide additional stresses may significantly negatively impact population viability. The alpine tundra ecosystem is fragile, in that it is slow to recover from disturbance. The growing season is very short, and environmental conditions can be severe. It is likely that some practices, such as mining and certain recreational activities, have impacted some occurrences. A major problem is that there is little information on which to base predictions of this species' response to specific disturbance types or levels. Evidence suggests that *D. grayana* has a low reproductive rate and a propensity for poor seedling establishment. These factors will negatively influence population recovery after a loss is experienced. Apomixis is understood to be the reproductive strategy of *D. grayana*. However, if it is pseudogamous, rather than solely agamous, the importance of a healthy and appropriate arthropod population assumes importance. A lack of information prevents accurate estimates of its genetic vulnerability. It is likely that the most geographically separated populations will have the greatest genetic divergence and a significant loss of genetic diversity will likely result if populations at the edge of its range, or in obviously disjunct localities, are lost.

Tools and practices

Documented inventory and monitoring activities are needed for this species. Most of the occurrence information is derived from herbarium specimens or relatively casual observations by botanists that do not provide quantitative information on abundance or spatial extent of the populations. In addition, there is little information on population structure and persistence of either individuals or populations.

Species inventory

Relatively little information has been collected on *Draba grayana*. An important consideration in inventorying this particular species is that it may be easily confused with other species. Species with which it has been confused include *D. streptocarpa*, *D. aurea*, and *D. exunguiculata* (annotations to specimens at the Kathryn Kalmbach Herbarium). In addition, the phenotypic variation displayed by sympatric species may also be perplexing in the field. The current field survey forms for endangered, threatened, or sensitive plant species used by the Gunnison National Forest and the Colorado Natural Heritage Program both request the collection of data that is appropriate for inventory purposes. The number of individuals, the area they occupy, and the apparent potential habitat are important data for occurrence comparison. The easiest way to describe occurrences over a large area may be to count patches, making note of their extent, and to estimate or count the numbers of individuals within patches. Collecting information on phenology is also valuable in assessing the vigor and sustainability of an occurrence.

Habitat inventory

The available information on habitat supplied with descriptions of occurrences is generally too diverse and in insufficient detail to make accurate analyses. Habitat descriptions suggest that, within the restrictions of geology and the eco-climate zones in which it exists, this species grows in a variety of habitats. It would likely be prudent to consider any fellfields, talus slopes, or gravelly areas with granitic soils in alpine tundra and sub-alpine regions above 3,500 m as potential habitat. However, there is an insufficient understanding of all the features that constitute "potential" habitat to be able to make a rigorous inventory of areas that will actually be colonized. There are no studies that relate the abundance or vigor of populations to habitat conditions or even elevation.

Population monitoring

No monitoring or demographic studies have been reported. Occurrence records from the 1880s provide evidence of persistence in general locales, but there is no data on changes in population size and vigor. It is very important to clearly define the goals of any monitoring plan and to identify the methods of data analyses before beginning of a project. The time commitment per year will depend on the protocols adopted, the skill of the surveyor, and the distance between monitoring plots.

Lesica (1987) has discussed a technique for monitoring non-rhizomatous, perennial plant species using permanent belt transects. He also described life stage, or size, classes and reproductive classes that would be most appropriate to consider for *Draba grayana* (Lesica 1987). Moseley and Mancuso (1991, 1992, 1993) successfully employed such methods when studying the population structure over time of *D. trichocarpa*. Permanent transects may be the most accurate way to study long-term trends. Elzinga et al. (1998) and Goldsmith (1991) have discussed using a rectangular quadrant frame along transect lines to effectively monitor the "clumped-gradient nature" of populations that would apply to the most abundant populations.

An effective method for population monitoring and determination of demography is to tag individual plants for an annual, or more frequent, census. Measures such as plant diameter, number of leaves, and flower and fruit number are all useful in evaluating the vigor and fecundity of a population (Price 1979). However, on a scree slope this type of detailed study may not be appropriate because of the potential for disturbance. It is very important not to contribute to either direct or indirect (for example, accelerated erosion) disturbance when monitoring occurrences.

Photopoints and photoplots are very useful in visualizing changes over time, especially in places like steep talus/scree slopes that are relatively inaccessible and/or can easily be disturbed by monitoring activities. Even though digital copies are convenient and easy to store, many museums and researchers suggest storing additional slides or even hardcopies, as in 50 years time the technology to read memory sticks and CDs may no longer be available.

Habitat monitoring

The relative lack of information on habitat requirements makes it premature to consider that habitat monitoring in the absence of plants can effectively occur. Habitat monitoring in the presence of plant occurrences should be associated with population monitoring protocols. Descriptions of habitat should always be recorded during population monitoring activities in order to link environmental conditions with abundance over the long-term. Conditions several years prior to the onset of a decrease or increase in population size may be more important than conditions existing during the year the change is observed. Current land use designation and evidence of land use activities are important to include with monitoring data. For example, it should be noted if occurrences are in a heavy use recreational area or within a mining claim.

Population or habitat management approaches

There have been no systematic monitoring programs for the populations in protected areas, and therefore the benefits of protection cannot be evaluated. Beneficial management practices that have been generally implemented within national forests include restricting recreational vehicle traffic, erecting signs to warn of sensitive plant species, and routing hikers to designated trails. In many cases such policies have been initiated relatively recently, and their consequences have not been documented.

Information Needs

At the present time *Draba grayana* appears to be a naturally uncommon species although one cannot say with certainty that it has not experienced a decline in the last century. The most pressing need is for more information on the numbers and distribution of this species. The present knowledge of its distribution indicates a population center with some relatively disjunct occurrences. Its perceived rarity may be partially due to a lack of specific surveys, and it may be that it has often been overlooked or misidentified in the field. Monitoring pre-existing sites, for example those located along the Continental Divide Trail, is essential in order to understand the implications of existing and new management practices. Where management practices are likely to change, inventories should be taken to collect baseline data and periodic monitoring should be conducted after the new policy is initiated. Similarly, if disturbance levels are anticipated to increase, for example by an increasing mountain goat density, only monitoring will reveal the impact.

Habitat requirements need to be more rigorously defined. This species' ability to tolerate competition is speculated as low, and it appears good management practice to eliminate non-native invasive species swiftly. However, it is unclear what constitutes optimal, adequate, and marginal (implying unsustainable) habitat. The factors that limit population size and abundance and that contribute to the variable occurrence sizes are not known and should be determined. The rate of colonization and the extent of potential habitat influence how populations recover after significant disturbance, for example after activities related to mining or ski area development, as well as localized trampling. Because the rate of recruitment is unknown, the impact of extirpating, or reducing the size of individual populations cannot be estimated.

Another important aspect to understand is the method by which *Draba grayana* reproduces. Current evidence indicates that *D. grayana* is apomictic. However, if it reproduces by pseudogamospermy, arthropod visitors assume an importance and management practices may need to be modified to ensure the viability of an appropriate arthropod community.

In summary, information needs include:

- ❖ Further inventory of new sites
- ❖ Periodic monitoring of existing sites
- ❖ Critical assessment of habitat requirements and rates of colonization
- ❖ Clarification of the method of reproduction

DEFINITIONS

Agamospermy — Occurs when a diploid embryo sac (sporophyte) develops by somatic division of a nucellus or integument cell; no meiosis takes place, so the diploid sporophyte gives rise directly to a diploid gametophyte (Allaby 1992).

Allopolyploid — "A polyploid formed from the union of genetically distinct chromosome sets, usually from different species" (Allaby 1992).

Apomixis — A type of asexual reproduction in plants, that is reproduction without fertilization or meiosis (Allaby 1992).

Caudex — The perennial, often woody, region between the base of the stem and the top of the roots that is slowly elongating and commonly branched.

Edaphic — Pertaining to the soil; conditions that are determined by the physical, chemical, and biological characteristics of the soil.

Endemic — The situation when a species is restricted to one particular geographical area or restricted to a specific environmental condition, for example a particular geological formation.

Hemicryptophyte — A life from category that describes a plant whose perennating buds are at ground level, the aerial parts are dying down at the onset of unfavorable conditions (Raunkiaer 1934)

Polyploidy — "The condition in which an individual possesses 1 or more sets of homologous chromosomes in excess of the normal 2 sets found in a diploid organism" (Allaby 1992).

Pseudogamy — Development of an ovum into a new individual as a result of stimulation by a male gamete. However, its nucleus does not fuse with that of the ovum, and it contributes nothing to the genetic constitution of the embryo (Abercrombie et al. 1973).

Ranks — NatureServe and the Heritage Programs Ranking system (Internet site: http://www.natureserve.org/explorer/granks.htm).

Rank		**Meaning**
G2	=	"Imperiled—Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50)."
S2	=	"Imperiled—Imperiled in the subnation [state] because of rarity or because of some factor(s) making it very vulnerable to extirpation from the nation or subnation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000)".

Silicle — The short fruits, usually not more than twice as long as wide, of the Brassicaceae of Cruciferae (mustard) family.

Silique — The long fruits, usually more than twice as long as wide, of the Brassicaceae or Cruciferae (mustard) family.

Stochastic — Uncertainty. "Of, pertaining to, or arising from chance" (Guralnik 1982).

Sympatric — 'The occurrence of species together in the same area' (Allaby 1992).

COMMONLY USED SYNONYMS OF PLANT SPECIES

The commonly used synonyms of plant species (Kartesz 1994) mentioned in this report. The reference in parenthesis refers to a flora in Region 2 in which the synonym is used:

Geum rossii	*Acomastylis rossii* (Weber and Wittman 2001b)
Eritrichium aretioides	*Eritrichum aretioides* (Weber and Wittman 2001b)
Hymenoxys grandiflora (Dorn 2001)	*Rydbergia grandiflora* (Weber and Wittman 2001b)
Lidia obtusiloba (Weber and Wittman 2001b)	*Minuartia obtusifolia* (Dorn 2001)
Saxifraga chrysantha	*Hirculus serpyllifolius* (Weber and Wittman 2001b)
Senecio spp.	*Ligularia* spp. (Weber and Wittman 2001b)
Arenaria fendleri var. *fendleri*	*Eremogone fendleri* (Weber and Wittman 2001b)

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