Draba globosa Payson (beavertip draba): A Technical Conservation Assessment

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

February 27, 2004

Juanita A. R. Ladyman, Ph.D.
JnJ Associates
6760 S. Kit Carson Circle East
Centennial, CO 80122

Peer Review Administered by
Center for Plant Conservation

Ladyman, J.A.R. (2004, February 27). *Draba globosa* Payson (beavertip draba): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/drabaglobosa.pdf [date of access].

ACKNOWLEDGEMENTS

The time spent and help given by all the people listed in the References 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 the access to files and assistance given to me by Andrew Kratz, Region 2 U.S. Forest Service, and Chuck Davis, U.S. Fish and Wildlife Service. The conversations I had with Carla Scheck, Bureau of Land Management, Barry Johnston, U.S. Forest Service, Gunnison National Forest, and Terry Ireland, Bureau of Land Management, Grand Junction were also particularly valuable. I appreciate the thoughtful reviews made by Beth Burkhart and unnamed reviewers and thank them for their time in considering the document.

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 globosa*

Status

Draba globosa (beavertip draba) is a rare mustard. The NatureServe Global rank for this species is vulnerable, G3. In Region 2, the Colorado Natural Heritage Program has designated it critically imperiled, S1, and the Wyoming Natural Diversity Database has designated it imperiled, S2. Outside of Region 2, this species is designated critically imperiled, S1, by the Montana Natural Heritage Program and imperiled, S2, by the Idaho Conservation Data Center and by the Utah Natural Heritage Program. It is not designated a sensitive species by the USDA Forest Service - Region 2, but it is by USDA Forest Service – Region 4. It is on the Montana USDI Bureau of Land Management watch list.

Primary Threats

Recreational use of habitat, such as foot traffic and activities related to skiing, may pose a threat to some populations throughout its range. As the human population grows in areas within easy access to *Draba globosa* habitat and as the recreational use increases, the impacts may become substantially more significant. This is particularly true for Colorado (Region 2) where the human population grew 30.6 percent between 1990 and 2000. Although the rate of population growth may slow, it is unlikely to stop in the foreseeable future. Mining activities are not perceived as a threat to any of the currently known populations, although individual populations may have been impacted in the past. Introduced mountain goats are likely to have a negative impact on habitat in Utah (Region 4) and in Colorado (Region 2). Invasive weeds may pose an additional risk to long-term sustainability. Some invasive species have already been observed at the timberline in Colorado (Region 2). Wet nitrogen deposition (acid rain) poses a substantial risk to forb communities in alpine tundra in some regions. Within Region 2, airborne pollution is a particular problem in 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 globosa is a regional endemic. It is restricted to elevations above 2,743 m (9,000 feet) in western Wyoming, central Colorado, southwestern Montana, south central Idaho, and northwestern Utah. *Draba globosa* appears to be a naturally uncommon species that is well-adapted to its fragile alpine habitat. The majority of the known occurrences are located on land managed by the USDA Forest Service. In general, there is a lack of precise information concerning *D. globosa*'s abundance, distribution, and biology. The information currently available suggests that several populations are relatively secure because they occur in areas that are afforded protection either by land use designation, for example USDA Forest Service Research Natural Area and Wilderness Area, or by their remote, relatively inaccessible location. *Draba globosa* apparently relies on relatively long-lived mature individuals, and thus management practices that increase either the frequency or intensity of natural perturbations, or by themselves apply additional stresses to the plants, may significantly negatively impact population viability. There are no management plans directly concerning *D. globosa*.

Table of Contents

EDITOR: Beth Burkhart, USDA Forest Service, Rocky Mountain Region

List of Tables and Figures

Tables:

Figures:

INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region, USDA Forest Service. *Draba globosa* (beavertip draba, rockcress draba or round-fruited whitlow grass) is the focus of an assessment because it is a regional endemic species whose population viability is identified as a concern based on its limited global distribution. It is designated as a sensitive species in Region 4 of the USDA Forest Service. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or in habitat capability that would reduce its distribution (USDA Forest Service 1995). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Draba globosa* throughout its range in Region 2. The 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 a thorough discussion of the biology, ecology, conservation, and management status of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations but provides the ecological background upon which management must be based. It focuses on the consequences of changes in the environment that result from management (i.e. management implications). Furthermore, it cites management recommendations proposed elsewhere and, when management recommendations have been implemented, the assessment examines the success of the implementation.

Scope

The *Draba globosa* assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of the Rocky Mountain Region of the USDA Forest Service (Region 2). Although some of the literature relevant to the species originates from field investigations 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 *Draba globosa* 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 the assessment, I reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on *Draba globosa* may have been referenced in the assessment, although an effort was made to consider all relevant documents. The assessment emphasizes the refereed literature because this is the accepted standard in science. Some non-refereed literature was used in the assessment because information was unavailable elsewhere. In some cases, non-refereed publications and reports may be regarded with greater skepticism. However, many reports or non-refereed publications on rare plants are reliable, and 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 important in estimating the geographic distribution and population sizes. These data required special attention because of the diversity of persons and methods used in collection. Records that were associated with locations at which herbarium specimens had been collected at some point in time were weighted higher 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 includes 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 sciences, and often observations, inference, good thinking, and models must be relied on to guide the understanding of ecological relations. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent the strongest approach to developing knowledge, alternative methods (modeling, critical assessment of observations, and inference) are accepted approaches to understanding features of biology.

The rarity of a taxon can be particularly difficult to establish. There is the always the possibility that additional surveys would reveal more occurrences. When most information has been collected relatively casually, a criticism with defining a taxon as rare is that there are extensive areas as yet unsurveyed. To some extent this is true, but rarity is also relative and many taxa are regarded as not being rare precisely because casual observation has noted that they occur frequently. Another basis of uncertainty with *Draba globosa* is that there appears a likelihood of mistaken identity. Mistaken identity can lead to over- and under-estimates of its abundance. This situation indicates that specimen collection and deposition at accessible herbaria are very important considerations for this taxon.

Publication of the Assessment on the World Wide Web

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

Peer Review

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

Management Status and Natural History

Management Status

The NatureServe Global[1] Rank and the National Heritage Status Rank for *Draba globosa* is vulnerable, G3 and N3, respectively (NatureServe 2001). It is designated critically imperiled, S1, by both the Colorado Natural Heritage Program and the Montana Natural Heritage Program. It is designated imperiled, S2, by the Wyoming Natural Diversity Database, the Utah Natural Heritage Program, and the Idaho Conservation Data Center (NatureServe 2003).

Draba globosa is designated a sensitive species by the USDA Forest Service in Region 4. It is not designated a sensitive species in either Region 1 or Region 2 (USDA Forest Service 2003; Shelly personal communication 2002). A sensitive species is a plant or animal "species identified by the Regional Forester for which population viability is a concern as evidenced by a significant current or predicted downward trend in population number or density and/or a significant current or predicted downward trend in habitat capability that would reduce a species' existing distribution" (USDA Forest Service 1994). *Draba globosa* is on the Montana Bureau of Land Management watch list (Montana Natural Heritage Program at http://nhp.nris.state.mt.us/).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Draba globosa occurs on USDA Forest Service land and likely also on private land within the boundaries of Region 2 (Johnston personal communication 2002). Occurrences have been reported from the Gunnison National Forest, the San Isabel National Forest, the Arapaho National Forest, and the White River National Forest (all in Colorado) and the Shoshone National Forest (in Wyoming). Some location information within the White River National Forest is vague, and occurrences may be on patented mining claims (Johnston personal communication 2002). In the Gunnison National Forest, at least one population is in a designated wilderness area, the Fossil Ridge Wilderness Area. Occurrences have been recorded in the Absaroka-Beartooth, North Absaroka, and Popo Agie wilderness areas in the Shoshone National Forest. A wilderness area is defined in the law as "an area of undeveloped

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

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 and sometimes limits visitor numbers in wilderness areas, although Congress has granted exemptions.

One occurrence is in the proposed Beartooth Butte Research Natural Area (RNA) in the Shoshone National Forest (Fertig 1998). One of the objectives in conveying RNA status is to protect the elements of biological diversity for which it was established (Research Natural Areas undated). The proposed Beartooth Butte Research Natural Area is recognized as notable because it encompasses "alpine tundra, barren slopes, a mosaic of upper timberline conifer woodlands and herbaceous meadows, and a suite of rare plants," including specifically *Draba globosa* (Jones and Fertig 1999). Therefore, the proposed RNA is likely to be managed to maintain habitat for *D. globosa*.

Field guides that include *Draba globosa* have been compiled for the Pike and San Isabel national forests and the Shoshone National Forest to assist field staff in identifying rare and sensitive species (Kettler et al. 1993, Mills and Fertig 1996). Few formal surveys have been conducted for this species, and there are no management or conservation plans specifically for this species within Region 2.

Outside of Region 2, occurrences have been documented on lands managed by the Bureau of Land Management (BLM) and the USDA Forest Service. The majority of the known occurrences are on Forest Service land. *Draba globosa* is designated sensitive in Region 4 (USDA Forest Service 2001). As in Region 2, some occurrences are afforded some level of protection through general land-use designation. *Draba globosa* exists in the Bridger Wilderness Area and the Osborn Mountain RNA in Bridger-Teton National Forest (USDA Forest Service 1999, Marsh personal communication 2002). The Osborn Mountain RNA was established, in part, because it provided occupied habitat for *D. globosa* (USDA Forest Service 1999). This area has apparently never been grazed by domestic livestock and represents climax vegetation, to the extent that "climax" may be applied to the alpine zone, which tends to be outside the strictly linear model of succession (USDA Forest Service 1999). In Montana (Region 1), one occurrence is within the Cave Mountain RNA on the Beaverhead-Deerlodge National Forest. This area has experienced a low amount of livestock grazing in the past, and it is currently managed under a stipulation of non-manipulation research (USDA Forest Service 1996). A least three occurrences have also been reported from the Grand Teton National Park. No livestock grazing or mechanized travel off designated roads is allowed in wilderness areas, RNAs, or in national parks. There are no mineral leases in the Osborne Mountain RNA. *Draba globosa* is known to occur within the Bureau of Land Management Challis Resource Area, Idaho, but the management of *D. globosa* is not addressed in the Resource Management Plan (Redick personal communication 2002).

Because *Draba globosa* appears "widespread, if not abundant" in the Uinta Mountains of Utah, Stone (1995) has suggested it be removed from the USDA Forest Service Region 4 sensitive species list. However, he proposed that it should still be managed as a sensitive species or under the Service's biodiversity regulations in areas where it is rare, which he determined to include parts of Region 4, specifically the Salt Lake Ranger District, Wasatch-Cache National Forest in Utah, and the Sawtooth National Recreation Area in Idaho, as well as the Gallatin National Forest, Montana in Region 1 and in the San Isabel and Gunnison national forests, Colorado in Region 2.

Biology and Ecology

Classification and description

Systematics and synonymy

Draba is the largest genus of the Brassicaceae or Cruciferae family, 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 in 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 apiculata C.L. Hitchcock and *D. densifolia* Nutt. var. *apiculata* (C.L. Hitchc.) Welsh are both commonly used synonyms of *D. globosa* Payson (Kartesz 1994). Welsh et al. (1993) recognized *D. globosa* as a "weakly defined, arbitrarily separable, sympatric variant" of *D. densifolia*, namely, variety *apiculata*. Hitchcock associated *D. globosa* and *D. daviesiae* by naming them *D. apiculata* var. *daviesiae* and *D. apiculata* var. *apiculata* (Hitchcock and Cronquist 1973). Currently they are recognized as distinct species that are not particularly related (Rollins 1993). *Draba daviesiae* has a matted, loosely branching caudex with elongated leafy branches, and the tips of the leaves are rounded rather than pointed (Rollins 1993). In contrast *D. globosa* has leaf clusters in dense rosettes terminating the caudex branches, and the leaves are abruptly pointed at the tip. Most recently, isozyme and DNA analysis indicates that *D. globosa* is most closely related to *D. maguirei* var. *burkei*, which may soon be recognized as the full species *D. burkei* (Windham and Beilstein 1998). The close phylogenetic relationship between *D. globosa* and *D. burkei*, indicated by the results of nuclear ribosomal DNA analysis, was somewhat surprising because even though Hitchcock (1941) noted some similarities between the two species, no treatment of the *Drabas* has ever suggested a relationship between these two taxa. In the molecular phylogenetic study, *D. densifolia* is a clearly separable taxon from *D. globosa*.

History of species

Draba globosa was first collected near Alta in the Wasatch Range in Utah in 1879 (Payson 1917). In 1898, it was collected at the "La Plata Mines" in the Snowy Range in Wyoming by E. Nelson (*E. Nelson 5246a* holotype RM). Nearly one hundred years later in 1984 it was thought to have been first documented in Colorado (E.L. *Hartman and Rottman 6025* COLO, UC; Hartman and Rottman 1984). However, it actually had been collected prior to that time, in about 1918 by L.M. and N.T. Schedin who reported it from "probably near Leadville" (*L.M.* and *N.T. Schedin 227* RM Herbarium specimen accession *97160*; Ewan and Ewan 1981).

Non-technical description

Draba globosa is a diminutive, compact, mound-forming perennial with short leafless stems (scapes) terminating in a cluster of flowers. The stems are 0.5 to 3 cm tall. The small, thick, oval to lance-shaped leaves densely overlap at the base of the stems and are 3 to 6 mm long. The leaves are hairless except for a few small hairs (apiculate trichomes) at the margins. The marginal hairs are small, unbranched, narrow-based and tend to collapse and curl during drying. There are two to five flowers per flower cluster (inflorescence). The petals are pale yellow or white, and there are four petals per flower. The fruits or "pods" (silicles) are on 2 to 4 mm long stalks and are ovate to oblong, hairless and 3 to 6 mm long. The styles are 0.2 to 0.75 mm long, and the seeds approximately 2 mm long. This description is taken largely from Rollins (1993) and Windham and Beilstein (1998) who recently made a careful study of Utah populations of *D. globosa*. Interestingly, the epithet "globosa" does not describe the somewhat elongated egg-shaped silicles, but rather it refers to Payson's original graphic description of the leaves "forming globose tufts on the ends of caudex-branches" (Rollins 1993).

Payson (1917) noted that the type specimen was found on the same sheet with specimens of *Draba oligosperma* (synonym *D. andina*), which is a phenotypically similar but more ubiquitous species. One distinctive character that separates the two is that the under surface of the leaves of *D. oligosperma* is covered by short, soft hairs (pubescent). Payson (1917) warned that the two species were also mounted together on specimen sheets in other herbaria. *Draba densifolia* is also very similar to *D. globosa* but has hairy fruits. In Utah, several specimens of both *D. densifolia* and *D. oligosperma* have been misidentified as *D. globosa* (Stone 1995). In Idaho, several specimens of *D. globosa* were originally misidentified as *D. daviesiae* (Fox and Moseley 1991). The morphological characters of *D. globosa* and several taxa that have been mistaken for it are summarized in **Table 1**. An illustration of *D. globosa* is in **Figure 1**.

It is important that both leaves and fruit are available when making identifications (Mills and Fertig 1996). Hair morphology is a particularly important characteristic amongst the *Draba* species (Rollins 1993, Stone 1995). Generally the hairs of *D. globosa* are unbranched whereas other alpine *Draba* species, at least in Wyoming, have more densely pubescent leaves with forked or pectinate hairs (USGS Northern Prairie Wildlife Research Center 2002).

References to technical descriptions, photographs, line drawings and herbarium specimens

Comprehensive technical descriptions are published in Payson (1917) and Rollins (1993). Technical descriptions are also in Dorn (2001), in Weber and Wittmann (2001a, 2001b), in Welsh et al. (1993) and Scott (1995) where it is treated as *Draba densifolia* var. *apiculata*, and in Dorn (1984) where it is treated as *D. apiculata*. A detailed technical description and line drawings showing the leaf and fruit characters of *D. globosa* are in Hitchcock (1941). Descriptions, photographs, and line drawings are published in Spackman et al. (1997) and on the Colorado Natural Heritage Program website (2002). A photograph and a general description are published on the Montana Natural Heritage Program website (2002).

Table 1. Morphological characteristics of *Draba globosa*, and taxa that have been mistaken for *D. globosa* (after Hitchcock 1941, Hitchcock and Cronquist 1973, and Rollins 1993).

***Draba* species**	**Habit**	**Basal leaf characters**	**Flowering stem height**	**Stem (cauline) leaves**	**Flower (petal) color**	**Fruit**
globosa	tufted (caespitose); caudex with short compact branches.	3-6 x 1-2 mm; pointed at the apex; few stiff simple or forked hairs	0.5-3 cm	0	(pale) yellow or white	3-6 x 2-3.5 mm; hairless
daviesiae	matted loosely branching caudex with elongated leafy branches	4-8 x 1.5-2.5 mm; hairless but leaf margins fringed with many simple hairs (ciliate)	(2) -4- (8) cm	0	yellow	~5 mm long; hairless
crassa	thick crown	20-80 x 5-10 mm; hairless with few hairs on the leaf margins	5-15 cm	2-6	yellow	10-16 x 3-5mm; hairless
densifolia	caespitose	2-9 x 0.5-3 mm; stiff hairs on the leaf margins, some forked or stellate	0.3-15 cm	0	yellow	2-7 x 2-3.5 mm; hairless or with some long hairs
fladnizensis	branched or simple caudex	5-10 x 1-2 mm; long soft hairs on the leaf margins, simple or forked	2-9 cm	1-2	white	3-6 x 1.5-2 mm; hairless or with short hairs
oligosperma	caespitose	3-11 x 0.7-1.8 mm; closely appressed and comb-like hairs, hairs on the leaf margins	1-10 cm	0	yellow	2.5-8 x 2-4 mm; simple or forked hairs, or sometimes hairless

Descriptions, line drawings, and photographs of its habitat are also published in Fertig et al. (1994) and on the USGS Northern Prairie Wildlife Research Center website (2002). A more detailed description and a line drawing are also published on the Wyoming Natural Diversity Database website (2002). A photograph of the holotype herbarium specimen (*E.B. Payson 5048* with L.B. Payson 19 July 1926) is on the New York Botanical Garden webpage (2002) under *D. apiculata* C. L. Hitchcock. See the References section for internet site addresses.

Distribution and abundance

Draba globosa is one of the several *Draba* species found in the alpine tundra zone of the Rocky Mountains. Its occurrences tend to be very disjunct within its range that covers parts of Colorado, Utah, Wyoming, Idaho and Montana (**Figure 2**). Approximately 52 documented occurrences have been reported; approximately 20 in Wyoming, 18 in Utah, five in Colorado, five in Idaho, and four in Montana (**Table 2**, **Figure 3**). Of the 52 total occurrence observations, 27 were located since 1990. The majority of known occurrences are on land managed by the USDA Forest Service (**Table 2**). Ten occurrences are on USDA Forest Service Region 2 lands.

There are typically two or three plants per clump and, in general, only a few plants are found at any one occurrence. However, there are areas where the species is locally quite abundant. Populations may comprise 1,000 to 3,000 individuals over several acres and, a large subpopulation may contain as many as 217 plants in an area of 25 m^2 (Wyoming Natural Diversity Database

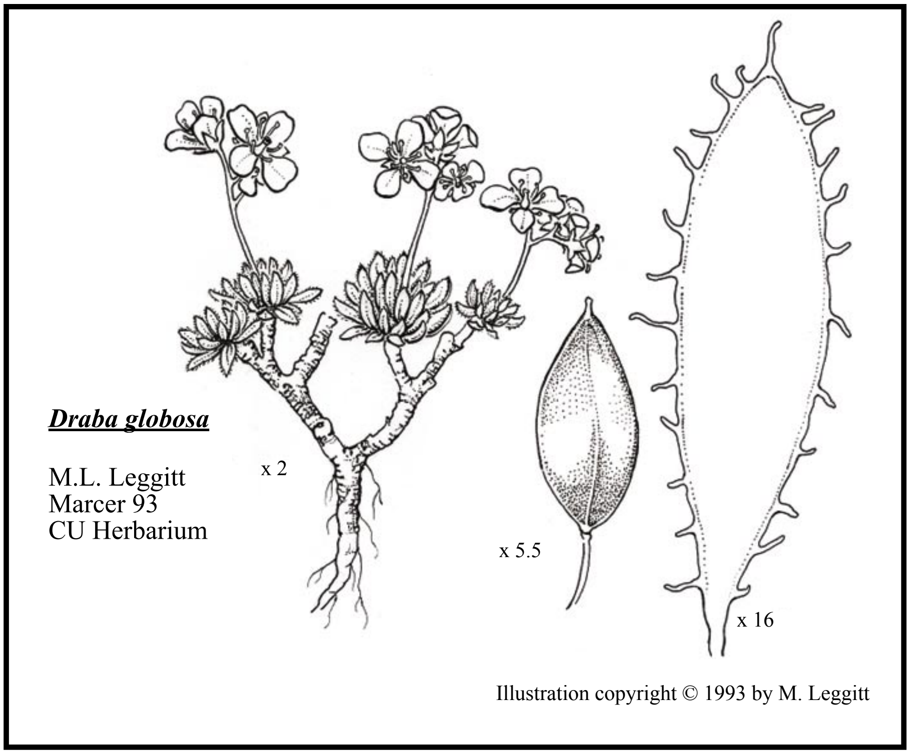

Figure 1. Illustration of *Draba globosa*. Illustration by Marjorie Leggitt. Used with permission.

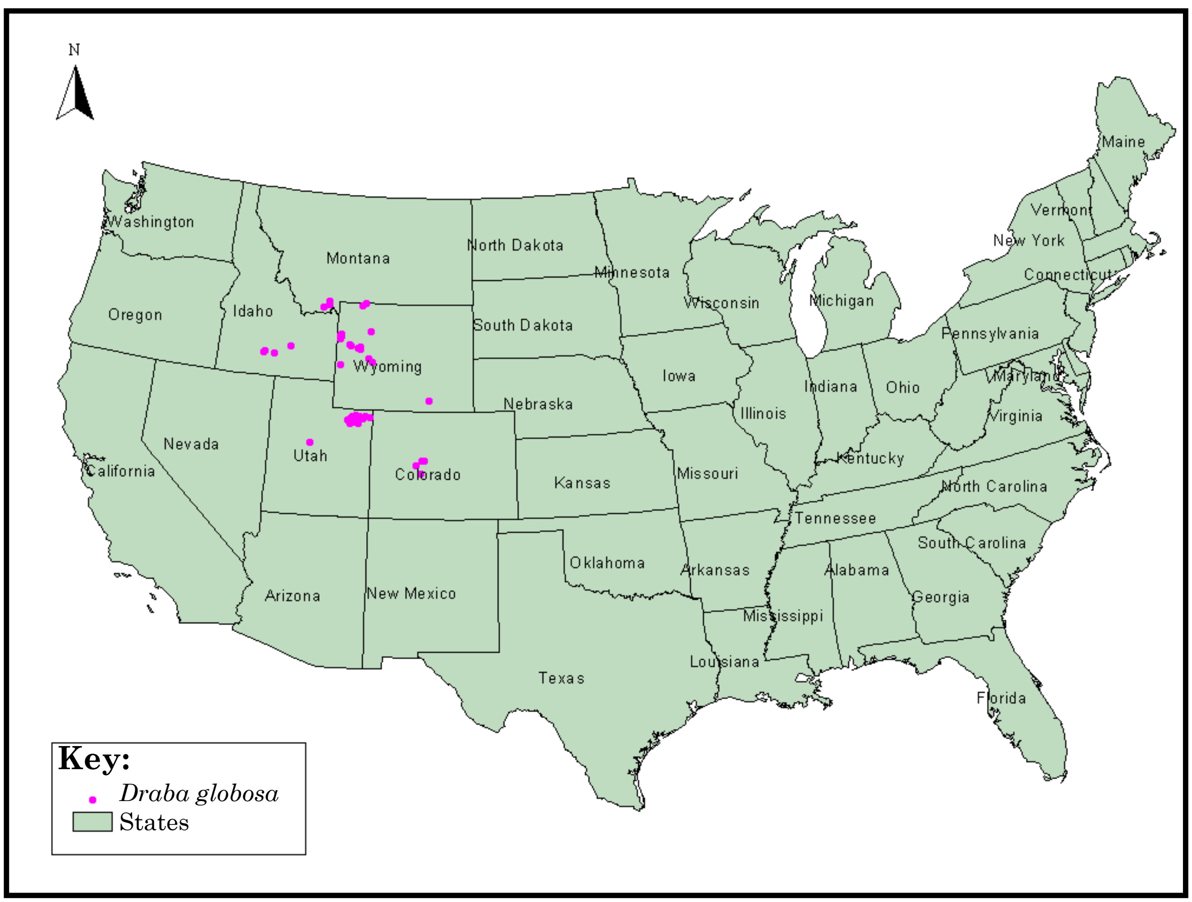

Figure 2. Range of *Draba globosa* throughout the United States.

Table 2. Occurrences of *Draba globosa*. Those occurrences with specimen verification are indicated in the column marked "sources of information." The letters associated with each occurrence number denotes the state in which it is found.

Arbitrary Occurrence Number	Managed Area	County	Dates Observed	Location	Sources of Information
1-CO	San Isabel National Forest. Region 2	Lake	8/20/1986	East slope - Rocky Mountains. Mount Champion Basin. Occurrence extends over 8 sections.	Colorado Natural Heritage Program element occurrence records 2002. Specimens: *Emily L. Hartman and Mary Lou Rottman 6664 & 2935*. COLO. Also at University of Colorado at Denver.
2-CO	Gunnison National Forest, Fossil Ridge Wilderness Area. Region 2	Gunnison	1989; 7/30/1989; 7/10/1990	West Slope - Rocky Mountains. In Fossil Ridge Wilderness Area. Another specimen from Fossil Ridge area, approximately 400m south of Fossil Mountain, was likely from same population.	Colorado Natural Heritage Program element occurrence records 2002. Specimens: *Paula Lehr 1298* COLO. *Paula Lehr 1232* "County voucher" COLO.
3-CO	White River National Forest - Arapaho National Forest. Region 2	Clear Creek	6/23/1996; 7/23/1996	East slope - Rocky Mountains. Front range Loveland Pass area.	Colorado Natural Heritage Program element occurrence records 2002. Specimens: *Loraine Yeatts 3812* COLO, KHD.
4-CO	White River National Forest - Gunnison National Forest. Region 2	Pitkin	8/6/1998	West Slope - Rocky Mountains. Taylor Pass Area.	Colorado Natural Heritage Program element occurrence records 2002.
5-CO	Unknown	Lake (?)	3/17/1939	"Probably near Leadville".	Specimens: *LM and NT Schedin, sn*. RM.
1-WY	Medicine Bow National Forest, Laramie Ranger District. Region 2	Albany	1898; 7/27/1985; 8/29/1898	Medicine Bow Mountains, Snowy Range, north-northeast of Brooklyn Lake (in 1898 location described as "La Plata mines").	Wyoming Natural Diversity Database element occurrence records 2002. Payson (1917).
2-WY	Shoshone National Forest, Washakie Ranger District, Popo Agie Wilderness Area. Region 2	Fremont	8/10/1975	East slope of the Wind River Range, above High Meadow Lake (T33N R103W S34).	Wyoming Natural Diversity Database element occurrence records 2002.
3-WY	Bridger-Teton National Forest, Kemmerer and Greys River ranger districts, Region 4	Lincoln	7/30/1978	Salt River Range, West Sheep Pass area.	Wyoming Natural Diversity Database element occurrence records 2002.
4-WY	Shoshone National Forest, Greybull Ranger District. Region 2	Park	8/22/1984	Absaroka Range, Chief Mountain to Galena Ridge. Occurrence extends over 2 sections.	Wyoming Natural Diversity Database element occurrence records 2002.
5-WY	Shoshone National Forest, Clarks Fork Ranger District, North Absaroka Wilderness Area. Region 2	Park	7/5/1988	Northern Absaroka Range, Hurricane Mesa area. Occurrence extends over 2 sections.	Wyoming Natural Diversity Database element occurrence records 2002.
6-WY	Shoshone National Forest, Clarks Fork Ranger District, Absaroka Beartooth Wilderness Area. Region 2	Park	7/17/1939; 7/11/1996	Beartooth Range, Beartooth and Clay buttes, 2 discrete locations: one on the west of Clay Butte and the other at the north end of Beartooth Butte.	Wyoming Natural Diversity Database element occurrence records 2002. Rollins (1953). Fertig (1997). Hitchcock (1941). Jones and Fertig (1999).

Table 2 (cont.).

Arbitrary Occurrence Number	Managed Area	County	Dates Observed	Location	Sources of Information
7-WY	Shoshone National Forest, Clarks Fork Ranger District, Absaroka Beartooth Wilderness Area. Region 2	Park	7/17/1939; 7/11/1996	Beartooth Range, Beartooth and Clay buttes. Occurrence extends over 2 sections. Occurrence 6-WY and Occurrence 7-WY are most likely to be part of the same population.	Wyoming Natural Diversity Database element occurrence records 2002. Rollins (1953). Fertig (1997). Hitchcock (1941). Jones and Fertig (1999).
8-WY	Private or Bridger-Teton National Forest. Region 4	Sublette	7/2/1995	Wyoming Mountains. Dry Piney drainage off Deadline Ridge.	Specimens: *Jim & Jean Jewell 795121*, CS.
9-WY	Bridger-Teton National Forest, Pinedale Ranger District, Bridger Wilderness Area. Region 4	Sublette	8/17/1982	Wind River Range, southeast of Lee Lake, between Pronghorn Peak and Nylon Peak.	Wyoming Natural Diversity Database element occurrence records 2002.
10-WY	Bridger-Teton National Forest, Pinedale Ranger District, Bridger Wilderness Area. Region 4	Sublette	8/9/1990	Northwest Wind River Range, on Gypsum Mountain, southwest of Lower Green River Lake. This occurrence potentially contiguous with Occurrence 11-WY.	Wyoming Natural Diversity Database element occurrence records 2002. Fertig (1992a). Hartman and Nelson (1991).
11-WY	Bridger-Teton National Forest, Pinedale Ranger District, Bridger Wilderness Area. Region 4	Sublette	8/4/1992	West Slope Wind River Range, on Big Sheep Mountain, west of Lower Green River Lake.	Wyoming Natural Diversity Database element occurrence records 2002.
12-WY	Bridger-Teton National Forest, Pinedale Ranger District, Bridger Wilderness Area. Region 4	Sublette	8/17/1991	Northwest Wind River Range, on slope of Lost Eagle Peak and extending to the southeast end of White Rock Mountain. Occurrence extends over 2 sections.	Wyoming Natural Diversity Database element occurrence records 2002. Fertig (1992a).
13-WY	Bridger-Teton National Forest, Pinedale Ranger District, Bridger Wilderness Area , Osborn Mountain Research Natural Area. Region 4	Sublette	8/17/1984; 8/2/1998	Northwest Wind River Range, on Osborn Mountain.	Wyoming Natural Diversity Database element occurrence records 2002. Fertig and Jones (1994). Specimens: *Welp* 7888 & Fertig at RM.
14-WY	Bridger-Teton National Forest, Jackson Ranger District, Gros Ventre Wilderness Area. Region 4	Teton	6/28/1994. Plants could not be re-located in 1997.	Gros Ventre Mountains, just north of Corner Peak at the headwaters of Swift Creek. Occurrence extends over 2 sections.	Wyoming Natural Diversity Database element occurrence records 2002. Hartman (1995).
15-WY	Jackson Hole Ski Corporation and Bridger-Teton National Forest. Region 4	Teton	7/31/1996	Teton Range, Rendezvous Mountain, between Granite Canyon and Jackson Hole.	Wyoming Natural Diversity Database element occurrence records 2002. Markow (1996). Specimens: *Stuart Markow 11374* at RM.
16-WY	Grand Teton National Park	Teton	8/8/1967	Teton Range, east side of Timberline Lake.	Wyoming Natural Diversity Database element occurrence records 2002. Shaw (1976).
17-WY	Grand Teton National Park, Targhee National Forest	Teton	9/16/1995	Teton Range, near Hurricane Pass along the divide between Grand Teton National Park and Targhee National Forest.	Wyoming Natural Diversity Database element occurrence records 2002.

Table 2 (cont.).

Arbitrary Occurrence Number	Managed Area	County	Dates Observed	Location	Sources of Information
18-WY	Grand Teton National Park	Teton	7/8/1952	Teton Range, in Upper South Cascade Canyon.	Wyoming Natural Diversity Database element occurrence records 2002.
19-WY	Bridger-Teton National Forest	Teton	8/4/1998	Gros Ventre Range, on the flank of Darwin Peak.	Specimens: *Laura Welp 7901b* at RM.
20-WY	Bridger-Teton National Forest, Big Piney Ranger District, Gros Ventre Wilderness Area. Region 4	Teton; Sublette	8/5/1994; 8/4/1998	Gros Ventre Range, on slopes and saddles interconnecting Palmer, Darwin, Triangle, and Doubletop Peaks. (This occurrence consists of 4 subpopulations within a 5 square mile area extending over 3 sections).	Wyoming Natural Diversity Database element occurrence records 2002. Hartman (1995).
1-ID (Occurrence needs confirmation)	Targhee National Forest, Dubois Ranger District	Lemhi	6/24/1996	At treeline above an old mining camp northeast of Big Windy Peak in the Lemhi Range.	Idaho Natural Heritage Program element occurrence records 2002.
2-ID	Sawtooth National Forest, Sawtooth National Recreation Area. Region 4	Custer	1980; 8/13/1990	Summit of peak in White Cloud Peaks, southwest of the Livingston Mine.	Idaho Natural Heritage Program element occurrence records 2002. Specimens: *R. K. Moseley 2127* at ID. *R. K. Moseley 2136* at ID. M. Mancuso 482 at ID. *Taylor 7042* at Sawtooth NRA herbarium.
3-ID	Sawtooth National Forest, Sawtooth National Recreation Area. Region 4	Custer	8/5/1986	On divide between Big Boulder Creek and Warm Springs Creek.	Idaho Natural Heritage Program element occurrence records 2002. Specimens: *R. K. Moseley 950* at ID.
4-ID	Salmon and Challis national forests and Sawtooth National Forest, Sawtooth National Recreation Area. Region 4	Custer	8/11/1978	In cracks in high granite ridge south of Sapphire Lake in the White Cloud Mountains. Near Occurrence 3-ID with which the populational relationship not known.	Idaho Natural Heritage Program element occurrence records 2002.
5-ID	BLM - Upper Columbia-Salmon Clearwater District, Challis Resource Area.	Custer	6/29/1984	On the summit of Jerry Peak.	Idaho Natural Heritage Program element occurrence records 2002.
1-MT	Gallatin National Forest, Hebgen Lake Ranger District, Lee Metcalf Wilderness Area. Region 1	Madison	8/1/1981	At the east end of Taylor Basin in the Madison Range.	Montana Natural Heritage Program element occurrence records 2002. Specimens: *P. Lesica 1728* at MONTU.
2-MT	Gallatin National Forest, Hebgen Lake Ranger District, Lee Metcalf Wilderness Area. Region 1	Madison	9/7/1981	Near top of Sphinx Mountain in a section of Burlington Northern land in the Madison Range.	Montana Natural Heritage Program element occurrence records 2002. Specimens: *P. Lesica 1868* MONTU.
3-MT	Beaverhead and Deerlodge national forests, Cave Mountain Research Natural Area. Region 1	Madison	7/19/1991	On the east slope of Cave Mountain.	Montana Natural Heritage Program element occurrence records 2002. Specimens: Lesica and Garde 5489, MONTU.
4-MT	BLM - Dillon Field Office	Beaverhead	8/1/1993	Southeast of Taylor Mountain near the Continental Divide in the Centennial Mountains.	Montana Natural Heritage Program element occurrence records 2002. Specimen collected by L. Bacon August 1993, verified by P. Lesica but specimen not saved for voucher.

Table 2 (cont.).

Arbitrary Occurrence Number	Managed Area	County	Dates Observed	Location	Sources of Information
1-UT	Ashley National Forest, High Uintas Wilderness Area. Region 4	Duchesne	7/8/1946; 8/14/1965	Vicinity of Mount Emmons.	Utah Natural Heritage Program element occurrence records 2002. Hitchcock (1941), Stone (1995). Specimen: *Hermann 5042* GH no date; *C. Lynn Hayward 135* BRY 1946-07-08; *R. Murdock 12* BRY; 1950-07-11; *J.R. Murdock 551*;BRY 1965-07-29; *R.S. Bjerregaard 96* BRY 1965-08-14.
2-UT	Ashley National Forest, High Uintas Wilderness, Duchesne Ranger District. Region 4	Duchesne	7/18/1994	Ridge south of Kidney Lake.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995), Hitchcock (1941). Specimen: *A. Huber 1924* BRY 1994-07-18.
3-UT	Ashley National Forest, Duchesne Ranger District. Region 4	Duchesne	8/16/1994	Ridge south of Grandaddy Lake.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995). Specimen: *A. Huber, S. Goodrich 2268*, BRY 1994-08-16.
4-UT	Ashley National Forest, High Uintas WildernessArea, Vernal Ranger District. Region 4	Duchesne	6/21/1994	Ridge west of Rasmussen Lakes	Utah Natural Heritage Program element occurrence records 2002. Stone (1995) Specimen: *A. Huber 1070* BRY 1994-06-21.
5-UT	Wasatch-Cache National Forest, likely Kamas Ranger District. Region 4	Duchesne, Summit	7/10/1975; 7/10/1991	Vicinity of Bald Mountain Pass.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995). Specimen: George Briggs; 14, UTC, 1975-07-10.; *S. Goodrich 14,842*, BRY;, 1980-08-04; *M.D. Windham, D. Lyngholm 91-160*, UT, 1991-07-10.
6-UT	Ashley and Wasatch-Cache national forests, High Uintas Wilderness Area. Region 4	Duchesne, Summit	7/8/1936; 8/25/1993	Gilbert Peak.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995). Specimen: *Bassett Maguire, D.A. Hobson, and R.R. Maguire* 14,486 UTC, WTU 1936-08-07; *Maguire, Hobson, and Maguire 14,546* UTC 1936-08-10; A. Huber and S. Goodrich 429 BRY 1993-08-25; *Huber and Goodrich 435* BRY 1993-08-25.
7-UT	Wasatch-Cache National Forest, High Uintas Wilderness Area. Region 4	Duchesne, Summit	8/16/1933	Mount Agassiz	Utah Natural Heritage Program element occurrence records 2002. Stone (1995).Specimen: *Bassett Maguire, A.G. Richards, R. Maguire 4133* UTC 1933-08-16.
8-UT	Wasatch-Cache National Forest, High Uintas Wilderness Area. Region 4	Duchesne, Summit	7/22/1988	Ridge southwest of Tamarack Lake.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995). Specimen: *M.A. (Ben) Franklin 6294* BRY 1988-07-22.
9-UT	Wasatch-Cache National Forest, High Uintas Wilderness, Area. Region 4	Summit	7/19/1926	Stillwater Fork, La Motte Peak area.	Utah Natural Heritage Program element occurrence records 2002. Specimen: *E.B. Payson 5048* with L. B. Payson HOLOTYPE *D. apiculata* at NY. UC, GH, MO, POM, DS, RM, WTU, WSC, BRY 1926-07-19.
10-UT	Wasatch-Cache National Forest (likely in High Uintas Wilderness). Region 4	Summit	Before 1941	East fork of Bear River.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995). Specimen cited in Hitchcock (1941): *Goodman 1969* MO, RM, no date.

Table 2 (concluded).

Arbitrary Occurrence Number	Managed Area	County	Dates Observed	Location	Sources of Information
11-UT	Wasatch-Cache National Forest, High Uintas Wilderness Area. Region 4	Summit	7/27/1978	Bald Mountain.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995). Specimen: *Kent Ostler, Karl McKnight 1621* BRY 1978-07-27.
12-UT	Wasatch-Cache National Forest, High Uintas Wilderness Area. Region 4	Summit	7/18/1970	Tokewanna Peak.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995). Specimen: *Carl Bauer; s.n.* UT 1970-07-18.
13-UT	Wasatch-Cache National Forest, High Uintas Wilderness Area, Region 4	Summit	8/19/1936	Flat top Mountain/Mount Powell.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995) , Hitchcock (1941). Specimen: Specimen: *Bassett Maguire, A.G. Richards, Ruth Maguire 14683* UTC 1936-08-19; *Maguire, Richards, Maguire 14713* UTC, WTU 1936-08-19.
14-UT	Ashley National Forest, Vernal and Flaming Gorge ranger districts. Region 4	Uintah, Daggett	7/9/1971; 7/6/1994	Leidy Peak.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995) Specimen: *Sheldon B. Waite 256* BRY 1971-07-09; *E. Neese, J.S. Peterson 6401* BRY 1978-07-30; *J. Scott Peterson, E. Neese 1344* UTC 1978-07-30; *D. Atwood 7334* BRY 1979-07-09; *E. Neese 15,175* BRY 1983-09-01. *A. Huber 993* BRY 1994-06-16; *A. Huber 1537* BRY 1994-07-06.
15-UT	Private and/or Wasatch-Cache National Forest, Salt Lake Ranger District. Region 4	Salt Lake	1882; 8/13/1995	Devils Castle vicinity.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995), Hitchcock (1941) Specimen: M.E. Jones s.n. POM 1882; W.P. Cottam, Fred Rowland 16,812 UT 1961-06-29; R.D. Stone #1860 UT 1995-08-13.
16-UT	Private and/or Wasatch-Cache National Forest, Salt Lake Ranger District. Region 4	Salt Lake	6/14/1960	Above Lake Catherine.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995). Specimen: *W.P. Cottam, John Allen, R.R. Ream, F.C. Rowland 16,139* UT 1960-06-14.
17-UT	BLM-Richfield District, House Range Resource Area	Juab	7/16/1943; 7/13/1983	Ibapah Azimuth Peak.	Utah Natural Heritage Program element occurrence records 2002. Stone (1995). Specimen: *Bassett Maguire, A.H. Holmgren 21995* UTC 1943-07-16.; *S. Goodrich 19011*, UT, UTC 1983-07-13.
18-UT	Unknown	Unknown	6/17/1902	Fish Lake, Uintah Mountains.	Utah Natural Heritage Program element occurrence records 2002. Specimen cited in Payson (1917): *L.N. Goodding s.n.*1902-06-17.

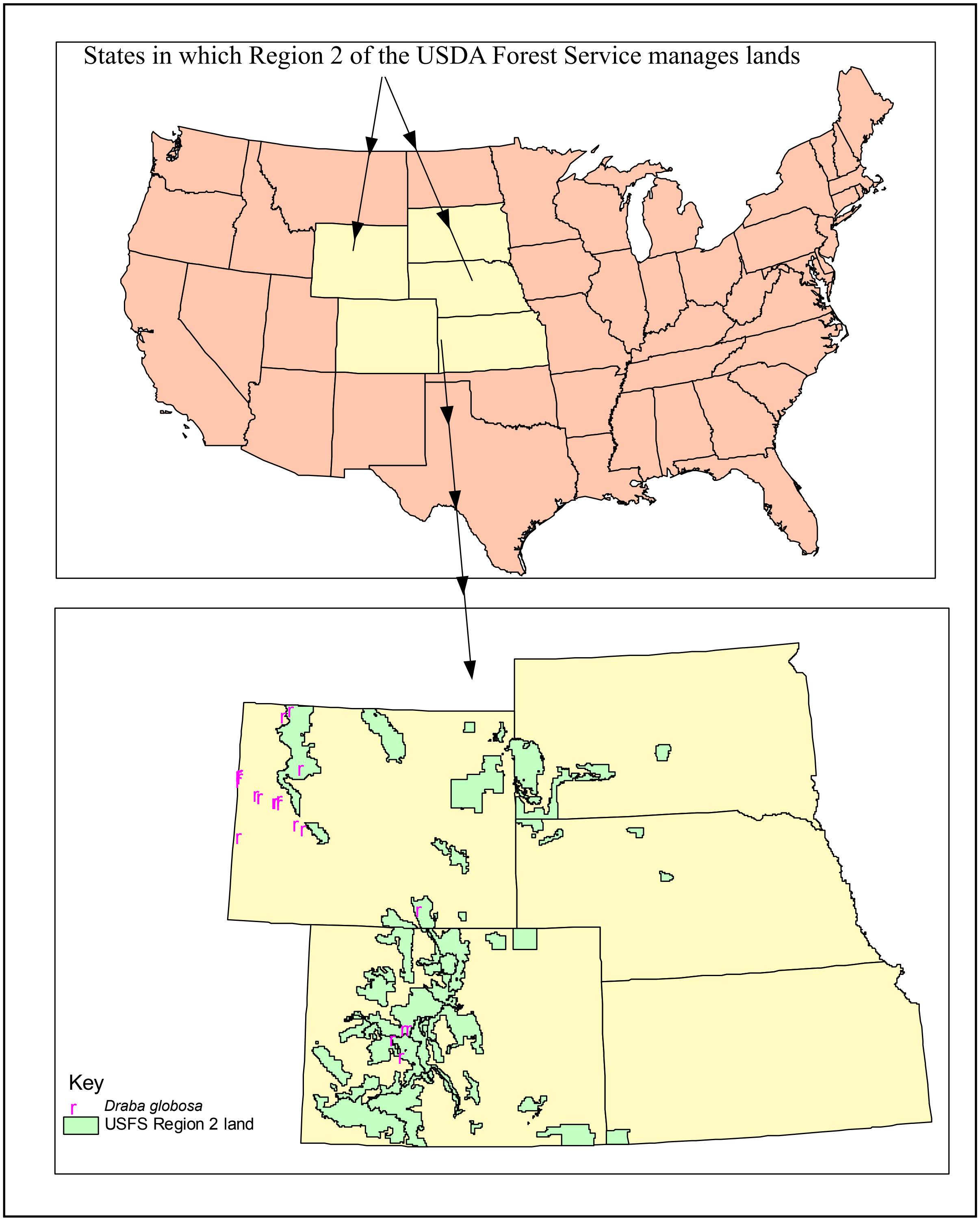

Figure 3. Distribution of *Draba globosa* within USDA Forest Service Region 2.

element occurrence records 2002). No occurrences with such large numbers of plants have been reported within Region 2. Although *Draba globosa* has a relatively wide geographical range, it is not inevitably found in suitable alpine habitats within that range. Fertig (1992a) observed that surveys in seemingly appropriate habitat have failed to discover additional populations. In addition, plants are frequently restricted to small microsites even though there appears to be additional suitable habitat in the vicinity of where plants are found (Fertig 1998). The total number of individuals currently extant is difficult to estimate. The taxon appears to be locally abundant in certain parts of Utah and Wyoming (Stone 1995, Wyoming Natural Diversity Database element occurrence records 2002). Within Region 2 there are likely to be fewer than 700 individuals total.

Occurrence data has been compiled from the Colorado Natural Heritage Program, the Wyoming Natural Diversity Database, the Idaho Conservation Database Center, the Montana Natural Heritage Program, the Utah Natural Heritage Program, specimens at the University of Colorado Herbarium (COLO), Colorado State University Herbarium (CS), The Rocky Mountain Herbarium (RM), the Kathryn Kalmbach Herbarium at the Denver Botanic Gardens (KHD), and from the literature (Payson 1917, Hitchcock 1941, Rollins 1993). It must be noted that many, particularly older, records do not have precise location information and 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.

Stone (1995) has emphasized the problems associated with including historical reports without checking actual herbarium specimens that may no longer be extant. He also commented on the imprecise nature of old location data. One example Stone (1995) gives is the herbarium specimen cited by Hitchcock (1941) as "Utah: 'w. of Reeve's River,' Engelmann in 1859 (MO)." Stone (1995) was unable to locate Reeves's River anywhere in Utah and hypothesized that the collection was wrongly ascribed to Utah and was most likely to be in the South Park area of Central Colorado. However, Henri Engelmann who was collecting plant species across the Great Basin of the Territory of Utah in 1859, may have made the collection from "Reese's River" in a part of the country that is no longer recognized as being within the current state of Utah (Jennings personal communication 2003; Hartman 1999). Such reports are most valuable in providing guidance on where to survey.

Population trend

There are insufficient data in the literature, associated with herbarium specimens, or at the Natural Heritage Programs to determine the long-term trends for the species over the entire range or even within Region 2 land of the USDA Forest Service. *Draba globosa* has been documented in approximately 11 locations within Region 2 of the USDA Forest Service (ten occurrences on National Forest System lands), but the number of extant populations and their persistence are not well defined. Observations at Clay Butte, Wyoming, in 1939 and 1996 (Rollins 1953, Fertig 1996 in Wyoming Natural Diversity Database element occurrence records 2002) provide evidence that populations can persist over at least one, if not several, decades.

Outside of Region 2, plants were found on Osborn Mountain, Wyoming, in 1984 and 1998 (Wyoming Natural Diversity Database element occurrence records 2002) and at one site in the Sawtooth National Forest in Idaho in 1980 and 1990 (Idaho Conservation Database Center element occurrence records 2002). Plants have also been collected in the same general vicinity at intervals of greater than a decade apart at six locations in Utah. One population that seems to have considerable longevity is that in the Devil's Castle vicinity from which a specimen was collected in 1882, another in 1961, and the most recent in 1995 (**Table 2**). One occurrence in Wyoming first observed in 1994 could not be relocated in 1997 (**Table 2**). However, this taxon appears to naturally occur infrequently, and there is little evidence to suggest it is either more or less common at the present time than in the past.

Habitat

Draba globosa grows in the alpine tundra and less commonly in sub-alpine zones at elevations between 2,743 and 3,962 m, with the majority of occurrences located between 3,200 and 3,700 m (**Figure 4**). Where a range was given for an occurrence, the lowest and highest elevations reported were included in the analysis. The lowest elevation was reported from Idaho at 2,743 m and the highest from Utah at 3,962 m. The elevation where it has been found is not strictly related to latitude.

Draba globosa grows on both limestone and granitic soils (Spackman et al. 1997, Colorado Natural Heritage Program element occurrence records 2002, Utah Natural Heritage Program element occurrence records 2002, Wyoming Natural Diversity Database element occurrence records 2002). Plants are often

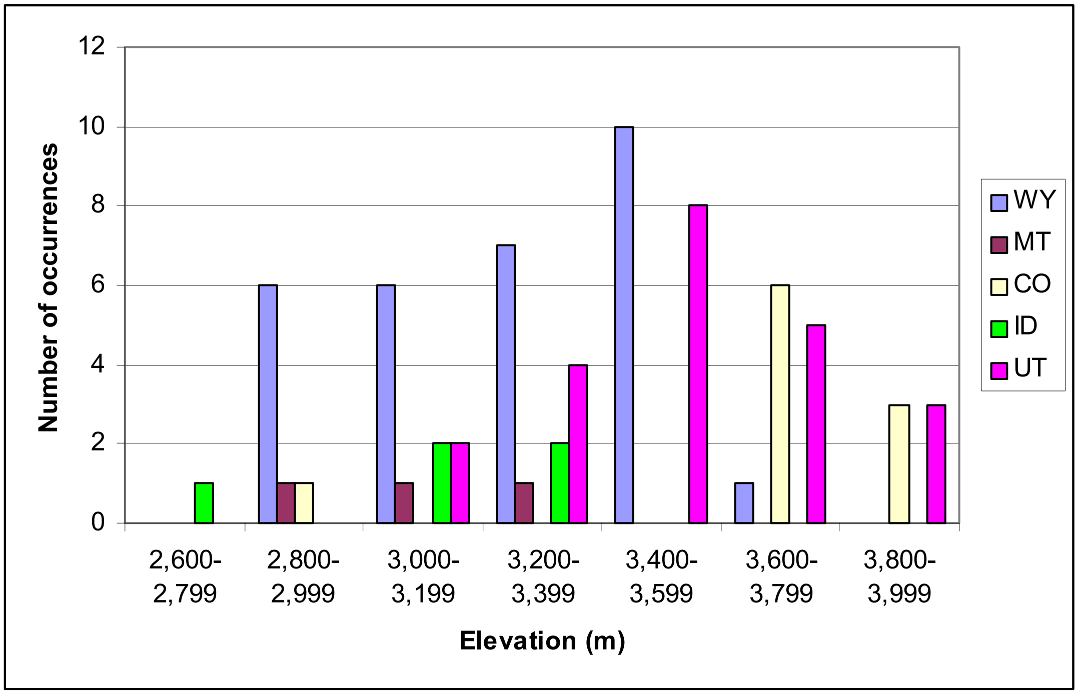

Figure 4. Range in elevations reported for the occurrences of *Draba globosa*.

found on rocky, low ridges of semi-bare limestone gravel or granite, at the base of limestone talus slopes, on rocky outcrops of limestone/dolomite, or amongst granitic-gneiss boulders and talus (Scott 1995, Colorado Natural Heritage Program element occurrence records 2002, Utah Natural Heritage Program element occurrence records 2002, Wyoming Natural Diversity Database element occurrence records 2002). In Utah, it was noted that *D. globosa* prefers quartzite and granitic rocks (Windham and Beilstein 1998), but in other states, element occurrence records and reports (for example Fertig 1992b) indicate that limestone is equally or even more commonly colonized. Occurrences have been described specifically on limestone/dolomite rock slabs of the Ordovician age and limestone gravels and rocks of the Madison or Darby Formations. One occurrence in Idaho was reported on shallow volcanic-derived soils.

Draba globosa has been reported on fellfield associations in Colorado, Idaho, and Montana (element occurrence data 2002 from Colorado Natural Heritage Program, Idaho Conservation Database Center, and Montana Natural Heritage Program). 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 caespitose, ground-hugging growth habit of *D. globosa* likely makes it well adapted to such adverse environmental conditions.

Slopes where *Draba globosa* has been reported are generally 0 to 20 degrees, but some occurrences have been reported on slopes as steep as 55 percent. It may be that human accessibility accounts for the more common reporting of gentle slopes. Most, if not all, of the areas where *D. globosa* occurs are in a relatively undisturbed condition. In all states when habitat is described, plants are always associated with a high rock or talus cover and are often noted amid snowfields or in wet or moist areas (Colorado Natural Heritage Program element occurrence records 2002, Goodrich personal communication 2002, Montana Natural Heritage Program element occurrence records 2002, Wyoming Natural Diversity Database element occurrence records 2002). In addition, plants have been reported to grow on aspects facing north, east, northeast, and less commonly on southeast and west facing slopes; this further implies that the species favors more mesic sites. Habitat at each of the occurrence sites is summarized in **Table 3**.

Common vegetation types associated with *Draba globosa* include a *Carex elynoides* and *Festuca brachyphylla* community, an alpine cushion plant community (fellfield/cushion plants physiognomic type; USDA Forest Service 1996) and a *Dryas octopetala*-turf community. One alpine community in which it grows

Table 3. Habitat summary information at each occurrence site. The information was taken from Natural Heritage Program element occurrence records, herbarium voucher labels, and/or the literature (see text and **Table 2**).

Arbitrary Occurrence Number	Area Management	Habitat information taken from Heritage Program element occurrence records, herbarium voucher labels and the literature (see text).	Elevation (ft)	Occurrence Size
1-CO	San Isabel National Forest	"Rock crevices".	12,450	No information.
2-CO	Gunnison National Forest	"Gentle N-facing slope on carbonate (limestone) substrate in late lying snow area and near top of east-facing cirque headwall on carbonate substrate (Fremont dolomite)."	12,600	Approximately 50 individuals.
3-CO	White River National Forest -Arapaho National Forest	"Precambrian schist and gneiss. In sparsely developed tundra above timberline on southeast facing shallow slope following snow melt by 2 weeks. With *Primula angustifolia*, *Draba crassifolia*, *Silene acaulis*, *Acomastylus rossii*, *Androsace septentrionalis*, *Eritrichium aretioides*, *Carex rupestris*, *Kobresia myosuroides*, *Selaginalla densa.*"	12,150, and 12,293 to 12,900	Occasional and scattered.
4-CO	White River - Gunnison National Forest	On a "flat to gentle slope (0-20 degrees) with *Geum rossii*, *Phlox*, *Erigeron*, *Artemisia*, *Besseya*, *Kobresia*, *Astragalus*, *Smelowskia*, *Chionophila*, *Castilleja* and *Dryas*. In gravels and rocks with 50-70% bare ground."	12,400	Small population <10 individuals in fruit.
5-CO	No information	No information	No information	No information.
1-WY	Medicine Bow National Forest	"Occurs with *Arenaria*, *Artemisia*, and *Paronychia*" species.	10,800	No information.
2-WY	Shoshone National Forest, Popo Agie Wilderness Area	"Tundra in hanging cirque."	11,250	No information.
3-WY	Bridger-Teton National Forest	In "detritus in exposed moist soil of northeast aspect. Probably occurs on Triassic or Jurassic age limestone, shale, and siltstones. Occurs with *Saxifraga rhomboidea* and *Senecio fremontii*."	10,450	Uncommon.
4-WY	Shoshone National Forest	"Alpine meadows and talus slope."	11,500 to 12,000	No information.
5-WY	Shoshone National Forest, North Absaroka Wilderness Area	"Alpine meadows and rock outcrops."	10,400 to 11,060	No information.
6-WY	Shoshone National Forest, Absaroka Beartooth Wilderness Area	In three main habitats: "(1) rocky low ridges of semi-bare limestone gravel at base of limestone talus slope in community of *Carex elynoides* and *Festuca brachypyhlla*; (2) In *Phlox pulvinata* cushion plant community on rocky outcrop of limestone/dolomite. Forb cover ca 40%, graminoid and fern cover 10%, bare exposed rock and gravel ca 50%. Soil lithic cryorthent with 15% bare ground, 43% gravel, and 20% cobbles; (3) In pockets of thin, clay-loam orangish soil amid talus and outcrops of orangish-gray dolomite among patches of *Dryas octopetala* turf."	9,600 to 10,090	Populations very small. Estimate 20-40 plants in one population; for example observed 5 flowering/fruiting plants in small patch. Observed 1 flowering plant in another survey. Described as "very uncommon" and "locally uncommon."
7-WY	Shoshone National Forest, Absaroka Beartooth Wilderness Area	Same as 6-WY.	9,600 to 10,090	No information.
8-WY	Private or Bridger-Teton National Forest	"In rocks at base of *Pinus flexilis* on west-facing slope."	9,300	No information.

Table 3 (cont.).

Arbitrary Occurrence Number	Area Management	Habitat information taken from Heritage Program element occurrence records, herbarium voucher labels and the literature (see text).	Elevation (ft)	Occurrence Size
9-WY	Bridger-Teton National Forest, Bridger Wilderness Area	"North-facing alpine slopes."	11,000	No information.
10-WY	Bridger-Teton National Forest, Bridger Wilderness Area	"Open, flat alpine summits on exposures of the Lower Mississippian and Upper Devonian Darby Formation."	11,500	No information.
11-WY	Bridger-Teton National Forest, Bridger Wilderness Area	"Base of east-facing stable talus slope of the Darby Formation."	11,200 to 11,400	One plant.
12-WY	Bridger-Teton National Forest, Bridger Wilderness Area	"Open rocky talus slopes of the Lower Mississippian and Upper Devonian Darby Formation or Archean granitic gneiss and grassy, alpine summits."	10,600 to 11,200	Plants distributed over 3+ acres.
13-WY	Bridger-Teton National Forest, Bridger Wilderness Area , Osborn Mountain Research Natural Area	In "alpine cushion plant community on light-colored Archean granitic-gneiss boulder and talus field on rim and summit above deep canyon of Mill Creek. Vegetative cover approximately 20-40%. " In 1998 associates reported to be: "*Draba incerta*, *Polygonum bistortoides*, *Silene acaulis*, *Geum rossii*, *Sibbaldia procumbens* and *Carex breweri*." In 1984 associates reported to be: "*Claytonia megarhiza*, *Hymenoxys grandiflora*, and *Artemisia scopulorum*."	11,400 to 11,600	Population estimated at 500 to 1,000. Individual colonies with 2-3 plants per clump. Largest subpopulation contained 217 plants in 25 square meter area.
14-WY	Bridger-Teton National Forest, Gros Ventre Wilderness Area	Calcareous substrate - " probably on Ordovician-age quartzitic sandstones and limestones."	10,800	No information.
15-WY	Jackson Hole Ski Corporation and Bridger-Teton National Forest	"Cliffs and ridges with sparse, low-forb dominated vegetation. Substrate moist limestone. Limestone cliffs and ridges with sparse, forb-dominated vegetation. Occurs with *Carex elynoides*, *Oxytropis deflexa*, *Poa alpina*, *Potentilla diversifolia*, and *Antennaria media*."	9,600; 9,500; 9,800	Plants observed in approximately 0.1 acres.
16-WY	Grand Teton National Park	"Morainal rock and coarse soil."	10,400	Rare.
17-WY	Grand Teton National Park, Targhee National Forest	"Sparsely-vegetated area of nearly level rubble in an area that is late to melt."	10,480	No information.
18-WY	Grand Teton National Park	No information.	9,200	No information.
19-WY	Bridger-Teton National Forest	Near to the "top of limestone talus ridge on south facing slope. Sparsely vegetated with *Salix reticulata*, *Potentilla ovina*, *Saxifraga oppositifolia*, *Phlox pulvinata*, and *Polemonium viscosum*."	10,800	No information.
20-WY	Bridger-Teton National Forest, Gros Ventre Wilderness Area	Occurs in 4 main habitats: "1) Near top of sparsely-vegetated, south-facing limestone talus slope with scattered *Phlox*, *Silene*, *Salix reticulata*, and other alpine cushion species" or "*Carex nardina*, *Astragalus kentrophyta*, and *Phlox pulvinata* with occasional *Dryas octopetala*." " 2) Alpine cushion plant community on northeast-facing ridgeline of limestone gravel and rock (Madison or Darby Formation) bordering cirque meadow. Vegetative cover (including cryptogam crusts)" approximately "40%, bare rock and soil approximately 60%." " 3) Tilted limestone/dolomite rock slabs (Ordovician age) dipping steeply to the southeast amid snowfields and wet *Carex/Ranunculus* meadows. In some regions rock cover approximately 75-80%. 4) Moist, loamy, Carex-turf at base of rock slabs and talus."	10,400 to 11,000	Large population estimated at 1,000 to 3,000 individuals. Population consists of four main subpopulations in area of 2.5 x 2 miles. Plants typically in scattered clusters of 25 to 50 plants or less, for example 10 fruiting plants observed on rocky edge of tundra meadow.

Table 3 (cont.).

Arbitrary Occurrence Number	Area Management	Habitat information taken from Heritage Program element occurrence records, herbarium voucher labels and the literature (see text).	Elevation (ft)	Occurrence Size
1-ID (Needs confirmation)	Targhee National Forest	Occurring at "treeline in an avalanche trough; 55% slope; 316° aspect. Adjacent to species *Pinus albicaulis*, *P. flexilis*, and *Ribes montigenum*."	9,000	No information.
2-ID	Sawtooth National Forest, Sawtooth National Recreation Area	"Alpine fellfield; nearly level or slight slope to east; gravelly soil derived from granite substrate. " Associated with "*Draba densifolia*, *Oxytropis viscida*, *Phlox pulvinata*, *Carex elynoides*, *Astragalus kentrophyta*, and *Smelowskia calycina*."	10,817	Locally common.
3-ID	Sawtooth National Forest, Sawtooth National Recreation Area	On "dry northeast-facing ledges. Associated with *Silene acaulis* and *Eriogonum ovalifolium*. Granite substrate."	10,500	Locally common.
4-ID	Salmon and Challis national forests and Sawtooth National Forest, Sawtooth National Recreation Area	No information.	10,200	No information.
5-ID	BLM, Challis Resource Area.	On "gentle southwest slope"; "very shallow volcanic soil between large rocks, snow deflated community."	10,010	No information.
1-MT	Gallatin National Forest, Lee Metcalf Wilderness Area	On "open, frost-churned ground at the edge of a snowbank. Limestone parent; with *Sibaldia procumbens* and *Ranunculus escholtzii*."	10,000	No information.
2-MT	Gallatin National Forest, Lee Metcalf Wilderness Area	North aspect in "gravelly soil of parent limestone formation. With *Silene acaulis* and *Astragalus kentrophyta*."	10,700	No information.
3-MT	Beaverhead-Deerlodge national forests, Cave Mountain Research Natural Area	On "open, moist fellfield, limestone mountain slope with *Festuca ovina*, *Phlox pulvinata*, *Carex rupestris*, *Silene acaulis* and *Ranunculus escholtzii*." Slopes of 30% with northeast aspect.	No information	500-100 plants.
4-MT	BLM - Dillon Field Office	No information.	9,400	No information.
1-UT	Ashley National Forest, High Uintas Wilderness Area	"Dry alpine meadow." "Near snowbank - moist meadow." "Moraine deposit, north slope, *Dryas* association."	No information	No information.
2-UT	Ashley National Forest, High Uintas Wilderness Area	On "talus slopes, quartzite substrate."	No information	No information.
3-UT	Ashley National Forest	"Alpine snowflush, gravelly soils, east exposure, limestone substrate."	No information	No information.
4-UT	Ashley National Forest, High Uintas Wilderness Area	"Talus slopes of Red Pine Shale."	No information	No information.
5-UT	Wasatch-Cache National Forest	"Above timberline, rocky exposed ridge." "Among quartzite rocks on east-facing talus slope. Exposed locality in alpine tundra community." "Dry, rocky slopes."	No information	Rare.

Table 3 (concluded).

Arbitrary Occurrence Number	Area Management	Habitat information taken from Heritage Program element occurrence records, herbarium voucher labels and the literature (see text).	Elevation (ft)	Occurrence Size
6-UT	Ashley and Wasatch-Cache national forests, High Uintas Wilderness Area	"Steep talus slope, Red Pine Shale barrens, alpine plant community." "Dry area." "About snow bank following receding snow. Under rocky ledges." "Talus slope, west exposure."	No information	No information.
7-UT	Wasatch-Cache National Forest, High Uintas Wilderness Area	No information.	No information	No information.
8-UT	Wasatch-Cache National Forest, High Uintas Wilderness Area	"Open rocks and soil due to late snow bank melt. Alpine community."	No information	No information.
9-UT	Wasatch-Cache National Forest, High Uintas Wilderness Area	"Grassy slopes."	10,500 to 12,000	No information.
10-UT	Wasatch-Cache National Forest, likely in High Uintas Wilderness Area	No information.	No information	No information.
11-UT	Wasatch-Cache National Forest, High Uintas Wilderness Area	Tundra community.	No information	No information.
12-UT	Wasatch-Cache National Forest, High Uintas Wilderness Area	"Alpine tundra."	No information	No information.
13-UT	Wasatch-Cache National Forest, High Uintas Wilderness Area	"In talus below snow bank" and on "Rocky sedge slopes."	No information	No information.
14-UT	Ashley National Forest	"Above timberline." "Scanty soil of crevices, boulder field, Precambrian quartzite." "Above krummholz on open, dry slope." "Fine talus slopes of Red Pine Shale and quartzite mix." "Dry alpine meadows and fellfields, quartzite substrate." "Subalpine tundra" with "*Eritrichium*, *Festuca*, *Smelowskia*, *Poa* and *Lychnis*."	No information	No information.
15-UT	Private and/or Wasatch-Cache National Forest	"Subalpine, growing from near the base of the slope almost to the ridgeline, primarily in moist, rocky soil near the edges of receding snowbanks. Assoc. *Ranunculus adoneus*, *Thlaspi montanum*, *Saxifraga rhomboidea*, *Salix cf. reticulata*, *Draba cf. albertina*. Limestone parent material."	No information	Locally frequent - forming scattered colonies.
16-UT	Private and/or Wasatch-Cache National Forest	No information.	No information	No information.
17-UT	BLM - House Range Resource Area	"Gravelly soil." "Alpine community with *Geum rossii* and *Phlox*."	No information	"Frequent" in 1943.
18-UT	Unknown	No information.	No information	No information.

is classified as "AL13-Mountain dryad/curly sedge-alpine fescue" in a manual of the USDA Forest Service Region 2 (Johnston and Huckaby 2001). Communities of which *D. globosa* is part have been described in most detail in Wyoming, where estimates of ground cover have also been made (Fertig in Wyoming Natural Diversity database element occurrences records 2002). Forb, graminoid, fern, and cryptogamic crust cover is reported from 20 to 50 percent with the balance mainly comprised of rock with cobbles or gravels and relatively little bare ground. Plants have also been noted in wet *Carex/Ranunculus* meadows where rock cover was estimated to be 75 to 80 percent and in moist, loamy, *Carex*-turf at the base of rock slabs and talus (Wyoming Natural Diversity Database occurrence records 2002). *Phlox* species are particularly common associates. Associated species reported with *D. globosa* are listed in **Table 4**. It has been found in close proximity to two rare and related *Astragalus* species: *A. molybdenus* in Colorado and *A. shultziorum* in Wyoming. Nine other species of *Draba* have been reported to co-occur with *D. globosa* (**Table 4**). When *D. globosa* occurs at the treeline, associated species included *Pinus albicaulis*, *Pinus flexilis*, and *Ribes montigenum*.

Reproductive biology and autecology

Draba globosa is a perennial species that reproduces by seed. Flowering occurs from June to early August (Hartman 1995), and fruits are present in August (Mills and Fertig 1996). *Draba* is a reproductively interesting genus as examples of self-fertilization, self-incompatibility, and apomixis have all been reported (Mulligan and Findlay 1970, Mulligan 1971, Brochmann et al. 1992).

There is no specific information on the reproductive strategy of *Draba globosa*, but some deductions can be made from the available information. Stone (1995) and Windham and Beilstein (1998) reported that *D. globosa*, like *D. densifolia*, is likely to reproduce by apomixis, specifically agamospermy. Apomixis, or "reproduction without fertilization," is relatively common among vascular plants (Grant 1981). 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 to be exhibited by *D. globosa*. 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. A single population of an apomictic taxon is likely to show little genetic variation, and isozyme studies of *D. globosa* indicated that most populations are genetically invariant (Windham and Beilstein 1998). *Draba globosa* also sets abundant seed despite having abortive anthers and this provides further evidence of apomictic seed production (Windham and Beilstein 1998). However, many species are not exclusively apomictic, they exhibit facultative agamospermy and may reproduce sexually depending upon conditions (Grant 1981). There are also instances where some populations of a predominantly apomictic taxon reproduce sexually. For example, in Montana, some populations of the primarily apomictic *D. oligosperma* are probably sexual (Mulligan and Findlay 1970). Alternatively, there are examples of apomictic populations among predominately sexually reproductive species. Some populations of *Draba densifolia* in Alaska and Canada were reported to be apomictic (Mulligan 1976).

Fox and Moseley (1991) reported that a collection made in the White Cloud Peaks and Boulder Mountains was likely an intermediate between *Draba apiculata* (synonym for *D. globosa*) and *D. densifolia* (*Taylor 7042*, Sawtooth National Recreation Area Herbarium). This evidence of hybridization between *Draba globosa* and a sympatric species would suggest that *D. globosa* is able to reproduce sexually depending upon the conditions. However, this specimen has not been studied in depth and may actually be a variant of *D. globosa*, *D. densifolia*, or even another taxon. *Draba densifolia* has been observed to have a strong phenotypic response to desiccation and elevation (Hitchcock 1941, Rollins 1993). At higher elevations, especially in more exposed areas where plants encounter high winds and desiccating conditions, the leaves of *D. densifolia* become smaller and more densely imbricated and the scapes (stems) become shorter (Hitchcock 1941, Rollins 1993). Another consideration in assessing putative hybrids is that apomixis can contribute to a high degree of diversity among populations of the same species and that may also explain unusual specimens (Grant 1981, Rollins 1993). Agamospermy can lead to specific local fitness, and thus genetic differences between populations may be significant as colonies are adapted to specific microenvironments. It is also well documented that the apomictic taxon *D. oligosperma* exhibits a highly variable morphology between populations (Price 1979, Rollins 1993).

If sexual reproduction does occur, flies are likely the pollinators. Price (1979) reported that insect pollinators were comparatively few for all species of *Draba* when he studied the *D. crassa* complex in the alpine zone in Colorado. He observed that even when

Table 4. Plant species associated with *Draba globosa*.

Associated Species	State	Associated Species	State
Androsace septentrionalis	CO	*Hymenoxys grandiflora*	WY
Antennaria media	WY	*Kobresia myosuroides*	CO
Arenaria obtusiloba	WY	*Kobresia* spp.	CO
Artemisia scopulorum	WY	*Lesquerella paysonii*	WY
Artemisia spp.	CO, WY	*Lychnis* spp.	UT
Astragalus kentrophyta	ID, MT	*Myosotis alpestris*	WY
Astragalus cf. molybdenus	CO	*Oxytropis borealis*	WY
Astragalus shultziorum	WY	*Oxytropis deflexa*	WY
Besseya spp.	CO	*Oxytropis viscida*	ID
Carex brewerio	WY	*Paronychia* spp.	WY
Carex elynoides	ID, WY	*Parrya nudicaulis*	WY
Carex nardina	WY	*Pedicularis pulchella*	WY
Carex rupestris	CO, MT, WY	*Phlox* spp.	CO, ID, MT, UT, WY
Castilleja spp.	CO	*Phlox pulvinata*	ID, MT, WY
Chionophila spp.	CO	*Poa* spp.	UT
Claytonia megarhiza	WY	*Poa alpina*	WY
Douglasia montana	WY	*Polemonium viscosum*	WY
Draba cf. albertina	UT	*Polygonum bistortoides*	WY
Draba caba	WY	*Potentilla diversifolia*	WY
Draba crassifolia	CO	*Potentilla gracilis*	WY
Draba densifolia	ID	*Potentilla ovina*	WY
Draba incerta	WY	*Potentilla uniflora*	WY
Draba lonchocarpa	WY	*Primula angustifolia*	CO
Draba oligosperma	WY	*Ranunculus adoneus*	UT
Draba paysonii	WY	*Ranunculus escholtzii*	MT
Draba pectinipila	WY	*Salix cf. reticulata*	UT
Dryas spp.	CO, UT, WY	*Salix reticulata*	WY
Dryas octopetala	WY	*Saxifraga oppositifolia*	WY
Eretrichium spp.	UT	*Saxifraga rhomboidea*	UT, WY
Erigeron radicatus	WY	*Sedum lanceolatum*	WY
Erigeron simplex	WY	*Selaginella densa*	CO, WY
Erigeron spp.	CO	*Senecio fremontii*	WY
Eriogonum ovalifolium	ID	*Sibbaldia procumbens*	MT, WY
Eritrichium aretioides	CO	*Silene acaulis*	CO, ID, MT, WY
Eritrichium nanum	WY	*Smelowskia* spp.	CO, UT
Festuca spp.	UT	*Smelowskia calycina*	ID, WY
Festuca baffinensis	WY	*Solidago multiradiata*	WY
Festuca brachyphylla	WY	*Thlaspi montanum*	UT
Festuca ovina	MT	*Townsendia alpigena*	WY
Geum rossii	CO, UT, WY	*Valeriana edulis*	WY
Hedysarum sulphurescens	WY		

plants of *Draba* and *Trifolium nanum* (alpine clover) formed dense populations, alpine bees ignored the *Draba* flowers while preferentially visiting the clover. Of those few arthropod visitors, most were flies of the Syrphidae, Muscidae, and Anthmyiidae families. Price (1979) noted that only members of the Syrphidae are likely to be effective pollinators.

Polyploidy is reported to be associated with apomixis in *Draba* (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). However, the diploid *Arabis holboelli* complex within the mustard family also exhibits gametophytic apomixis and thus conclusions as to chromosome number without direct evidence must be cautious (Grant 1981). Unfortunately, chromosome counts in *D. globosa* have not been obtained despite several careful attempts (Windham and Beilstein 1998). Windham and Beilstein (1998) suggested that if *D. globosa* is a triploid it may have originated from hybridization between *D. burkei* and another related species such as *D. crassifolia*. 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. globosa* and other species of alpine *Draba*. It was concluded by Mulligan (1976) 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 low (25 percent or less), it was not zero and that some hybrids did produce some poorly formed seed, although most silicles were aborted, indicating that sexual reproduction was not impossible although probably unlikely. 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. They suggest that hybridization will more likely occur between polyploids, rather than between a diploid and polyploid.

The rate of seed recruitment to the seed bank, the longevity of seed 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). Untreated seeds of arctic-alpine *Draba* are reported to germinate very poorly, whereas pretreatments such as scarification and/or gibberellic acid increase germination considerably (Brochmann et al. 1992). Seed dispersal mechanisms are also not known. Wind, ubiquitous in the alpine-tundra, may be effective in dispersing seeds. In general wind-dispersed seeds move only short distances (Silvertown 1987).

Demography

Draba globosa is a perennial that reproduces by seed. No demographic studies or analyses of population viability have been undertaken. Transition probabilities between the different stages, from seed production to the flowering adult are unknown. *Draba globosa* populations appear to be largely comprised of adults. Information associated with herbarium specimens and element occurrence records provided by the Natural Heritage Programs reports that individuals were either in fruit or flower, indicating that seedlings were few or particularly inconspicuous. Seed production has been reported to be high (Wildham and Beilstein 1998), and therefore, the absence of seedlings may be due to high mortality rate or poor seed germination, or they are just overlooked.

A three-year demographic study was made on another 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, apparently, not a close relative to *D. globosa*. However, the results of this demographic study may be useful when considering *D. globosa*. In the *D. trichocarpa* study non-reproductive and reproductive individuals were stable, but the seedling mortality rate was very high (Moseley and Mancuso 1993). In long-lived perennials, seed production may be low and the most important life cycle components are the growth and survival of the adult plants (Silvertown et al. 1993). In this case, assets are allocated to favor the survival of the adult. Interestingly, in both *D. globosa* and *D. trichocarpa* considerable energy appears to be expended towards abundant seed production, but few seedlings and, in the case of *D. globosa*, vegetative individuals are observed. *Draba globosa* populations thus appear to be skewed in favor of reproductive adults. 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. It would be very useful to undertake this type of demographic study for *D. globosa*.

Seed germination and seedling establishment are very sensitive to environmental conditions, and the high elevation environment of *Draba globosa* has high variability. As a long-lived perennial, the strategy may be to produce abundant seed in as many years as possible for storage in the soil seed bank so that seed germination and seedling establishment may occur in ideal environmental conditions. One particularly "good" year among several that are inappropriate for seedling establishment may thus sustain a small long-lived population. Abundant seed production in most years may circumvent the situation where conditions that are ideal for seedling establishment are immediately preceded by conditions that lead to poor seed fill. The current evidence suggests that *D. globosa* is a perennial species that is maintained in established, small populations and corresponds to the profile of a k-selected species apparently having a stress-tolerant life strategy (MacArthur and Wilson 1967, Grime et al. 1988).

Unfortunately, there are more questions than facts pertaining to the life cycle of this species, and speculation is a poor substitute for facts. A simple life cycle model of *Draba globosa* can be diagrammed (**Figure 5**). Heavy arrows indicate the phases in the life cycle that appear most prominent, and lighter weight arrows indicate the phases that are either apparently less significant or unknown. 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 if plants flowering one year revert to vegetative plants in following years or if 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 substrate and other edaphic conditions such as moisture.

Population viability analyses for this species have not been undertaken. Apomictic taxa may be thought to be at an evolutionary disadvantage, but

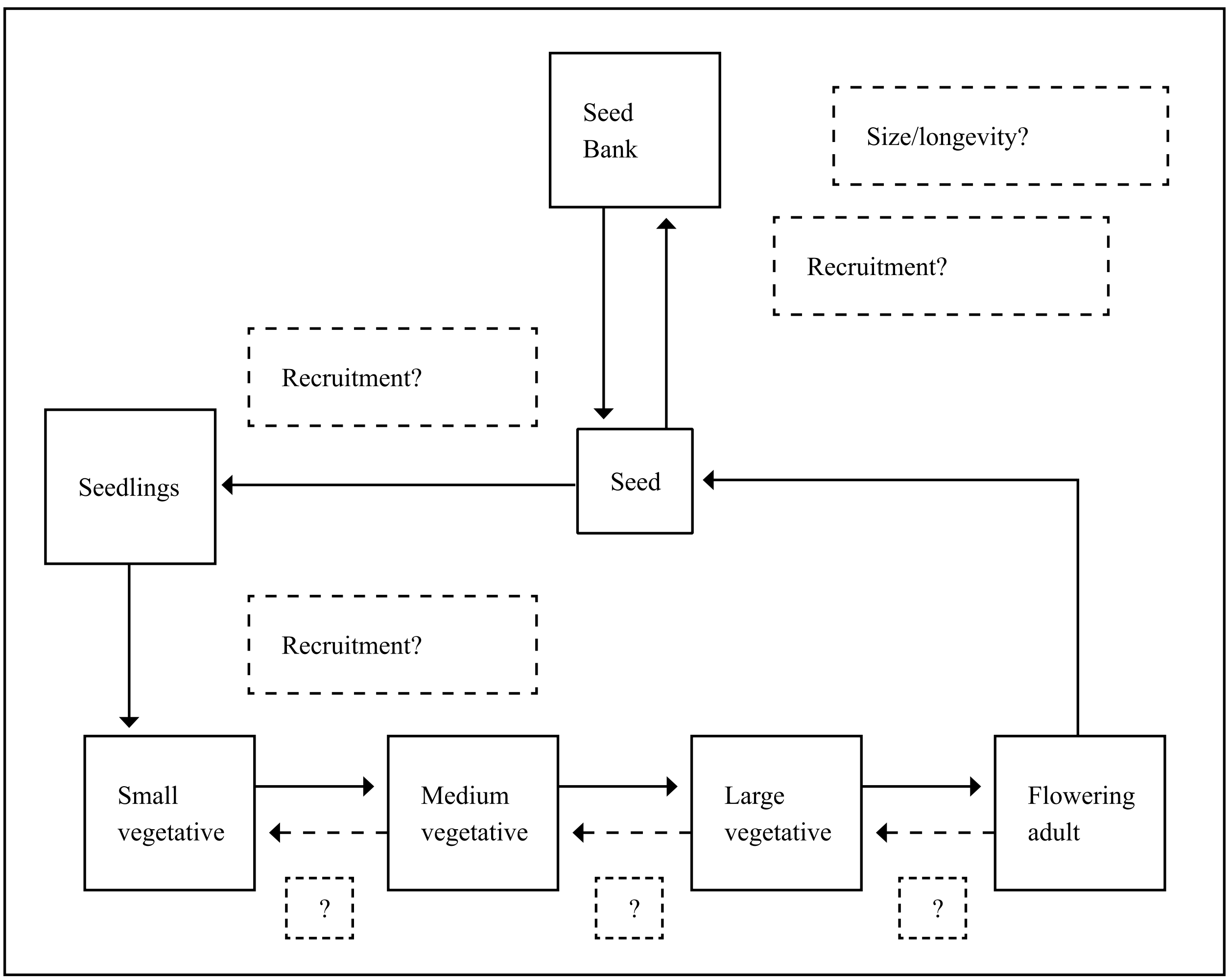

Figure 5. A proposed life cycle diagram for *Draba globosa*.

many purely asexual taxa, for example *Taraxacum officinale* (common dandelion), have proved to be very successful for fairly long periods of time (Grant 1981, Menges 1991). The ecological consequences of the complicated reproductive systems and complexity of polyploidy in *Draba* are not well defined. Brochmann (1993) hypothesizes that allopolyploidy, which may be exhibited in *D. globosa*, prevents genetic depauperation in the arctic *Draba*. In the case of *D. globosa*, 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 *D. globosa* often exists in patches, or rather as a subdivided population. It is unknown if there is a balance of frequent local "extinctions and colonizations" within a colonized area or whether, once established, microsites are occupied for long periods of time.

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 globosa* are often separated by considerable distances of inappropriate habitat, local selection pressures may have led to increased fitness to local conditions. Because it is unclear as to the reproductive mechanisms of *D. globosa*, unanticipated consequences may arise if individuals are transplanted or seeded in areas outside of the immediate range of the population.

Community ecology

The population size of this species is quite variable. Less than ten individuals or as many as 500, or even 3,000, may comprise a population (see Distribution and abundance section). The causes of the difference in population size are unknown. It appears that *Draba globosa* does not flourish in highly competitive communities and favors more environmentally harsh and sparsely vegetated sites such as fellfields (see Habitat section). Invasive weed species have not been specifically reported at any of the recorded occurrences although several species of noxious weed have been reported above the treeline (Ray 2001). 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.

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 may also be applied to describe the condition of plant species. Those components that directly impact *Draba globosa* make up the centrum, and the indirectly acting components comprise the web (**Figure 6** and **Figure 7**). Unfortunately, as mentioned previously, much of the information to make a comprehensive envirogram for *D. globosa* is unavailable. The envirograms in **Figure 6** and **Figure 7** are constructed to outline some of the major components known to directly impact the species and also include some more speculative factors that can be tested in the field by observation or by management manipulation. Dotted boxes indicate resources or malentities that are either likely but not proven, or are of a regional nature. At the micro-site level some interactions can be deduced, such as locally colonizing more mesic sites (see Habitat section), but 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 and are dangerous to use in predicting responses to management decisions.

Resources have been listed as calcareous or granitic soils providing a suitable edaphic environment and soil moisture for adequate growth (**Figure 6**). Snow pack appears important in providing sufficient soil moisture at some occurrence sites (**Table 3**, occurrences 2-CO, 20-WY, 1-MT, 1-UT, and others). Snow pack itself may be a resource if it gives protection against wind erosion and windchill, but its importance is speculative and must be local in nature. For example, occurrences on fellfields would not have the chance to benefit from snow pack (see Habitat section and **Table 3**). Alternatively snow pack over consecutive growing seasons in periods of high snowfall may be conjectured to be a significant malentity (**Figure 7**). However, because reduced snow pack may be a more likely consequence of global climate change, prolonged snow pack does not appear to be a significant threat. Disturbance in the form of slides from snow pack and precipitation may aid in the dispersal of seeds, but there is no evidence to support this speculation. Pollinators for sexual reproduction have not been included because current evidence suggests that the species is apomictic.

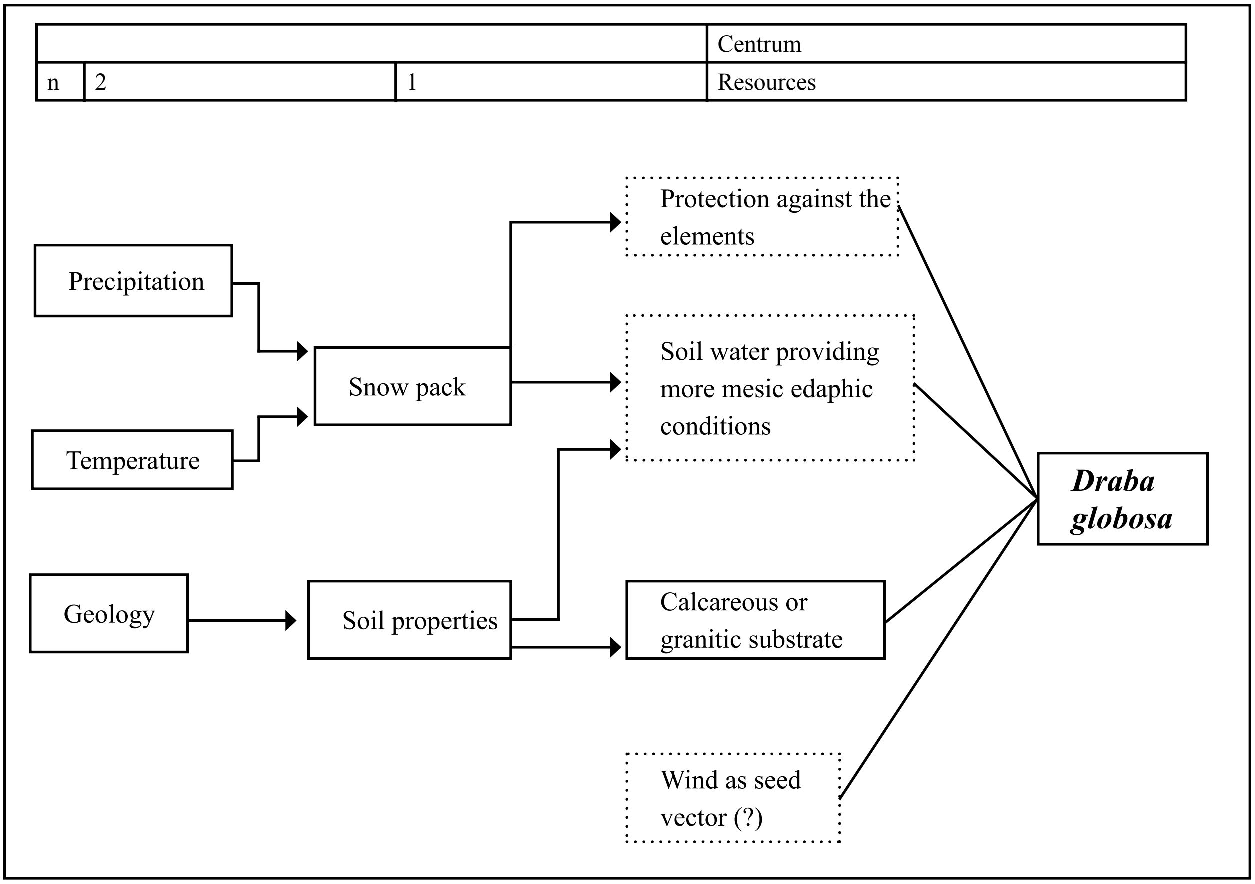

Figure 6. Envirogram of the resources of *Draba globosa*. Dotted boxes indicate resources that are either likely but not proven, or of a regional nature.

Conservation

Threats

Natural catastrophes and environmental stochasticity are likely the primary threats to *Draba globosa* at the range-wide scale. The role of disturbance in the life history of *D. globosa* is unknown. In alpine areas disturbance by anthropogenic activities, for example increased soil erosion and cumulative soil compaction due to repeated foot traffic on a trail, has different ecological consequences than that of natural disturbance, such as cryoturbation. Therefore the impacts and consequences of a specific "disturbance" must be clearly recognized, and management decisions should reflect this comprehension. It is generally assumed that there are few anthropogenic threats to the species because of its largely inaccessible habitat. However, at the level of individual populations several specific threats have been identified.

Although areas where *Draba globosa* occurs tend to be remote, many can be affected by anthropogenic activities. Several populations may be subjected to pressures imposed by human recreation. Ski areas are established throughout the range and habitat of *D. globosa*, but the impacts of skiing and related maintenance and construction activities are not well documented. In Wyoming, 10 to 15 *D. globosa* individuals were found at the edge of a proposed expansion development of the Jackson Hole Ski Area within the Bridger-Teton National Forest - Region 4 (Markow 1996). Although not in the way of the proposed project construction activity, this population may face a threat from increased recreational use of the area (Markow 1996). In summer, visitors can leave the tram and walk around the Jackson Hole Ski Area. Although there is an effort to restrict visitors to paths and trails, the openness of the area leads to a significant amount of trampling (Delmatier personal communication 2002). Foot traffic is a significant threat in many other areas. Known populations in Colorado (Region 2) are in areas, such as Loveland Pass (see site 3-CO **Table 2**), where there is considerable use by hikers (Johnston personal communication 2002). Impacts from recreational pressures are becoming increasingly apparent in Region

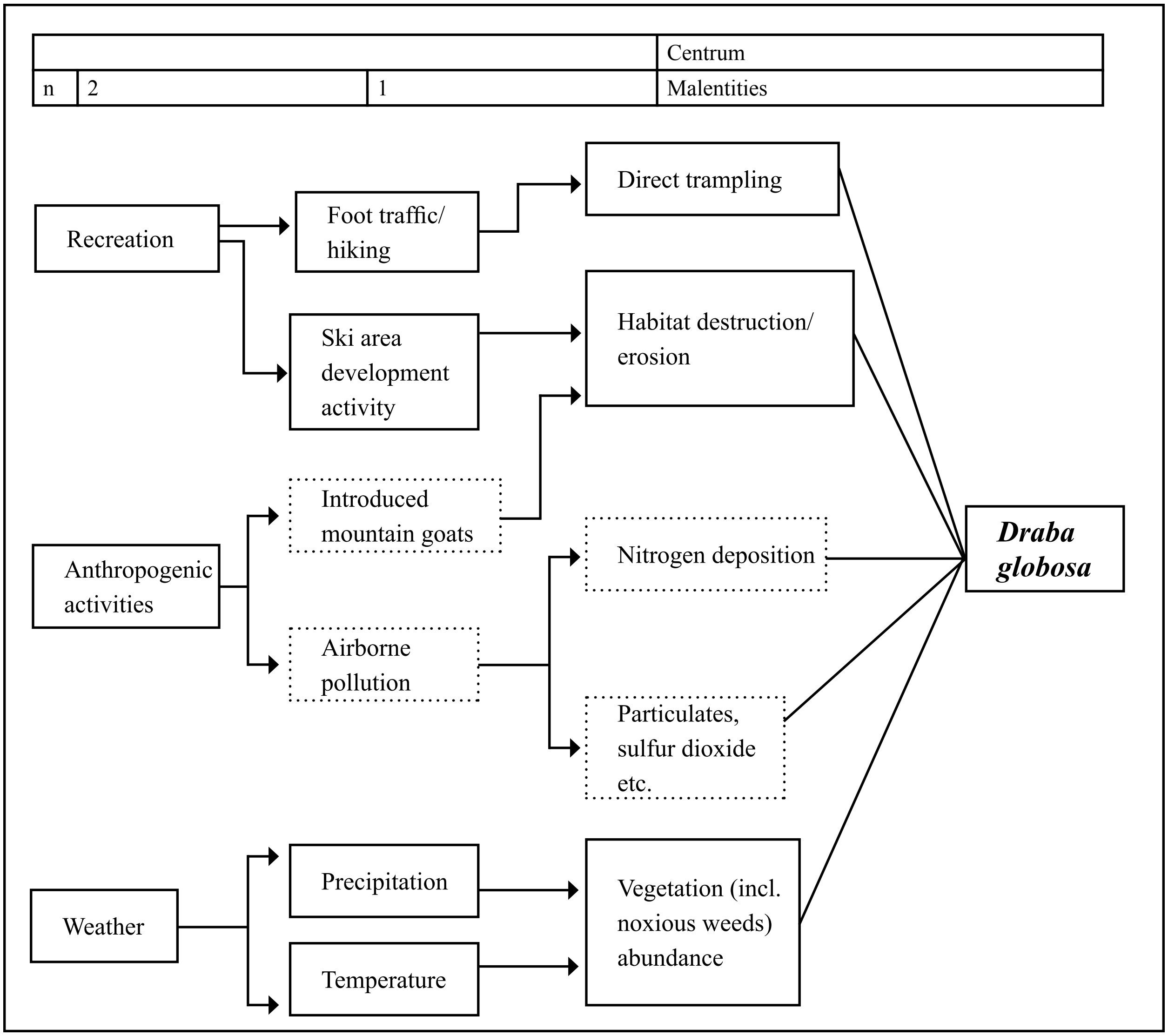

Figure 7. Envirogram outlining the malentities to *Draba globosa*. Dotted boxes indicate malentities that are either likely but not proven, or of a regional nature.

2. For example, thousands of people are estimated to walk in the alpine tundra regions in Colorado each weekend during the spring, summer, and autumn; on one trail alone, 250 people were counted on one weekend day (Morrow 2002). Hiking trails have become 12 to 15 feet wide in some areas, caused by people walking at the sides of established trails that become slippery (Morrow 2002). In addition, Morrow (2002) reported some people were so averse to following designated trails that they destroyed markers. Although there is high year-long recreational use of the areas in which *D. globosa* occurs in Idaho, the occurrences are not perceived to be threatened (Mancuso personal communication 2002). Utility lines and roads, particularly in ski areas, may impact certain populations, especially within Wyoming (Ozenberger personal communication 2002).

Mining activities may have affected some populations because *Draba globosa* grows in areas that have been exploited for their rich mineral deposits, for example near Leadville, Colorado on USDA Forest Service Region 2 land and in the Cave Mountain area in Montana. Cave Mountain Research Natural Area (RNA) in Region 1 has experienced limited exploratory drilling for iron. At the present time there do not appear to be any valuable mineral deposits outside of the patented mining claims that are adjacent to, but not within, the RNA, and no threat of mining development is anticipated (USDA Forest Service 1996). Another occurrence was observed above an old mining camp in Idaho. There are no confirmed instances where mining has directly impacted populations, and it is unknown what the consequence of past mining activities has had on the overall abundance of the species. Another potential threat directly from human activity, 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 1986, USDA Forest Service 2001).

The effects of historic sheep grazing cannot be estimated (Fertig 1998), but present-day grazing by domesticated animals is unlikely to be a significant threat because livestock grazing is presently discouraged above the timberline (Goodrich personal communication 2002). For example, in Region 2, occurrences in the Taylor Pass area (**Table 2**, 4-CO) and the Fossil Ridge Wilderness Area (**Table 2**, 2-CO) are within active cattle grazing allotments but, in keeping with current Gunnison National Forest grazing policies, cattle are never herded above the timberline and there is only occasional trespass to the higher elevations (Hatcher personal communication 2004). Similarly, small parts of the Beartooth and Clay Buttes area (**Table 2**, 6-WY and 7-WY) are in the upper reaches of active livestock grazing allotment but it is most likely that livestock do not frequent the upper reaches of the basin where *Draba globosa* occurs (Hicks personal communication 2004). The occurrences (**Table 2**, 2-WY, 4-WY, and 5-WY) in the Clarks Fork, Greybull and Washakie ranger districts of the Shoshone National Forest are outside any active grazing allotments (Hicks personal communication 2004). In addition, there is no livestock grazing permitted in alpine habitats above Loveland Pass (Sumerlin personal communication 2004, Nelson personal communication 2004).

In Utah, introduced mountain goats have been cited as a possible threat to *Draba globosa* and its habitat (USDA Forest Service 2001). Mountain goats have also been introduced into Colorado and may be a threat to some occurrences although there is no specific information on which occurrences may be most vulnerable.

Invasive weeds, such as *Linaria vulgaris* (yellow toadflax), *Centaurea biebersteinii* (spotted knapweed), and *Matricaria perforata* (scentless chamomile) have been reported at or above the treeline and are potential threats through competition for resources to endemic alpine species (Ray 2001). 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 take advantage of any opportunity for colonization (MacArthur and Wilson 1967). In addition to noxious weeds, some persistent species that have been used for re-vegetation projects may also pose a threat through competition.

Loss of genetic integrity can be caused by hybridization. If *Draba globosa* reproduces solely by agamospermy, hybridization is not a threat. However, considering the lack of specific information currently available, hybridization with native sympatric species is a possibility (see Demography section; Brochmann et al. 1992). The possibility of hybridization also raises the dangers of using *D. globosa* originally from distant regions in re-vegetation or re-introduction programs (see Reproductive biology and autecology section).

A significant threat to alpine tundra plants is global climate change. Warming could affect alpine areas, causing tree lines to rise by roughly 350 feet for every degree Fahrenheit of warming (U.S. Environmental Protection Agency 1997). Mountain ecosystems such as those found in the Rocky Mountains could shift upslope, reducing habitat for many subalpine and alpine tundra species and increasing the likelihood that alien aggressive species will invade higher elevations (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% in many parts of the state. Based on projections made by the Intergovernmental Panel on Climate Change and 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 (range 1 to 8 °F) and 5 to 6 °F in summer and winter (range 2 to 12 °F).

Atmospheric deposition of nitrogen oxides and ammonium are 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 (Region 2) when compared with the rest of the West (Barron 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). Grasses particularly increase in abundance, at the expense of other species, in dry meadows in response to additional nitrogen. Therefore, there is the potential that an increase in nitrogen cycling will have a detrimental impact in the form of increased competition on *Draba globosa*. Air quality is also a concern in the Wind River Range in Wyoming where field developments associated with resource extraction are contributing to a high level of air pollution (Ozenberger personal communication 2002). Given the remote locations of most occurrences, other forms of pollution seem an unlikely threat. However, a study sponsored by the Colorado School of Mines, the National Park Service, and 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.

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 there are few numbers of plants (less than 50 individuals) in a population, demographic uncertainties may be significant (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. This potential vulnerability is therefore relevant to all the occurrences on land managed by the USDA Forest Service in Region 2.

At the current time malentities or threats tend to be of regional, rather than universal, importance and are indicated as such in the envirogram in **Figure 7** by dotted lines. Sources of disturbance include hikers, casual summer sightseers at ski areas, and mountain goats. Trampling is directly deleterious, but such disturbance also has indirect impacts such as soil erosion and habitat destruction. Air pollution has been included in the envirogram as it is a significant threat within parts of *Draba globosa*'s range including that within Region 2. As mentioned above, potential malentities include invasive plant species that will be direct competitors for resources such as water, nutrients, and light. The extent and duration of malentities are important factors and need further study.

In summary, the threats to *Draba globosa*, including those concerned with global climate change, are likely largely dependent upon their extents and intensities. 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. Similarly, recreational activities appear to be of concern at relatively few sites at the current levels. However, the emphasis is on "current levels." Even if the intensity of a threat remains the same, an increase in its area of impact will eventually have negative consequences on the species. In addition, 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 should also 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 Region 2 or within its total range. Although in parts of its range it is fairly frequent, in others, particularly in Colorado within Forest Service Region 2 lands, it appears to be very rare. At the present time the majority of occurrences are on land managed by the Forest Service.

Although Stone (1995) suggested *Draba globosa* be removed from the USDA Forest Service Region 4 sensitive species list, he proposed that it should still be managed as a sensitive species or under the Forest Service's biodiversity regulations in areas where it is rare, which he determined to include parts of Region 4, specifically the Salt Lake Ranger District, Wasatch-Cache National in Utah, and the Sawtooth National Recreation Area in Idaho, as well as the Gallatin National Forest in Montana in Region 1 and the San Isabel and Gunnison national forests, Colorado in Region 2. *Draba globosa* is actually rare throughout Region 2. Although this de-listing might be logical in principle, de-listing a species that is rare (except for a limited area where it is locally common) may not serve to conserve the species. The fraction of the large populations that can be lost without increasing the species' vulnerability is not known. For conservation purposes, the total number of occurrences is as important as the total number of individuals. One large population is more vulnerable to one localized environmental (such as drought) or biological (such as fungal infection) event than several disjunct small populations.

It should be noted that designation of a species as sensitive does not prohibit loss of individual plants to development or other projects, but only that the impact of the project must be carefully evaluated and that Forest Service actions will not contribute to a loss of population viability (USDA Forest Service 2003). If the USDA Forest Service - Region 2 designates a taxon as sensitive, then a biological evaluation must be made to determine the potential impact to the viability of populations within the project area. Each project is individually biologically evaluated in the context of the specific area. If a taxon is particularly abundant in a certain area and a portion of the population may be lost, the project may still proceed because it can be justified that the loss would not affect the viability of the population in total. Consideration of project impacts to species viability would seem to be appropriate for a rare regional endemic species such as *Draba globosa*.

At the present time, within Region 2 jurisdiction, there appear to be several populations of *Draba globosa* that are unlikely to be adversely affected by anthropogenic activities because of specific designation of land management unit, for example wilderness area, or remote location (see Distribution and abundance section). Although Congress has granted exemptions, commercial activities, motorized access, roads, bicycles, structures, and facilities are prohibited or restricted in wilderness areas. In addition, designated wilderness areas that are administered by the USDA Forest Service are subject to President Clinton's roadless area directive (Environmental Media Services 2001).

Management of the Species in Region 2

Implications and potential conservation elements

Draba globosa apparently relies on relatively long-lived mature individuals, and thus management practices that increase either the frequency or intensity of natural perturbations or that provide additional stresses may significantly negatively impact population viability.

The reproductive strategy and genetic structure, such as ploidy level, of *Draba globosa* is uncertain (see sections on Demography and Reproductive biology and autecology). This lack of information prevents accurate estimates of its genetic vulnerability. Small populations are often considered genetically depauperate as a result of changes in gene frequencies due to inbreeding, or founder effects (Menges 1991). Although it is not invariable, locally endemic species tend to exhibit reduced levels of polymorphism (Karron 1991, Gitzendanner and Soltis 2000). These concerns associated with small populations may not be applicable if *D. globosa* is polyploid and apomictic, in which case genetic variation may be essentially stored and deleterious recessive genes masked. However, 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 the range or in obviously disjunct localities, such as those in Colorado in Region 2, are lost.

Management plans have not specifically addressed this species. It is clear that the alpine tundra ecosystem of which *Draba globosa* is a part is fragile; it is slow to recover from disturbance. The growing season is very short, and environmental conditions can be severe which may limit reproduction. It is likely that some practices, such as mining and certain recreational activities, have impacted populations. The problem is that there is little information on which to base predictions as to the species' response to specific disturbance types or levels.

Tools and practices

Documented inventory and monitoring activities are needed for this species. Most of the occurrence information is derived from herbarium specimens or from relatively casual observations by botanists, and it does not provide quantitative information on the abundance or spatial extent of the populations. In addition, there is little information on the population structure and persistence of either individuals or populations. Furthermore, there is no information with which to assess how management decisions (such as Wilderness or RNA restrictions etc.) have benefited or impacted those populations.

Species inventory

Relatively little information has been collected on *Draba globosa* in Region 2. An important consideration in inventories of this particular species is that it may be easily confused with other species. Species with which it has been confused include *D. daviesiae* and *D. oligosperma*. In addition, the phenotypic variation displayed by sympatric species such as *D. oligosperma* and *D. densifolia* may also be perplexing in the field. **Table 1** outlines distinguishing characteristics of several *Draba* taxa with which *D. globosa* has been confused. The current "Field survey form for endangered, threatened or sensitive plant species" used by the Gunnison National Forest and the data collection forms used by the Natural Heritage Programs all request information that is appropriate for inventory purposes (see Natural Heritage Program internet sites in References section for examples of data collection forms). The number of individuals, the area they occupy, and the apparent suitable habitat is important data for occurrence comparison. However, it is important to note that any estimate of suitable habitat without prior critical habitat modeling is subjective and may not be an accurate measure of the area that can be colonized by the taxon. The easiest way to describe populations over a large area may be to count patches, making note of their extent, and to count the numbers of individuals within patches. A sketch of the site indicating the plants locations is helpful for future reference. Collecting information on reproductive status and whether the plants are flowering or fruiting is also valuable in assessing the vigor and reproductive potential of a population.

Habitat inventory

The available information on habitat supplied with descriptions of occurrences is generally too diverse and insufficient in detail to make accurate analyses of the habitat requirements of *Draba globosa*. There is an insufficient understanding of all the features that comprise "potential" habitat to be able to make a rigorous inventory of areas that can actually be colonized (see Habitat section). 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 rocky areas of calcareous or granitic soils in alpine tundra and sub-alpine regions above 9,000 feet as potential habitat. There are no studies that relate the abundance or vigor of populations to habitat conditions or even to elevation.

Population monitoring

No monitoring or demographic studies have been reported. A few revisits to occurrences have provided evidence of persistence, but there are no data on changes in population size and vigor. 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 globosa* (Lesica 1987). Moseley and Mancuso (1991, 1992, 1993) successfully employed such methods when studying the population structure of *D. trichocarpa* over time. 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 be applicable to the most abundant populations.

The use of photopoints and photoplots is recommended. Photographic documentation is very useful in visualizing vegetation changes over time and is increasingly used in monitoring plans. Photopoints are collections of photographs of the same field of view that have been re-taken from the same position over some given time period. Photoplots are usually relatively close-up photographs showing a birds-eye-view of the monitoring plot. In both cases, a rebar or some other permanent marker should be placed to mark the location where the photographer stands and compass directions and field-of-view details must be recorded to make sure the photograph can be accurately re-taken. Even though digital copies are convenient and easy to store, many museums and researchers suggest storing additional slides or even hardcopies. In 50 years time, the technology to read media such as memory sticks and CDs may no longer be available.

Specific monitoring plots with photopoints are very useful, not only in areas with recreational or resource extraction activities but also in more pristine areas where the consequences of disturbances such as erosion, landslides, and local soil disturbance can be evaluated. This is also a particularly suitable approach for the steep and relatively inaccessible habitats of *Draba globosa*. In such a case, a range-finder can be used to measure the distance the plot is away from the observer.

The monitoring scheme should address the patchy and possibly dynamic nature of some of these occurrences. Problems associated with spatial auto-correlation can occur when using permanent plots to monitor a dynamic population. If the size of the plot is too small or the establishment of new plots is not part of the original scheme, when plants die within the plot and no replacement occurs it is impossible to know the significance of the change without studying a very large number of similar plots. The appropriate frequency for monitoring should be evaluated after sites are visited yearly for three to five years. If relatively little change has occurred, a monitoring schedule at 3-yearly, or perhaps more, intervals may be the most time and cost effective.

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 plants 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. Parameters that should be recorded include aspect, slope, availability of perennial or ephemeral water, vegetative cover, including lichen and moss, litter, exposed soil, and rock. The size of the rocks, cobbles, and gravels should be noted. If possible, snowfall and the persistence of snowpack should also be recorded. Conditions several years prior to the onset of a decrease or increase in population size may be more important than conditions during the year that the change is observed. Current land use designation and evidence of land use activities are important to include with monitoring data. For example, where possible, it should be noted that populations are on an active grazing allotment even though no use by livestock is observed. Of course, any signs of local grazing or other herbivory, for example by insects, should also be noted. Similarly it may be useful in the future to explain changes observed if notes are made on whether the area is popular for hiking or if the occurrence is adjacent to an apparent trail.

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 and routing hikers to designated trails. In many cases such policies have been initiated relatively recently, and their consequences have not been documented. It is very valuable to monitor sites both before and after management practices change or developments, such as the establishment or closure of a trail, are made.

Information Needs

At the present time *Draba globosa* 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, rangewide, is for more information on the numbers and distribution of this species. The present knowledge of its distribution indicates the occurrences are widely disjunct. For example, those occurring in central Colorado are several hundred miles away from the next nearest site, even though there appears to be intervening suitable habitat. The species' perceived rarity may be due to a lack of surveys, and it may be that it has often been overlooked or misidentified in the field and is more common than believed. Monitoring pre-existing sites is essential in order to understand the implications of existing and new management practices. Where management practices are likely to change, inventory should be taken to collect baseline data and periodic monitoring conducted after the new policy is initiated. Therefore, inventory and periodic monitoring of existing sites appear to be the most important needs.

Habitat requirements for *Draba globosa* need to be more rigorously defined. It is unclear as to what constitutes optimal, adequate, and unsustainable habitat. A critical definition of suitable habitat would help assess the potential tolerance of *D. globosa* to management decisions that lead to habitat disturbance. The ecology, reproductive biology, and relative importance of different stages of its life cycle are largely inferred by comparison to other *Draba* species rather than through direct studies on *D. globosa*. The factors that limit population size and abundance and that contribute to the variable occurrence sizes are not known and should be determined. The third most important aspect to understand is the species' method of reproduction. Current evidence suggests that *D. globosa* is apomictic. However, if it reproduces by facultative agamospermy, pollinators assume an importance. Management practices may need to be modified if specific pollinators are found essential for cross-pollination.

In summary, activities that would be beneficial to *Draba globosa* include:

- gathering additional information on the numbers and distribution of this species within Region 2.
- monitoring known sites at appropriate intervals.
- confirming its reproductive mechanism.
- characterizing suitable habitat.
- determining factors that limit population size and abundance.

DEFINITIONS

Abbreviation for herbaria:

COLO. The herbarium at the University of Colorado at Boulder, Colorado.
CS. The herbarium at Colorado State University, Fort Collins, Colorado.
BRY. Stanley L. Welsh Herbarium (), Monte L. Bean Life Science Museum, Brigham Young University, Provo, Utah.
KHD. Kathryn Kalmbach Herbarium, Denver Botanic Gardens, Denver, Colorado.
MO. Herbarium at the Missouri Botanical Garden, St. Louis, Missouri.
RM. Rocky Mountain Herbarium at the University of Wyoming, Laramie, Wyoming.
UC. Herbarium University of California, Berkeley, California.
UT. Garrett Herbarium, Utah Museum of Natural History, University of Utah, Salt Lake City, Utah.
UTC. Intermountain Herbarium, Utah State University, Logan, Utah.

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.

Caespitose. Growing in tufts (Harrington and Durrell 1957).

Pectinate. Comb-like; pinnatifid with the segments narrow and ranged like a comb (Harrington and Durrell 1957).

Ranks. NatureServe and the Heritage Programs Ranking system (Internet site: http://www.natureserve.org/explorer/granks.htm). G3 indicates *Draba globosa* is "vulnerable globally either because it is very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination". "S1" designation indicates that the species is "critically imperiled because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the subnation [state]". For an S1 designation there are typically 5 or fewer extant occurrences or less than 1,000 remaining individuals. "S2" designation indicates it is "imperiled in the subnation [state] because of rarity or because of some factor(s) making it very vulnerable to extirpation from the subnation".

Trichome. Hair-like outgrowth from the epidermis (Harrington and Durrell 1957).

Commonly Used Synonyms of Plant Species

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:

Sedum lanceolatum	*Amerosedum lanceolatum* (Weber & Wittman 2001)
Geum rossii	*Acomastylis rossii* (Weber & Wittman 2001)
Eritrichium aretioides	*Eritrichum aretioides* (Weber & Wittman 2001)
Saxifraga rhomboidea	*Micranthes rhomboidea* (Weber & Wittman 2001)
Hymenoxys grandiflora	*Rydbergia grandiflora* (Weber & Wittman 2001)

References

Allaby, M. 1992. The concise Oxford dictionary of Botany. Oxford University Press, New York, NY.

Andrewartha, H.G. and L.C. Birch. 1984. The ecological web: more on the distribution and abundance of animals. University of Chicago Press, Chicago, IL.

Baron, J.S. 2001. Acid Rain in the Western United States. Statement of Jill S. Baron, ecologist U.S. Geological Survey. Before the House Committee on Science. United States House of Representatives. May 3, 2001. Internet site: http://www.greennature.com/article869.html [Accessed April 2002].

Baron, J.S., H.M Rueth, A.M. Wolfe, K.R. Nydick, E.J. Allstott, J.T. Minear, and B. Moraska. 2000. Ecosystem responses to nitrogen deposition in the Colorado Front Range. Ecosystems 3:352-368.

Bowman, W.D., T.A. Theodose, J.C. Schardt, and R.T. Conant. 1993. Constraints of nutrient availability on primary production in alpine communities. Ecology 74:2085-2098.

Brochmann, C. 1993. Reproductive strategies of diploid and polyploid populations of artic *Draba* (Brassicaceae). Plant Systematics and Evolution 185(1-2):55-83

Brochmann, C., B. Stedje, and L. Borgen. 1992. Gene flow across ploidal levels in *Draba* (Brassicaceae). Evolutionary Trends in Plants 6(2) 125-134.

Colorado Natural Heritage Program. 2002. Biological Conservation Database: Element Occurrence Records. Colorado State University, Fort Collins, CO. [Not reviewed]

Colorado Natural Heritage Program On-line Rare Plant Guide, Fort Collins, Colorado. Internet site: http://www.cnhp.colostate.edu/rareplants/cover.html [Accessed January, 2002].

Delmatier, Charmaine. 2002. U.S. Fish and Wildlife Service, Austin, Texas. Personal communication.

Dorn, R.D. 1984. Vascular plants of Montana. Mountain West Publishing, Cheyenne, WY.

Dorn, R.D. 2001. Vascular plants of Wyoming. 3rd edition. Mountain West Publishing, Cheyenne, WY.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and monitoring plant populations. Bureau of Land Management Technical Reference 1730-1. U.S. Department of Interior, Bureau of Land Management, Denver, CO.

Environmental Media Services. 2001. Definitions for Public Land Designations, Last update: April 27, 2001. Internet site: http://www.ems.org/ [Accessed December 2003]

Ewan, J. and N.D. Ewan. 1981. Biographical dictionary of Rocky Mountain Naturalists, 1682-1932. Dr. W. Junk Publishers, The Hague, The Netherlands.

Fertig, W. 1992a. Checklist of the vascular plant flora of the west slope of the Wind River Range and status report on sensitive plant species of the Bridger-Teton National Forest. Unpublished report. Bridger-Teton National Forest, WY. [Not reviewed]

Fertig, W. 1992b. A floristic survey of the west slope of the Wind River Range, Wyoming. M.S. thesis. University of Wyoming, Laramie, WY. [Not reviewed]

Fertig, W. 1998. The status of rare plants on Shoshone National Forest: 1995-97 Survey results. Unpublished report. Shoshone National Forest, WY. [Not reviewed]

Fox, L. and R.K. Moseley. 1991. Taxonomic investigation of the genus *Draba* (Brassicaceae) in the White Cloud Peaks and Boulder Mountains, Idaho. Natural Heritage Section, Nongame/Endangered Wildlife Program, Idaho Department of Fish and Game, Boise, ID. [Not reviewed]

Gitzendanner, M.A. and P.S. Soltis. 2000. Patterns of genetic variation in rare and widespread plant congeners. American Journal of Botany 87(6):783-792.

Goldsmith, F.B. 1991. Monitoring for conservation and ecology. Chapman and Hall, New York, NY.

Goodrich, Sherel. 2002. USDA Forest Service, Ashley National Forest, Utah. Personal communication.

Grant, V. 1981. Plant speciation. 2nd edition. Columbia University Press, New York, NY.

Grime, J.P., J.G. Hodgson, and R. Hunt. 1988. Comparative plant ecology – a functional approach to common British species. Allen and Unwin, Inc., Winchester, MA.

Harrington, H.D., and L.W. Durrell. 1957. How to identify plants. Reprinted in 1986. Swallow Press, Athens, OH.

Hartman, E. and M.L. Rottman. 1984. Noteworthy collection. Madrono 32(3):191-193.

Hartman, J.H. 1999. Antebellum Scientific Exploration of the American West. Energy & Environmental Research Center, University of North Dakota. Internet site: http://www.frontierheritage.org/scientific.shtml [Accessed February 2004]

Hartman. R. 1995. General floristic/sensitive plant species survey of the Gros Ventre Range, Wyoming. Unpublished document. USDA Forest Service, Bridger-Teton National Forest, Jackson Hole, WY. [Not reviewed]

Hartman, R.L. and B.E. Nelson. 1991. General floristic survey of the west slope of the Wind River Range, Bridger-Teton National Forest, 1990. Report prepared by the Rocky Mountain Herbarium, University of Wyoming, Laramie, WY. [Not reviewed]

Hatcher, Mark. 2004. USDA Forest Service, Grand Mesa, Uncompahgre, and Gunnison National Forest, Colorado. Personal communication.

Hicks, Joe. 2004. USDA Forest Service, Shoshone National Forest, Wyoming. Personal communication.

Hitchcock, C.L. 1941. A revision of the *Drabas* of Western North America. University of Washington Publications in Biology 11:1-132.

Hitchcock, C.L. and A. Cronquist. 1973. Reprinted 2001. Flora of the Pacific Northwest. University of Washington Press, Seattle, WA.

Idaho Conservation Database Center. 2002. Element occurrence records. Received from Idaho Conservation Database Center, Boise, ID.

Jennings, Bill. 2003. Botanist, Denver, Colorado. Personal communication.

Jones, G.P. and W. Fertig. 1999. Ecological evaluation of the potential Beartooth Butte Research Natural Area within the Shoshone National Forest, Park County, Wyoming. Unpublished report prepared for the Shoshone National Forest, USDA Forest Service by the Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY. [Not reviewed]

Johnston, B. and L. Huckaby. 2001. Ecological types of the Upper Gunnison Basin. Technical Report R2-RR-2001-01. USDA Forest Service, Rocky Mountain Region, Denver, CO. [Review status unknown].

Johnston, Barry. 2002. USDA Forest Service, Gunnison National Forest, Colorado. Personal communication.

Karron J.D. 1991. Patterns of genetic variation and breeding systems in rare plant species. In: Genetics and conservation of rare plants. Pages 87-98 in D.A. Falk and K.E. Holsinger, editors. Oxford University Press, New York, NY.

Kartesz, J. 1994. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. Volume 1 - Checklist. 2nd edition. Timber Press, Portland, OR.

Keiding, N. 1975. Extinction and exponential growth in random environments. Theoretical Population Biology 8: 49-63.

Kettler S. M., N.D. Lederer, D. Bacher, and S. Spackman. 1993. Pike and San Isabel National Forests and Comanche and Cimarron National Grasslands, plants of special concern. Unpublished document. December. Colorado Natural Heritage Program, Boulder, CO. [Not reviewed].

Landes, R.1988. Genetics and demography in biological conservation. Science 241:1455-1460.

Lesica, P. 1987. A technique for monitoring nonrhizomatous, perennial plant species in permanent belt transects. Natural Areas Journal 7(2):65-68

MacArthur, R.H. and E.D. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, NJ.

Mancuso, Michael. 2002. Idaho Conservation Database Center, Boise, Idaho. Personal communication.

Marsh, Susan. 2002. USDA Forest Service, Bridger-Teton National Forest, Wyoming. Personal communication.

Markow, S. 1996. A sensitive species and general floristics survey of the Bridger Ridge ski area development area. Unpublished document. USDA Forest Service, Bridger-Teton National Forest, Jackson, WY. [Not reviewed].

McGraw, J.B. and M.C. Vavrek. 1989. Buried viable seeds in Artic and alpine communities. Page 96 in M.A. Leck V.T. Parker and R.L. Simpson, editors. Ecology of soil seed banks. Academic Press Inc, San Diego, CA.

Menges, E.S. 1991. The application of minimum viable population theory to plants. Pages 45-61 in: D.A. Falk and K.E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, NY.

Mills S. and W. Fertig. 1996. Field guide to rare and sensitive plants of the Shoshone National Forest. Limited publication. Prepared for the USDA Forest Service, Shoshone National Forest. Wyoming Natural Diversity Database, The Nature Conservancy, Laramie, WY. [Not reviewed].

Montana Natural Heritage Program. 2001. Element occurrence records. Received from Montana Natural Heritage Program, MT.

Montana Natural Heritage Program, Missoula, Montana. Internet site: [Accessed May 2002].

Morrow, Bruce. Education and Outreach Manager, "Colorado Fourteeners Initiative". Radio broadcast, "Colorado Matters", Colorado Public Radio. April 17, 2002.

Moseley, R.K. and M. Mancuso. 1991. Long-term demographic monitoring of two Stanley Basin endemics, *Draba trichocarpa* and *Eriogonum meledonum*. I. First-year results. Natural Heritage Section, Nongame/Endangered Wildlife Program, Idaho Department of Fish and Game, Boise, ID. [Not reviewed]

Moseley, R.K. and M. Mancuso. 1992. Long-term demographic monitoring of two Stanley Basin endemics, *Draba trichocarpa* and *Eriogonum meledonum*. II. Second-year results. Conservation Data Center, Nongame/Endangered wildlife program. Idaho Department for Fish and Game, Boise, ID. [Not reviewed]

Moseley, R.K. and M. Mancuso. 1993. Demographic monitoring of two Stanley Basin endemics, *Draba trichocarpa* and *Eriogonum meledonum*. III. Third-year results. Conservation Data Center, Nongame/Endangered wildlife program. Idaho Department for Fish and Game, Boise, ID. [Not reviewed]

Mulligan, G.A. 1971. Cytotaxonomic studies of *Draba* species of Canada and Alaska: *D. ventosa, D. ruaxes, and D. paysonii*. Canadian Journal of Botany 49:1455-1460.

Mulligan, G.A. 1976. The *Draba* in Canada and Alaska: key and summary. Canadian Journal of Botany 54:1386-1393

Mulligan, G.A. and J.N. Findlay. 1970. Sexual reproduction and agamospermy in the genus *Draba*. Canadian Journal of Botany 48:269-270.

NatureServe. 2003. NatureServe Explorer: An online encyclopedia of life [web application]. Version 1.8. NatureServe, Arlington, Virginia. Internet site: http://www.natureserve.org/explorer. [Accessed: February 2004].

NatureServe Web site. Version 1.6 (03 December 2001). Data last updated November 2001. Global Heritage Status Rank assigned 05 Jan1998 with Global Ranking Factors Edition Date: 17 May 1996.

National Heritage Status Rank assigned 22 Dec 1997. Internet site: http://www.natureserve.org/explorer/servlet/NatureServe?init=Species [Accessed April 19, 2002].

Nelson, W. 2004. USDA Forest Service, White River National Forest, Colorado. Personal communication.

New York Botanical Garden. Herbarium records. Internet site: http://scisun.nybg.org:8890/searchdb/owa/wwwcatalog.detail_list?this_id=4374920 [Accessed May 2002].

Ozenberger, J. 2002. USDA Forest Service, Bridger-Teton National Forest, Jackson, Wyoming. Personal communication.

Payson. E.B. 1917. The perennial scapose *Drabas* of North America. American Journal of Botany 4(5):253-267.

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

Pollard, J.H. 1966. On the use of the direct matrix product in analyzing certain stochastic population models. Biometrika 53:397-415.

Price, R.A. 1979. The *Draba crassa* complex (Brassicaceae): systematics and geography. MS Thesis, University of Wisconsin – Madison, Madison, WI. . [Limited review]

Ray, J. 2001. Leadville Milkvetch (*Astragalus molybdenus* Barneby). Unpublished report from the Center for Native Ecosystems for the Colorado Natural Heritage Program, Fort Collins, CO. [Not reviewed]

Redick, L. 2002. Bureau of Land Management, Challis Resource Area, Upper Columbia-Salmon Clearwater District, Idaho. Personal communication. May 2002

Research Natural Areas. Undated. USDA Forest Service Northern Region, Rocky Mountain Region, Southwestern Region, Intermountain Region, Rocky Mountain Research Station, and the Montana Natural Heritage Program. Internet site: http://nhp.nris.state.mt.us/rna/ [Accessed December 2003]

Rollins, R.C. 1953. *Draba* on Clay Butte. WY. Rhodora 55:229-235.

Rollins, R.C. 1993. The Cruciferae of continental North America, systematics of the mustard family from Artic to Panama. Stanford University Press, Stanford, CA.

Rueth, H.M. and J.S. Baron. 2002. Differences in Englemann spruce forest biogeochemistry east and west of the Continental Divide in Colorado. Ecosystems 5:45-57.

Scott, R.W. 1995. The alpine flora of the Rocky Mountains. Vol. 1. The Middle Rockies. University of Utah Press, Salt Lake City, UT.

Shaw, R.J. 1976. Field guide to the vascular plants of Grand Teton National Park and Teton County, Wyoming. Utah State University Press, Logan, UT.

Shelly, J.S. 2002. USDA Forest Service Region 1, Missoula, MT. Personal communication.

Silvertown, J.W. 1987. Introduction to plant population ecology. 2nd edition. Longman Scientific and Technical, Harlow, England, United Kingdom.

Silvertown, J., M. Franco, I. Piasanty, and A. Mendoza. 1993. Comparative plant demography – relative importance of life cycle components to the finite rate of increase in woody and herbaceous perennials. Journal of Ecology 81:465-476.

Skid Marks Newsletter. 2000. Study finds snowmobile pollution in snow. Issue #26 October 27.

Spackman, S. B. Jennings, J. Coles, C. Dawson, M. Minton, A. Kratz, and C. Spurrier. 1997. Colorado Rare Plant Field Guide. Prepared for the Bureau of Land Management, the USDA Forest Service, and the U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program, Fort Collins, CO.

Stone, R.D. 1995. Status Review of *Draba globosa* Payson (Brassicaceae) [= *D. densifolia* var. *apiculata* (C.L. Hitchcock)Welsh] and related species [*D. densifolia* Nutt. Ex Torrey & Gray, D. davisiae (C.L. Hitchcock) Rollins]. Final report. Unpublished report. Utah Department of Natural Resources and USDA Forest Service, Intermountain Region, Salt Lake City, UT. [Not reviewed]

Sumerlin, Doreen. 2004. USDA Forest Service, Arapaho National Forest, Colorado. Personal communication.

Theodose, T.A. and W.D. Bowman. 1997. Nutrient availability, plant abundance, and species diversity in two alpine tundra communities. Ecology 78(6):1861-1872.

USDA Forest Service. 1993. Region 2 - Regional Forester Sensitive Species List. Internet site: http://roadless.fs.fed.us/documents/feis/data/sheets/summspd/tes_supp/r2_ssspecies.pdf [Accessed March 2002].

USDA Forest Service. 1994. Forest Service Manual, Title 2600-Wildlife, Fish and Sensitive Plant Habitat Management; Region 2 Supplement 2600-94-2, Section 2672.11a, Exhibit 1.

USDA Forest Service. 1996. Establishment Record for Cave Mountain Research Natural Area within Beaverhead-Deerlodge National Forest, Beaverhead County, Montana. Unpublished document. Beaverhead-Deerlodge National Forest, Beaverhead County, MT. [Not reviewed]

USDA Forest Service. 1999. Establishment Record for Osborn Mountain Research Natural Area within Bridger-Teton National Forest, Sublette County, Wyoming. Unpublished document. Bridger-Teton National Forest, Sublette County, WY. [Not reviewed]

USDA Forest Service. 2001. Wasatch-Cache National Forest - Draft Environmental Impact Statement May 2001. Unpublished document. Wasatch-Cache National Forest, UT.

USDA Forest Service. 2003. Forest Service Manual Chapter 2670 – Threatened, endangered and sensitive plants and animals. Supplement No.: 2600-2003-1. USDA Forest Service Rocky Mountain region (Region 2), Denver, CO.

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

USGS Northern Prairie Wildlife Research Center. 2002. Internet site: http://www.npwrc.usgs.gov/resource/resource.htm [Accessed March 2002].

Utah Natural Heritage Program. 2002. Element occurrence records. Received from Utah Natural Heritage Program, Salt Lake City, UT.

Weber, W.A. and R.C. Wittmann. 2001a. Colorado Flora, eastern slope. 3rd edition. University Press of Colorado, Boulder, CO.

Weber, W.A. and R.C. Wittmann. 2001b. Colorado Flora, western slope. 3rd edition. University Press of Colorado, Boulder, CO.

Welsh, S. L., N.D. Atwood, S. Goodrich, and L.C. Higgins. 1993. A Utah Flora. Second edition-revised. Brigham Young University, Provo, UT.

Willard, B.E. 1979. Plant sociology of alpine tundra, Trail Ridge, Rocky Mountain National Park, Colorado. Colorado School of Mines quarterly: Vol. 4, No. 4.

Williams, J. 1986. Rocky Mountain Alpines. Timber Press, Portland, OR.

Windham, M.D. and M. Beilstein. 1998. A taxonomic study of *Draba maguirei* and allied taxa (Brassicaceae). Unpublished report. USDA Forest Service, Wasatch-Cache National Forest, Ogden, UT. [Not reviewed]

Wyoming Natural Diversity Database. 2002. Element occurrence records. Received from Wyoming Natural Diversity Database, Laramie, WY.

Wyoming Natural Diversity Database, Laramie, Wyoming. Internet site: http://uwadmnweb.uwyo.edu/wyndd/ [Accessed March 2002].