Draba exunguiculata (O.E. Schulz) C.L. Hitchcock (Garys Peak draba): A Technical Conservation Assessment

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

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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 exunguiculata*

Status

Draba exunguiculata (Garys Peak or clawless draba) is a rare member of the mustard family that was designated a sensitive species by the USDA Forest Service, Rocky Mountain Region in 2003. The NatureServe global rank for this species is globally imperiled (G2), reflecting that there are likely fewer than 20 extant populations. It is designated imperiled (S2) in Colorado by the Colorado Natural Heritage Program.

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 exunguiculata* habitat and recreational use increases, the impacts may become substantially more significant. Mining activities are not currently perceived to be a threat to any of the known populations although individual populations may have been impacted in the past. Mountain goats (*Oreamnos americanus*) trample individuals and are also likely to have a negative influence on habitat condition in some parts of its range. The magnitude of the impact is related to the size of the mountain goat population. Wet nitrogen deposition (acid rain) and air pollution pose a substantial risk to forb communities in alpine tundra especially along the Front Range where *D. exunguiculata* occurs in Colorado. Global warming is a potential threat to all species currently restricted to sub-alpine and alpine-tundra zones. Although not a current threat, invasive weeds may pose an additional risk to long-term sustainability.

Primary Conservation Elements, Management Implications and Considerations

Draba exunguiculata is a rare species endemic to high elevations in the Rocky Mountains of Colorado. It appears to be a naturally uncommon species that is well adapted to its fragile alpine habitat. Relatively little information concerning its abundance, distribution, and biology is available. It appears to be most abundant within the region around Gray's Peak. More than 75 percent, and most likely 88 percent, of the known occurrences are on land managed by the USDA Forest Service, in the Pike-San Isabel and Arapaho-Roosevelt national forests. Although some populations have been impacted in areas with high recreational use, the current information available suggests that several populations are relatively secure because they occur in areas that are afforded protection either by land use designation, such as wilderness area, or by their remote, relatively inaccessible location. There are no management plans specifically for *D. exunguiculata*; however, its sensitive species status in Region 2 dictates that it receive consideration in Forest and project level planning on National Forest Systems lands within Region 2.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Draba exunguiculata* (Garys Peak or clawless draba) is the focus of an assessment because it is a rare species endemic to the Rocky Mountains in Colorado (**Figure 1**) and is designated a sensitive species by the Regional Forester of Region 2 (USDA Forest Service 2003). 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 (FSM 2670.5 (19)). A sensitive species may require special management so knowledge of its biology and ecology is critical. This assessment addresses the biology, conservation and management of *D. exunguiculata* throughout its range in USDA Forest Service Region 2.

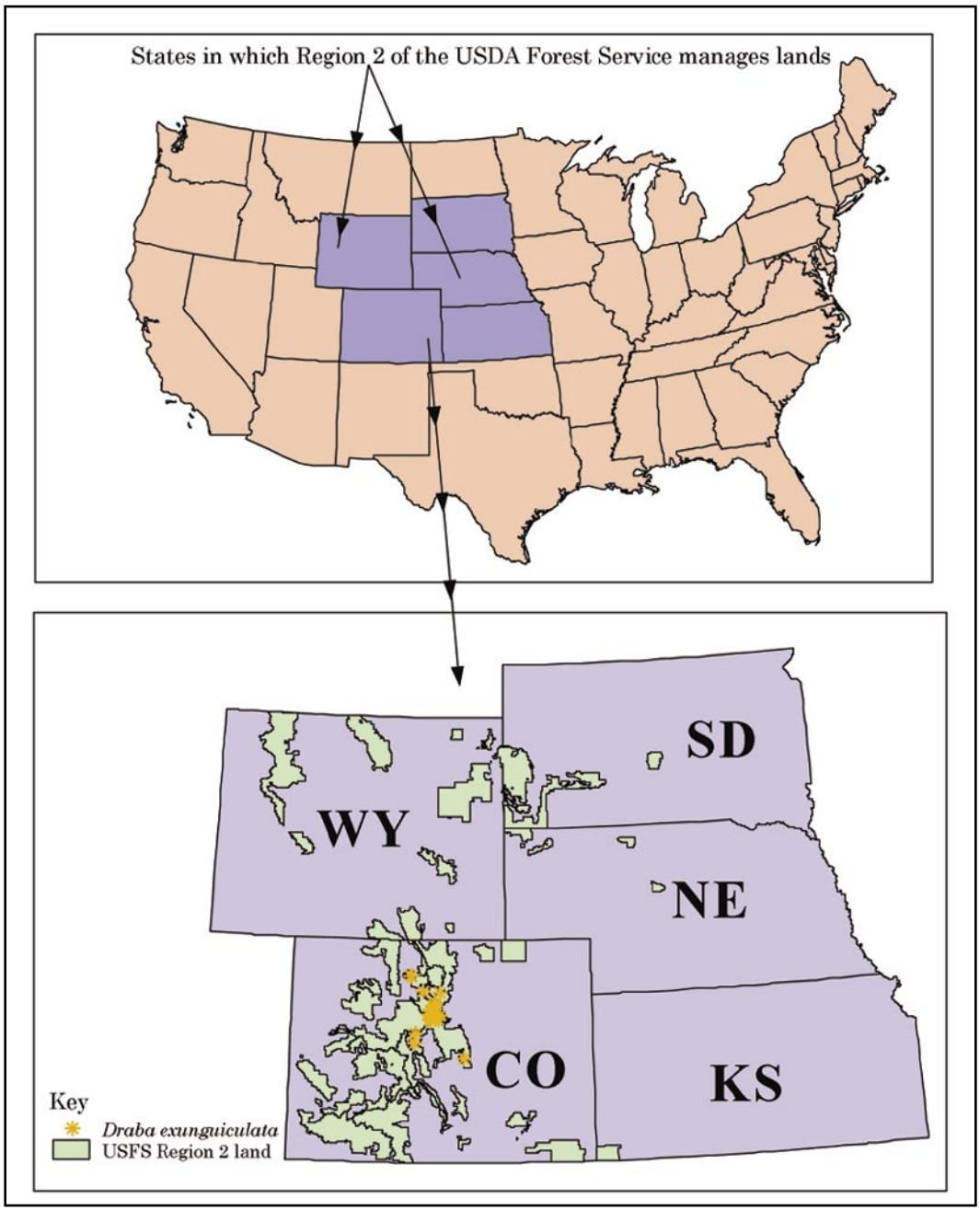

Figure 1. Range of *Draba exunguiculata*.

Goal

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

Scope

This assessment examines the biology, ecology, conservation status, and management of *Draba exunguiculata* with specific reference to the geographic and ecological characteristics of the USDA Forest Service Rocky Mountain Region. 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 context of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *D. exunguiculata* 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 placed in a current context.

In producing this assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. Not all publications on *Draba exunguiculata* may have been referenced in the assessment, although an effort was made to consider all relevant documents. Refereed literature is preferred because it is the accepted standard in science. In some cases, non-refereed publications and reports were used because information was unavailable elsewhere, but are regarded with greater skepticism. Many reports or non-refereed publications on rare plants are often 'works-in-progress' or isolated observations on phenology or reproductive biology and are reliable sources of information. 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 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 with more significance than observations only.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct critical experiments in the ecological relations. Therefore, while well-executed experiments represent the strongest approach to developing knowledge, alternative methods, such as observations, inference, good thinking, and models must be relied on to guide the understanding of features of biology. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Publication of Assessment on the World Wide Web

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

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior

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

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Draba exunguiculata (Garys Peak draba, clawless draba, or Colorado whitlow wort) is a rare member of the Brassicaceae, or mustard family, and is endemic to the Rocky Mountains of Colorado (**Figure 1**). The NatureServe global[1] rank (2002) for this species is globally imperiled (G2). It is designated imperiled (S2) in Colorado by the Colorado Natural Heritage Program. *Draba exunguiculata* is designated a sensitive species by the USDA Forest Service in Region 2 (USDA Forest Service 2003). A sensitive species "is a plant 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 of predicted downward trend in habitat capability that would reduce a species' existing distribution" (USDA Forest Service 1993). In 1975, *D. exunguiculata* was designated a Category 2 candidate for listing under the Endangered Species Act (U.S. Fish and Wildlife 1975). In 1996, the U.S. Fish and Wildlife Service eliminated the Category 2 status, retaining a single candidate status for species under review for possible listing (U.S. Fish and Wildlife 1996). The U.S. Fish and Wildlife Service now relies on other information sources such as state lists of rare and endangered species, state natural heritage program databases, and NatureServe's database system to identify those species that may be vulnerable. There are no petitions or plans for a federal listing of *D. exunguiculata* at the current time.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies.

The majority of the known occurrences (at least 17 of 24) of *Draba exunguiculata* are on land managed by the USDA Forest Service, Region 2, on the Pike-San Isabel and Arapaho-Roosevelt national forests (**Table 1**). At least three occurrences are probably also on private land, at least two occurrences are on State of Colorado land, and at least one occurrence is on land managed by the Bureau of Land Management. Several populations are in designated wilderness areas, specifically the Mount Evans and Indian Peaks wilderness areas, where they are afforded some protection from anthropogenic activities (**Table 1**, arbitrary occurrences 4, 13, 14, 15, 16, and 22). A wilderness area is defined in the law as "an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions" (Environmental Media Services 2001). In general, the Wilderness Act prohibits commercial activities, motorized access, roads, bicycles, structures and facilities, although Congress has granted exemptions. Sometimes, the managing forest administration limits visitor numbers in wilderness areas. In addition, one population is in the Mount Goliath Natural Area (**Table 1**, arbitrary occurrence 13). Designated natural areas preserve a wide variety of Colorado's ecological and geological diversity on both public and private lands. The Colorado Natural Areas program does not purchase property, but works with local, state, and federal agencies to develop voluntary agreements protecting natural resources, such as rare and endemic plant taxa, of these areas (West personal communication 2002, Colorado Natural Areas Program 2004).

Few formal surveys have been conducted for this species, and there are no management or conservation plans prepared specifically for the species. However, *Draba exunguiculata* is included by name in a document outlining general management strategy for selected plant species in the Grand Mesa, Uncompahgre, Gunnison, San Juan, Rio Grande, Pike, and San Isabel national forests published by Region 2 of the Forest Service (USDA Forest Service 1999b). It was considered in the biological assessment for endangered, threatened, and sensitive species prepared for the Continental Divide Trail Project, and adverse impacts to some populations were determined to be acceptable (Thompson 1997). It was also considered during the project that repaired and relocated the Mt. Goliath trail and trailhead (USDA Forest Service 1998). In this case, disturbance of the plants was considered not to be acceptable, and the USDA Forest Service planned to have a botanist available during the trail layout to ensure that plants would be avoided.

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

Table 1. Summary of the occurrences of *Draba exunguiculata*. Herbarium abbreviations: COLO = Herbarium, University of Colorado, Boulder, Colorado; CS = Herbarium, Biology Department, Colorado State University, Fort Collins, Colorado; KHD = Kathryn Kalmbach Herbarium, Denver Botanic Gardens.

Arbitrary number	County	Management authority	Dates observed	Location	Habitat summary	Abundance summary and comments	Source of information
1	Boulder, Grand	Unknown	7/29/1906	Arapaho Mountain	Above timber line.	Reproductive status: flower and fruit. [Original identification as *Draba streptocarpa* 1906; revised to be *D. watsonii* (=*D. chrysantha* Wats.) by C.L. Hitchcock, 1939. Identified as *D. exunguiculata* by R. Price, July 1987.COLO Accession 13288].	*F. Ramaley2406, 2431 with W.W. Robbins* COLO.
2	Park, Lake	San Isabel National Forest and/or private	8/4/1990	In vicinity of Weston Pass	"Cracks of limestone outcrop on south-facing slope" at 12,300 feet.	With fruit.	Colorado Natural Heritage Program element occurrence records. *L. Vierling 181* 1990. Colorado College Herbarium.
3	El Paso	Pike National Forest	7/7/1923	Between Bottomless Pit to Peak. Note: county was not originally reported	No information.	With flowers and fruit. [Originally identified as *Draba ventosa*; Identified as *D. exunguiculata* (by H.D. Harrington, 1947. Confirmed *D. exunguiculata* by Price 1987 who made the annotation that "this population has unusually well-developed petals".	Colorado Natural Heritage Program element occurrence records. *L. Bonar 45* 1923 COLO.
4	Boulder	Arapaho National Forest, Indian Peaks Wilderness	7/1/1972	North slopes of Kiowa Peak in the Green Lakes	No direct information (see Komárková 1979).	With flowers and fruit.	Colorado Natural Heritage Program element occurrence records. *V. Komárková s.n. Accession 262678* COLO
5	Gilpin	Roosevelt National Forest	7/4/1972	Slope of the cirque on the northeast side of James Peak	"Slope of a cirque. "	With flowers and fruit.	Colorado Natural Heritage Program element occurrence records. *V. Komárková. s.n.* 1972 COLO; Komárková 1979
6	Clear Creek, Grand	Arapaho National Forest	7/1/1978	Colorado Mines Peak, ca .5 mi E of Berthoud Pass summit	"North-facing slope; on fellfield with *Arenaria obtusiloba*, *Silene acaulis*, *Trifolium nanum*, *Luzula spicata*." at approximately 12,350 ft/3,764 m.	No information.	*R A Price 177* 1978 COLO, CS

Table 1 (cont.).

Arbitrary number	County	Management authority	Dates observed	Location	Habitat summary	Abundance summary and comments	Source of information
7	Clear Creek, Grand	Arapaho-Roosevelt National Forest	9/11/1983; 7/14/1997	On north ridge of Mt. Flora near summit, Mount Flora, mid-slope of peak on west side. Between Colorado Mines Peak and Mt. Flora along the divide	1983: on gravel flat 1998: Midslope of peak on west side in cobblestone soils; w/ *Draba grayana*. Occasional on fell field of alpine tundra. Alpine ridge At 12,600 to 13,000 feet.	1983: "Rare only 3 plants seen." 1998: "This element occurrence contains a total of two sub-occurrences. Together they contain 18+ plants."	Colorado Natural Heritage Program element occurrence records *L. Yeatts, 842* 1983 KHD, *N. Redner s.n.* 1997 COLO, *A. Petterson s.n.* 1997 CS
8	Clear Creek	Arapaho National Forest and/or private	7/18/1978	Vicinity west of Kelso Mountain near Stevens Gulch	1978: Along edge of trail, in fellfield, or near boulders. Elevation approximately 12,600 feet.	No information.	Colorado Natural Heritage Program element occurrence records. *R.A. Price 244* 1978 Herbarium of the Smithsonian Institute
9	Clear Creek	Arapaho National Forest	7/28/1994	Saddle between Bard and Robeson Peaks, 2 miles north of Bakerville	On north-facing steep fellfield, with *Silene acaulis*, *Trifolium nana*, *Hirculus serpyllifolia.*	"20 plants counted, widely scattered; there are probably many more" Population covers 0.1 acre. Phenology: some flowering, some fruiting. Vulnerable to hiker disturbance; "as of July 28, 110 people had signed the peak register in 1994".	Colorado Natural Heritage Program element occurrence records. *Nan Lederer 4434* COLO
10	Clear Creek, Summit	Arapaho National Forest	9/1/1951; 7/13/1978; 8/2/1994	East of Loveland Pass summit; Ridge east of Loveland Pass summit. Sub-population at Loveland Pass parking area. Population within approximately 4 sections	1951: Stony alpine slopes at eleavation 12,000 feet. 1978: "Northwest-facing clope. In fell field with *Silene acaulis*, *Arenaria obtusiloba*, *Geum rossii*. 1994: In rocky tundra. Glaciated mountain ridge of igneous rock; northwest aspect, on dry upper part of 30 – 50 percent convex-shaped slope with open light exposure.	1951: Fruit. 1978: With expanded petals. 1994: referring to sub-population at Loveland Pass parking area: "Only a few scattered individuals, all fruiting. Area receives some trampling from hikers."	Colorado Natural Heritage Program element occurrence records. *R. A. Nelson 6390* 1951 COLO, *R. A. Price 232* 1978 COLO, CS
11	Clear Creek	Arapaho National Forest	7/29/1993	Continental Divide above Loveland Ski Area	"Rocky tundra with *Luzula spicata*, *Festuca brachyphylla* ssp. *coloradensis*, *Trifolium nanum*."	With flowers and fruit.	*N. Lederer 4157* COLO

Table 1 (cont.).

Arbitrary number	County	Management authority	Dates observed	Location	Habitat summary	Abundance summary and comments	Source of information
12	Clear Creek	Arapaho National Forest	8/16/1993	Saddle between Squaretop Mountain and Argentine Peak	Gravelly tundra with *Trifolium nanum*.	With fruit.	*N. Lederer 4198* COLO
13	Clear Creek	Arapaho National Forest	8/11/1957; 7/15/1961; 8/15/1962	Mt. Goliath	1961: At about 12,000 feet elevation, trailside, above timberline on open ground 1962: Western exposure. Growing under sheltering overhang of large boulder.	1961: Not abundant.	*R. Werner s.n.* 1957 KHD
14	Clear Creek	State and or/Arapaho National Forest	7/30/1953	Northwest shore of Summit Lake, Mt. Evans, near saddle above Chicago Lakes basin	Among huge boulders.	No information.	Colorado Natural Heritage Program element occurrence records. *W.A. Weber, 8603* 1953 COLO
15	Clear Creek	State and or/Arapaho National Forest	7/13/1963	Below summit of Mt. Evans	No information.	With flowers and fruit.	*G.N. Jones 36724* CS
16	Clear Creek	Pike-San Isabel National Forest	7/28/1993	Vicinity of Epaulet Mountain	1993: Dry tundra. On saddle on 5 percent slope with open exposure. Gravel, derived from granite, soil. Tree, shrub, graminoid, moss/lichen cover all 0 percent. Forb cover 5 percent. Bare ground cover 95 percent. No other species nearby. Elevation: 13,200 feet.	1993: Only a few scattered individuals seen. Size of area covered by population: 1/100 acre. Phenology: all flowering, early fruiting.	Colorado Natural Heritage Program element occurrence records
17	Clear Creek	Arapaho National Forest (available information indicates most likely authority)	7/15/2000	Front Range Gray's Peak. North side of ridge and trail	Precambrian gneiss substrate. North side of ridge and trail in well developed alpine tundra turf community on gentle fell field slope stabilized by *Acomastylis rossii*, *Trifolium nanum*, *Luzula spicata*, *Silene acaulis* ssp. *subacaulescens*, *lidia obtusiloba*, *Eritrichium aretioides*, *Hirculus serpyllifolia* ssp. *chrysantha*, *Festuca brachyphylla*, *Carex rupestris* ssp. *drummondiana*, *Trisetum spicatum*, *Poa glauca* ssp. *rupicola*, *Artemisia scopulorum*, *Draba grayana*, *Erigeron pinnatisectus*.	Obvious yellow sepals, clasping fruit, locally common (>100 plants).	*L. Yeatts 4468 with D. Yeatts* COLO

Table 1 (cont.).

Arbitrary number	County	Management authority	Dates observed	Location	Habitat summary	Abundance summary and comments	Source of information
18	Clear Creek, may extend into Summit	Arapaho National Forest	7/18/1970; 7/22/1993	Area of Gray's Peak and the saddle between Torrey's and Gray's Peak in Arapahoe National Forest	1970: Fell-field with *Trifolium nana*, *Paronychia pulvinata*, *Luzula spicata*. 1978: Saddle between two summits at 13,700 feet. 1978: Along trail edge in fell field or near boulders. 1985: "Against boulder at base of north-facing fell field" 1993: Fell-field saddle. Open light exposure. On dry granite gravel soil ridgetop. Tree, shrub, 0 percent, moss/lichen cover 10 percent, forb cover 30 percent, graminoid cover 10 percent, bare ground cover 40 percent. Associated with *Paronychia pulvinata*, *Draba fladnizensis*, *Draba grayana*, *Selaginella densa*, *Trifolium nanum*, *Lazula spicata*, *Festuca brachyphylla* ssp. *coloradensis*.	1993: A few scattered individuals, 70 % flowering, 40% fruiting, in 1/4 acre. 1985: Rare. Sepals and petals yellow and clinging to fruits.	Colorado Natural Heritage Program element occurrence records. *N. Lederer, 4144* 1993 COLO, *B.E. Willard 70110 with A.N. Zwinger* 1970 COLO
19	Summit	Arapaho National Forest and/or private	August 1997	Ridgeline, near Santa Fe Peak	1997: "Plant population is close to the ridgeline of the Continental Divide in alpine tundra: soil was wet from springs with snow melt above saturating this area. Steep high rocky alpine tundra mountain soil with "cobbly soil and medium sized (and various sized) boulders with pockets of soil." Granite parent materials. The population begins at the base of the saddle and continues up the slope approximately 350 feet. On 15 to 25 percent incline convex-shaped slope with north-northwest aspect. Open aspect. Summer sun is mid morning until sunset, winter sun is late morning until mid afternoon, generally snow free in winter.	1997: 20+ plants were inventoried, with clumps of 10 to over 30 individual flowers, 100 percent in fruit.	Colorado Natural Heritage Program element occurrence records.
20	Summit	Arapaho National Forest	8/22/1997	Growing on south side of Continental Divide between Mt. Edwards to Argentine Pass	1997: "On high alpine tundra slope with dry cobbly soil between various sized boulders. Granite parent material. Slope 15 to 25% incline with concave shape and south aspect .Summer sun is early moring until late afternoon, winter sun is mod-morning until afternoon. Generally snow-free. Plant population is close to ridgeline of the Continental Divide. Tree and shrub cover 0%, forb cover 35%, graminoid cover 15%, moss/lichen cover 10%, bare rock cover 40%. Associated plant community: *Carex rupestis/Lidia obtusiloba*. Other associated species: *Silene acaulis, Acomastylis rossii, Trifolium nanum, Luzula spicata, Artemisia scopulorum, Festuca brachyphylla*."	1997:The population is scattered in the saddle "and covers a minimum area of a quarter mile"	Colorado Natural Heritage Program element occurrence records. *N. Redner s.n.* 1997 COLO, CS

Table 1 (concluded).

Arbitrary number	County	Management authority	Dates observed	Location	Habitat summary	Abundance summary and comments	Source of information
21	Summit	Arapaho National Forest	7/23/1997	Geneva Peak in a saddle on the Continental Divide	1997: On a wind scarred gentle sloping (5 to 15% incline) saddle close to the peak's summit on the Continental Divide in high rocky alpiine tundra mountain. Soil was dry but it is seasonally wet during Spring run-off. Soil surface is gravel, with "cobbly-stony subsurface" derived from granite. Tree, shrub, and moss/lichen cover 0 percent, forb cover 30 percent, graminoid cover 10 percent, bare rock cover 60 percent. Associated plant community: Cushion plant community with areas of wind scars, *Carex rupestris, Trifolium dasyphyllum, Lidia obtusiloba, Paronychia pulvinata, Trifolium nanum, Luzula spicata, Artemisia scopulorum*.	1997: 13 plants inventoried, 100% flowering, 100% starting to fruit. "The population is located where the cushion plants are large enough to have established protected areas. The plant habitat is limited to a small area covering approximately 15 square meters. The plant population seems to cover all suitable habitat in the area."	Colorado Natural Heritage Program element occurrence records. *N. Redner s.n.* COLO, CS
22	Park	Arapahoe National Forest, Mt. Evans Wilderness	8/23/1993	Rosalie Peak	Fell-field with *Silene acaulis, Paronychia pulvinata*.	With flowers and fruit.	*N. Lederer 4238* COLO
23	Park	Bureau of Land Management and/or private	7/15/2000	Mosquito Pass Road to Cooney Lake. Plants on the western bank of the lake, south of the inlet	2000: "Growing in an alpine rock garden."	2000: Approximately 20 plants.	Colorado Natural Heritage Program element occurrence records
24	Grand, may extend into Clear Creek	Arapahoe National Forest	7/13/1999	Front range; Continental Divide ridge between Bobtail Peak and Mt. Nystrom trail (may be within the Vasquez Peak Wilderness)	"Precambrian granite. In gritty gravel and poorly developed soil on south facing fellfield ridge slope of knob 12673 with *Trifolium nanum, Smelowskia calycina, Eremogone fendleri, Paronychia pulvinata, Trisetum spicatum, Mertensia lanceolata, Oreoxis alpina, Selaginaella densa*."	"Flowers and sepals greenish yellow clinging to fruits. Relatively common, local."	*L. Yeatts 4274 with P. Francis* KHD

Biology and Ecology

Classification and description

Systematics and synonymy

Draba is the largest genus of the Brassicaceae or Cruciferae family, commonly known as the mustard family. *Draba* species are found almost worldwide in relatively cooler habitats, at either high elevation or high latitude. There are approximately 350 species worldwide and 104 throughout 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 exunguiculata was originally described as a variety of *D. chrysantha*, namely *D. chrysantha* var. *exunguiculata* (Schulz 1927). Hitchcock (1941) reported *D. exunguiculata* is easily distinguishable as a unique species as are the closely related and sympatric species, *D. crassa* and *D. grayana*. Even though these species grow very near each other, no intergrades have been evident (Hitchcock 1941).

History of species

Georg Engelmann visited Clear Creek County, Colorado during the summer of 1874 chiefly to study the conifers of the region (Ewan and Ewan 1981). Apparently during this time he explored Parry's Peak and made one of the first, or possibly the first, collection of *Draba exunguiculata*. One of the next specimens of *D. exunguiculata* to be collected was by H.N. Patterson in July or August 1885 from "high mountains" in the Gray's Peak vicinity near the headwaters of Clear Creek. The published label information indicating the specimen was found at 1,219 m is apparently in error. This collection, the isosyntype, was examined by Schulz (1927) and remains in the U.S. National Herbarium (for internet address for access to label information see References section). This collection formed the type specimen of C. Leo Hitchcock in 1941. Since this time both amateur and professional botanists have observed this species periodically, but its range has not extended significantly and it remains a taxon unique to the Rocky Mountains of Colorado.

Non-technical description

Draba exunguiculata is a diminutive, low perennial. The taproot is thick only at the top, and the caudex is branched and covered with old leaves and leaf bases. The persistent leaves tend to form thick tufts. The basal leaves are very sparsely hairy with a thin hairy fringe at the margins. They are linear in shape, or somewhat tapering at the point of attachment, and 10 to 25 mm long but only 1 to 3 mm broad. Several stems arise from the basal rosettes and are topped by a cluster of flowers. The stems tend to be decumbent, or lie down, at their base and are 2 to 7 cm tall. There are one to four leaves on the stem, and these are much smaller than the basal leaves. There are five to 20 flowers per flowering stalk (inflorescence). The flower petals are yellow, but they are scarcely longer than the sepals and there are four per flower. The style is 1.0 to 1.5 mm long. The obvious yellow, or greenish-yellow, sepals tend to cling and clasp to the fruit. The fruits or "pods" (silicles) are smooth, hairless, 2 to 3 mm broad, and 5 to 14 mm long. There are 20 to 30 seeds per silicle. The seeds are approximately 0.8 to 1.0 mm in length. This description is taken principally from Rollins (1993) and Hitchcock (1941).

Unlike several other species of *Draba*, including *D. grayana*, the petals of *D. exunguiculata* are clawless. The epithet "exunguiculata" is derived from this feature of the petals. "Unguiculata" means "clawed" in Latin and thus "exunguiculata" means without claws. *Draba crassa* and *D. grayana* are both in close sympatry with *D. exunguiculata* (Price 1979). These species are superficially very similar to each other and the distinguishing features among the three species are described in **Table 2**.

Technical descriptions, photographs, line drawings and herbarium specimens

A detailed technical description and line drawings showing the leaf and fruit characters of *Draba exunguiculata* are in Hitchcock (1941). A line drawing is provided in **Figure 2**. Other comprehensive technical descriptions are published in Schulz (1927), Harrington (1954), Rickett (1973), Rollins (1993), and Weber and Wittmann (2001). A photograph and general description are published in the Colorado Rare Plant Guide (Spackman et al. 1997, Colorado Natural Heritage Program Internet site 2002). In addition, an excellent illustration is in Zwinger and Willard (1996).

Distribution and abundance

Draba exunguiculata is endemic to high elevations in the Rocky Mountains of Boulder, Clear Creek, Grand, Lake, Park, and Summit counties of Colorado (**Figure 2**). In addition, in 1923, one collection was made in an area that appeared to be located in El Paso County (Lee Bonar 45 specimen at Herbarium at University of

Table 2. Distinguishing features of *Draba exunguiculata*, *Draba crassa*, and *Draba grayana* (after Hitchcock 1941).

Characteristic	*Draba exunguiculata*	*Draba crassa*	*Draba grayana*
Root	Thick only at top.	Thick and fleshy (3 to 5 mm).	Not thick.
Basal leaves	10 to 25 mm long, 1 to 5 mm wide, ciliate, sparsely hairy with short, soft hairs and with few long simple hairs.	Fleshy, 20 to 80 mm long, 5 to 10mm wide, hairless except for a few thick cilia.	5 to 15 mm long, 1 to 1.72 mm wide, long ciliate and sparsely hairy with short, simple or forked hairs.
Stems	2 to 7 cm tall, hairless or with very sparse long hairs.	5 to 15 cm tall, quite hairy with short, soft, simple or branched hairs.	2 to 5 cm tall, densely hairy with short simple or branched hairs.
Pedicel (stalk of individual flower)	1 to 5 mm long, hairless or with few simple straight hairs.	5 to 10 mm long, quite hairy with short, soft, simple or branched hairs.	2 to 5 mm long, densely hairy with short, simple or branched hairs.
Petals	3 to 5 mm long, clawless.	4 to 8 mm long.	3 to 4.5 mm long, with claws.
Fruit	5 to 14 mm long, 2 to 3 mm broad.	10 to 14 mm long, 3 to 4 mm broad.	4 to 8 mm long, 2 to 3 mm broad.

Figure 2. Illustration of *Draba exunguiculata*, by Janet Wingate, used with permission.

Colorado), and an undocumented reference was made to occurrence(s) in Routt County (U.S. Fish and Wildlife Service 1978).

Since 1906 approximately 24 documented occurrences have been reported, 16 of which have been observed within the last 20 years (**Table 1**). An occurrence is generally ascribed to a population, which may be composed of two or more sub-occurrences that interact either through pollination or seed dispersal. In some cases an occurrence in **Table 1** may be more accurately described as a sub-occurrence, being part of

a larger population, but there is insufficient information to make an accurate delineation. *Draba exunguiculata* appears to occur in small isolated patches of only a few individuals. Although one report indicated that more than 100 plants were observed and another report indicated that more than 1,000 individuals were estimated east of Loveland Pass, most occurrence data indicate fewer than 20, and often fewer than 10, individuals are distributed amongst several suboccurrences per population (Colorado Natural Heritage Program element occurrence records, U.S. Fish and Wildlife records, Price 1980). Even though two or more sections (one section is 640 acres) may have been examined during a particular survey, plants may be dispersed in sub-occurrences over a range of only 0.04 to 0.1 ha (0.1 to 0.25 acres), or they may be restricted to a single isolated 15 m^2 area. Approximately nine occurrences, or possibly more precisely sub-occurrences, were found within approximately a 117 km^2 area in the Indian Peaks area even though more than double that amount of land had been surveyed (Komárková 1979). The occurrence number in this Indian Peak study is approximate, as not all occurrences were vouchered and one voucher made by Komárková (1979) was subsequently found to be *D. crassifolia* (annotations to collection at the herbarium at the University of Colorado, accession 262678). This situation is an example that suggests observations without vouchers and photographs must be treated with some caution (see Introduction section).

Occurrence data have been compiled from the Colorado Natural Heritage Program, and specimens at the University of Colorado Herbarium (COLO), Colorado State University Herbarium (CS), the Kathryn Kalmbach Herbarium at Denver Botanic Gardens (KHD), the Gray Herbarium at Harvard University (GH), the New York Botanical Garden Herbarium (NY), and from the literature (Schulz 1927, Hitchcock 1941, Price 1979). It must be noted that many, particularly older, records do not have precise location information, and errors may have 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.

Draba species have frequently been misidentified. This appears to be primarily because of two general characteristics of many members of the genus. First, plants are often diminutive in stature, and hair morphology and other minute features can be difficult to discern without a microscope, or at least a hand lens. Therefore, it can be difficult to distinguish one species from another in the field. Second, plants are often in inaccessible locations and sufficiently rare that, at least historically, an inadequate amount of material has been available to characterize a species definitively or to differentiate one species from another (Hitchcock 1941, Rollins 1993). Misidentification may contribute to both under- and over-estimation of *D. exunguiculata*'s rarity.

Population trend

There are insufficient data in the literature, associated with herbarium specimens, or at the state natural heritage programs to determine the long-term population trends. This species appears naturally to occur infrequently, and there is little evidence to suggest that, on a rangewide basis, it is either more or less common at the present time than in the past. Its total range does not appear to have either expanded or contracted significantly since it was first discovered. Few occurrence sites have been visited more than once, and when revisits have occurred, specific abundance data are lacking. Some populations along the Continental Divide National Scenic Trail are likely to have been, or will be, impacted by both trail construction and hiker activity (Schmidt 1995, Yeatts 1999, Yeatts personal communication 2002). In addition, several *Draba* species, including *D. exunguiculata*, along the saddle between Gray's Peak and Torrey's Peak have declined in abundance within the last decade (Yeatts personal communication 2002).

Habitat

Draba exunguiculata is one of the several *Draba* species found in the sub-alpine and alpine tundra zone of the Rocky Mountains. It grows at elevations between 3,566 m (11,700 feet) and 4,267 m (14,000 feet), with the majority of occurrences located between 3,600 m and 4,000 m (**Figure 3**). Where a range was given for an occurrence, the lowest and highest elevations reported were included in the analysis. The ranges reported likely account for the bimodal distribution and the actual distribution more likely fits a bell-shaped curve (**Figure 2**). However, a bell-shaped distribution may also reflect sampling error. The paucity of surveys at high elevations may account for the lower number of observations at high elevations. *Draba exunguiculata* often occurs in narrow sympatry with another rare endemic *Draba* species, *D. grayana*. These species have been found within 0.5 m of each other (Price 1979).

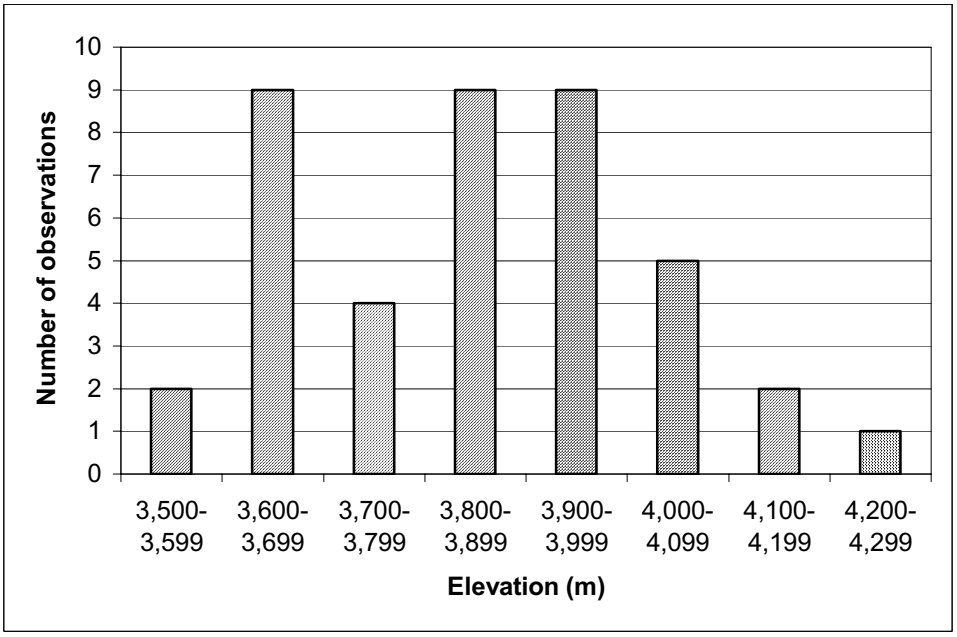

Figure 3. Range in elevation reported for the occurrences of *Draba exunguiculata* in Colorado.

Habitat appears limited to fellfields and gravel or cobblestone soils on both steep and fairly flat slopes. Plants are often associated with a high amount of rock, boulder, or stone cover. Several observers have remarked that they tend to grow under rock overhangs or among boulders, where they likely are afforded protection and a favorable microclimate. For example, because solid rocks have a high heat capacity, they will remain at a higher temperature than the surrounding air throughout the night in open, irradiated habitats (Ellenberg 1988). Generally *Draba exunguiculata* grows on acidic soils with soil pH as low as approximately 4.7 (Price 1979). Igneous, granite, and gneiss parent materials are most common where geology was reported (Price 1979, Colorado Natural Heritage element occurrence records 2002, specimens at University of Colorado Herbarium 2002). However, the species is unlikely to be restricted to acidic soils because one occurrence was reported in the cracks of a limestone rock outcrop (Vierling 181, 1990, specimen at Colorado College Herbarium, in Colorado Natural Heritage element occurrence records). It is found on slopes of less-than-five to fifty percent incline. Observer accessibility may account for plants being most often found on less steep slopes. The exposure is generally open and sunny. Habitat is described as both dry and, less commonly, as seasonally wet or, in one case, seasonally saturated. The aspect also appears to be somewhat variable. Plants have been most frequently reported to grow with aspects facing north and northwest, and less commonly south and west. In addition, the Saxifrago-Claytonian alliance of which *D. exunguiculata* is diagnostic (Komárková 1979) occurs on mesic, northwest-facing sites (Walker et al. 2001).

Draba exunguiculata is a member of cushion plant communities. These low-growing species generally have their highest woody, perennial parts flat on the soil surface and are described as hemicryptophytes according to Raunkiaer's life form system (Raunkiaer 1934). According to Colorado Natural Heritage element occurrence records (2002), specific association types were reported to be *Deschampsia caespitosa/ Acomastylis rossii* (community type AL05, tufted hairgrass/alpine avens in Johnston and Huckaby 2001), *Carex rupestris/Lidia obtusiloba* (curly sedge/ alpine sandwort), and *Trifolium nanum/Lidia biflora* (community type AL12, dwarf clover/alpine sandwort in Johnston and Huckaby 2001). Based on relevés and collections in the Indian Peaks Area, Komárková (1979) described the plant alliance for *Draba exunguiculata* as *Saxifrago-Claytonion megarhizae* where the diagnostic taxa comprised *Sagina saginoides*, *Poa lettermanii*,

Saxifraga rivularis, *Saxifraga cernua*, *Carex albo-nigra*, *Saxifraga platysepala* ssp. *crandalii*[2], *Poa abbreviata* ssp. *pattersonii*, *D. exunguiculata*, *Taraxacum lyratum*, *Barbula brachyphylla* (moss), *Timmia austriaca* (moss), and *Desmatodon systylis* (moss). She found *D. exunguiculata* at nine sites within an approximate 117 km^2 survey area and described it as occasional and limited to the *Saxifrago-Claytonion* habitat type.

Other plant species reported to be associated with *Draba exunguiculata* are listed in **Table 3**. This is not an exhaustive list and represents only the observations that were made on herbarium sheets and in occurrence records.

Numerical estimates of ground cover around the patches of plants were made for eight occurrences, and the mode and average percentage values of each cover class are given in **Figure 4** (raw data obtained from the Colorado Natural Heritage Program element occurrence records 2002). *Draba exunguiculata*'s alpine and sub-alpine environment is devoid of trees and shrubs, and bare ground (including gravels etc.) is often greater that 50 percent of the cover.

Reproductive biology and autecology

Draba exunguiculata flowers from late June through August, and fruits are present from mid-July through August. It is a perennial species. Similar to many other hemicryptophytes, the perennating buds of *D. exunguiculata* are usually protected by old dead leaves and leaf bases. The retention of marcescent leaves is likely to provide insulation from freezing

Table 3. Plant species associated with *Draba exunguiculata*.

Species	Species
Acomastylis rossii	*Luzula spicata*
Arenaria obtusiloba	*Mertensia lanceolata*
Artemisia scopulorum	*Oreoxis alpina*
Carex albo-nigra	*Paronychia pulvinata*
Carex rupestris	*Poa abbreiviata* ssp. *pattersonii*
Carex rupestris ssp. *drummondiana*	*Poa glauca* ssp. *rupicola*
Castilleja occidentalis	*Poa lettermanii*
Draba crassa	*Sagina saginoides*
Draba fladnizensis	*Saxifraga cernua*
Draba grayana	*Saxifraga playsepala* ssp. *crandalii*
Draba streptocarpa	*Saxifraga rivularis*
Eremogone fendleri	*Saxifraga serpyllifolia*
Erigeron pinnatisectus	*Selaginaella densa*
Erigeron simplex	*Silene acaulis*
Eritrichum aretioides	*Silene acaulis* ssp. *acaulescens*
Festuca brachyphylla	*Silene acaulis* ssp. *subacaulescens*
Festuca brachyphylla ssp. *coloradensis*	*Smelowskia calycina*
Geum rossii	*Taraxacum lyratum*
Hirculus serpyllifolia	*Trifolium dasyphyllum*
Hirculus serpyllifolia ssp. *chrysantha*	*Trifolium nanum*
Lidia obtusiloba	*Trisetum spicatum*

[2] *Saxifraga platysepala* ssp. *crandalii* was reported as an associated species by several observers. This name may cause some confusion if only the Colorado Flora (Weber and Wittmann 2001) is consulted because there is a circular naming of synonyms. Weber and Wittmann (2001) indicate that *Hirculus platysepala* (Trautvetter) Weber ssp. *crandalii* (Dandoger) Weber is synonymous with *Saxifraga flagellaris*. Kartesz (1994) indicates that *Saxifraga platysepala* (Trautvetter) Tolm. is synonymous with *Hirculus playsepala* (Trautvetter) Weber, and that *Hirculus platysepala* ssp. *crandalii* is synonymous with Saxifraga flagellaris Willd. ex Sternb. ssp. crandallii (Dandoger) Hultén (*Saxifraga flagellaris* var. *crandallii* (Dandoger) Dorn in Dorn 2001).

Cover class	Percent cover mode	Percent cover average
Total tree cover	0	0
Total shrub cover	0	0
Total forb cover	40	31
Total graminoid cover	10	7
Total moss/lichen cover	10	8
Total bare ground cover	40	54

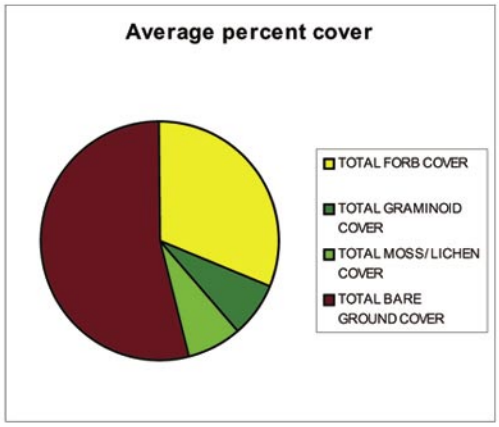

Figure 4. Estimates of percentage cover averaged from eight occurrences of *Draba exunguiculata* (summarized from Colorado Natural Heritage Program element occurrence records 2002). The mode is the most frequently occurring value within a range.

temperatures in alpine environments (Smith 1979, Goldstein and Meinzer 1983). However, some rosette plants, such as *D. chionophila*, which grows up to 4,800 m in the Andes Mountains of Venezuela, are actually intrinsically freeze-tolerant. Freezing injury occurs only when temperatures drop below the temperature at which extracellular ice formation begins (Azócar and Goldstein 1988).

Draba is a reproductively interesting genus as examples of self-fertilization, self-incompatibility, and apomixis have all been reported (Mulligan and Findlay 1970, Mulligan 1976, Brochmann et al. 1992). Apomixis, or "reproduction without fertilization," is relatively common among vascular plants (Grant 1981). In one form of apomixis, adventitious embryony, there is no gametophyte stage, and the embryo is derived from a somatic cell of the ovule. Another form of apomixis is agamospermy, in which seed formation also occurs without fertilization. Interestingly, gametophytic agamospermy, where a morphological gametophyte is present but unreduced, is most common in plants of northern and colder regions. This is apparently the form of agamospermy exhibited by *D. exunguiculata*. Price (1979) reported that *D. exunguiculata* reproduces by apomixis, specifically agamospermy, and that pollen stimulation is not required for apomictic seed production. He demonstrated that seed production per fruit was the same from bagged, emasculated flowers as from flowers that were only bagged. Apomixis in *Draba* is reportedly associated with polyploidy (Mulligan 1976), and apomictic species are often triploid (Grant 1981). The pollen in triploid species often fails to mature normally because the three sets of chromosomes are unable to align effectively during meiosis (Grant 1981). In keeping with these general rules, *D. exunguiculata* is a high polyploid, approximately 14-ploid if the base number is x = 8 (Price 1979). Irregular tetrads with additional tiny cells were very common in all the plants Price (1979) studied. A single population of an apomictic taxa may show little genetic variation, and locally adapted races are likely. Some geographical variability appears to exist for morphological features of *D. exunguiculata*. The plants collected by Lee Bonar (45 at the University of Colorado herbarium) had "unusually well developed petals" as annotated by R. Price, July 1987 (University of Colorado Herbarium specimen accession no. 13287). Several *Draba* species are not exclusively apomictic, exhibiting only facultative agamospermy, and they may reproduce sexually depending upon conditions (Grant 1981). It is not known if this is the case for *D. exunguiculata*. 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).

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 *Draba* species. Brochman et al. (1992) demonstrated that interspecific hybridization across ploidy levels, up to 10-ploid or perhaps 16-ploid, in *Draba* can result in re-establishment of fertility and probably euploid chromosome numbers. They suggest that it is more likely that hybridization will occur between two polyploids rather than between a diploid and a polyploid.

The rate of seed recruitment to the seed bank, seed longevity in the soil, and the extent of seed predation are all unknown. Relative to other species, *Draba* seeds generally are less abundant in the tundra seed bank (McGraw and Vavrek 1989). *Draba exunguiculata* can be propagated by seed, and planting should be in the spring (Slabý 2002). The need for pretreatment was not noted. In general, 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 not known. Being in alpine tundra regions, wind may be effective in dispersing seed although wind-dispersed seeds frequently may move only short distances (Silvertown 1987, Ellenberg 1988).

Demography

Draba exunguiculata is a perennial that reproduces by seed. Its populations appear to be largely comprised of adults. A common observation is that all the plants in an occurrence are flowering or with fruit. Only limited demographic studies have been undertaken, and transition probabilities between the different stages, from seed production to the flowering adult are unknown.

In a one-year, three-location study there was significant variation in the numbers of fruits per plant, seeds per plant and seeds per fruit (Price 1979). There were approximately three or fewer seeds per fruit and from three to 105 seeds per plant (Price 1979). In addition, the data suggested that there was a significant loss of seed-bearing fruit as the growing season progressed. Twenty-one plants were observed with an average of approximately 17 fruits early in the season, but later in the season only six plants were reported to have fruits remaining (Price 1979). Seed set was not reported if the seeds were either dispersed or immature. Therefore, whether this decline was due to earlier fruit maturity and subsequent seed dispersal, fruit immaturity, or actual fruit and thus seed failure, or predation, is not clear. If the latter is the cause, it indicates that significant reproductive effort is expended with little obvious benefit to either the individual plant or to population sustainability. However, seed predation by arthropods is not necessarily bad at levels under which the species has evolved and may be important to long term species sustainability. In some cases it may have had an important influence on population dynamics and diversity. This is at least true within the genus *Astragalus* (Green and Palmbald 1975, Mancuso and Moseley 1993).

A three-year demographic study was made on a perennial, rock-dwelling *Draba* in Idaho, *D. trichocarpa* (Moseley and Mancuso 1991, 1992, 1993). This species grows at somewhat lower elevations (approximately 6,200 feet), and apparently it is not a close relative of *D. exunguiculata*. However, in the absence of information on *D. exunguiculata* or closely related species, the results of this demographic study may be useful for comparative purposes when considering *D. exunguiculata*. Information associated with herbarium specimens and element occurrence records provided by the Natural Heritage Programs report *D. exunguiculata* individuals were either in fruit or flower indicating that seedlings were few or particularly inconspicuous. In the *D. trichocarpa* study non-reproductive and reproductive individuals were stable but the seedling mortality rate was very high (Moseley and Mancuso 1993). 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. In long-lived perennials, seed production may be low, and the most important life cycle components are growth and survival of the adult plants (Silvertown et al. 1993). In this case, assets are clearly allocated to favor the survival of the adult. However, for *D. trichocarpa* the growth and survival of the adult plants appear equally critical to population sustainability even though significant energy is put into flower and fruit production.

This may also be the case for *Draba exunguiculata*. Seed germination and seedling establishment are very sensitive to environmental conditions. The high elevation environment of *D. exunguiculata* has considerable year-to-year variability in the length of growing season that makes yearly recruitment unlikely. This supports the notion that survival of the adult is important. Experimental evidence indicates that for many alpine species with high seed production and good seed germination rates, few seedlings are able to develop

and mature because there is a paucity of sites suitable for plant establishment, even on expansive scree and gravelly slopes (Ellenberg 1988). In fact, most alpine species have a long-lived stage in their life cycle (Johnston and Huckaby 2001). High annual seed production may be a buffer against the vagaries of the alpine environment and high seedling mortality. The potential high seed production of *D. exunguiculata* may be a characteristic of a ruderal species, but current evidence suggests that *D. exunguiculata* 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 few facts available pertaining to the life cycle of this species, and speculation is accepted as a poor substitute for facts. A simple life cycle model of *Draba exunguiculata* is diagrammed in **Figure 5**. Heavy arrows indicate 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 "?" 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.

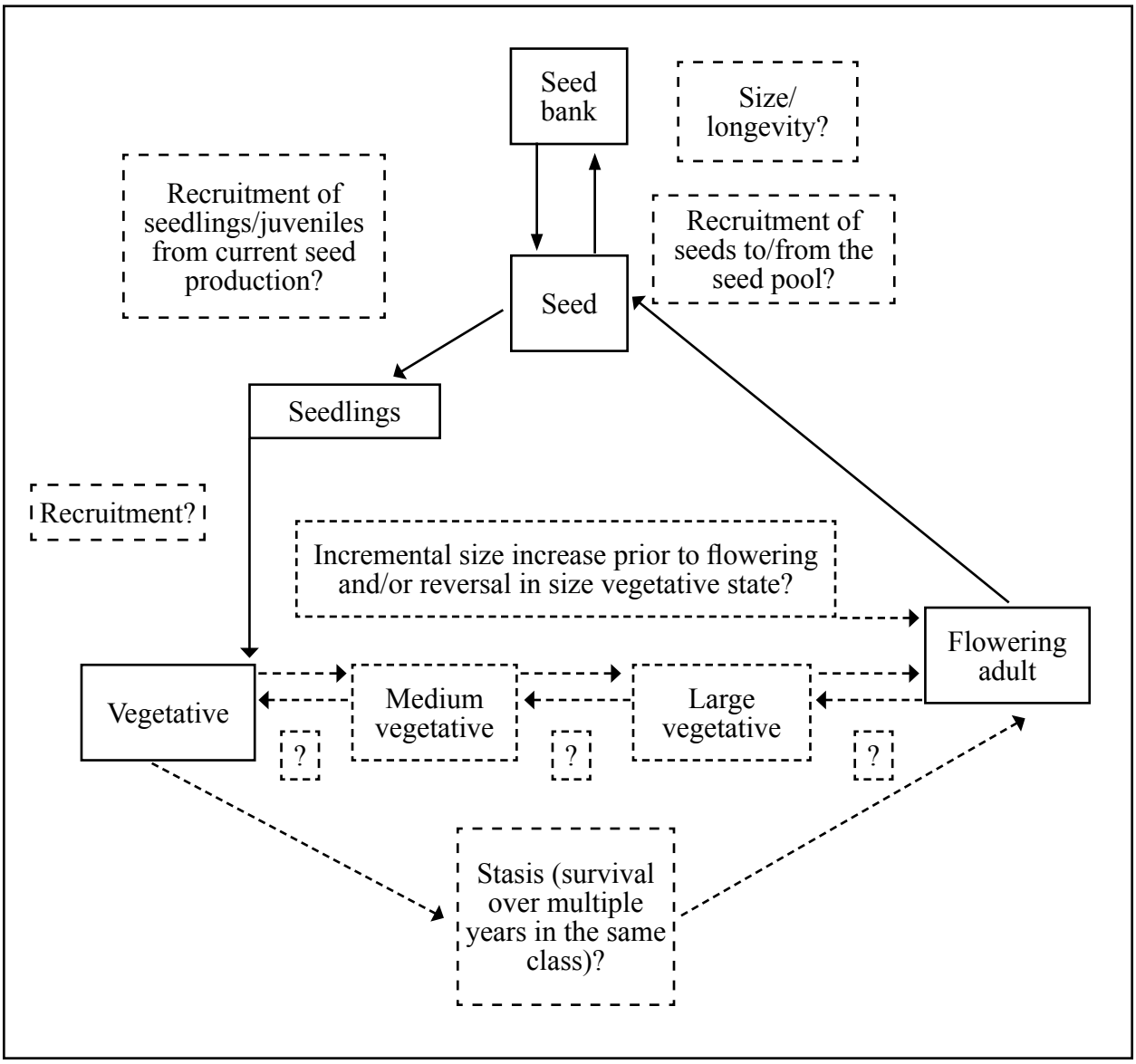

Figure 5. Life cycle diagram for *Draba exunquiculata*. Dotted lines indicate these are stages that need clarification.

It is likely that environmental conditions, for example moisture, have a primary effect on plant size. Limits to population growth are not defined.

Population viability analyses for this species have not been undertaken. Apomictic taxa may be thought to be at an evolutionary disadvantage, but many purely asexual taxa, for example dandelions (*Taraxacum officinale*), 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 prevents genetic depauperation in the arctic *Draba*. In the case of *D. exunguiculata* 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. exunguiculata* often exists in very small patches, or rather as a subdivided population. It is unknown if there is a balance of frequent local extirpations and colonizations within a colonized area or whether, once established, microsites are occupied for long periods of time.

Community ecology

There is little information on the interactions between *Draba exunguiculata* and the ecosystem to which it belongs. Interactions with the fauna of its associated community, for example the role of arthropods or pikas in potential herbivory, seed dispersal, or seed predation have not been documented. Pikas also store vegetation, and this activity may contribute to seed dispersal. Associated mosses and lichens have not been specified other than those described by Komárková (1979) in the *Saxifrago-Claytonion megarhizae* alliance. In this alliance, three of the 12 diagnostic taxa were mosses. The association between *D. exunguiculata* and moss may be significant and contribute to its the patchy distribution. A high moss cover would significantly influence the micro-environment, particularly the soil moisture, at a site. Moss retains water and may provide a moister substrate-water balance than exposed micro-sites. On the other hand, competitive interactions can also potentially exist between different species. There is, however, insufficient information to speculate further on the interactions between *D. exunguiculata* and associated species. Both abiotic factors, such as soil pH, and biotic factors control the species pool at any given site (Gough et al. 2000). Many factors must be taken into account when studying local co-existence and speculation based solely on casual observation may lead to misconceptions.

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 exunguiculata* make up the centrum, and the indirectly acting components comprise the web (**Figure 6** and **Figure 7**). Factors in the web are causally related to the factor in the centrum and indicated as such by n = 1, 2 *ad infinitum*. Unfortunately, much of the information to make a comprehensive envirogram for *D. exunguiculata* is unavailable. The envirogram in **Figure 6** is constructed to outline some of the components that appear to directly and favorably impact the species; these are termed resources. As mentioned above, there is a lack of direct studies on this species, and this 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.

This species appears to occur in small patches, and a typical population is also likely to be composed of relatively few individuals (see Distribution and abundance section). The causes of the rarity are unknown although limitations in suitable microhabitat niches may be a contributing factor. It appears that *Draba exunguiculata* favors more environmentally harsh and sparsely vegetated sites, such as gravel slopes and ridgetop fellfields (Williams et al. 1986). In fact, this species may be a sufficiently poor competitor, only able to successfully colonize areas with low vegetation cover. Conversely, the species does not appear to be limited by narrow edaphic requirements. Boulders or rocky outcrops have been listed as resources, as it has been speculated that they provide suitable microhabitat conditions (see Habitat section; Colorado Natural Heritage Program element occurrences records 2002). Wind is speculated to contribute to seed dispersal. Disturbance from slides initiated by snow pack and precipitation may also aid seed dispersal, although there is no evidence to suggest that this is a primary method of dispersal. Fellfield habitats of this species typically do not accumulate deep snow cover, partly because of the frequent high winds experienced at these exposed, high-altitude sites. It can

only be theorized that the patchy nature of its distribution is influenced by natural disturbance, or a lack thereof. Disturbance may contribute to opening up microhabitat sites or, alternatively, a lack of disturbance may provide stable habitat for long-lived adults. Pollinators for sexual reproduction have not been included because current evidence indicates that the species is primarily, if not solely, apomictic.

CONSERVATION

Threats

Natural catastrophes and environmental stochasticity are likely the primary threats to *Draba exunguiculata* at the rangewide scale. Few comments can be made on the influence of "demographic stochasticity" on individual populations because there is no information on the survival probability of individuals at any given life-stage or age (see Demography section).

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

It is generally assumed that there are few threats to *Draba exunguiculata* because of its largely inaccessible habitat. However, at the level of individual populations, several specific threats have been identified. Activities associated with recreation, mountain goat disturbance, mining, and over-collection are all potential threats. Although areas where *D. exunguiculata* occurs tend to be remote, many are affected by anthropogenic

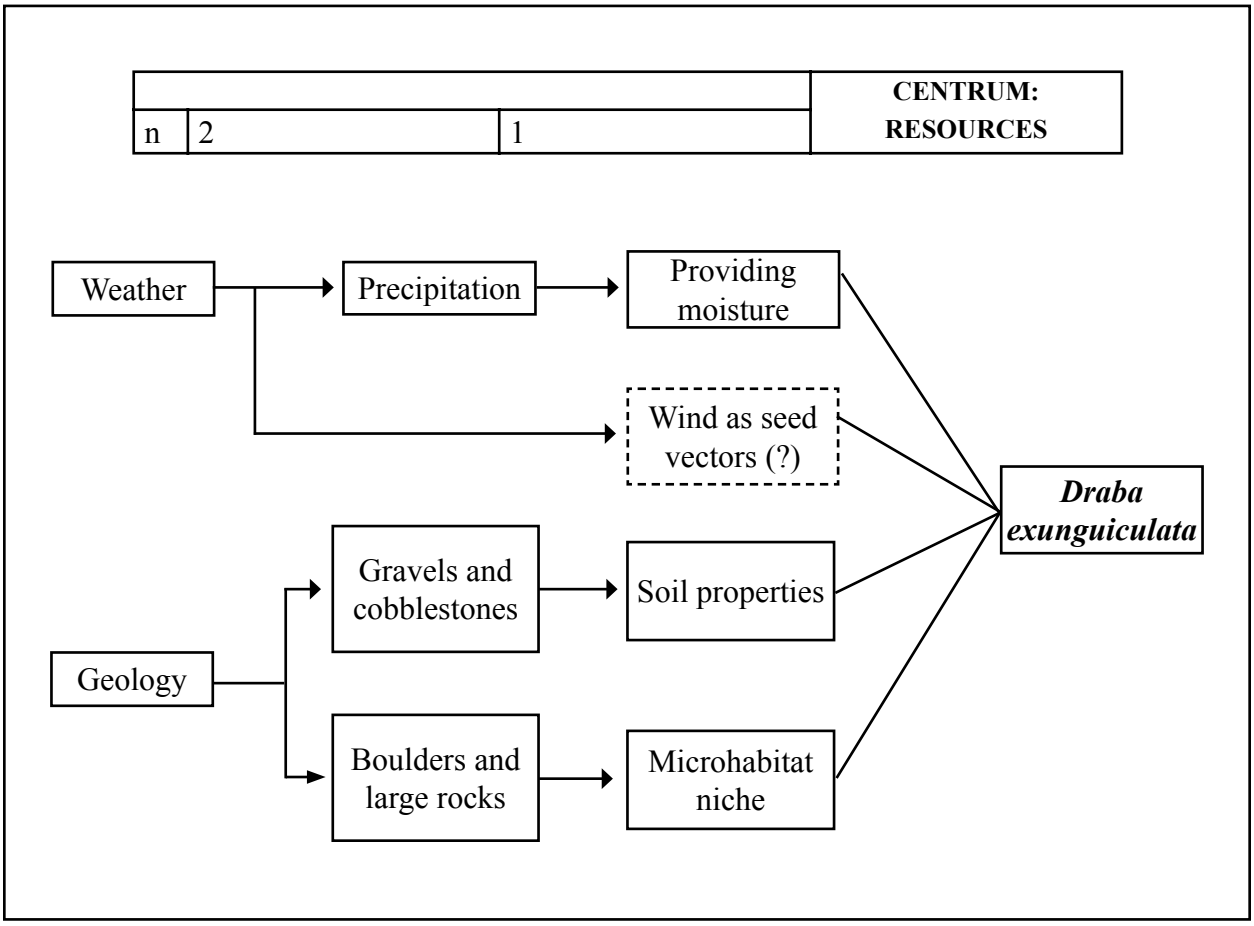

Figure 6. Envirogram of the resources of *Draba exunguiculata*. A dotted line indicates the factor is a speculative resource. Factors in the web are indicated as related to the factor in the centrum by n = 1, 2 *ad infinitum*.

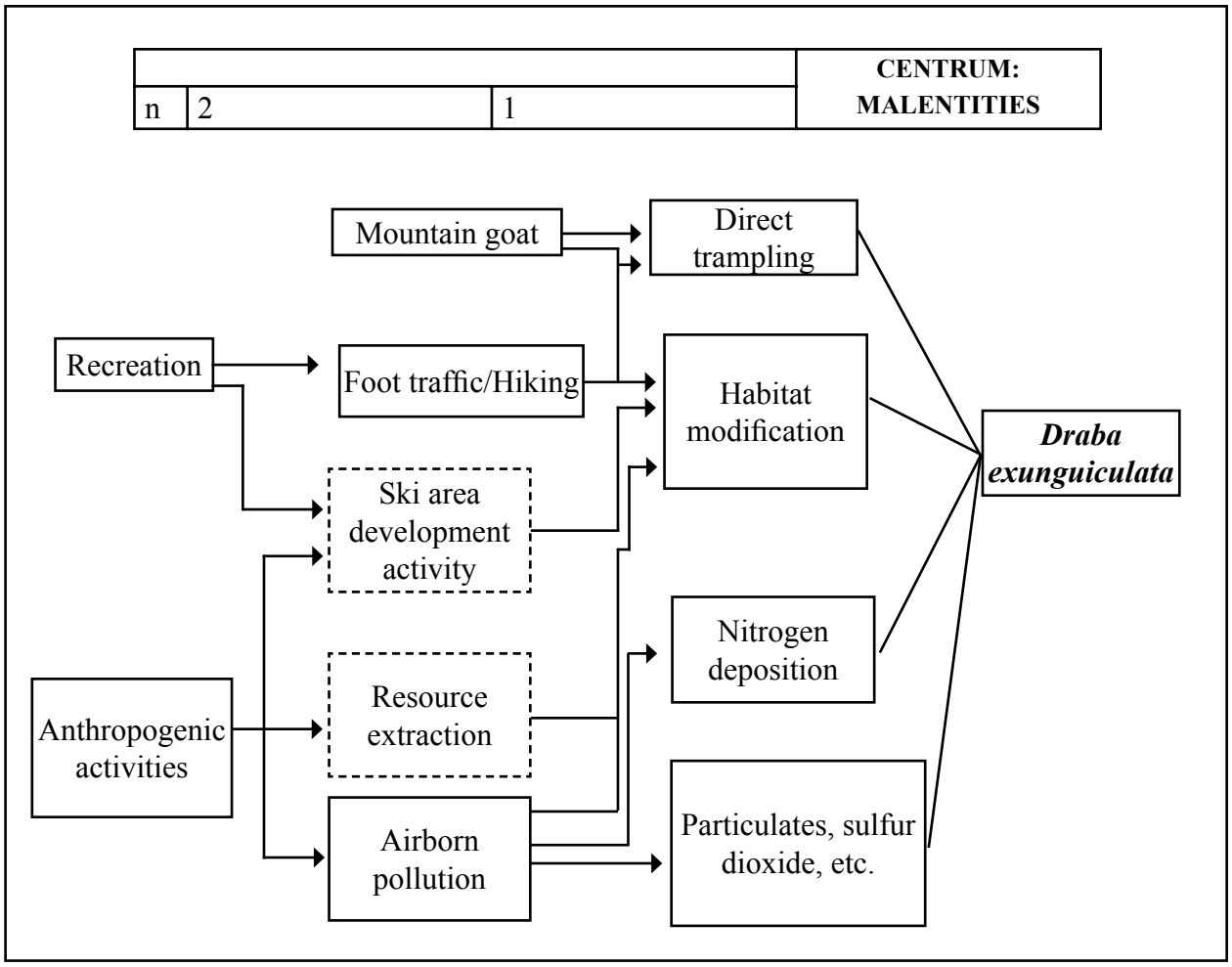

Figure 7. Envirogram outlining the malentities to *Draba exunguiculata*. A dotted line indicates the factor is not a well-documented malentity. Factors in the web are indicated as related to the factor in the centrum by n = 1, 2 *ad infinitum*.

activities. Foot traffic is a significant threat in many areas. Off-trail hiking in the vicinity of busy trails, such as the Continental Divide Trail, is of particular concern. One known occurrence site (number 10 in **Table 1**) in the Arapaho National Forest in Region 2 is at a parking lot, and several other occurrences (i.e., numbers 9, 16, 18, 19, 20 in **Table 1**) are within popular hiking areas; and thus, are particularly vulnerable to hikers tramping across occupied, as well as potential, habitat. Impacts from mountain bicycles are also a concern in some areas. Utility lines and roads, particularly in and near ski areas, may impact certain populations. Ski areas are established throughout the range and habitat of *D. exunguiculata*, but the impacts of skiing and related maintenance and construction activities have not been documented. Another potential threat, especially in areas within easy reach of urban centers, is the over-collection of desirable rock garden species, such as *Draba*, by amateur and professional gardeners (Williams et al. 1986, USDA Forest Service 2001).

Introduced mountain goats have been reported to be a threat to some populations of *Draba exunguiculata*, particularly those around Gray's Peak on land managed by the USDA Forest Service, Region 2 (Colorado Heritage Program element occurrence records 2002, Yeatts personal communication 2002). Trampling by mountain goats, rather than browsing or grazing, is cited to be the particular problem. In recent years, the number of mountain goats killed by hunters has increased significantly, which suggests that mountain goat populations are increasing in size (Colorado Division of Wildlife 2001). It may be a concern that one of the areas in which the increases in mountain goat population size were most noticeable was Gray's Peak.

Mining activities may have affected some *Draba exunguiculata* populations in areas that have been exploited for their rich mineral deposits, for example occurrence number 19 in **Table 1**. However, there are no confirmed instances where mining has directly impacted populations and it is therefore unknown what the consequence of past mining activities has been to the overall abundance of the species. Mining at the current levels appears to present no problems, as there are large tracts of suitable habitat that should be unaffected by current mining activities.

The competitive ability of *Draba exunguiculata* is likely low considering the habitat to which it is adapted. Invasive weeds such as yellow toadflax (*Linaria vulgaris*), spotted knapweed (*Centaurea biebersteinii*), and scentless chamomile (*Matricaria perforata*) have all been reported at or above the treeline and are potential threats to endemic alpine species (Ray 2001). When considering community types over a wide region, high elevation sites can be likened to virtual islands (see Systematics and synonymy section). Unfortunately, one important difference between true islands, those surrounded by large expanses of water, and high elevation habitats is that the latter are separated by lands that are inhabited by a multitude of potential competitors that may have many opportunities for colonization (MacArthur and Wilson 1967).

A significant threat to alpine tundra plants is global climate change. Warming could affect alpine areas, causing tree lines to rise by roughly 350 feet for every degree Fahrenheit of warming. Mountain ecosystems such as those found in the Rocky Mountains could shift upslope, reducing habitat for many sub alpine and alpine tundra species (U.S. Environmental Protection Agency 1997). In the last one hundred years the average temperature in Fort Collins, Colorado, has increased 4.1 °F, and precipitation has decreased as much as 20 percent in many parts of the state (U.S. Environmental Protection Agency 1997). Based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), a model that accounts for both greenhouse gases and aerosols, by 2100 temperatures in Colorado could increase by 3 to 4 °F in spring and fall, with a range of 1 to 8 °F, and 5 to 6 °F in summer and winter with a range of 2 to12 °F (U.S. Environmental Protection Agency 1997).

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 when compared with the rest of the West (Baron 2001). Wet nitrogen deposition occurring in the high mountain areas of the Colorado Front Range is high enough to cause chemical and ecological change (Baron et al. 2000, Baron 2001, Rueth and Baron 2002). Experiments have indicated that nitrogen additions in alpine tundra influence the species composition of the community (Bowman et al. 1993, Theodose and Bowman 1997). Grasses particularly increased 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 deposition will have a detrimental impact on *Draba exunguiculata*, especially in its dry meadow habitats. Given the remote locations of most occurrences, other forms of pollution are probably not a threat. However, a study sponsored by the Colorado School of Mines, the National Park Service, and the Public Counsel of the Rockies analyzed the chemical content of snow near a snowmobile route (Skid Marks Newsletter 2000, Ray 2001). It reported "an unnatural level of pollution", and at least 20 hydrocarbon compounds, some toxic and carcinogenic, were located 50 feet above the snowmobile route. The significance of this finding to the sustainability of plant populations that are located near such routes cannot be evaluated without further information.

In general, the threats to *Draba exunguiculata*, including those concerned with global climate change, are largely dependent upon the extent and intensity of the activity and the habitat restrictions of the species. At the present time, all threats appear to be at either low or manageable levels. However, the emphasis is on current levels. Impacts from recreational pressures are becoming increasingly apparent. For example, thousands of people are estimated to walk in the alpine tundra regions in Colorado each weekend during the spring, summer, and autumn (Morrow 2002). On one trail alone, 250 people were counted on one weekend day and 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 averse to following designated trails to the extent that trail markers were destroyed. Alpine tundra systems are relatively fragile and are not able to recover rapidly from destructive forces. After 40 years of disuse, one two-track trail has remained clearly defined and without vegetation in the alpine tundra of the Rocky Mountain National Park (Willard 1979). In addition, the potential colonization

by invasive and competitive plant species that will be exacerbated by anthropogenic disturbances and warming temperatures should not be underestimated.

While the envirogram in **Figure 7** outlines some of the known and potential threats, it must be noted that, at the current time, malentities and threats are not well defined. In summary, disturbance either directly, such as by trampling by hikers or mountain goats, or indirectly, such as a force contributing to soil erosion and habitat destruction, is deleterious and may be the primary threat on land managed by the USDA Forest Service in Region 2. Air pollution has been included in the envirogram because it is a significant threat to the Front Range of the Rocky Mountains in Colorado (Baron 2001, Tonnessen 2001). Invasive weed species that would directly compete for resources such as water, nutrients, and light have not been reported at any of the recorded occurrences although several species of noxious weed have been reported above the treeline (Ray 2001). However, invasive plant species have not been included in the envirogram because significant impact from known invasive species appears slight at the present time. Both the extent and duration of all malentities are important factors and need further study.

Conservation Status of the Species in Region 2

There is no evidence that the distribution or abundance of *Draba exunguiculata* is changing. The majority (at least 17 and possibly 21 out of 24) of the known occurrences occur on land managed by Region 2 of the USDA Forest Service (**Table 1**). It appears relatively rare in all parts of its range. However, within the Gray's Peak area on the Arapaho National Forest it is locally quite common.

Within Region 2 at the present time, there appear to be several populations that are relatively secure because of specific designation of land management unit, for example wilderness status, or due to its remote location; but there are also several occurrences that are impacted by recreational activities and mountain goats (see Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies section and Threats section).

Management of the Species in Region 2

Implications and potential conservation elements

Existing management plans have not specifically addressed this species. One problem is that there is little information on which to base predictions about its response to specific disturbance types or levels. The alpine tundra ecosystem is fragile, in that it is slow to recover from disturbances. Off-trail hiking, trail erosion, and gully formation are significant concerns. It is likely that some practices, such as mining and certain recreational activities, have impacted some populations. The habitat colonized by *Draba exunguiculata* appears to be relatively stable, but the cumulative impacts from disturbance, such as foot traffic and mountain goats, are unknown. Apparently, *D. exunguiculata* has evolved with another large mammal, bighorn sheep (*Ovis canadensis*), whose numbers were kept in check by predators. However, mountain goats were introduced into the Rocky Mountains of Colorado in the 1940s, and the long-term consequences of interaction between them and rare native plant species is difficult to assess. The absolute number and range of these co-existing species are important considerations, but sustainable population sizes cannot be estimated without further information.

Sustainability of *Draba exunguiculata* is likely to rely on relatively long-lived mature individuals, and thus management practices that increase either the frequency or intensity of natural perturbations, or provide additional stresses may significantly negatively impact population viability. The growing season is very short, and environmental conditions can be severe. Thus recruitment of individuals is unlikely to be a yearly event at all occurrences. This species' ability to tolerate competition is speculated as being very low, and it is likely to be good management practice to eliminate non-native invasive species swiftly.

Draba exunguiculata is apomictic, but its genetic vulnerability is unclear (see Demography section and Reproductive biology and autecology section). It is likely that the most geographically separated populations will have the greatest genetic divergence, and a significant loss of genetic diversity will result if populations at the edge of the range, or in obviously disjunct localities, are lost. Commercial collection on National Forest System lands and the value of permitting regulations to track the impact on accessible populations are important considerations when planning management guidelines.

Tools and practices

Documented inventory and monitoring activities are needed for this species. Most of the occurrence information is derived from herbarium specimens or relatively casual observations by botanists and does not provide quantitative information on abundance or spatial extent of the populations. In addition,

there is little information on population structure and persistence of either individuals or populations.

Species inventory

Relatively little information has been collected on *Draba exunguiculata*. An important consideration in inventorying this particular species is that it may be easily confused with other species. It is also essential to remember during field identification that *D. exunguiculata* grows in close association with other species of *Draba*. For example, it has been described growing within 0.5 m of *D. grayana*, *D. steptocarpa*, and *D. crassa*. The current field survey forms for endangered, threatened, or sensitive plant species that are used by the Gunnison National Forest and the Colorado Natural Heritage Program both request the collection of data that is appropriate for inventory purposes. The number of individuals, the area they occupy, and the apparent potential habitat are important data for occurrence comparison. The easiest way to describe populations over a large area may be to count patches, making note of their extent, and estimate or count the numbers of individuals within patches. Collecting information on phenology is also valuable in assessing the vigor of a population. Observations on habitat should also be recorded. In addition, habitat differences may assist in alerting the observer that more than one species of *Draba* is present. At an occurrence site at Loveland Pass, although *D. crassa* and *D. exunguiculata* were in very close proximity, *D. crassa* was found on rocks while *D. exunguiculata* was found on gravel (Hitchcock 1941).

Habitat inventory

The available information on habitat supplied with descriptions of occurrences is generally too diverse and insufficient in detail to make accurate analyses. These habitat descriptions suggest that, within the restrictions of the eco-climate zones in which it exists, this species grows in fellfields and a variety of gravelly habitats. Thus, it would likely be prudent to consider essentially any fellfields or gravel slopes in alpine regions above 3,500 m as potential habitat. However, there is an insufficient understanding of all the features that constitute "potential" habitat to be able to make a rigorous inventory of areas that can actually be colonized. For example, no sites with an eastern aspect have been reported so far, but without a deliberate and comprehensive study it is premature to exclude such sites. There are no studies that relate the abundance or vigor of populations to habitat conditions or even elevation. The patchy and sparse distribution pattern of *Draba exunguiculata* suggests that certain microclimate conditions need to be met to support plants, but these conditions are currently unknown.

Population monitoring

No monitoring or demographic studies of *Draba exunguiculata* have been reported. It is very important to clearly define the goals of any monitoring plan and to identify the methods of data analyses before the beginning of the project. The time commitment per year will depend on the protocols adopted, the skill of the surveyor, and the distance between monitoring plots.

Lesica (1987) has discussed a technique for monitoring non-rhizomatous, perennial plant species using permanent belt transects. He also described life stage or size classes and reproductive classes that would be appropriate to consider for *Draba exunguiculata* (Lesica 1987). Moseley and Mancuso (1991, 1992, 1993) successfully employed such methods when studying the population structure over time of *D. trichocarpa*. Permanent transects may be the most accurate way to study long-term trends. Elzinga et al. (1998) and Goldsmith (1991) have discussed using a rectangular quadrat frame along transect lines to effectively monitor the "clumped-gradient nature" of populations. This method would apply to the most abundant populations *D. exunguiculata*. 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 and no replacement occurs it is impossible to know the significance of the change without studying a very large number of similar plots.

An effective method for population monitoring and determination of demography is to tag individual plants for an annual, or more frequent, census. Measures such as plant diameter, number of leaves, and flower and fruit number are all useful in evaluating the vigor and fecundity of a population (Price 1979). However, on a scree slope this type of detailed study may not be appropriate because of the potential for disturbance. It is very important not to contribute to either direct or indirect (for example accelerated erosion) disturbance when monitoring occurrences. Photopoints and photoplots are very useful in visualizing changes over time, especially in places such as steep talus/scree slopes that are relatively inaccessible and/or can easily be disturbed by monitoring activities. Even though digital copies are convenient and easy to store, for example on CDs, many museums and researchers suggest storing

additional slides or even hardcopies, as in 50 years time the technology to read memory sticks and CDs may no longer be available.

Habitat monitoring

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

Population or habitat management approaches

There have been no systematic monitoring programs for the populations in protected areas, and therefore the benefits of protection cannot be evaluated. Beneficial management practices that have been generally implemented within national forests include restricting recreational vehicle traffic and routing hikers to designated trails. In many cases, such policies have been relatively recently initiated and their consequences have not been documented. Creating designated trails is particularly important to some known populations that are on heavily used routes, for example, the Continental Divide Trail on land managed by USDA Forest Service Region 2. It would be very useful to obtain baseline information on the distribution and abundance of the populations there and then monitor them at yearly, or at least three year, intervals. As well as providing information on how trail management impacts the species, such monitoring would aid in understanding the spatial dynamics of individuals and populations. Another example where monitoring may have helped assess the consequences of a particular management decision was along Colorado Highway 5 where occurrences of *Draba exunguiculata* had been reported. A withdrawal of mineral rights was established along the roadside of a portion of Highway 5 in Clear Creek County on August 30, 1965. The impact of this restriction on *D. exunguiculata* occurrences has not been documented. Documented detailed observations on the abundance of individuals in this area before as well as after the management decision could have provided information to assess the value of such a measure. It is absolutely essential in these circumstances to know the abundance and spatial distribution of individuals prior to the action or decisions that are implemented.

Information Needs

The most pressing need is for more information on the numbers and distribution of this species. The present knowledge of its distribution indicates that it has a relatively narrow range, and although it may be locally quite common in a few locations it is otherwise rare throughout its range. While the current evidence indicates that it is naturally a rare species, its perceived rarity may be due to a lack of surveys or because it has often been overlooked or misidentified in the field. Monitoring pre-existing sites, for example those located along the Continental Divide Trail, is essential in order to understand the implications of existing and new management practices. Where management practices are likely to change, inventory should be taken to collect baseline data and periodic monitoring conducted after the new policy is initiated. Similarly, if disturbance levels are anticipated to increase, for example by an increasing mountain goat density, only monitoring will reveal the impact. Therefore, inventory of new sites and periodic monitoring of existing sites appear to be equally important.

Habitat requirements of *Draba exunguiculata* need to be more rigorously defined to appreciate the extent of potential habitat. It is unclear what constitutes optimal or unsustainable habitat. The spatial dynamics of populations are unknown. It is known that this species colonizes relatively stable habitats, but the rate at which it does so is not known. The rate of colonization and the extent of potential habitat influence how populations recover after significant disturbance, for example activities related to mining or ski area development as well as localized trampling. The relative importance of different stages in the life cycle needs to be clarified. The factors that limit population size and abundance and that contribute to the variable occurrence sizes are not known and should be determined. Because the rate of recruitment is unknown, the impact of extirpating, or reducing the size, of individual populations cannot be estimated.

In summary, information needs include:

- Further inventory of new sites
- Periodic monitoring of existing sites
- Critical assessment of habitat requirements
- Knowledge of rates of colonization or recolonization especially after anthopogenic and mountain goat disturbance

DEFINITIONS

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

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

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

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

Diploid — An individual with two chromosome sets in each cell; a diploid state is written *2n* to distinguish it from the haploid state of *n*.

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

Euploid — An individual composed of cells having any number of complete chromosome sets.

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

Herbarium abbreviations:

COLO = Herbarium, University of Colorado, Boulder, Colorado

CS = Herbarium, Biology Department, Colorado State University, Fort Collins, Colorado

GH = Gray Herbarium, Harvard University, Boston, Massachusetts

KHD = Kathryn Kalmbach Herbarium, Denver Botanic Gardens, Denver, Colorado

NY = New York Botanical Garden Herbarium, New York, New York

Isosyntype — A duplicate of the syntype.

Marcescent — Dry and persistent; withering but not falling off, as a blossom that persists on a twig after flowering (The American Heritage Dictionary of the English Language. 2000. Fourth Edition. Houghton Mifflin Company, Boston, Massachusetts).

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

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

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

Scree — Scree is comprised of rocks the size of a fist or smaller, down to gravel size, and also offers little in the way of secure footing, especially when the gravels are ankle deep (Zwinger and Willard 1996). "A term commonly used in Great Britain as a loose equivalent of talus; it may also include any loose fragmental material lying on or mantling a slope." (Bates and Jackson 1984).

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

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

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

Syntype — Any of two or more specimens listed in the original description of a taxon where the holotype was not designated.

Talus — "Talus slopes are composed of rocks the size of a fist or larger, usually sharp and loose" (Zwinger and Willard 1972). "Rock fragments, usually coarse and angular, lying at the base of a cliff or steep slope from which they have been derived; also, the heap or mass of such broken rock, considered as a unit. Synonym: scree" (Bates and Jackson 1984).

Commonly Used Synonyms of Plant Species

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

Carex albo-nigra	*Carex albonigra* (Weber and Wittmann 2001)
Eritrichium aretioides	*Eritrichum aretioides* (Weber and Wittmann 2001)
Geum rossii	*Acomastylis rossii* (Weber and Wittmann 2001)
Hirculus serpyllifolia ssp. *chrysanthus*	*Saxifraga chrysantha* (Weber and Wittmann 2001)
Saxifraga serpyllifolia	*Hirculus serpyllifolius* (Kartesz 1994)

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