# *Ranunculus karelinii* Czern. (ice cold buttercup): A Technical Conservation Assessment

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

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## Cover Photo Credit

A close-up of *Ranunculus karelinii* (ice cold buttercup). Photograph by Mike Figgs. Used with permission.

# SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *RANUNCULUS KARELINII*

## *Status*

*Ranunculus karelinii* Czern. (ice cold buttercup) is a small and inconspicuous member of the Buttercup family (Ranunculaceae). It has short stems that support flowers with small, yellow petals. This widespread species of *Ranunculus* is known from arctic regions and high mountain peaks throughout the northern hemisphere, including Asia, Canada, and the United States. The distribution of *R. karelinii* in the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS) is limited relative to its global range; it is found in 21 locations in Wyoming and Colorado. The total number of plants in Region 2 is estimated to be fewer than 500, covering less than 21 acres; however, information on population size and extent is not well documented. It is likely that more occurrences will be found by additional searches.

*Ranunculus karelinii* is ranked globally secure (G4G5) by NatureServe. The Colorado Natural Heritage Program ranks this species imperiled (S2), and Wyoming Natural Diversity Database ranks it critically imperiled (S1). USFS Region 2 has designated *R. karelinii* a sensitive species.

Of the 21 occurrences of *Ranunculus karelinii* in Region 2, at least fifteen are on National Forest System lands. This species has also been documented on private lands in Region 2; one occurrence is entirely on private land, and five others have locational information that is too imprecise to determine ownership. At least one occurrence may include public lands administered by the Bureau of Land Management.

## *Primary Threats*

Observations of *Ranunculus karelinii* in Colorado and Wyoming indicate that although there are threats to the persistence of this species in Region 2, the severity and extent of the threats are moderate to low. Potential threats include the effects of small population size, global climate change, motorized and non-motorized recreation, grazing, exotic species invasion, mining, and pollution.

## *Primary Conservation Elements, Management Implications and Considerations*

Despite its rarity within Region 2, *Ranunculus karelinii* occurs on lands administered by six national forests (Arapahoe-Roosevelt, Gunnison, Pike-San Isabel, Uncompahgre, and White River national forests in Colorado; the Shoshone National Forest in Wyoming). Eight occurrences have some protection in the Collegiate Peaks Wilderness Area, the Buffalo Peaks Wilderness Area, and the Big Blue Wilderness Area in Colorado, and the North Absaroka Wilderness in Wyoming.

Research is needed to better understand threats to the persistence of *Ranunculus karelinii* in Region 2, and threat mitigation is needed to prevent the loss of occurrences. Further inventory for this species is a high priority and is likely to locate new occurrences. Research is needed to clarify the population biology and autecology of *R. karelinii* so that conservation efforts on its behalf can be most effective.

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# INTRODUCTION

This assessment is one of many being produced by the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Ranunculus karelinii* is the focus of an assessment because it has been designated a sensitive species in Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (FSM 2670.5(19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *R. karelinii* throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

## *Goal of Assessment*

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

## *Scope of Assessment*

The assessment examines the biology, ecology, conservation status, and management of *Ranunculus karelinii* with specific reference to the geographic and ecological characteristics of Region 2. Although some, or even a majority, of the literature on the species may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *R. karelinii* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies and other investigators were reviewed. Other than the original published description, there are no peer-reviewed publications devoted to *Ranunculus karelinii*, but it is mentioned in a few sources. Given the paucity of basic research on many facets of the biology of *R. karelinii*, literature on its congeners was used to make inferences. The refereed and non-refereed literature on the genus *Ranunculus* and its included species is quite extensive, so we focused on the literature available on species closely related to *R. karelinii*, especially *R. adoneus* and *R. acris*. All known publications on *R. karelinii* are referenced in this assessment, and many of the experts on this species were consulted during its synthesis. Specimens were viewed at RM (Rocky Mountain Herbarium), COLO (University of Colorado Herbarium), CS (Colorado State University Herbarium), KHD (Kalmbach Herbarium, Denver Botanic Gardens), and GREE (University of Northern Colorado). The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were regarded with greater skepticism, but they were used in the assessment since very little refereed literature specifically addresses *R. karelinii*. Much of the information about past and current conditions affecting *R. karelinii* was compiled through conversations with land managers and other agency employees. For an unstudied species such as *R. karelinii*, these personal communications constitute an important body of knowledge that can provide a baseline for more formal investigations. Unpublished data (e.g., Natural Heritage Program records, specimen labels) were important in providing historical information.

## *Treatment of Uncertainty in Assessment*

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and observations 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 strong experiments that produce clean results in the ecological sciences. Often, observations, inference, good thinking and models must be relied on to guide our understanding of ecological relations. Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

### *Treatment of This Document as a Web Publication*

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

### *Peer Review of This Document*

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

## Management Status and Natural History

### *Management Status*

*Ranunculus karelinii* was added to the list of sensitive species in Region 2 during the revision of the document released in November 2003. This species is found on six national forests in Region 2: the White River, Pike-San Isabel, Arapaho-Roosevelt, Gunnison, and Uncompahgre national forests in Colorado, and the Shoshone National Forest in Wyoming. It also occurs on private land and may occur on lands administered by the Bureau of Land Management (BLM). It is not included on the Colorado or Wyoming Sensitive Species lists maintained by the BLM state offices. It has not been documented on state lands within Region 2, nor is it recognized by any Colorado or Wyoming State legislation. It is not included on the U.S. Fish and Wildlife Service Endangered Species list.

NatureServe (2004) considers *Ranunculus karelinii* to be globally secure (G4G5). It is considered imperiled (S2) in Colorado where it is known from only 17 very small occurrences, each of which contains between five to fifty individuals (Colorado Natural Heritage Program 2005). *Ranunculus karelinii* is considered critically imperiled (S1) in Wyoming because it is known from five occurrences in the state (four in Region 2) and very little information is available regarding population size (Wyoming Natural Diversity Database 2005). Additional documentation of the distribution and total population of *R. karelinii* in Region 2 is needed. The state heritage ranks of this species will be re-evaluated as additional information becomes available. For explanations of NatureServe's ranking system, see the **Definitions** section of this document.

If the population of *Ranunculus karelinii* in Region 2 is as small as it appears to be, extirpation due to stochastic events or global warming is a possibility. While extirpation due to habitat destruction is not likely given the remote nature of some of the occurrences, this species is potentially threatened in Colorado and Wyoming by motorized and non-motorized recreation, grazing, exotic species invasion, mining, and pollution. Eight of the 21 occurrences of *R. karelinii* are in wilderness areas (the Collegiate Peaks Wilderness Area and the Buffalo Peaks Wilderness Area in the Pike-San Isabel National Forest, the Big Blue Wilderness Area in the Uncompahgre National Forest, and the North Absaroka Wilderness in the Shoshone National Forest). As designated wilderness areas, these areas prohibit off-road vehicle use but may allow mining and grazing.

### *Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies*

As of this writing, a conservation strategy has not been written for *Ranunculus karelinii* at a national or regional level by the USFS or any other agency. No management plans have been drafted that specifically address the conservation needs of *R. karelinii*. The USFS requires that activities be managed to avoid disturbances that would result in a trend toward federal listing or loss of population viability of sensitive species, such as *R. karelinii* (USDA Forest Service Manual, Region 2 supplement, 2670.22). All areas of potential habitat must be surveyed before activities that could affect sensitive species are allowed. There are no laws in place that protect this species on private lands.

While there is only one clearly documented occurrence on private land in Region 2, it is likely that the species occurs elsewhere on private lands.

Reports of this species in Region 2 provide little detailed information, and there are very few repeat observations. Therefore, it is unclear whether or not current laws and regulations (none of which are specific to *Ranunculus karelinii*) are adequate to conserve the species. Establishing management plans and monitoring to detect population trends or habitat destruction might confer the protection needed to ensure the persistence of *R. karelinii* in Region 2. There have been no known cases in which an occurrence of *R. karelinii* was extirpated due to the failure to enforce any existing regulations.

The Colorado Natural Heritage Program (2005) has identified four Potential Conservation Areas (PCAs) that contain *Ranunculus karelinii*: (1) Gray's Peak in Summit and Clear Creek counties, (2) the Mosquito Range in Summit, Lake, and Park counties, (3) Mount Belford and Mount Missouri in Chaffee County, and (4) Italian Mountain in Gunnison County. Information describing these PCAs has been supplied to Park County (Spackman et al. 2001), and the USFS (Spackman et al. 1995) to facilitate awareness of this species and its habitat during planning and management activities. PCAs are an estimate of the primary area supporting the long-term survival of targeted species and plant communities, based on an assessment of the biotic and abiotic factors affecting the persistence and population viability of the targets within the area. PCA boundaries do not confer any regulatory protection of the site, nor do they automatically exclude any activity (Colorado Natural Heritage Program 2005).

## *Biology and Ecology*

### Classification and description

*Ranunculus karelinii* Czern. is a member of the Buttercup or Crowfoot family (Ranunculaceae) in class Magnoliopsida (dicotyledons), subclass Magnoliidae, and order Ranunculales (USDA Natural Resources Conservation Service 2004). The Ranunculaceae has between 1,900 and 2,500 species in 46 to 60 genera (Zomlefer 1994, Whittemore and Parfitt 1997). Members of the Ranunculaceae are found primarily in temperate to boreal regions of the northern hemisphere and are especially diverse in eastern North America and eastern Asia (Zomlefer 1994).

Some taxonomists and authors consider *Ranunculus karelinii* to be synonymous with *R. gelidus*, *R. gelidus* ssp. *grayi*, or *R. grayi* (Hartman and Nelson 2001, Snow and Brasher 2004). The Flora of North America (Whittemore 1997) and Weber and Wittmann (2001) use the name *R. gelidus*, noting that there is some question as to whether or not *R. grayi*, which was described from a specimen at Gray's Peak (occurrence #3), is really synonymous (see also Love et al. 1971). *Ranunculus verecundus*, previously documented from Wyoming, is now also considered to be synonymous with *R. gelidus* (Whittemore 1997). For the purposes of this assessment, we consider all of these names (*R. gelidus*, *R. gelidus* ssp. *grayi*, *R. grayi*, and *R. verecundus*) to be synonymous with *R. karelinii*. Although there is some question as to the correct name for this species of *Ranunculus*, there does not appear to be any question regarding the validity of *R. karelinii* as a distinct taxon.

Linnaeus described the genus *Ranunculus* in 1753 (Weber and Wittmann 1992). Systematic analyses of the genus *Ranunculus* done by Benson (1948, 1954) have not been superseded. Nine subgenera are recognized within the genus, and Benson (1948) places *R. karelinii* (=*R. gelidus*) in the subgenus *Euranunculus*. The subgenus *Euranunculus* is further divided into five sections, and *R. karelinii* is placed in the section *Epirotes*. This section contains about 23 species, including the species most closely related to *R. karelinii*. Of these, *R. eschscholtzii*, *R. adoneus*, *R. pygmaeus*, and *R. pedatifidus* occur in alpine habitats in Region 2.

The genus *Ranunculus* is included in Volume 3 of the Flora of North America (Whittemore 1997). Whittemore follows the work of Benson (1948, 1954). A small difference is that the subgenus *Euranunculus* (Benson 1948) is called subgenus *Ranunculus* by Whittemore (1997) to follow modern practices (Whittemore personal communication 2005). Whittemore (1997) also notes that the genus *Ranunculus* is badly in need of additional systematic work.

#### *History of knowledge*

*Ranunculus karelinii* was first described in 1842 by Karelin and Kirilow using material collected in the high peaks of the Alatau, near the headwaters of the Lepsa River in Central Asia (Hitchcock et al. 1977, Russian translation courtesy of Johnston 2005). This area is in what is now southeast Kazakhstan. Karelin and Kirilow called the specimen *R. gelidus*. In 1981, Sergei Kirillovich Czerepanov, a Russian botanist, examined the specimen, decided that something about the label and/or specimen was incorrect, and re-named the collection as *R. karelinii*, choosing a replacement name in honor of one of the original authors, Karelin (Johnston personal communication 2005). Most taxonomists have decided that the change made by Czerepanov was not warranted and that the original specimen and label were acceptable (Johnston personal communication 2005). The name *R. karelinii* is not mentioned in the Flora of North America (Whittemore 1997).

The first discovery of *Ranunculus karelinii* in Region 2 was made in 1864 by Parry who provided a vague description of his collection location: "Colorado: Lat. 39° to 41°" (Benson 1948). The next discovery in Region 2 was made in 1875 by Patterson who collected *R. karelinii* on Gray's Peak in Clear Creek County, Colorado, Arapaho-Roosevelt National Forest; and also in "Georgetown, Colorado" (Colorado Natural Heritage Program 2005). Since there is no alpine habitat in Georgetown, we presume that Patterson made the collection somewhere in the alpine in the vicinity of Georgetown, which could also have been Gray's Peak. In 1892 or 1893, C. A. Purpus collected a specimen in Colorado that is now deposited at the Museum National d'Histoire Naturelle in Paris, France. Unfortunately the collection location cannot be determined. The specimen label, as reported by Benson (1954) is "gravelly places, mountains north of Trenton, 12-13,000 ft." We were unable to find a "Trenton" in Colorado through available Geographic Information System (GIS) layers or the index of Colorado Geographic Names. In 1893, S.H. Camp collected *R. karelinii* somewhere in the vicinity of "Ironton", which is in Ouray County, Colorado (Colorado Natural Heritage Program 2005). It appears that *R. karelinii* was not collected again until 1951, when Penland collected a specimen on Mount Lincoln in Park County, Colorado. Dr. William Weber discovered a location in 1967 at Hilltop Mine in the Mosquito Range, also in Park County. In 1970, Betty Willard and Ann Zwinger collected *R. karelinii* at Mosquito Pass in Lake County, Colorado. In 1973, Vera Komarkova collected the species on Peak 10 in Summit County, Colorado. In 1978, Mike Figgs discovered a new location on Grizzly Peak in Chaffee County, Colorado, the largest known occurrence in Region 2, with between 25 and 50 plants. Also in 1978, Barry Johnston documented *R. karelinii* at Iowa Amphitheatre in Lake County, Colorado. In 1979, Robert Dorn and Bob Lichvar made the first collections in Wyoming at Galena Creek, in Park County. In the 1980s, four new locations were documented, three in Wyoming and one in Colorado. In the 1990s six new locations were documented in Colorado; no new locations have been discovered in Region 2 since 1999.

In summary, the four Wyoming occurrences of *Ranunculus karelinii* were discovered between 1979 and 1983. Available information suggests that only one of these occurrences has been revisited; a 1981 collection location was visited in 1983 (Wyoming Natural Diversity Database 2005). In Colorado, 17 occurrences were discovered between 1864 and 1999. Only one of these occurrences was ever revisited; the Gray's Peak location was revisited in 1950, 1978, and 1989, but it is clear that the observers were viewing different sub-occurrences in the Gray's Peak area.

Within Region 2, *Ranunculus karelinii* has been documented from 21 occurrences in Chaffee, Clear Creek, Gunnison, Hinsdale, Lake, Ouray, Park, and Summit counties in Colorado, and in Park County in Wyoming. It has also been documented outside of Region 2 in Wyoming in Teton County. It has not been seen in Ouray County, Colorado since 1893. Fifteen of the 21 records have not been updated in more than 20 years (Colorado Natural Heritage Program 2005, Wyoming Natural Diversity Database 2005). This lack of follow-up makes it difficult to assess trends and threats to this species.

Overall, the information available for *Ranunculus karelinii* in Region 2 is sparse. In most cases, only minimum amounts of data were gathered to document a herbarium specimen. Only one of the Wyoming records reports any information about population size or extent, indicating that the plants were "frequent".

### *Non-technical description*

*Ranunculus karelinii* is a small, inconspicuous, perennial plant. The stems are short (3 to 9 cm), erect or ascending, almost scapose, with most of the plant buried in loose scree (Weber and Wittmann 2001). Each stem supports a single (although sometimes as many as five) terminal flower. Roots are a fibrous mass (Weber and Wittmann 2001). Basal leaves are biternately dissected (3 to 13 lobes), with petioles that are long and slender. Sepals are purplish, spreading or reflexed, and 2 to 5 mm long. The flowers are yellow, and each of the five petals (3 to 5 mm long) exceeds the sepals in length and tapers to a narrow stalk at the base. As with other species of *Ranunculus*, *R. karelinii* has numerous stamens. The fruit is a cluster of 30 to 80 glabrous achenes, short-cylindrical in shape, and 5 to 9 mm long. Each achene is 2 to 2.5 mm long with a stout, recurved beak (Harrington 1954, Markow and Fertig 1999, Weber and Wittmann 2001, Montana Natural Heritage Program 2005).

*Ranunculus karelinii* could be confused with *R. adoneus*, *R. eschscholtzii*, *R. pedatifidus*, or *R. pygmaeus*, which also grow in the alpine of Colorado and Wyoming. *Ranunculus karelinii* can be distinguished by its spreading habit, small size (3 to 9 cm tall), and relatively large flowers, nearly scapose stems with most of the plant buried in loose scree, and basal leaves that are biternately-dissected (Weber and Wittmann 2001). *Ranunculus pygmaeus* is also very small, but the leaves are distinctly 3-lobed and the flower petals are only 3.5 mm long or less, just equaling the sepals (Weber and Wittmann 2001). *Ranunculus pedatifidus* has basal leaves that are cleft nearly to the leaf base (Weber and Wittmann 2001). *Ranunculus adoneus* and *R. eschscholtzii* both grow up to 26 cm tall and have flowers that are 3.8 cm across (Guennel 1995). *Ranunculus adoneus* has hairy, purplish sepals; the sepals of *R. karelinii* are not covered by dark hairs. *Ranunculus eschscholtzii* has greenish yellow stamens, petals that are 6 to 15 mm long, and fruits with a straight, slender beak (Guennel 1995, Markow and Fertig 1999). **Table 1** summarizes the identifying characteristics of *Ranunculus* species that occur in alpine areas of Wyoming and Colorado.

### *Published descriptions and other sources*

Detailed descriptions of *Ranunculus karelinii* are available in A Treatise on the North American Ranunculi (Benson 1948), Manual of the Plants of Colorado (Harrington 1954), Circumpolar Arctic Flora (Polunin 1959), Flora of Alaska and Neighboring Territories: A Manual of the Vascular Plants (Hulten 1968), Anderson's Flora of Alaska and Adjacent Canada (Welsh 1974), Vascular Plants of Continental Northwest Territories, Canada (Porsild and Cody 1980), and Flora of the Yukon Territory (Cody 2000). Dorn (1992) and Weber and Wittmann (2001) are the most readily available sources with keys for field identification within Colorado and Wyoming, but they do not include full descriptions of the species.

**Figure 1** and **Figure 2** illustrate *Ranunculus karelinii* and its habitat. Other photographs and illustrations of this species are in the Colorado Rare Plant Field Guide (Spackman et al. 1997a) and the Rare Vascular Plants of Alberta (Alberta Native Plant Council 2001). Illustrations of *R. karelinii* are available in Circumpolar Arctic Flora (Polunin 1959), Flora of Alaska and Neighboring Territories: A Manual of the Vascular Plants (Hulten 1968), Vascular Plants of the Pacific Northwest (Hitchcock et al. 1977), Vascular Plants of Continental Northwest Territories, Canada (Porsild and Cody 1980), The Alpine Flora of the Rocky Mountains (Scott 1995), and Flora of the Yukon Territory (Cody 2000). **Figure 3** is the illustration of *R. karelinii* included in the Colorado Rare Plant Field Guide (Spackman et al. 1997a).

### Distribution and abundance

Range-wide, *Ranunculus karelinii* is known from arctic regions and high mountain peaks in the northern hemisphere, from Asia to Alaska and

**Table 1.** Identifying characteristics of *Ranunculus* species occurring in alpine areas of Wyoming and Colorado (Harrington 1954, Whittemore 1997, Markow and Fertig 1999, Weber and Wittmann 2001, Montana Natural Heritage Program 2005).

| Species | Height | Leaves | Petals | Sepals | Achenes |
|---|---|---|---|---|---|
| *Ranunculus adoneus* | Up to 26 cm | Very finely dissected into threadlike divisions | 6-15 mm long, showy | Sparsely pilose | 2 mm long, with a straight beak, glabrous |
| *R. eschscholtzii* | Up to 26 cm | Cleft to the middle or below. 3- parted with segments again lobed. | 6-15 mm long | Pilose | 1.5-2 mm long with a straight, slender beak |
| *R. karelinii* | 3-9 cm | 3-parted, with the segments again lobed | 3-5 mm long | Glabrous. Petals longer than sepals, often twice as long | 2-2.5 mm, with a stout recurved beak, glabrous |
| *R. pedatifidus* | 12-30 cm | Cleft nearly to the leaf base | 6-10 mm long | Densely tomentose | Achenes 2 mm long, pubescent |
| *R. pygmaeus* | Up to 5 cm | 3-lobed | 3.5 mm or less, minute | Petals just equal in length to sepals | Achenes about 1 mm long, nearly glabrous |

**Figure 1.** Close-up of *Ranunculus karelinii* in fruit. Photograph by Susan Spackman Panjabi.

**Figure 2.** *Ranunculus karelinii* habitat on Missouri Mountain. Photograph by Susan Spackman Panjabi.

western Canada, and south into Washington, Oregon, Montana, Idaho, Utah, Wyoming, and Colorado (Whittemore 1997). Outside of Region 2, *R. karelinii* is not ranked or tracked by State and Provincial Heritage Programs and Conservation Data Centers in Alaska, Washington, Oregon, Idaho, Utah, Alberta, British Columbia, Northwest Territories, or the Yukon Territory (NatureServe 2005). It is ranked S1 (critically imperiled) in Montana (Montana Natural Heritage Program 2005). The Idaho Native Plant Society ranks *R. karelinii* a State Priority 1 species, indicating that it is in danger of becoming extirpated in Idaho (Idaho Native Plant Society 2001). Kartesz and Meacham (1999) report that *R. karelinii* is rare in Alberta, Alaska, Montana, Idaho, and Colorado. Distribution maps are provided in the Flora of North America (Whittemore 1997), and the Synthesis of the North American Flora (Kartesz and Meacham 1999), but Kartesz and Meacham (1999) do not show the species occurring in Washington or Oregon.

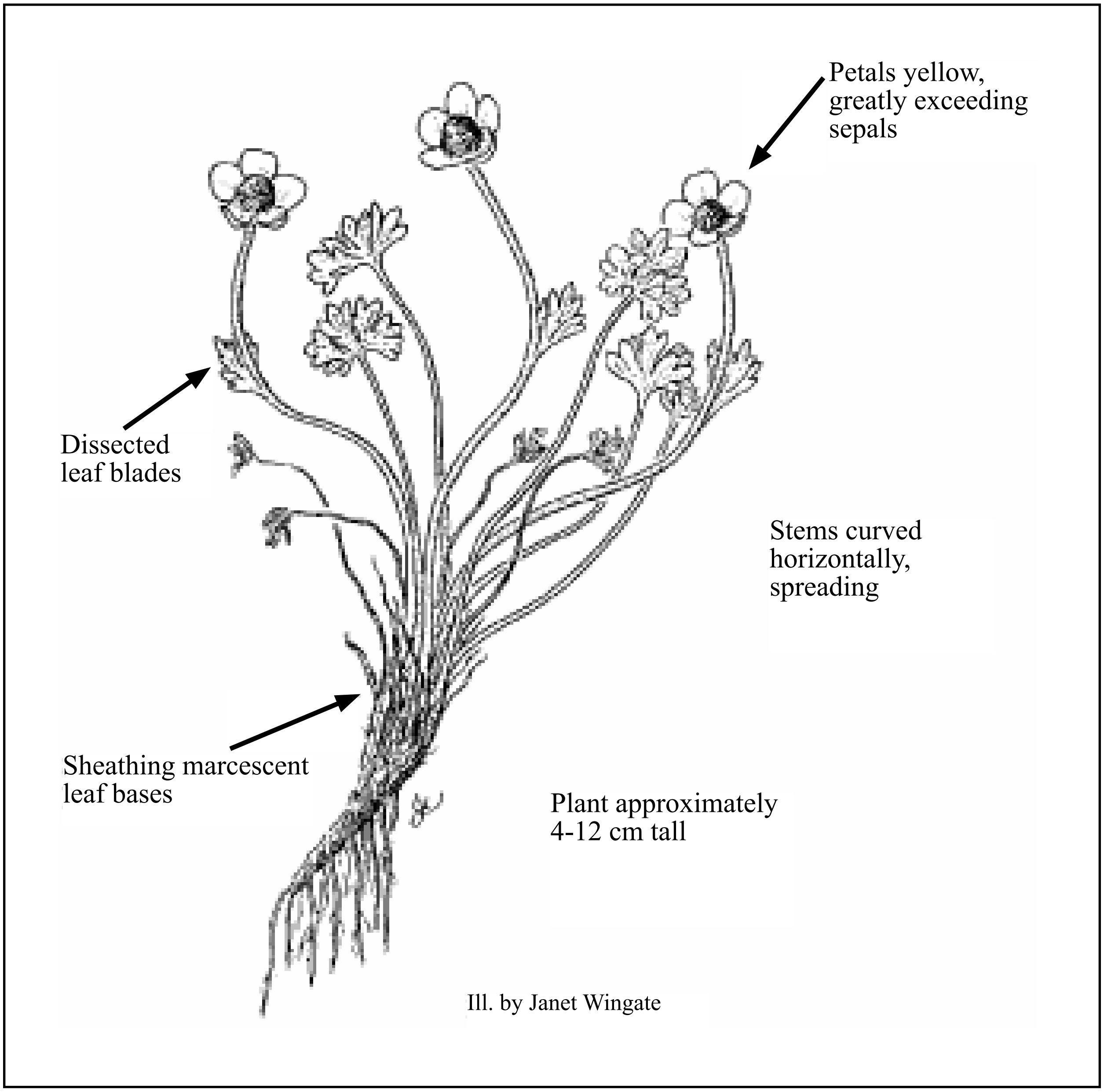


**Figure 3.** Illustration of *Ranunculus karelinii* by Janet Wingate.

Region 2 is peripheral to the main range of *Ranunculus karelinii*. Within Region 2, this species is known from high elevation areas in northwestern Wyoming and southwestern and central Colorado (**Figure 4**). It reaches the southern limit of its range in the mountains of southwestern Colorado. The habitat for *R. karelinii* in Region 2 is discontinuous on the landscape, so the species' distribution is likewise patchy. The range of *R. karelinii* within Region 2 is approximately 200 miles by 500 miles. Within this range there are 21 locations scattered across high elevation areas, and all the known populations of *R. karelinii* in Region 2 are estimated to occupy less than 21 acres (Colorado Natural Heritage Program 2005, Wyoming Natural Diversity Database 2005). Some of the occurrences in Region 2 are situated in close proximity to other occurrences and others are widely disjunct (**Figure 4**). While the occurrences in Wyoming are all within 20 miles of each other, they are almost 400 miles from the closest occurrences in Colorado. Additional occurrences are likely to be discovered with further inventories.

It is possible that *Ranunculus karelinii* once ranged more widely. Its extremely limited range suggests a glacial relict species whose range has been

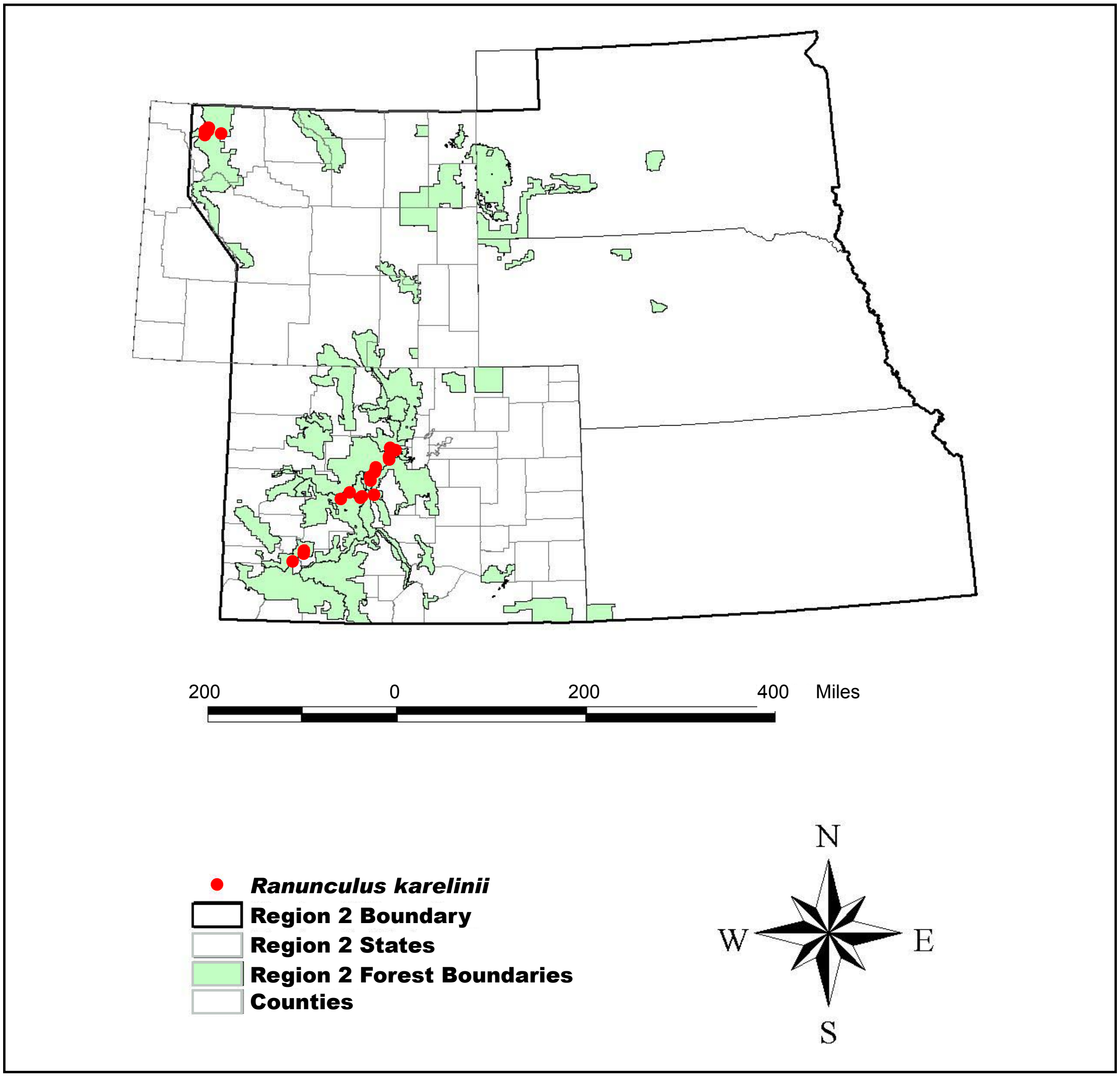


**Figure 4.** Distribution of *Ranunculus karelinii* within USDA Forest Service Region 2.

diminished by naturally occurring habitat contraction and fragmentation. The habitat for this species might have been more common and widespread during cooler and/or wetter climatic periods.

**Table 2** contains summary occurrence and habitat data for the 21 known locations of *Ranunculus karelinii* in Region 2. It is possible that populations vary from year to year. It should also be noted that *R. karelinii* may be easily overlooked when not in flower because it is very small and inconspicuous (Johnston personal communication 2005). If the plants are in flower, they probably would not be missed if one is specifically looking for them (Lederer personal communication 2005).

There has been no rigorous quantification of the total population of *Ranunculus karelinii*. In Region 2 it is known from 21 occurrences, but most of the occurrences have an unknown number of individuals. Based on the sizes of the occurrences that have had the total number of individuals estimated (three to 50 plants), it appears that most occurrences of *R. karelinii* are small. Some occurrences of *R. karelinii* appear to be small enough to be susceptible to inbreeding depression. Among the seven occurrences where abundance was reported, the

**Table 2.** Summary data for the 21 documented occurrences of *Ranunculus karelinii* within Region 2. Location names are provided for reference and are not intended to identify a specific location. Habitat descriptions were taken directly from herbarium labels, field notes, and personal communications (Colorado Natural Heritage Program 2005, Wyoming Natural Diversity Database 2005).

| State | Occurrence # | County | Location name | Date last observed | Observers | Plant count summary | Occurrence size information | Land owner / manager | Habitat information | Elevation (ft.) |
|---|---|---|---|---|---|---|---|---|---|---|
| CO | 1 | Park | Mount Lincoln | 28-Jul-1951 | C.W.T. Penland | 10 | None provided (assume at least 10) | Pike National Forest and/or private | Among rocks on southeast slope | 13,400 |
| CO | 2 | Chaffee | Grizzly Peak | 03-Jul-1978 | Mike Figgs | 50 | Estimated number of individuals: 25-50 | San Isabel National Forest, Collegiate Peaks Wilderness Area | Aspect: south; soil: rocky; along trail | 13,900 |
| CO | 3 | Clear Creek | Gray's Peak | 21-Jul-1989 | Loraine Yeatts, Mike Figgs, William Weber, Patterson, Letterman | 20 | [Yeatts 1989:] Occasional [Figgs 1978:] Population size: probably quite small [Weber 1950:] Very rare | Arapaho-Roosevelt National Forest | [Yeatts 1989:] In ridgetop scree and boulders; gneiss and schist substrate; aspect: north; slope: 0-20 degrees; associated taxa: *Oxytropis podocarpa, Trifolium nanum, Ligularia soldanella,* and *Draba lonchocarpa*<br>[Figgs 1978:] Ridgetop facing south-southeast; growing in the lee side of small boulders. Soil: gravel<br>[Weber 1950:] Fell fields, north slope; growing with *Senecio soldanella* and *Papaver radicatum* | 13,000-14,100 |
| CO | 4 | Hinsdale | Uncompahgre Peak | 1983 | Mike Figgs | 10 | None provided (assume at least 10 individuals) | Uncompahgre National Forest, Big Blue Wilderness Area | On ridgetops where windy and sparsely vegetated | 14,000 |
| CO | 5 | Park | Hilltop Mine | 12-Jul-1967 | William Weber | 10 | None provided (assume at least 10 individuals) | Forest and/or private | Slopes in tundra and snowmelt area | 13,790 |
| CO | 6 | Lake | Iowa Amphitheatre | 25-Jul-1978 | Barry Johnston and D. Shafer | 10 | None provided (assume at least 10 individuals) | San Isabel National Forest | Moderately-steep calcareous talus slope on side of ridge; under protecting talus rocks | 12,693 |
| CO | 7 | Lake | Pass | 03-Jul-1970 | Betty Willard and Ann Zwinger | 10 | None provided (assume at least 10 individuals) | Private, very near Bureau of Land Management Royal Gorge | In cracks of frost scars | 12,050 |

**Table 2 (cont.).**

| State | Occurrence # | County | Location name | Date last observed | Observers | Plant count summary | Occurrence size information | Land owner / manager | Habitat information | Elevation (ft.) |
|---|---|---|---|---|---|---|---|---|---|---|
| CO | 8 | Gunnison | Italian Mountain | 17-Jul-1980 | Barry Johnston | 50 | 50 or fewer (Johnston personal communication 2005) | Gunnison National Forest | In little white-limestone saddle; geology: calcareous | 13,000 |
| CO | 9 | Summit | Peak 10 | 01-Jul-1973 | Vera Komarkova | 10 | None provided, assume at least 10 individuals | White River National Forest | None provided | 13,000-13,500 |
| CO | 12 | Clear Creek | Engelmann-Robeson Peaks Saddle | 28-Jul-1994 | Nan Lederer and Marion Reid | 10 | Estimated number of individuals: 10 individuals counted, possibly more in general area; size of area covered by population: 0.01 acre | Arapaho-Roosevelt National Forest | Alpine scree slope; total tree cover: 0 percent; total shrub cover: 0 percent; total forb cover: 40 percent; total graminoid cover: 0 percent; total moss/lichen cover: 10 percent; total bare ground cover: 60 percent; associated species: *Trifolium dasyphyllum, Papaver lapponicum, Ligularia holmii, Ligularia soldanella, Hirculus serpyllifolius, Hirculus flagellaris, Saxifraga cernua, Polemonium viscosum, Besseya alpina, Smelowskia calycina, Acomastylis rossii,* and *Claytonia megarhiza;* aspect: west; slope: 30 percent; slope shape: convex; light exposure: open; topographical position: crest; moisture: dry; parent material: igneous; geomorphic land form: glaciated mountain saddle; soil texture: gravelly | 12,950 |
| CO | 13 | Chaffee | Missouri Mountain | 27-Jul-1994 | Susan Spackman and Mark Duff | 40 | 40 individuals in five patches | San Isabel National Forest, Collegiate Peaks Wilderness Area | Fellfield, talus, rock outcrop; calcareous rocks (determined with hydrochloric acid) | 13,800-14,000 |
| CO | 14 | Chaffee | Mount Belford | 21-Jun-1995 | Hilary Johnson | 5 | Five individuals | Pike-San Isabel National Forest, Collegiate Peaks Wilderness Area | Growing with *Papaver kluanense* and *Draba* spp.; on level ground; this area is at the bottom of the rocky ridge area as the trail begins to head into the saddle’s dry meadow; north facing, side of the trail | 13,520-13,560 |

**Table 2 (cont.).**

| State | Occurrence # | County | Location name | Date last observed | Observers | Plant count summary | Occurrence size information | Land owner / manager | Habitat information | Elevation (ft.) |
|---|---|---|---|---|---|---|---|---|---|---|
| CO | 15 | Summit | Bullion Mine | 29-Aug-1997 | Susan Spackman | 3 | Three individuals; size of area covered by population: 1 acre | White River National Forest and/or private | Rocky alpine ridgeline surrounded by high quality *Deschampsia* meadows; historical mining sites and associated roads surround the rare plant occurrence; total vegetation cover is about 10percent; aspect: north – northeast; slope: 40 degrees; light exposure: full sun; moisture: xeric; landform: rocky ridge; dominant plant community: sparsely vegetated alpine rock outcrop; associated taxa: *Senecio fremontii var. blitoides, Dryas, Draba, Claytonia megarhiza,* and *Geum rossii* | 12,400-12,480 |
| CO | New 1 | Chaffee | West Buffalo Peak | 12-Jul-1998 | Rea Orthner | 10 | None provided (assume at least 10 individuals) | San Isabel National Forest, Buffalo Peaks Wilderness Area | Alpine talus slope with *Besseya alpina, Erysimum capitatum, Claytonia megarhiza, Oreoxis alpina, Trifolium nanum, Cirsium* sp., *Draba aurea, Packera werneriifolia, Eritrichium aretioides, Hirculus platysepalus, Phlox condensata,* and *Erigeron compositus* | 13,000 |
| CO | New 2 | Ouray | Ironton | 1893 | S.H. Camp | 10 | None provided (assume at least 10 individuals) | Unknown | None provided | Not enough information to determine |
| CO | New 3 | Clear Creek | Georgetown | 1875 | Patterson | 10 | None provided (assume at least 10 individuals) | Unknown | None provided | Not enough in formation to determine |
| CO | New 4 | Hinsdale | Silver Mountain | 30-Jul-1999 | Arnett, Melanie and Kevin Taylor | 10 | None provided (assume at least 10 individuals) | Uncompahgre National Forest | Alpine tundra | 12,400-13,681 |
| WY | 1 | Park | Galena Creek | 14-Aug-1979 | Robert Dorn and R.W. Lichvar | 50 | Reported as “frequent” | Clarks Fork Ranger District, Shoshone National Forest | North and east-facing talus slopes. 30-degree slope. Gravelly loam soils; moist; at headwaters; occurs with *Geum, Senecio*, and *Epilobium* | 10,000 |

**Table 2 (concluded).**

| State | Occurrence # | County | Location name | Date last observed | Observers | Plant count summary | Occurrence size information | Land owner / manager | Habitat information | Elevation (ft.) |
|---|---|---|---|---|---|---|---|---|---|---|
| WY | 3 | Park | Sleeping Giant Mountain | 13-Aug-1983 | E.F. Evert | 10 | None provided (assume at least 10 individuals) | Shoshone National Forest North Absaroka Wilderness Area, Wapiti Ranger District | Wet talus, cliffs, and seepage banks above laker | 10,000-10,600 |
| WY | 4 | Park | East Fork Big Creek | 02-Aug-1983 | E.F. Evert | 10 | None provided (assume at least 10 individuals) | Shoshone National Forest, North Absaroka Wilderness Area, Wapiti Ranger District | Tundra; at headwaters | 10,000-11,000 |
| WY | 5 | Park | Sulphur Creek | 11-Aug-1982 | E.F. Evert | 10 | None provided (assume at least 10 individuals) | Shoshone National Forest, Clarks Fork Ranger District | Along streamlets in tundra; at headwaters | 10,000 |

maximum number of individuals estimated is 50 plants, and one report indicated that the plants were "frequent" (**Table 2**). The largest occurrences known are at Grizzly Peak and Missouri Mountain in Colorado, and at Galena Creek in Wyoming. These occurrences were never rigorously quantified, and for most of the other occurrences the observers did not report the population size. Fourteen of the 21 occurrences have not been visited in more than 20 years, and 13 of 21 do not report occurrence size. For the purposes of this report, based on what we know about the occurrence sizes for this species in Region 2 (**Table 2**), we estimate that, unless otherwise noted, each occurrence had at least 10 plants at the time it was observed, and that the total population size in Region 2 is at least 358 individuals.

Similarly, there has been no rigorous quantification of the total area occupied by *Ranunculus karelinii*. Only two botanists have reported visual estimates of the total area of certain occurrences, one reporting one acre and the other reporting 0.01 acre of occupied habitat. The remaining 19 of 21 reports provide no information regarding the area of occupied habitat (Colorado Natural Heritage Program 2005, Wyoming Natural Diversity Database 2005). For the purposes of this research, based on what we know about the extent of occurrences in Region 2 (**Table 2**), we conclude that each occurrence probably occupies less than one acre, and that the known occupied habitat is less than 21 total acres.

The known distribution of *Ranunculus karelinii* in Region 2 is limited to National Forest System lands and private lands (**Figure 4**). Within Region 2 in Wyoming, *R. karelinii* is on the Shoshone National Forest. In Colorado it is on the Arapaho-Roosevelt, Gunnison, Uncompahgre, White River, and Pike-San Isabel national forests. Several botanical surveys have detected *R. karelinii* in Colorado (e.g., Spackman et al. 1995, Spackman et al. 1997b, Orthner 1999, Johnston personal communication 2005), and there is much potential habitat that remains to be searched in Colorado and Wyoming. Limited access to remote, high-elevation areas and private land has made it difficult to thoroughly search areas within the known distribution of *R. karelinii*. While it is possible that it is limited to the range as we know it, further focused inventory work is necessary to verify this.

### Population trend

There are no quantitative data that could be used to infer the population trend of *Ranunculus karelinii* in Region 2. Occurrence sizes presented in **Table 2** are rough estimates, often based on incomplete searches, and there have been no repeat observations or monitoring that could determine a population trend. Land use (e.g., recreation, grazing, historical mining, associated roads) within the areas that *R. karelinii* grows in Region 2 suggests that there may have been at least a slight downward trend since the area was settled in the mid-1800s.

*Ranunculus karelinii* abundance is likely to fluctuate naturally due to annual climatic variation. While drought probably reduces or eliminates recruitment of *R. karelinii* seedlings, juvenile and adult plants may be capable of surviving one or more bad years. Fluctuations such as this make it difficult to assess population size accurately in any given year.

### Habitat

Range-wide, *Ranunculus karelinii* is found on "open arctic and alpine slopes" (Whittemore 1997). Hitchcock et al. (1977) describe the habitat as "alpine meadowland and talus slopes", and Porsild and Cody (1980) report that the habitat is "moist, gravelly talus slopes." The habitat in Alaska is described by Hulten (1968) as "wet places, scree slopes". *Ranunculus karelinii* is considered to be a facultative wetland species in Alaska, which means that it is equally likely to occur in wetlands or non-wetlands (U.S. Fish and Wildlife Service 1988). In Utah and western Colorado, *R. karelinii* is considered to be an obligate upland species, indicating that it occurs almost always (estimated probability 99 percent) in non-wetlands (U.S. Fish and Wildlife Service 1988). In Wyoming, Montana, Idaho, Washington, and Oregon, there is insufficient information to determine wetland indicator status (U.S. Fish and Wildlife Service 1988).

Little is known about the habitat for *Ranunculus karelinii* in Region 2. What is known has been documented largely through reports to the Colorado Natural Heritage Program (Colorado Natural Heritage Program 2005), and herbarium labels of specimens deposited at the University of Colorado Herbarium (COLO) and the Rocky Mountain Herbarium (RM). All information regarding habitat that is available for each occurrence within Region 2 is presented in **Table 2**. *Ranunculus karelinii* appears to grow primarily in dry, rocky, alpine sites in Region 2, including talus, scree, rock outcrops, fellfields, tundra, and ridgetops (Colorado Natural Heritage Program 2005, Wyoming Natural Diversity Database 2005). In the Colorado Rare Plant Field Guide, Spackman et al. (1997a) report that the species is found "among rocks and scree on exposed summits and slopes." Snow melt areas that provide seasonally wet conditions may also be important for *R. karelinii* (Johnston personal communication 2005). In four of the records from Region 2, the observers have suggested that the site was mesic, including a "snowmelt area", "wet talus and seepage banks", and "along streamlets." Overall, habitat information is very sparse, making the habitat in Region 2 difficult to characterize.

Element occurrences records (Colorado Natural Heritage Program 2005) for *Ranunculus karelinii* document soil parent material as igneous, gneiss, schist, and limestone. Three of the records from Colorado report that the plants are found on a calcareous substrate (Colorado Natural Heritage Program 2005). The soils at three of the occurrences of *R. karelinii* in Region 2 have been reported to be rocky and gravelly (Colorado Natural Heritage Program 2005). Our understanding of the distribution of *R. karelinii* in Region 2 would benefit from more complete descriptions of distribution patterns of this species in relation to geologic and edaphic characteristics.

The range of elevation for *Ranunculus karelinii* occurrences documented by the Colorado Natural Heritage Program (2005) and Wyoming Natural Diversity Database (2005) is 10,000 ft. (all four occurrences in Wyoming) to 14,100 ft. (on Gray's Peak in Colorado), with the plants reaching higher elevations in the southern part of the range. *Ranunculus karelinii* is found on flat to steeply sloping terrain, and it has been documented on all aspects (Colorado Natural Heritage Program 2005). However, slopes and orientation are not reported for most of the known locations (Colorado Natural Heritage Program 2005, Wyoming Natural Diversity Database 2005).

Within Colorado, *Ranunculus karelinii* occurs in the central portion of the Southern Rocky Mountain Ecoregion, and in Wyoming, it occurs in the northern portion of the Utah-Wyoming Rocky Mountain Ecoregion in the classification of Bailey (1995). These ecoregions comprise mountainous areas in Colorado and Wyoming, and define the south-central region of the Rocky Mountain Range in North America.

The climate of alpine areas supporting *Ranunculus karelinii* is characterized by long, cold winters and short summers. To obtain more specific information on the local climate at the *R. karelinii* sites, we referred to data compiled between 1949 and 2003 by the Western Regional Climate Center (2003). The closest weather station with a similar elevation to the populations of *R. karelinii* is Climax, Colorado, at approximately 11,500 ft in Summit County. During the fall, winter, and spring the Climax weather station receives snow every month totaling 2 to 49 inches until midsummer when the ground is free of snow cover. *Ranunculus karelinii* is probably most actively growing in July and August when precipitation from rain is greater than 2 inches per month, and average maximum temperatures peak. Average maximum temperatures are 64.5 ºF in July and 62.4 ºF in August (Western Regional Climate Center 2003).

Occurrences of *Ranunculus karelinii* in Region 2 are usually in remote, infrequently visited areas (Colorado Natural Heritage Program 2005, Dorn personal communication 2005, Houston personal communication 2005, Johnston personal communication 2005). *Ranunculus karelinii* plants have been documented along trails at Gray's Peak, Grizzly Peak, Missouri Mountain, and Mount Belford, and near roads associated with Bullion Mine and Hilltop Mine.

High-quality versus marginal habitat parameters are not known for *Ranunculus karelinii*. Areas with natural vegetation that support dense populations and have minimal impact from human activities probably represent the best examples of high quality habitat. Characterization of high quality sites is a research priority for *R. karelinii*.

### Reproductive biology and autecology

Very little is known about the reproductive ecology and autecology of *Ranunculus karelinii*. While the plants are likely entomophilous (pollinated by insects), it is not known if this species is self-incompatible and an obligate outcrosser, or if it is capable of self-pollination. Plants are hermaphroditic (have both male and female sexual organs). The diploid chromosome number 2n = 16 has been reported for *R. karelinii* (Love et al. 1971).

The fruit of *Ranunculus karelinii* is a cluster of 30 to 80 achenes (seeds), and each achene is about 2 mm long (Harrington 1954, Hitchcock et al. 1977). The life span and growth rate of *R. karelinii* have not been investigated. It is reported to be a short-lived perennial (Montana Natural Heritage Program 2005), but the source for this information is unclear (Mincemoyer personal communication 2005).

In the absence of information specific to *Ranunculus karelinii*, in the following sections of this document we report information about the reproductive biology of closely related species. In particular, we report information about related *Ranunculus* species that occupy similar habitats, primarily *R. adoneus* and *R. acris*. *Ranunculus acris* is in subgenus *Ranunculus*, section *Ranunculus*, whereas *R. karelinii* and *R. adoneus* are in subgenus *Ranunculus*, section *Epirotes* (Whittemore 1997).

### *Pollinators and pollination ecology*

The pollination ecology of *Ranunculus karelinii* has not been investigated. Plants in the Ranunculaceae are usually pollinated by insects (Zomlefer 1994). *Ranunculus* species have nectaries at the base of the petals (Zomlefer 1994), which may attract insects. Insects may also be attracted to pollen. Open flowers such as *Ranunculus* are usually visited by a variety of insects because the floral morphology is not restrictive (Zomlefer 1994). Flowers of Ranunculaceae are generally protandrous, meaning that the anthers release their pollen before the stigma of the same flower begins to mature; this encourages cross-pollination although self pollination is possible (Zomlefer 1994). Insect visitors to *R. karelinii* have not been documented, and it is not known if the species is pollen-limited.

*Ranunculus adoneus*, a relative of *R. karelinii* also known from alpine habitats in Region 2, is self-compatible (Stanton et al. 1997). The showy flowers of *R. adoneus* nonetheless attract flies, small bees, and wasps (Stanton et al. 1997), which encourages cross pollination. The plants are strongly protogynous; the female parts develop first, then after one or two days the anthers begin to dehisce (Galen et al. 1993, Galen and Stanton 2003). Muscid, calliphorid, and syrphid flies are common visitors to *R. adoneus* (Cooley 1995), and they are most active during times that are sunny, during mid-morning to mid-afternoon hours (Galen et al. 1993).

*Ranunculus acris* is a circumpolar plant with a wide elevation range and is in the same subgenus as *R. karelinii*, though perhaps not as closely related as *R. adoneus*, based on its placement in a different section within the genus (Benson 1948, Whittemore 1997). The flowers of *R. acris* are protogynous (but with overlapping stages) like in *R. adoneus*, but they are also self-incompatible, thus requiring cross pollination by insects to produce seeds (Totland 1994). *Ranunculus acris* is pollinated primarily by flies in the Muscidae and the Anthomyiidae where it was studied in southwest Norway (Totland 2001). The insects appear to be primarily attracted to the pollen of *R. acris*, though there is a small amount of nectar secreted at the base of each petal. At lower elevations, *R. acris* plants responded positively to increased pollen availability, suggesting that they were pollen limited. However, at high elevations (in alpine environments) *R. acris* is not pollen limited, and it is thought that the plants do not respond to increases in pollen loads because reproduction is already restrained by low temperatures (Totland 2001). Similarly, Totland (2003) found that although insects showed a strong preference for larger flowers of *R. acris*, the increase in visitation did not increase the level of reproductive success. Again, it was found that the plants are not pollen limited.

The flowers of *Ranunculus adoneus* and *R. acris* are heliotrophic, which means that the flowers closely track the sun's rays (Galen and Stanton 2003, Totland 2004). This has been shown to create substantial benefits with respect to pollen development and subsequent germination (Galen and Stanton 2003). Heliotrophism increases the temperature of reproductive organs, increases evapotranspiration, and increases seed size (Galen and Stanton 2003). Larger seeds result in better seedling survival and lifetime fitness (Stanton and Galen 1997, Galen and Stanton 1991). It is not known whether *R. karelinii* flowers are heliotrophic.

### *Phenology*

*Ranunculus karelinii* bears one to five flowers on a short (usually less than 12 cm), spreading stem (Spackman et al. 1997a). As an alpine species with a limited growing season, *R. karelinii* has a relatively short period of flowering. In Region 2, it typically flowers and produces fruit between July and August (Markow and Fertig 1999, Colorado Natural Heritage Program 2005), but it is not likely to be in flower for the entire period. By late August most flowers have dried and given way to fruit.

In general, the timing of growth and flowering of alpine plants depends on the timing of precipitation, the balance between summer and winter precipitation, snow deposition patterns, and the timing and rate of snow melt (Billing and Bliss 1959, Galen and Stanton 1995, Walker et al. 1995, Totland and Alatalo 2002). Alpine plants often begin growing when air and soil temperatures are still near the freezing point of water (Billings and Bliss 1959). In their study of 34 alpine plants in the Medicine Bow Mountains of Wyoming, Billings and Bliss (1959) found that most of the alpine plants reached maximum flowering three weeks after initial growth and seed maturation and dispersal within about seven to eight weeks. Overall, maximum plant productivity happens soon after release of snow cover and then tapers off erratically until the end of the growing season (Billings and Bliss 1959). The early productivity is enabled by stored resources from the previous year (Billings and Bliss 1959). Initial growth uses stored carbohydrates and nutrients to produce new leaves and flowers, and then the plants photosynthesize and produce nutrients and carbohydrates to store for the following summer (Walker et al. 1995).

The flowers of *Ranunculus adoneus*, a snowbed specialist, begin to expand on or before snowmelt, and the leaves begin to develop at the onset of snowmelt, earlier than many other alpine species (Galen and Stanton 1995). This phenology maximizes the time for seed maturation and growth (Galen and Stanton 1993, Galen et al. 1993). Fully developed flowers appear from beneath 1 to 3 cm of snow, and flowering is complete within 10 days of emergence from snow (Stanton and Galen 1997). *Ranunculus acris* begins flowering about three weeks after snowmelt (Totland 2001). Another alpine species, *R. glacialis* (subgenus Cymodes) flowers two to three weeks after snowmelt (Totland and Alatalo 2002). The specific growth patterns for *R. karelinii* are not known.

### *Fertility and propagule viability*

Seed germination requirements for *Ranunculus karelinii* have not been investigated. The seeds (achenes) of *R. adoneus* and *R. acris* are green throughout development, which may contribute to energy for seed production (Galen et al. 1993, Totland 2001). The seeds of *R. adoneus* usually remain dormant for two years before germinating (Galen et al., in press, as reported in Stanton et al. 1997). Larger seeds were found to survive longer in soil than smaller seeds (Stanton and Galen 1997), and seed mass of *R. adoneus* increased with growing season length (Galen and Stanton 1993). Based on observations during experiments involving planting seeds, Galen and Stanton (1999) assumed that seeds of *R. adoneus* that failed to germinate after three years in the soil were dead. *Ranunculus adoneus* seedlings from large seeds have much better survival than seedlings from smaller seeds (Galen and Stanton 1991).

*Ranunculus adoneus* plants require at least five years to reach reproductive maturity (Stanton et al. 1997). Seedlings that fail to produce true leaves during their first summer are at a disadvantage for surviving the winter months (Galen and Stanton 1999). Galen and Stanton (1999) defined seedling establishment as the successful transition from seed to seedling at two years of age. At this age, all seedlings have true leaves. *Ranunculus adoneus* plants were found to be more restricted by a shorter growing season in nutrient poor habitats (Galen and Stanton 1999). However, microsites that are conducive to seedling establishment are not necessarily advantageous overall. Plants may still be vulnerable at other phases of their life cycle (Galen and Stanton 1999).

Seeds and seedlings of *Ranunculus karelinii* probably respond to a combination of temperature and light (growing season length), moisture, and possibly other factors, such as soil chemistry. Additional research is needed to determine factors most important to the germination and growth of *R. karelinii*. It is not known whether *R. karelinii* can spread vegetatively.

### *Dispersal mechanisms*

Dispersal mechanisms for *Ranunculus karelinii* have not been investigated. Seeds of *R. adoneus* disperse by gravity and snowmelt run-off, and they disperse only 0.1 to 1 m (Scherff et al. 1994). Seeds of this species are also reported to adhere to the fur of small mammals, suggesting that longer-distance dispersal is possible (Galen et al., in press as reported in Stanton et al. 1997). Seed size is variable in *R. adoneus*, and this may affect dispersal (Galen and Stanton 1993), as larger seeds move shorter distances than smaller seeds (Harper 1977 as reported in Galen and Stanton 1993). It is not known if this is the case for *R. karelinii*.

The seeds of *Ranunculus karelinii* are probably also dispersed by gravity, snowmelt run-off, mammals (Martin et al. 1951 as reported by Handley et al. 2002), and possibly wind. The seeds of *R. karelinii* are about 2 to 2.5 mm long and have a stout, recurved beak, which may enable dispersal by mammals (Harrington 1954). Wind dispersal is less likely because of the size of the seeds and the prostrate growth form of the plants; wind dispersed plants tend to grow with their seeds higher off the ground.

### *Phenotypic plasticity*

Levels of phenotypic plasticity exhibited by *Ranunculus karelinii* are not known. Stanton and Galen (1997) found that for *R. adoneus*, flowering time, flower number, seed production, seed size, age-specific leaf size, leaf number, and seed dormancy are all traits that are highly responsive to microsite variation along a snow depth gradient.

*Ranunculus karelinii* plants may also vary in size, stature, and reproductive effort because of annual variations in climate. A range of phenotypic variation may exist for this species across its full range. For example, plants may be taller in more northern parts of its range, especially at lower elevations. However, this has not been investigated for *R. karelinii*.

Totland (2001) found a correlation between flower number and elevation in *Ranunculus acris*, a circumpolar plant species with a wide elevation range that includes alpine areas. Plants of this species found at high elevations typically produce just one flower while plants at lower elevations produce one to five flowers per year. It is not know if a similar pattern exists for *R. karelinii*, but it is possible that plants exhibit morphological differences (i.e., number of flowers, overall size of plants) based on elevation and/or latitudinal changes.

*Mycorrhizal relationships*

The roots of *Ranunculus karelinii* have not been assayed for the presence of mycorrhizal symbionts. Vesicular arbuscular mycorrhizal (VAM) fungi have been reported to form symbioses with *R. adoneus* in alpine habitats in Colorado (Mullen and Schmidt 1993, Scherff et al. 1994). The arbuscles were present for just a few weeks during the growing season, and their presence corresponded with an increase in phosphorus in the roots and shoots of *R. adoneus*. This peak in the accumulation of phosphorus and mycorrhizal development occurred well after plant reproduction, and after most of the plant growth had occurred (Mullen and Schmidt 1993). Evidently, the mycorrhizae store phosphorus that *R. adoneus* uses during early season growth and flowering the following spring. This relationship makes it possible for *R. adoneus* to flower before soils thaw (Mullen and Schmidt 1993).

VAM fungi belong to a group of nondescript soil fungi (Glomales) that are difficult to identify because they seldom sporulate (Fernando and Currah 1996). However, they are the most abundant type of soil fungi (Harley 1991) and infect up to 90 percent of all angiosperms (Law 1985). VAM fungi are generally thought to have low host specificity, but there is increasing evidence for a degree of specificity between some taxa (Rosendahl et al. 1992, Sanders et al. 1996). While this group has not previously been thought of as particularly diverse, recent studies are suggesting that there is unexpectedly high diversity at the genetic (Sanders et al. 1996, Varma 1999) and single plant root (Vandenkoornhuyse et al. 2002) levels. As root endophytes, the hyphae of these fungi enter the cells of the plant roots where water and nutrients are exchanged in specialized structures.

*Hybridization*

Hybridization has not been documented in *Ranunculus karelinii*, but it is possible. Closely related congeners with which it could exchange pollen grow within its range. Interspecific hybridization is known to occur in several groups of buttercups (Whittemore 1997).

The species most closely related to *Ranunculus karelinii* that also occur in alpine habitats in Region 2 are *R. eschscholtzii*, *R. adoneus*, *R. pygmaeus*, and *R. pedatifidus*. The potential for hybridization among these taxa is not known. In *R. karelinii*, hybridization is not likely to be significant enough to lead to problems of outbreeding depression.

Demography

The demographics of populations of *Ranunculus karelinii* have not been investigated. For most of the occurrences in Region 2, the total number of individuals is not documented, nor have different age or size classes within occurrences been documented. Based on figures from occurrences that have had the total number of individuals estimated (3 to 50 individuals), it appears that many of the occurrences of *R. karelinii* in Region 2 are very small (**Table 2**). Several occurrences of *R. karelinii* appear to be small enough to be susceptible to inbreeding depression.

A minimum viable population size has not been determined for *Ranunculus karelinii*. Effective population sizes of 50 to 500 individuals are believed to be required to avoid inbreeding depression, and larger populations ($N_e$ = 500-5000 individuals) are required to maintain evolutionary potential (Soulé 1980). The small size of many occurrences of *R. karelinii* in Region 2, and its potential dependence on outcrossing, makes inbreeding depression, loss of genetic diversity, genetic drift, and population fragmentation potentially important issues for the conservation of the species.

Little is known about the population genetics of *Ranunculus karelinii*. The degree of connectedness among populations in Region 2 is not known, but current knowledge of the species' distribution suggests that many occurrences are genetically isolated from each other. Occurrences within Region 2 are separated by 1 to 500 miles (**Figure 4**). The four occurrences in Wyoming are almost 400 miles from the closest occurrences in Colorado while they are separated from each other by only 3 to 17 miles. The two occurrences on the Arapaho-Roosevelt National Forest are separated by approximately 7 miles, and one is about 4 miles from the closest occurrence on the White River National Forest. The other occurrence known from the White River National Forest is about 17 miles distant, and about 7 miles from the closest occurrence on the Pike-San Isabel National Forest. All of the occurrences on the Pike-San Isabel National Forest are separated by between 1 and sixteen miles. The one occurrence on the Gunnison National Forest is about 11 miles from the occurrences on the Pike-San Isabel National Forest. The two occurrences on the Uncompahgre National Forest are about 3 miles apart, and about 67 miles from the next closest occurrences on the Gunnison National Forest.

It is likely that pollen or seeds are being exchanged among a few *Ranunculus karelinii* occurrences, but certainly not among all occurrences in Region 2. Because of the large distances between occurrences within Region 2, there is probably some degree of inbreeding and local adaptation. Additional research is needed to acquire more accurate information on the distribution and size of occurrences. Studies of allele frequencies in the different population centers could also help to clarify the degree of population connectivity and to facilitate prioritization of protection efforts.

Migration, extinction, and colonization rates are unknown for *Ranunculus karelinii*. Baseline population dynamics and viability must first be assessed. Migration among extant occurrences may be negative or positive (Bonnin et al. 2002). Migration may increase genetic variability and thereby prevent inbreeding depression or improve a species' ability to deal with stochastic events. Migration may also hinder the plants ability to adapt to local environmental conditions (Bonnin et al. 2002). It is not known if similar patterns exist for *R. karelinii*.

The spatial distribution of *Ranunculus karelinii* at small scales is probably influenced by microhabitat characteristics, the distribution of suitable germination sites for seeds, seed dispersal mechanisms, and interactions with other vegetation.

The lifespan of *Ranunculus karelinii* has not yet been determined. There are no data regarding the proportion of individuals within an occurrence that reproduce in a given year. In favorable years, many or most of the plants probably set seed. The longevity and dormancy of *R. karelinii* seeds have not been studied.

*Ranunculus adoneus* is described as a long-lived species (Galen and Stanton 1999). Plants can live for decades (Sherry and Galen 1998), and they require at least five years to reach reproductive maturity (Stanton et al. 1997). Seedlings that fail to produce true leaves during their first summer are less likely to survive the winter months (Galen and Stanton 1999). Galen and Stanton (1999) defined seedling establishment as the successful transition from a seed to a two-year-old seedling. At this age, all seedlings have true leaves, and mortality rates decline sharply (Stanton and Galen 1997 as reported in Galen and Stanton 1999).

Galen and Stanton (1999) found that growing season length affected growth schedules of newly emerged seedlings of *Ranunculus adoneus* in a way that dramatically altered their chances of survival. True leaf production was suppressed by shorter growing seasons (Galen and Stanton 1999). Seedlings from large seeds had a much higher survival rate than seedlings from smaller seeds (Galen and Stanton 1991).

### Community ecology

There have been only a few reports of the community ecology and interspecific relationships of *Ranunculus karelinii* in Region 2; these have been derived from surveys, herbarium specimens, observations, and GIS data layers. Some effort has been devoted to documenting this species, and while this has provided a basic understanding of its distribution and habitat, our understanding of its interactions with other species remains poor and needs further study.

In the one element occurrence record where plant community structure is reported, trees, shrubs and graminoids are absent, total forb cover was estimated to be 40 percent, total moss and lichen cover was estimated at 10 percent, and total bare ground cover was 60 percent. Another record estimates the total vegetation cover to be 10 percent.

The habitat of *Ranunculus karelinii* has been subjected to some modification and land use practices (e.g., mining, grazing, and recreation) for at least 100 years. Thus, some of the natural vegetation and associated species for *R. karelinii* may have been disrupted or removed. A list of all associated species that have been documented with *R. karelinii* appears in **Table 3**.

#### *Herbivores*

The response of *Ranunculus karelinii* to browsing by herbivores has not been studied. It is possible that the plants are browsed to some extent, but they are

**Table 3.** Species that have been documented with *Ranunculus karelinii*.

| | |
|---|---|
| *Acomastylis rossii* | *Ligularia soldanella* |
| *Besseya alpina* | *Oreoxis alpina* |
| *Cirsium* sp. | *Oxytropis podocarpa* |
| *Claytonia megarhiza* | *Packera werneriifolia* |
| *Draba aurea* | *Papaver kluanense* (also a rare species in Region 2) |
| *Draba lonchocarpa* | *Papaver lapponicum* |
| *Draba* spp. | *Papaver radicatum* |
| *Dryas* sp. | *Phlox condensata* |
| *Epilobium* sp. | *Polemonium viscosum* |
| *Erigeron compositus* | *Saxifraga cernua* |
| *Eritrichium aretioides* | *Senecio fremontii* var. *blitoides* |
| *Erysimum capitatum* | *Senecio* sp. |
| *Hirculus flagellaris* | *Smelowskia calycina* |
| *Hirculus platysepalus* | *Soldanella* sp. |
| *Hirculus serpyllifolius* | *Trifolium dasyphyllum* |
| *Ligularia holmii* | *Trifolium nanum* |

so small that they are unlikely to be targeted for a food source. *Ranunculus karelinii* could be collected by pikas (*Ochotona princeps*), or grazed by other small mammals in the alpine, but this has not been documented (Johnston 2001).

*Ranunculus glacialis*, known from alpine habitats in the European Alps, showed considerable damage from herbivores, primarily snow mice (*Microtus nivalis*) at a study site in Austria (Diemer 1996). However, herbivory decreased as elevation increased, and it was absent at the highest elevations (Diemer 1996). *Ranunculus glacialis* is browsed by reindeer (*Rangifer*) and ptarmigan (*Lagopus*) in northern Norway (Diemer 1996). An overview of plant tolerance to consumer damage is presented in Stowe et al. (2000).

### *Competitors and symbioses*

The community ecology and interspecific relationships of *Ranunculus karelinii* have not been formally studied. In general, the habitat for *R. karelinii* is sparsely vegetated. It is possible that *R. karelinii* occupies these sites because there is less interspecific competition. For a discussion of the threats to *R. karelinii* from exotic species, please see the Threats section of this document. Herbarium specimens and occurrences observed showed no signs of parasites or disease. There have been no substantiated reports of symbiotic or mutualistic interactions between *R. karelinii* and other species.

# CONSERVATION

## *Potential Threats*

Although there are threats to the persistence of *Ranunculus karelinii* in Region 2 in Colorado and Wyoming, their severity and extent appear to be moderate to low. In order of decreasing severity, the potential threats are effects of small population size, global climate change, motorized recreation, grazing, non-motorized recreation, exotic species invasion, mining, and pollution. Each occurrence of *R. karelinii* is not necessarily threatened by all of these factors. Overall, the threats and the hierarchy ascribed to them are speculative; they may vary from site to site, and more complete information on the biology and ecology of this species may reveal other threats. Further, the scale and time frame within which these factors directly impact occurrences of *R. karelinii* are unknown. Assessment of threats to this species will be an important component of future inventory and monitoring work.

In general, the effects of land use within the habitat of *Ranunculus karelinii* appear to be minimal. Many of the occurrences are in isolated areas with few management concerns. However, alpine plants can be particularly vulnerable, even to small alterations (Willard and Marr 1971). For example, the removal of a rock providing shelter, a change in the course of a small rivulet of water, or the compaction of soil can destroy the microenvironment vital to a plant's survival (Colorado Native Plant Society 1997). At high elevations, small disturbances may result in severe consequences (Colorado Native Plant Society 1997). Occurrences of *R. karelinii* in Region 2 are often so small that even small scale disturbances could eliminate them.

### Small population size

*Ranunculus karelinii* may be vulnerable within Region 2 because of its small total population, with population estimates currently at approximately 358 individuals (**Table 2**; Johnston 2001, Colorado Natural Heritage Program 2005, Johnston personal communication 2005, Wyoming Natural Diversity Database 2005). Although rigorous population estimates are wanting, the prospect of catastrophes such as severe drought, disease or pest outbreak, severe trampling or other local surface disturbances, does make this species vulnerable to local extirpation. The degree to which *R. karelinii* can survive bad years will depend on how long individual plants can persist, or remain dormant as seeds, which is not known.

The small size of many occurrences of *Ranunculus karelinii* in Region 2 and the species' potential dependence on outcrossing make inbreeding depression, loss of genetic diversity, genetic drift, and population fragmentation important issues for the conservation of the species. Little is known about the population genetics of *R. karelinii*. The degree of connectedness among populations in Region 2 is not known, but current information suggests that many of the occurrences are genetically isolated from each other. Known occurrences within Region 2 are separated by approximately 1 to 500 miles (**Figure 4**; see also the Demography section of this report). It is likely that gene flow is occurring among a few occurrences within Region 2 but certainly not among all.

Small populations are particularly vulnerable to stochastic events (Huenneke 1991). They may have lower genetic variability and therefore be less able to adapt to a changing environment and less able to respond to pressures such as pests and disease (Barrett and Kohn 1991). Genetic drift has a particularly strong influence on small and isolated populations, and genetic variability is lost even more quickly, which makes these populations more prone to local extirpations (Barrett and Kohn 1991).

Small, isolated populations also have the potential problem of reduced gene flow, potentially leading to inbreeding depression (Barrett and Kohn 1991). However, the genetic system of *Ranunculus karelinii* may have adjusted to small population size since the occurrences have been naturally isolated for thousands of years (i.e., not anthropogenically caused isolation; Barrett and Kohn 1991).

Overall, the small number of occurrences and the high degree of isolation of individual occurrences suggest that *Ranunculus karelinii* is imperiled in Region 2. *Ranunculus karelinii* is very poorly understood, which is a liability because well-intended conservation actions cannot be as effective when basic information is not available. A high percentage of occurrences apparently have not been visited and assessed in over 20 years. This adds a great deal of uncertainty to any assessment using these data. Often when a species thought to be rare is actively sought and inventoried, it is found that the species is not as rare as previously believed.

### Global climate change

Anticipated increases in $CO_2$ and other "greenhouse" gases are predicted to warm the earth by several degrees Celsius during the 21$^{st}$ century (Price and Waser 1998). Global climate change is likely to have wide-ranging effects. Projections based on current atmospheric $CO_2$ trends suggest that average temperatures will increase while precipitation will decrease in Colorado (Manabe and Wetherald 1986). These changes will significantly affect soil moisture, nutrient cycling, vapor pressure gradients, rates of plant growth, and timing of plant growth (Price and Waser 1998). Temperature increase could cause vegetation zones to climb 350 ft. in elevation for every 1 ºF of warming (U.S. Environmental Protection Agency 1997). Habitat contraction induced by global climate change could affect the long-term survival of *Ranunculus karelinii*. Since this species relies on mesic to dry habitats, lower soil moistures in the growing season induced by decreased precipitation could have serious impacts. Further, as an alpines species, *R. karelinii* has limited options for migrating upwards, and it may be affected by competition from other lower elevation plants species that migrate to higher elevations as temperatures increase.

At high elevations, global warming is likely to result in a longer snow free period, which will affect plant growth and reproduction. Spring snow melt has been shown to be a very strong environmental cue that many alpine plants respond to when they begin initial springtime growth and flowering (Billings and Bliss 1959, Price and Waser 1998). Research by Price and Waser (1998) has shown that many plants respond to warming and earlier snow melt with a phenological shift: they flower earlier, but not necessarily for a longer period of time. Over time, this shift may be seen in other aspects of the plant community and ecological relationships. For example, animal mutualists (e.g., pollinators, seed dispersers) and enemies (e.g., herbivores, seed predators) may or may not, also shift (Price and Waser 1998). Further, community structure can shift and change how all species respond to the above interactions. For example, a shift in phenology may result in another plant species now competing for limited pollinator resources (Price and Waser 1998).

Other climate change models predict increased winter snowfall (e.g., Giorgi et al. 1998), which has other implications for *Ranunculus karelinii*. Increased snowfall could delay the onset of the growing season for *R. karelinii* if persistent snow covers occurrences late into the spring, again causing potential problems with phenological shifts discussed above. In this scenario, *R. karelinii* may have more options for migrating to lower elevations. However, an increase in competition from other lower elevation plant species could become a new stress to overcome. An increase in snow depth, extent, and duration may also affect the carbon and nitrogen dynamics in the soil (Williams et al. 1998). For example, if snowfall increases in alpine areas, then there may be increased decomposition rates (Williams et al. 1998).

### Motorized recreation

Motorized recreation (e.g., off-road and all-terrain vehicles, motorcycles, snowmobiles) poses a potential threat to the quality and availability of habitat for *Ranunculus karelinii* in parts of Region 2. Although motorized recreation has not been documented at any of the known occurrences of *R. karelinii* in Region 2, some occurrences are in areas that are open to this use, and the popularity of motorized recreation is increasing on public lands throughout Wyoming and Colorado. At least 12 of the 21 known occurrences in Region 2 appear to be secure in this regard. Eight occurrences are located within wilderness areas (Austin personal communication 2005, Houston personal communication 2005, Olson personal communication 2005) where roads and motorized vehicles are not allowed. There is no all-terrain vehicle or motorcycle access and no trails or roads within 1 mile of the Italian Mountain occurrence on the Gunnison National Forest (Austin personal communication 2005). The Peak 10 area on the White River National Forest is closed to all vehicles off established roads and trails, but snowmobile use may be permitted in this area in the future (Johnston 2001). The Bullion Mine location is also closed to all vehicles off established roads and trails, but it is open to snowmobile use. The ridge east of Grays Peak is closed to all vehicles off established roads, and there are no roads nearby (Johnston 2001, Turecek personal communication 2005). Motorized vehicle use is also prohibited at Engelmann and Robeson Peaks (Turecek personal communication 2005).

Nine occurrences of *Ranunculus karelinii* have the potential to be affected by motorized recreation. Off-road vehicle use is becoming an issue on the Shoshone National Forest, and resource managers are aware of potential problems (Houston personal communication 2004). This use could potentially affect the one occurrence in this forest that is not located in a wilderness area. The Bullion Mine and Hilltop Mine occurrences in Summit County, Colorado (White River National Forest) also appear to be vulnerable to motorized recreation uses (Colorado Natural Heritage Program 2005, Johnston personal communication 2005). Areas with old mining roads may be of particular concern for motorized recreation (Olson personal communication 2005). Unfortunately, federal agencies often lack the sufficient resources to patrol the vast areas they manage. It is not known whether motorized recreation does or does not pose a threat to other occurrences of *R. karelinii* in Region 2.

While the primary impact of motorized recreation on *Ranunculus karelinii* would be reduction of habitat, this use would also potentially affect individuals and occurrences directly and indirectly. Disturbed sites may offer fewer species of pollinators for *R. karelinii* than natural sites. Off-road vehicles could threaten occurrences of *R. karelinii* directly by altering habitat and killing individuals and indirectly as roads can be sources of erosion and dispersal corridors for exotic plant species. While it is likely that *R. karelinii* can self-pollinate, it may also be a primarily outcrossing species, and roads could act as barriers to pollinators for *R. karelinii* and prevent effective gene flow by disrupting the trap lines of pollinators.

The threats posed by snowmobiles are different than those posed by summer motorized recreation. Snowmobiles compact and move snow, resulting in a change of the timing of snow melt, which is an important factor for growth of alpine plants (Billings and Bliss 1959, Price and Waser 1998). Snowmobile use causes structural changes in the snow, changes in snow temperature gradients, water holding capacity, and melting rate (Neumann and Merriam 1972). Following snowmobile use, temperature gradients are less, and low temperatures extend further down into the snow, which may be more stressful for organisms that live beneath the compacted snowfields. The snow under snowmobile trails is denser and melts more slowly (Keddy et al. 1979). The compacted snow also creates a partial gas seal over the ground during snowmelt, which may affect decomposition and other ecological factors.

Researchers in Nova Scotia investigated the impacts from snowmobiles making one to 25 passes over an area (Keddy et al. 1979). They found that the first pass caused the greatest increase in snow compaction (75 percent). Increased intensity (more passes over same spot) caused less damage than increased frequency. The authors conclude from their observations that it is preferable for snowmobiles to use trails than diffuse use. They also found that areas covered with ice in the winter do not appear to be as damaged by snowmobile use, so it might help to divert snowmobile use to ice-covered areas. More research is needed to determine the impacts of motorized recreation, including snowmobile use, on *Ranunculus karelinii* in Region 2.

### Grazing

Grazing by domestic cattle and sheep, as well as wild ungulates (e.g., mountain goats [*Oreamnos americanus*], elk [*Cervus elaphus*], and bighorn sheep [*Ovis canadensis*]) poses a potential threat to some occurrences of *Ranunculus karelinii* in Region 2. Domestic sheep have grazed the tundra throughout the Rocky Mountains since the early 1900s (Colorado Native Plant Society 1997). The intensity of sheep grazing was heaviest in the early 1900s and is much less today (Vorhis personal communication 2004). Many of the occurrences of *R. karelinii* in Region 2 are located at elevations that are too high for cattle grazing. Elk and deer are known to graze the fruit of *R. adoneus* (Scherff et al. 1994). It is not known if *R. karelinii* is palatable to livestock animals or large native herbivores, but plants are vulnerable to trampling and soil compaction by grazers.

Very few sites for *Ranunculus karelinii* are known to have any current grazing activity. There are no active grazing allotments that include occurrences of *R. karelinii* on the Pike-San Isabel National Forest (Olson personal communication 2005). There is no evidence of grazing at Sleeping Giant Mountain or Galena Creek on the Shoshone National Forest (Houston personal communication 2005). There is no livestock grazing on Italian Peak in the Gunnison National Forest because it is too steep. However, there could be grazing here by mountain goats as they are known to utilize alpine vegetation on the nearby Taylor Pass (Austin personal communication 2005). At the Uncompahgre Peak occurrence, there is heavy elk use, especially on the south flank of the mountain (Austin personal communication 2005). A sheep allotment on the south flank was closed due to the elk use. Currently, sheep grazing occurs for 10 days on the northwest side of Uncompahgre and ten days on the northeast side including the alpine. There is also a livestock driveway running north-south through the area with sheep use every year for about five days. Outfitter guides also use this driveway for horse packing trips (Austin personal communication 2005). It is not known how these areas overlap with the occurrence of *R. karelinii*; location information lacks the precision to address this concern.

### Non-motorized recreation

Non-motorized recreation, especially hiking, trail construction, maintenance, and trail realignments, could threaten some of the occurrences of *Ranunculus karelinii* in Region 2 (Johnston 2001, Atchley and Madsen 2002). Although many of the occurrences are in remote locations that receive little human visitation, such as Italian Mountain on the Gunnison National Forest (Austin personal communication 2005), Galena Creek and Sulphur Creek on the Shoshone National Forest (Houston personal communication 2005), others are in areas that are popular for recreational use.

Potential impacts from hikers are particularly acute on the 14,000-foot peaks that support *Ranunculus karelinii*: Uncompahgre Peak, Missouri Mountain, and Gray's Peak. For example, it is not uncommon for Gray's Peak to have 200 people a day climbing to the summit on summer weekends (Turecek personal communication 2005). Use by hikers is also heavy on Uncompahgre Peak (Austin personal communication 2005). Hikers do not always stay on designated trails; people cut switchbacks, and many "social trails" form even though these activities are strongly discouraged with signs on Uncompahgre Peak (Austin personal communication 2005, Turecek personal communication 2005).

Hiking may also be a concern for some occurrences on the Pike-San Isabel National Forest (Olson personal communication 2005) and on the White River National Forest at the Bullion Mine (East of Montezuma) location (Johnston 2001). The occurrences at Grizzly Peak, Mount Belford, and Missouri Mountain on the Pike-San Isabel National Forest are located along trails (Colorado Natural Heritage Program 2005), and it is possible that some plants were lost with the construction of the trails. Specific problems posed by non-motorized recreation at the other occurrences of *Ranunculus karelinii* are not known.

The recreational uses discussed above could damage or kill individuals, change soil properties, or initiate erosion. Recovery from trampling depends on its duration and severity. If trampling is light (e.g., over just one year), the recovery time may be relatively short, such as one year. Recovery from severe trampling over longer periods takes much longer. Alpine areas are particularly vulnerable to trampling. For example, Willard and Marr (1971) studied an alpine area that that been trampled for 38 years. Four years of observation following the extensive trampling showed no improvement whatsoever. The authors estimate that tundra damaged for only a few seasons may require hundreds of years, possibly even a thousand years, to fully recover (Willard and Marr 1971). Trampling by recreational users has been shown to cause substantial declines in the number of plant species present and decreases in plant density and seed production (Colorado Native Plant Society 1997).

### Exotic species invasions

Although no exotic species have been documented with *Ranunculus karelinii* (Colorado Natural Heritage Program 2005, Wyoming Natural Diversity Database 2005), there are several aggressive weeds that have invaded areas of native plant habitat at high elevations in Colorado that pose a serious potential threat to this species and its habitat. To date, plants that are considered noxious weeds that have been reported at high elevations in Colorado include yellow toadflax (*Linaria vulgaris*), spotted knapweed (*Centaurea biebersteinii*), scentless chamomile (*Matricaria perforata*), ox-eye daisy (*Leucanthemum vulgare*), Shasta daisy (*L. maximum*), and Canada thistle (*Breea arvense*) (Lane personal communication 2003). Most likely, these noxious weeds come into areas following disturbances, and they could be spread by recreation activities including hiking and summer motorized recreation. Therefore, the occurrences of *R. karelinii* in closest proximity to roads and/or heavy recreational use are probably most vulnerable. The best strategy for protection of *R. karelinii* is to prevent the introduction of these non-natives by carefully monitoring occurrences for such a change in species composition, and to implement a weed management plan without delay if noxious weeds are detected.

### Mining

It is possible that occurrences of *Ranunculus karelinii* were impacted by historical mining activities in the mountainous areas of Wyoming and Colorado. Occurrences at Galena Creek, Bullion Mine, and Hilltop Mine are close to historic mining sites.

Currently, there is no known mining activity in close proximity to any of the known occurrences of *Ranunculus karelinii* (Austin personal communication 2005, Houston personal communication 2005, Johnston personal communication 2005, Olson personal communication 2005). However, mining could take place in the future, even in the wilderness areas, and none of the occurrences of *R. karelinii* in Region 2 are protected from mining over the long term. The impacts from even small-scale mining could be severe depending on the proximity of occurrences and/or potential habitat for *R. karelinii*. Extraction activity as well as associated roads could cause habitat degradation and destruction.

The Bullion Mine occurrence on the White River National Forest is close to lands with many privately owned mineral patents (Johnston 2001). This area has many old mining roads, and one is in close proximity to the occurrence of *Ranunculus karelinii*.

### Pollution

Atmospheric nitrogen deposition (of both organic and inorganic forms) is increasing worldwide. A recent analysis of available information on atmospheric nitrogen deposition in the Rocky Mountains of Colorado and southern Wyoming (Burns 2003) shows that this region receives nitrogen deposition at a level that may have already caused changes in otherwise pristine systems. The increase in nitrogen deposition is resulting from agricultural uses and burning fossil fuels (vehicles) east of the Rocky Mountains. Nitrogen deposition is generally greater east of the Continental Divide than west of the Divide along the Front Range, except in areas that are directly downwind of large power plants (Burns 2003). Westward movement of air from the Denver-Boulder-Fort Collins metropolitan area appears to be a strong contributor (Burns 2003). It is not known how specific occurrences of *Ranunculus karelinii* are responding to these changes.

Experimental nitrogen enrichment of alpine sites suggests that ecosystem processes are altered, and this results in species turnover (Bowman et al. 1993, Bliss and Gold 1999). Relatively low levels of nitrogen enrichment are advantageous to some species but deleterious to others, making it difficult to predict species- and community-level responses. Again, it is not known how *Ranunculus karelinii* would respond to these changes.

## *Conservation Status of Ranunculus karelinii in Region 2*

### Is distribution or abundance declining in all or part of its range in Region 2?

Given the changes that have taken place within the occupied habitat of *Ranunculus karelinii* over the last 100 years (e.g., mining, grazing, recreational uses), it can be assumed that in some places the distribution of this species has been diminished. Because the pre-settlement population size of *R. karelinii* is not known, it is difficult to assess the effects of historic land use, infrastructure, and management regimes on abundance. While prolonged or constant disturbance such as mining, overgrazing, and heavy off-road vehicle use is likely to extirpate occurrences, periodic light to moderate disturbance may be tolerable.

Because of the multiple management regimes in effect within the distribution of *Ranunculus karelinii* in Region 2, it is likely some properties are not managed in such as way as to allow the persistence of *R. karelinii*. While the net human impact on the distribution and abundance of *R. karelinii* is difficult and complicated to assess, the cumulative impact of historic mining, grazing, and recreation could be resulting in a current decline of *R. karelinii*. Further focused inventory and monitoring work will help to determine the current population trend of this species.

### Vulnerability due to life history and ecology

Assessing the vulnerability of *Ranunculus karelinii* in Region 2 is complicated by the paucity of information available about its life history and ecology. As a perennial plant, it is buffered to a degree from the effects of environmental stochasticity such as drought. Further, because it may have effective mechanisms for selfing, it may also be buffered from impacts that affect its pollinators. The degree to which it can survive stressful environmental conditions over consecutive years will depend largely on how long individual plants can persist, or remain dormant as seeds, which is not known.

### Evidence of populations in Region 2 at risk

Although there is some evidence that the known occurrences of *Ranunculus karelinii* in Region 2 are facing some risk, further inventory and research on *R. karelinii* are warranted before conservation actions are taken. Potential threats to *R. karelinii* in Region 2 include the effect of small population size, global climate change, motorized recreation, grazing, non-motorized recreation, exotic species invasion, mining, and pollution. These have the potential to put occurrences of this species at risk in Region 2. However, this is a species that is especially rare in Region 2 because it is on the edge of its natural range.

There are numerous areas that offer some protection to *Ranunculus karelinii* in Region 2: eight of the 21 occurrences are found in wilderness areas (the Big Blue Wilderness Area in the Gunnison National Forest, the Collegiate Peaks and Buffalo Peak wilderness areas in the Pike-San Isabel National Forest, and the North Absaroka Wilderness Area in the Shoshone National Forest). These areas prohibit off-road vehicle use, but they may allow mining and grazing.

The total population size of *Ranunculus karelinii* in Region 2 is very small (an estimated 358 plants documented). However, the occurrences may be viable, and it is likely that additional plants will be found with further inventory effort (Dorn personal communication 2005, Johnston personal communication 2005).

## *Management of Ranunculus karelinii in Region 2*

### Implications and potential conservation elements

The most current data available suggest that Region 2 is peripheral to the main geographic range of *Ranunculus karelinii* and that it is imperiled in this part of its range due to a small number of occurrences, and small population size. Additional inventory work is warranted to determine if this species is as rare as it appears. Management policies may need to address motorized recreation, human and natural disturbance regimes, pollinator resources, and restoration of native plant communities for occurrences that are in less remote areas. Given (1994) offers much practical advice regarding restoration that will assist with the development of effective management and restoration policies.

There is no documentation of the consequences of historic, ongoing, or proposed management activities on the abundance and distribution of *Ranunculus karelinii*. The autecology of *R. karelinii* is not yet understood well enough to understand cause-effect relationships between *R. karelinii* density and natural processes (i.e., drought) or human-mediated changes to the environment (i.e., livestock grazing).

Desirable conditions for *Ranunculus karelinii* persistence include occurrence in sufficiently large areas where the natural ecosystem processes persist unimpeded by human activities and their secondary effects, such as weeds. This can include maintaining a satisfactory degree of ecological connectivity between occurrences, which provides corridors and other nectar resources for pollinators. From a functional standpoint, ecosystem processes on which *R. karelinii* depends appear to remain intact to some extent. Whether this will remain true as the human population densities increase in the area and with the potential impacts of global warming is uncertain. Further research on the ecology and distribution of *R. karelinii* will help to develop effective approaches to management and conservation.

A thoughtful assessment of management practices on lands occupied by *Ranunculus karelinii* will probably identify opportunities for change that would be inexpensive and have minimal impacts on the livelihood and routines of local residents, managers, permittees, and recreationists while conferring substantial benefits to *R. karelinii*.

## Tools and practices

### *Species inventory*

Species inventories are among the highest priorities for research on *Ranunculus karelinii* in Region 2. Few places in the Region have been deliberately searched for this species (Johnston personal communication 2005). Collecting baseline information and developing a detailed map of the known distribution and abundance will provide a starting point from which population trend can be assessed, and it will help to assign appropriate conservation priorities for this species. Species inventories are simple, inexpensive, effective, and necessary for developing a sufficient understanding of the target species for developing a monitoring program. Contracting experts on this species to search for more occurrences and to update historic records would contribute greatly to our knowledge of *R. karelinii*.

During the 1980s, 1990s and early 2000s, several botanists who were aware of the significance of occurrences of *Ranunculus karelinii* conducted botanical research in the alpine areas of Colorado (Spackman et al. 1995, Spackman et al. 1997b, Spackman et al. 1999, Lyon and Sovell 2000, Spackman et al. 2001, Lyon et al. 2003, Yeatts personal communication 2004, Jennings personal communication 2005, Lederer personal communication 2005). During this time, 11 new locations were documented in Colorado, including new county records for Hinsdale and Gunnison counties.

Although *Ranunculus karelinii* is a relatively inconspicuous species, it is not difficult to distinguish from other members of *Ranunculus*. Field crews could be quickly taught to recognize it in the field. Areas with the highest likelihood of new occurrences are those in close proximity to the known occurrences. Many areas within the known range of *R. karelinii* have not been searched because of the difficulties in accessing remote areas. Search efforts could also target areas with similar habitats to the known occurrences, such as headwater streams, talus slopes, and alpine meadows.

### *Habitat inventory*

The Colorado Natural Heritage Program routinely uses aerial photography, topographic maps, soil maps, and geology maps to refine search areas when conducting inventories for particular species. This method is most effective for species about which there is basic knowledge of its substrate and habitat specificity from which distribution patterns and potential search areas can be deduced. Searches for *Ranunculus karelinii* could be aided by modeling habitat based on the physiognomy of known occurrences. The intersection of topography, geologic substrate, and vegetation could be used to generate a map of a probabilistic surface showing the likelihood of the presence of *R. karelinii* in given locations. This would be a valuable tool for guiding and focusing future searches. Techniques for predicting species occurrences are reviewed extensively by Scott et al. (2002). Habitat modeling has been done for other sensitive plant species in Wyoming (Fertig and Thurston 2003) and Colorado (Decker et al. 2005), and these methods apply to *R. karelinii* as well.

### *Population monitoring*

The best time for inventory and monitoring of *Ranunculus karelinii* in Colorado and Wyoming is from late June through early August, when the plants are flowering. Measuring seed production may require a visit later in the summer, after fruit set. A monitoring program for *R. karelinii* would begin by targeting the known occurrences; other occurrences could be added to the program as they are discovered. Since all of the known occurrences in Region 2 are very small (50 or fewer individuals), a complete count of each occurrence could be made. Because there could be a high annual variability in reproductive effort, annual re-sampling will be necessary for consecutive years to gain insight into the population dynamics of *R. karelinii*. If larger occurrences are discovered, then a more complex sampling design may be necessary. It will be important to define *a priori* the changes that the sampling regime intends to detect, and the management actions that will follow from the results (Schemske et al. 1994, Elzinga et al. 1998).

Monitoring sites that are being managed in different ways will help to identify best management practices for *Ranunculus karelinii* and will help to elucidate its population dynamics and structure. Suitable methods for monitoring pollinators are discussed in Kearns and Inouye (1993).

Adding a photo point component to population monitoring (Elzinga et al. 1998) could facilitate the tracking of individuals and add valuable qualitative information. A handbook on photo point monitoring (Hall 2002) is available that offers detailed instructions on establishing photo point monitoring plots. Monitoring sites should be selected carefully, and a sufficient number of sites should be selected if the data are intended to detect population trends. Several methods of monumentation are recommended in Elzinga et al. (1998) depending on the site physiography and the frequency of human visitation to the site. This is an important consideration that will reap long-term benefits if done properly at the outset of the monitoring program.

At present, priorities lie in gathering data on distribution and population sizes for *Ranunculus karelinii*. Gathering population size data can be done rapidly and requires only a small amount of additional time and effort (Elzinga et al. 1998). Thus, presence/absence monitoring is not recommended for *R. karelinii*.

### *Habitat monitoring*

Habitat monitoring would be particularly beneficial to *Ranunculus karelinii*. For sites that are occupied by *R. karelinii*, habitat monitoring should be conducted concurrently with population monitoring. Documenting habitat attributes, disturbance regime, and associated species during all population monitoring efforts will greatly augment our present understanding of this species' habitat requirements and management needs. Fields describing habitat characteristics could be incorporated into the field forms used for the sampling described above. If carefully selected environmental variables are quantified during monitoring activities, they may help to explain observations of population change. Habitat monitoring of known populations will alert managers of new impacts such as weed infestations and damage from human disturbance. Making special note of signs of degradation from recreational uses may help managers to prevent serious degradation proactively by implementing changes in the management regime. Evidence of current land uses and management are important to document while monitoring populations.

Estimating cover and/or abundance of associated species in the vicinity of the occurrences could permit the investigation of interspecific relationships through ordination or other statistical techniques. Gathering data on edaphic characteristics (e.g., moisture, texture, and soil chemistry) would permit the analysis of species-environment relationships. These data would facilitate hypothesis generation for further studies of the ecology of this species.

Observer bias is a significant problem with habitat monitoring (Elzinga et al. 1998). Thus, habitat monitoring is usually better at identifying new impacts than at tracking change in existing impacts. For example, estimating weed infestation sizes, using broad size classes helps to reduce the effects of observer bias. To assess trampling impacts, using photographs of impacts to train field crews will help them to consistently rate the severity of the impact.

The use of photopoints for habitat monitoring is described in Elzinga et al. (1998). This is a powerful technique that can be done quickly in the field. Although it does not provide detailed cover or abundance data, it can help to elucidate patterns observed in quantitative data.

### *Beneficial management actions*

Management practices that reduce the impacts of recreation and grazing (and possibly mining) on populations of *Ranunculus karelinii* will contribute to the long-term survival of this species in Region 2. Enforcing the exclusion of motorized recreation and reducing heavy non-motorized recreation within all known occurrences is most likely to be compatible with the persistence of *R. karelinii*. Use of travel restrictions, signs, and fencing to reduce recreation impacts on populations and habitat may be the best course of action in some places. Re-routing or closing trails or roads may be necessary in some cases. Another approach that might be considered on a site-by-site basis is the use of exclosures. Maschinski et al. (1997) found the use of exclosures to be effective in protecting the endangered sentry milkvetch (*Astragalus cremnophylax* var. *cremnophylax*) from trampling. Johnston (2001) also suggests protecting sites occupied by *R. karelinii* from road and trail construction and maintenance activities.

Establishing Research Natural Areas and Special Interest Areas at the known locations of *Ranunculus karelinii* would likely confer substantial benefits. Research Natural Areas do not permit motorized activities or mining, and they provide the highest possible level of protection.

Inventory and monitoring studies would benefit *Ranunculus karelinii*. Identifying large, undisturbed, high quality occurrences will help managers to prioritize conservation efforts. Much suitable habitat within the range of *R. karelinii* remains to be searched.

Appropriate management of natural vegetation in the vicinity of populations of *Ranunculus karelinii* is likely to benefit pollinators and may improve the likelihood of persistence for currently unknown populations. Avoiding activities that facilitate the invasion of noxious weeds and other non-native invasive plants would also be beneficial.

Maintaining genetic integrity and eliminating inbreeding depression are important management considerations for *Ranunculus karelinii*. Since it is may be an outcrossing species, *R. karelinii* could be even more vulnerable to inbreeding depression in small populations or in populations with limited pollinator activity. It is possible that *R. karelinii* can self-pollinate, but it may also be a primarily outcrossing species. An augmentation plan for populations whose existence appears threatened could be developed as necessary. If genetic studies suggest it, this may include increasing the number or size of *R. karelinii* occurrences by seeding (with local seed stock) or by improving the habitat.

#### *Seed banking*

No seeds or genetic material for *Ranunculus karelinii* are currently in storage at the National Center for Genetic Resource Preservation (Miller personal communication 2004). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (2002), but there are two other species of *Ranunculus* represented in the collection, *R. aestivalis* and *R. reconditus*. Collection of seeds of *R. karelinii* for long-term storage will be useful if future restoration work is necessary. Collection should be from populations representing the variability of the habitat.

## ***Information Needs***

### Distribution

Further species inventory work specifically targeting *Ranunculus karelinii* is a high research priority for this species in Region 2. Until we have a complete picture of its distribution and abundance, it will not be possible to accurately assess the conservation needs and priorities for this species. Often when a species thought to be rare is actively sought and inventoried, it is found that the species is not as rare as previously believed. Although *R. karelinii* has already been sought in several studies, habitat throughout its range in Region 2 has not been closely inventoried. Places to focus future search efforts include areas in close proximity to the known occurrences, areas with similar habitat to the known occurrences, and other alpine areas throughout Region 2. Obtaining estimates of occurrence size is a very high priority, and will contribute greatly to our understanding of this species.

If population size allows, specimens should be collected to document each new occurrence, and potentially each new observation. Specimens with flowers and fruit should be collected if possible so that accurate identifications can be made. Specimens are not available to document six of the known occurrences. As population size allows, collections should be made to document locations at Grizzly Peak, Missouri Mountain, Mount Belford, Engelmann-Robeson Peaks, Bullion Mine, and Uncompahgre Peak.

### Life cycle, habitat, and population trend

Research on *Ranunculus karelinii* is needed to understand its population ecology. Investigation of its lifespan and autecology would improve our ability to manage for the long-term survival of this species.

The habitat for *Ranunculus karelinii* has been roughly described, but the nature of its natural habitat and natural disturbance regime is poorly understood. Particular environmental variables to which *R. karelinii* responds are unknown. Understanding its habitat and being able to identify suitable habitat are particularly important for the conservation and management of *R. karelinii*. Autecological research is needed to help refine our definition of appropriate habitat and to facilitate effective habitat monitoring and conservation stewardship of this species.

The population trend of *Ranunculus karelinii* is not known. Understanding the population biology of *R. karelinii* is important for appropriate stewardship and management of this species.

### Response to change

Rates of reproduction and establishment and the effects of environmental variation on these parameters have not been investigated in *Ranunculus karelinii*. Thus, the effects of various management options cannot be assessed during project planning. Understanding the specific responses of *R. karelinii* to disturbance is important for determining appropriate management practices, but they are not clear and need further investigation.

### Metapopulation dynamics

Research on the population ecology of *Ranunculus karelinii* has not been done to determine the importance of metapopulation structure and dynamics to its long-term persistence at local or regional scales. Migration, extinction, and colonization rates are unknown for *R. karelinii*. Baseline population dynamics and viability must first be assessed. Studies of allele frequencies in the different occurrences of *R. karelinii* could clarify the degree of population connectivity, and facilitate prioritization of protection efforts.

### Demography

Only the broadest generalizations can be made at present regarding the demography of *Ranunculus karelinii*. Population size has not been assessed for many populations of *R. karelinii*. Growth and survival rates are also unknown, and the rate of reproduction is poorly understood. Our knowledge of the distribution of the species is incomplete. Therefore much work is needed in the field before persistence can be assessed with demographic modeling techniques. Short-term demographic studies often provide misleading guidance for conservation purposes, so complementary information such as historical data and experimental manipulations should be included whenever possible (Lindborg and Ehrlén 2002).

### Population trend monitoring methods

There has been no monitoring of *Ranunculus karelinii*, but methods are available to design a monitoring program. Lesica (1987) described a technique for monitoring populations of non-rhizomatous perennial plant species that would apply to *R. karelinii*. Selection of monitoring sites being managed in different ways is necessary to monitor population trend.

### Restoration methods

There have been no known attempts to restore habitat and populations of *Ranunculus karelinii*. Therefore, there is no applied research from which to draw in developing a potential restoration program. It is likely that *R. karelinii* may be readily propagated in a greenhouse environment, but it may be difficult to transfer plants successfully into a natural or quasi-natural (restored) setting.

### Research priorities for Region 2

Further inventory work is needed to identify the distribution of *Ranunculus karelinii* in Region 2. Focusing on expanding the boundaries of known populations, identifying new populations, and searching other areas in the vicinity of historic occurrences is the best first step towards developing a complete understanding of the distribution of this species. Targeted search efforts at phonologically-appropriate times (late June to early August) in suitable habitat will help to confirm the distribution and abundance of *R. karelinii* and may identify other opportunities for its conservation. Identifying robust occurrences in natural settings is important for setting conservation targets and priorities. Collecting detailed notes on associated species, habitat, geology, soil, and other natural history observations at all locations will be extremely useful information. Documentation of any threats and visible impacts to *R. karelinii* will help to develop conservation strategies, and will help managers act to mitigate these threats.

Reaching a better understanding of the influence of human activities on individuals and habitat of *Ranunculus karelinii* in Region 2 will confer substantial practical benefits for land managers and planners. Identifying life history and phenological stages when *R. karelinii* is less sensitive to recreational impacts would help greatly to mitigate threats by developing management practices that are compatible with *R. karelinii*.

The role of disturbance in the autecology of *Ranunculus karelinii* remains poorly understood. An understanding of the tolerances of *R. karelinii* to different human and natural disturbance regimes will assist with developing conservation strategies and management plans by determining the types of disturbance most likely to negatively impact it. Further research is warranted to determine the effects of the current levels of grazing to populations of *R. karelinii*.

Information gleaned from studies of the physiological and community ecology of *Ranunculus karelinii* will be valuable in the event that a population needs to be restored, and it will help to determine biotic and abiotic factors that contribute to its survival. Understanding the plant-environment relationship for *R. karelinii* will be insightful in understanding the coping strategies employed by this species, and it will help to model its potential distribution.

# DEFINITIONS

**Autecology –** the study of a single species and its relationship with the environment.

**Diploid –** having two similar complements of chromosomes.

**Ecoregion –** large geographically defined area that integrates various environmental conditions, such as climate and geology, and that supports distinctive groupings of species and ecological communities.

**Edaphic –** soil and the physical, chemical, and biological factors that influence organisms.

**Glabrous –** completely smooth, with no hairs.

**Mesic –** moist.

**Metapopulation –** discontinuous subpopulations that collectively exhibit certain population-like functions.

**Monumentation –** securing location markers for plots, transects, or population boundaries.

**Pilose –** having long soft hairs.

**Potential Conservation Area (PCA) –** a best estimate of the primary area supporting the long-term survival of targeted species or natural communities. PCAs are circumscribed for planning purposes only (Colorado Natural Heritage Program 2005).

**Propagules –** buds or shoots.

**Protogynous –** female organs appear before male parts/organs.

**Quadrat –** a small area used in an ecological survey to study the distribution and abundance of species in detail.

**Sepal –** one of the outer flower segments.

**Tomentose –** dense wooly or cottony hairs.

**Imperilment Ranks used by Natural Heritage Programs, Natural Heritage Inventories, Natural Diversity Databases, and NatureServe.**

Global imperilment (G) ranks are based on the range-wide status of a species. State-province imperilment (S) ranks are based on the status of a species in an individual state or province. State-province and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character. **These ranks should not be interpreted as legal designations.**

| | |
|---|---|
| **G/S1** | Critically imperiled globally/state-province because of rarity (5 or fewer occurrences in the world/state; or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction. |
| **G/S2** | Imperiled globally/state-province because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range. |
| **G/S3** | Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences). |
| **G/S4** | Apparently secure globally/state-province, though it might be quite rare in parts of its range, especially at the periphery. |
| **G/S5** | Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery. |
| **GX** | Presumed extinct. |
| **G#?** | Indicates uncertainty about an assigned global rank. |
| **G/SU** | Unable to assign rank due to lack of available information. |
| **GQ** | Indicates uncertainty about taxonomic status. |
| **G/SH** | Historically known, but not verified for an extended period, usually. |
| **G#T#** | Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5. |
| **S#B** | Refers to the breeding season imperilment of elements that are not permanent residents. |
| **S#N** | Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used. |
| **SZ** | Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliable identified, mapped, and protected. |
| **SA** | Accidental in the state or province. |
| **SR** | Reported to occur in the state or province, but unverified. |
| **S?** | Unranked. Some evidence that the species may be imperiled, but awaiting formal rarity ranking. |

**Notes:** Where two numbers appear in a G or S rank (e.g., S2S3), the actual rank of the element falls between the two numbers.

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