Parnassia kotzebuei Chamisso ex Sprengel (Kotzebue's grass-of-Parnassus): A Technical Conservation Assessment

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

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COVER PHOTO CREDIT

Parnassia kotzebuei (Kotzebue's grass-of-Parnassus). Photographs by Susan Spackman Panjabi.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *PARNASSIA KOTZEBUEI*

Status

Parnassia kotzebuei Chamisso ex Sprengel (Kotzebue's grass-of-Parnassus), a small and inconspicuous member of the Saxifrage family (Saxifragaceae), has short, leafless flowering stems that support single flowers with small white petals. On a global scale, this is a relatively common species of *Parnassia*. It grows in mesic to wet, arctic and alpine habitats across circumpolar areas of the northern hemisphere, and it is found in scattered locations at high elevations in Washington, Nevada, Idaho, Montana, Wyoming, and Colorado.

The distribution of *Parnassia kotzebuei* in the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS) is quite limited relative to its overall range. Within Region 2, this species is found only in Wyoming and Colorado. Some of the locations in Wyoming fall outside of Region 2, in Region 4. *Parnassia kotzebuei* is known from 27 locations in Region 2, and these occurrences contain an estimated 1,135 plants occupying less than 27 acres. It is likely that with additional searches, more occurrences will be found in Region 2, and additional surveys are warranted before conservation actions are proposed.

NatureServe ranks *Parnassia kotzebuei* as globally secure (G4). Within Region 2, the Colorado Natural Heritage Program and the Wyoming Natural Diversity Database both rank this species as imperiled (S2). USFS Region 2 considers *P. kotzebuei* a sensitive species. Of the 27 known locations in Region 2, at least 21 occurrences are on National Forest System land. Two occurrences are within Rocky Mountain National Park in Colorado. This species has also been documented on private land in Region 2. One occurrence is entirely on private land. The location information for three other occurrences is not specific enough to determine land ownership.

Primary Threats

Although *Parnassia kotzebuei* occurrences in Colorado and Wyoming are exposed to threats, the severity and extent of the threats are moderately low. In order of decreasing severity, potential threats to this species include effects of small population size, global climate change, motorized recreation, grazing, non-motorized recreation, exotic species invasion, mining, and pollution.

Primary Conservation Elements, Management Implications and Considerations

Despite its rarity within Region 2, *Parnassia kotzebuei* occurs on land administered by six national forests (Arapaho-Roosevelt, Pike-San Isabel, San Juan, and White River national forests in Colorado, Shoshone and Bighorn national forests in Wyoming). Ten occurrences are afforded some protection in the Indian Peaks, Flat Tops, Weminuche, Absaroka-Beartooth, North Absaroka, and Cloud Peak wilderness areas of the USFS, and two occurrences receive some protection within Rocky Mountain National Park.

Research is needed to clarify threats to the persistence of *Parnassia kotzebuei* in Region 2. Mitigation is needed to ensure that occurrences are not lost. Species inventories are a high priority for *P. kotzebuei* and are likely to identify new occurrences. Investigations of the population biology and autecology of *P. kotzebuei* will improve the effectiveness of conservation efforts on the species' behalf.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the USDA Forest Service (USFS), Rocky Mountain Region (Region 2). *Parnassia kotzebuei* is the focus of an assessment because it is 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 *P. kotzebuei* 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 the Assessment

Species assessments produced for 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. Instead, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and examines the success of those management recommendations that have been implemented.

Scope of the Assessment

The assessment examines the biology, ecology, conservation status, and management of *Parnassia kotzebuei* 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 studies outside the region, this document places that literature in the ecological and social contexts of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *P. kotzebuei* 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, peer-reviewed 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 *Parnassia kotzebuei*. It is mentioned in few other sources. Because little research has been conducted on the biology of this species, literature on its congeners was used to make inferences. The peer-reviewed and non-refereed literature on the genus *Parnassia* and its included species is more extensive, especially *P. palustris*, which is closely related to *P. kotzebuei* (Phillips 1982). All known publications that include *P. kotzebuei* are referenced in this assessment, and many experts on this species were consulted during its synthesis. Specimens were viewed at the Rocky Mountain Herbarium at the University of Wyoming, the University of Colorado Herbarium, Colorado State University Herbarium, University of Northern Colorado Herbarium, and the Kalmbach Herbarium at the Denver Botanic Gardens.

The assessment emphasizes peer-reviewed 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 there is very little peer-reviewed literature that specifically addresses *Parnassia kotzebuei*. Much of the information about past and current conditions affecting *P. kotzebuei* was compiled through conversations with land managers and other agency employees. For an unstudied species such as *P. kotzebuei*, 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 observations and information from individuals who could not be contacted during the preparation of this assessment.

Treatment of Uncertainty in Assessment

Science is a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are

always incomplete and our observations are limited, science includes techniques 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 described when appropriate.

Treatment of This Assessment as a Web Publication

To facilitate the use of species assessments in the Species Conservation Project, they will be published on the USFS 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. More important, it facilitates revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review of This Assessment

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

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Parnassia kotzebuei was added to the Regional Forester's sensitive species list that was released in November 2003. This species is found on six national forests in Region 2, including the White River, Pike-San Isabel, Arapaho-Roosevelt, and San Juan national forests in Colorado, and the Bighorn and Shoshone national forests in Wyoming. Within Region 2, *P. kotzebuei* is also found in Rocky Mountain National Park and on private land. It is not found on land administered by the Bureau of Land Management (BLM) in Region 2, nor is it included on the BLM's state sensitive species lists for either Colorado or Wyoming. This species has not been documented on state lands within Region 2. It is not listed as threatened or endangered under the federal Endangered Species Act, nor is it protected by any Colorado or Wyoming state laws.

NatureServe (2004) considers *Parnassia kotzebuei* to be globally secure (G4). It is ranked imperiled in Colorado (S2) because it is known from just 15 occurrences in the state, only three of which support at least 100 plants (Colorado Natural Heritage Program 2004a). *Parnassia kotzebuei* is also considered imperiled in Wyoming (S2) because it is known from just 16 occurrences in the state, 12 of which are in Region 2 and four of which are in Region 4. No information is available regarding the species' abundance in Wyoming (Wyoming Natural Diversity Database 2004). Work is needed to document the distribution and abundance of *P. kotzebuei* in Region 2. The state conservation ranks for this species will be re-evaluated as information becomes available. For explanations of NatureServe's ranking system, see the **Definitions** section of this assessment.

Parnassia kotzebuei is found in several sites with some protection. Ten of the 27 occurrences are located in USFS wilderness areas (the Indian Peaks Wilderness Area in the Arapaho-Roosevelt National Forest, the Weminuche Wilderness Area in the San Juan National Forest, the Flat Tops Wilderness Area in the White River National Forest, the Cloud Peak Wilderness Area in the Bighorn National Forest, and the Absaroka-Beartooth and North Absaroka Wilderness Areas in the Shoshone National Forest), and two occurrences are in Rocky Mountain National Park. These areas prohibit off-road vehicle use, but wilderness areas may permit mining and grazing (San Juan Mountains Association 2004).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

As of this writing, a conservation strategy has not been written for *Parnassia kotzebuei* at a national or regional level by the USFS or any other agency. No management plans specifically address its conservation needs. USFS mandates require that the agency avoid disturbing sensitive species, such as *P. kotzebuei*, in ways that would result in a trend toward federal listing or a loss of population viability. All potential habitat must be surveyed prior to activities that could affect sensitive species. There are no laws in place that protect this species on private lands. While there is only one

documented occurrence on private land in Region 2, it is likely that the species occurs elsewhere on private lands within its known range.

There have been no known cases in which an occurrence of *Parnassia kotzebuei* was extirpated due the failure to enforce existing regulations. If the total population of *P. kotzebuei* in Region 2 is as small as it appears to be, extirpation is possible but not likely given the remote nature of some of the occurrences and the extent of unsurveyed potential habitat. Since existing records of this species provide little detailed information, and since there are very few repeat observations, it is not clear whether current laws and regulations (none of which is specific to *P. kotzebuei*) are adequate to conserve the species in Region 2.

The Colorado Natural Heritage Program (2004a) has identified several Potential Conservation Areas (PCAs) that contain *Parnassia kotzebuei*. These include Glacier Basin in Larimer County; Mosquito Range, North Star Mountain, and Blue Lakes in Summit County; Mosquito Range and Mount Sheridan in Park County; and Burns Gulch and Balsam Lake in San Juan County. 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. In order to facilitate awareness of this species and its habitat during the management planning process, the Colorado Natural Heritage Program has provided information regarding these PCAs to Larimer County (Kettler et al. 1996), Summit County (Spackman et al. 1997b), Park County (Spackman et al. 2001), San Juan County (Lyon et al. 2003), and the USFS (Colorado Natural Heritage Program 2004b). PCA boundaries do not confer any regulatory protection of the site, nor do they automatically exclude all activities (Colorado Natural Heritage Program 2004a).

Biology and Ecology

Classification and description

Most taxonomists consider *Parnassia kotzebuei* Chamisso ex Sprengel to be a member of the Saxifragaceae (Dorn 1992, Watson and Dallwitz 1992, Flora of North America Association 2000, USDA Natural Resources Conservation Service 2004). The Saxifragaceae includes approximately 1,250 species in 80 genera (Heywood 1993). This family is in class Magnoliopsida (dicotyledons), subclass Rosidae, and order Rosales (USDA Natural Resources Conservation Service 2004). The Saxifragaceae is found primarily in temperate regions of the northern hemisphere (Watson and Dallwitz 1992, Heywood 1993).

Some taxonomists and authors place *Parnassia* in the Parnassiaceae (e.g., Phillips 1982, Cronquist et al. 1997, Weber and Wittmann 2001, Snow and Brasher 2004). Placed in the same class, subclass, and order as the Saxifragaceae, the Parnassiaceae includes only *Parnassia*, and about 25 (Cronquist et al. 1997) to 50 (Phillips 1982) species. Most of the species in this genus grow in the Altai and Himalaya regions of Asia (Weber 2003). Although there is some question as to the family placement of the genus *Parnassia*, there does not appear to be any question regarding the validity of *P. kotzebuei* at the generic or specific level.

The Parnassiaceae is not included in the Flora of North America (Flora of North America Association 2000). The Saxifragaceae is included in Volume 8, which is in production. *Parnassia* will be included in the Saxifragaceae and is being authored by Raymond Phillips of Colby College (Flora of North America Association 2000).

The genus *Parnassia* was first described by Linnaeus in 1753, using a specimen of *P. palustris* (Phillips 1982). Systematic analyses of the genus *Parnassia* were done in 1875 by Drude, and updated by Phillips in the early 1980s (Phillips 1982). Six sections are recognized with the genus, and Phillips places *P. kotzebuei* in section *Parnassia*. Species in this section have the most elaborately developed staminodia, which serve to attract pollinators. Phillips (1982) placed *P. kotzebuei* in the *P. palustris* group, which contains the species most closely related to *P. kotzebuei*, including *P. palustris*, *P. parviflora*, *P. fimbriata*, and *P. californica*. *Parnassia californica* is not known from Colorado or Wyoming (USDA Natural Resources Conservation Service 2004).

History of knowledge

Parnassia kotzebuei was first described in 1825 by C.P.J. Sprengel, using material collected by Ludolf Adalbert von Chamisso in 1816 in Eschscholtz Bay, Alaska (Cronquist et al. 1997, Harvard University Herbarium 2004). Chamisso was the botanist on a northern Pacific scientific expedition (Colorado Native Plant Society 1997). Sprengel named *P. kotzebuei* for Otto von Kotzebue, a Russian explorer and the commander of the expedition (Duft and Moseley 1989, Weber and Wittmann 2001). Isotypes are located at the Gray Herbarium at Harvard University, and at the Kew

Herbarium at the Royal Botanic Gardens in England (Cronquist et al. 1997).

Within Region 2, *Parnassia kotzebuei* has been documented from 27 occurrences in Clear Creek, Garfield, Grand, Larimer, Park, San Juan, and Summit counties in Colorado, and in Johnson and Park counties within Region 2 in Wyoming. Four locations outside of Region 2 in Wyoming occur in Teton and Sublette counties; these are not discussed in this assessment. *Parnassia kotzebuei* has not been seen in Grand County, Colorado since 1972. Fourteen of the 27 Region 2 records have not been updated in more than 20 years (Colorado Natural Heritage Program 2004a, Wyoming Natural Diversity Database 2004). The lack of information from repeat visits makes it difficult to assess trends and threats to this species.

In Region 2 in Wyoming, discoveries of *Parnassia kotzebuei* were made between 1979 and 1988, documenting a total of 12 occurrences. The first discovery of *P. kotzebuei* in Region 2 was in Wyoming in 1900 by F. Tweedy, who collected this species at the headwaters of Clear and Crazy Woman creeks in Johnston County. In 1979, *P. kotzebuei* was documented again in Wyoming, by Ron Hartman on the Bighorn National Forest in Johnson County. From 1980 through 1988, Erwin Evert documented this species in eight new locations in Wyoming, in the Shoshone and Bighorn national forests in Park and Johnson counties. In 1983 and 1984, Ron Hartman and Robert Dorn collected *P. kotzebuei* at two new locations on the Shoshone National Forest in Park County, Wyoming. Available information suggests that only one of these occurrences has ever been revisited; a 1984 collection location was revisited in 1989 (Wyoming Natural Diversity Database 2004).

The first discovery of *Parnassia kotzebuei* in Colorado was made in 1954 by William Weber, who collected this species along Monte Cristo Creek in Summit County (probably on the Dillon Ranger District of the White River National Forest but possibly on private land). In 1961, Joan Michener collected *P. kotzebuei* near Balsam Lake in the San Juan National Forest in San Juan County, Colorado. It was next documented in 1969 by Weber at another location along Monte Cristo Creek (probably on the Dillon Ranger District of the White River National Forest but possibly on private land). In 1972, Vera Komarkova documented four new locations while she was collecting in the Indian Peaks Wilderness on the Arapaho-Roosevelt National Forest in Boulder and Grand counties, Colorado. In 1982, Emily Hartman and Mary Lou Rottman found *P. kotzebuei* in Burns Gulch in San Juan County, Colorado, a location that is thought to be on private land (Colorado Natural Heritage Program 2004a). In 1987, Loraine Yeatts collected this species for the first time in Rocky Mountain National Park in Larimer County, Colorado. In 1991, Nancy Redner located a new occurrence in Summit County, Colorado, on the Dillon Ranger District, White River National Forest. In 1994, *P. kotzebuei* was documented for the first time in Clear Creek County, Colorado, in the Arapaho-Roosevelt National Forest by Linda Senser and others. In 1996, the species was documented for first time in Park County, Colorado, on the Pike National Forest by Tass Kelso (a specimen was not collected here due to the small population size). In 1996, Bill Jennings and others located a new occurrence in Clear Creek County, Colorado, on the Arapaho-Roosevelt National Forest. In 2000, a location was discovered in Rocky Mountain National Park in Boulder County by Nan Lederer and Mike Figgs. Also in 2000, USFS Botanist Karen Vail made a significant discovery of this species in Garfield County, a county record and a new location for the White River National Forest. Only two of these occurrences have been visited more than once; the 1982 Burns Gulch location was revisited in 2002, and the 1991 Summit county record was revisited in 1997.

Overall, the information available for *Parnassia kotzebuei* in Region 2 is very sparse. In most cases, minimal data were gathered to document a herbarium specimen collection. There is little to no information on occurrence size or the area occupied by plants. None of the Wyoming records in Region 2 reports any information about plant abundance or occurrence extent.

Non-technical description

Parnassia kotzebuei is a small, rather inconspicuous, perennial plant. The stems are short (up to 10 cm tall, possibly taller when fruiting), usually leafless, and erect, each supporting a single, terminal flower. Basal leaves are entire, elliptical in shape, and have petioles that are equal to or longer than the leaf blade. The flowers are white, and each of the five petals is rounded, with one to three veins. Petals, sepals, and stamens are approximately equal in length (4 to 7 mm); petals may exceed sepals slightly in length). The fruiting capsule is ovoid, papery, and twice as long as the flowers (Polunin 1959, Porsild 1964, Duft and Moseley 1989, USDA Forest Service 1989, Dorn 1992, Spackman et al. 1997a, Weber and Wittmann 2001). As with other species of *Parnassia*, *P. kotzebuei* has five stamens and alternating staminodia, which have shining

yellow stalked glands (Weber and Wittmann 2001). The ovary of *P. kotzebuei* is superior and has four carpels (Weber and Wittmann 2001).

Parnassia kotzebuei could be confused with *P. parviflora*, *P. palustris*, or *P. fimbriata*, which also grow at high elevations in Colorado and Wyoming. However, *P. kotzebuei* can be distinguished by its bractless flowering stem, and small, 1 to 3-veined petals. *Parnassia parviflora*, *P. palustris*, and *P. fimbriata* have bractlike leaves on the flowering stems, and five to 13 veins on their petals, which are larger than the sepals (**Table 1**; Weber and Wittmann 2001, Dorn 1992). *Parnassia fimbriata* also has fringed petals (Duft and Moseley 1989). The closest relatives to *P. kotzebuei* are probably *P. palustris*, *P. parviflora*, *P. californica*, and *P. fimbriata* (Phillips 1982).

Published descriptions and other sources

Detailed descriptions of *Parnassia kotzebuei* are available in Volume Three, Part A of the Intermountain Flora (Cronquist et al. 1997), Anderson's Flora of Alaska and Adjacent Canada (Welsh 1974), the Flora of the Canadian Arctic Archipelago (Aiken et al. 1999), the Flora of Alaska and Neighboring Territories (Hultén 1968), Circumpolar Arctic Flora (Polunin 1959), A Flora of the Alaskan Arctic Slope (Wiggins and Thomas 1962), and Vascular Plants of Continental Northwest Territories, Canada (Porsild and Cody 1980). Weber and Wittmann (2001) and Dorn (1992) are the most readily available and up-to-date sources with keys for field identification within Colorado and Wyoming, but they do not include full descriptions of the species.

Photographs and illustrations of *Parnassia kotzebuei* are in the Colorado Rare Plant Field Guide (Spackman et al. 1997a), the Idaho and Wyoming Endangered and Threatened Plant Field Guide (USDA Forest Service 1989), and the Flora of the Canadian Arctic Archipelago (Aiken et al. 1999). Photographs appear in Alpine Wildflowers of the Rocky Mountains (Duft and Moseley 1989), and the Rare Plants of Colorado (Colorado Native Plant Society 1997). **Figure 1** and **Figure 2** are photographs of *P. kotzebuei* and its habitat.

Illustrations of *Parnassia kotzebuei* appear in Colorado Flora, Eastern Slope and Western Slope (Weber and Wittmann 2001), Volume 3 Part A of the Intermountain Flora (Cronquist et al. 1997), the Illustrated Flora of the Canadian Arctic Archipelago (Porsild 1964), Circumpolar Arctic Flora (Polunin 1959), the Flora of Alaska and Neighboring Territories: A Manual of the Vascular Plants (Hultén 1968), as well as The Alpine Flora of the Rocky Mountains (Scott 1995). **Figure 3** is the illustration of *P. kotzebuei* that was included in the Colorado Rare Plant Field Guide (Spackman et al. 1997a).

Distribution and abundance

Parnassia kotzebuei has a circumpolar distribution in the northern hemisphere, from northeast Asia to Alaska, across Canada to Greenland, and south into the north Cascades of Washington. It is found in scattered locations throughout the Rocky Mountains of Montana, central Idaho, northwest Wyoming, and Colorado, and also in northern Nevada (Duft and Moseley

Table 1. Distinguishing characteristics of four species of *Parnassia* known from Colorado and Wyoming. Adapted from Weber and Wittmann (2001) and Dorn (1992). *Parnassia palustris* is reported to occur in Colorado (USDA Natural Resources Conservation Service 2004), but it is not included in the Colorado Flora (Weber and Wittmann 2001).

Species	Stem	Flowers	Leaves	Habitat
Parnassia kotzebuei	Bractless, or with a singe bract near the base	Petals small, about equal to sepals, 1 to 3 veined	elliptic	Moist rocky ledges, alpine, subalpine
Parnassia fimbriata	With a bract-like leaf, not near the base	Petals large, 5 to 13 veined, fringed below the middle	Cordate or reniform	Subalpine and alpine marshes and stream sides
Parnassia palustris	With a bract-like leaf, not near the base	Petals large (often over 7 mm long), 7 or more veined	Stem leaf often clasping	Moist areas mostly in the mountains
Parnassia parviflora	With a bract-like leaf, not near the base	Petals large (4 to 7 mm), 5 to 13 veined	Ovate, lanceolate, or elliptic	Subalpine marshes

Figure 1. Close-up photograph of plants and microhabitat for *Parnassia kotzebuei*. Photograph by Susan Spackman Panjabi.

Figure 2. Habitat for *Parnassia kotzebuei* is found along this lake shore. Photograph by Susan Spackman Panjabi.

1989, Spackman et al. 1997a). Several State Heritage Programs and Conservation Data Centers outside of Region 2 have ranked this species (NatureServe 2004). *Parnassia kotzebuei* is ranked imperiled (S2) in Idaho, critically imperiled (S1) in Washington, vulnerable (S3) in Alberta, secure (S4) in British Columbia, vulnerable to secure (S3S4) in Labrador, secure (S4) in Manitoba, imperiled to vulnerable (S2S3) in Newfoundland and Ontario, and critically imperiled (S1) in Saskatchewan. It is not ranked in Alaska, Montana, Nevada, Northwest

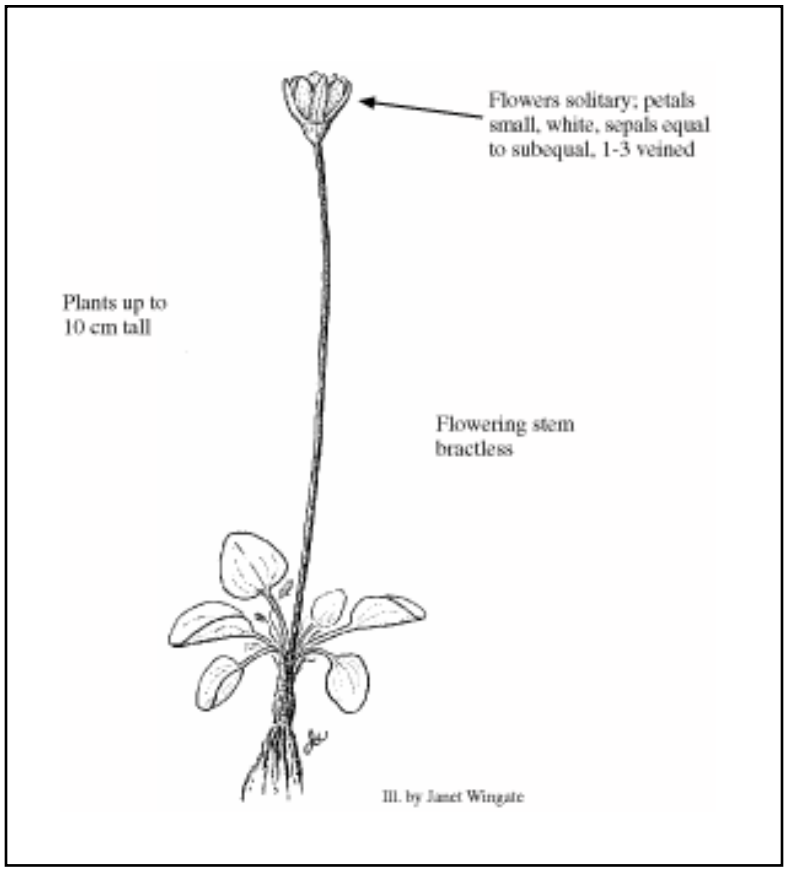

Figure 3. Illustration of *Parnassia kotzebuei* by Janet Wingate from the Colorado Rare Plant Field Guide (Spackman et al. 1997a). Used with permission of the artist.

Territories, Nunavut, Quebec, or the Yukon Territory. In Nevada, this species is only known from one location and would be ranked critically imperiled (S1). Cronquist et al. (1997) report that it is only known from one location in the Intermountain Region, undoubtedly referring to the Nevada location.

Parnassia kotzebuei is a peripheral species within Region 2, known from high elevation areas in Wyoming and Colorado (**Figure 4**). Habitat for *P. kotzebuei* in Region 2 is discontinuous on the landscape, so the species' distribution is patchy (Heidel and Laursen 2002). It is found in northwestern Wyoming and in the high mountains of Colorado. The range of *P. kotzebuei* within Region 2 is approximately 500 miles by 200 miles. Within this range there are 27 scattered locations; the known extant occurrences of *P. kotzebuei* in Region 2 are estimated to occupy a total of less than 27 acres (using available data from the Colorado Natural Heritage Program and Wyoming Natural Diversity Database in 2004). The occurrences in Wyoming are separated by almost 300 miles from the closest occurrences in Colorado. Some of the occurrences in Region 2 are close to other occurrences, and others are widely disjunct (**Figure 4**). Additional occurrences are likely to be discovered with further inventory.

The distribution of *Parnassia kotzebuei* in Region 2 is limited to National Forest System, National Park Service, and private land (**Figure 4**). In Wyoming within Region 2, *P. kotzebuei* is known from the Shoshone and Bighorn national forests. In Colorado, it is known from the Arapaho-Roosevelt, San Juan, White River, and Pike-San Isabel national forests. Although it is reported from the Grand Mesa, Uncompahgre and Gunnison National Forest (Heidel and Laursen 2002), we found no evidence to support this claim. Heidel (personal communication 2004) indicated that the information was provided to her by the USFS. *Parnassia kotzebuei* is suspected on the Medicine Bow National Forest in Wyoming since its distribution is similar to other circumpolar plants that have disjunct populations on that forest (Medicine Bow National Forest 2003).

It is possible that *Parnassia kotzebuei* once ranged more widely. The species' extremely limited distribution in the contiguous United States suggests that it is a glacial relict species whose range has been

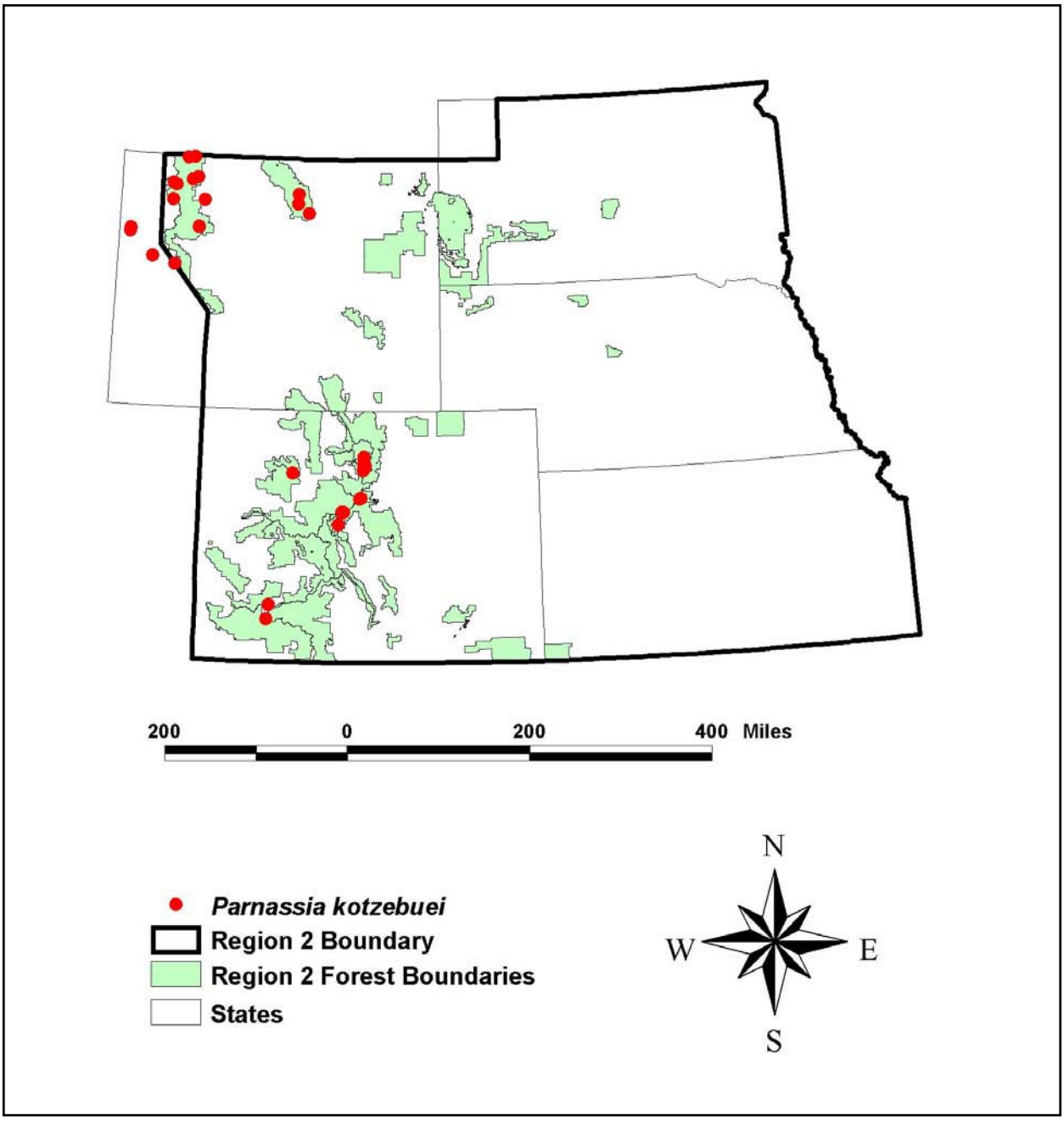

Figure 4. Distribution of *Parnassia kotzebuei* in relation to lands managed by the USDA Forest Service, Rocky Mountain Region.

diminished by naturally occurring habitat contraction. The habitat for this species might have been more continuous over a larger area during the cooler and wetter climate of the Pleistocene epoch.

Table 2 is a summary of the 27 known occurrences in Region 2. Abundance may vary from year to year, but there are few data to verify this. It should be noted that *Parnassia kotzebuei* is easily overlooked (Colorado Native Plant Society 1997, Lederer personal communication 2004) because it is inconspicuous and has a short flowering period (Kelso personal communication 2004, Yeatts personal communication 2004). Additional populations may remain undiscovered.

Several botanical surveys have detected *Parnassia kotzebuei* in Colorado (Komarkova 1979, Spackman et al. 1997b, Lyon et al. 2003, Jennings personal communication 2004), and there is much potential

Table 2. Summary data for the 27 known occurrences of *Parnassia kotzebuei* within USFS Region 2. Location names are provided for reference, rather than to identify a specific place on the ground. For example, the location called Headwaters of Clear Creek and Crazy Woman Creek is probably on the South Fork of Clear Creek, which is now called Sourdough Creek, and could be the headwaters of Sourdough and Caribou Creeks (Vorhis personal communication 2004). Habitat descriptions are taken from herbarium labels, field notes, and personal communications (Colorado Natural Heritage Program 2004, Wyoming Natural Diversity Database 2004).

State / Heritage Occurrence Number	County	Location Name	Land ownership/ management	Last observed	Observers	Number of plants	Occurrence size information	Site description, habitat information
CO 1	Larimer	Black Lake	Rocky Mountain National Park	10-Jul-1987	Loraine Yeatts	12	Eight plants in 1 m^2 area and a few others separated from main population; only place seen in area. Est #: 12	East-facing slope (ca 20%) on well-developed tundra ledges. Soil is deep pockets of organic granitic soil. Associated taxa include dense turf, moss. 11,200 ft.
CO 2	Summit	Monte Cristo Creek	Arapaho National Forest, Dillon Ranger District and/ or private	04-Jul-1954	W.A. Weber	10	None provided (assume at least 10 plants)	In deep moss mats along cold streamlet, deep spruce forest along creek. 10,800 feet. In mats of T*immia norvegica*, along small streamlets in deep wet spruce forest. Growing with *Carex capillaris*, *Parnassia fimbriata*, *Saxifraga adscendens*, and *Anemone parviflora*
CO 3	Grand	Pawnee Lake Cirque, Lone Eagle Peak	Arapaho-Roosevelt National Forests, Indian Peaks Wilderness	04-Aug-1972	V. Komarkova	10	None provided (assume at least 10 plants)	Lake cirque, glacier and base of southwest slopes of peak. 10,800 to 11,800 ft.
CO 4	Grand and Boulder	Lake Envy, Lake Gibraltar	Arapaho-Roosevelt National Forests, Indian Peaks Wilderness	20-Aug-1972	V. Komarkova	10	None provided (assume at least 10 plants)	Elevation 11,000 to 12,000 ft.
CO 6	Summit	Monte Cristo Creek, Blue Lake	White River National Forest, Dillon Ranger District and/ or private	02-Sep-1969	W.A. Weber	5	extremely rare (assume 5 plants)	Talus slope, on wet ledges. 11,800 ft.
CO 7	San Juan	Balsam Lake	San Juan National Forest, Weminuche Wilderness	24-Aug-1961	J. Michener	10	None provided (assume at least 10 plants)	Steep, wet moss-covered sites on the rare stable areas on an active talus slope. North-facing slope above lake. Elevation 12,000 ft.
CO 8	San Juan	Burns Gulch	Private	05-Jul-2002	Peggy Lyon	10	Only 6 plants seen, possibly would be more in a wetter year	Small wet ledge at top of scree slope with moss and some soil in moist crevice in cliff. Adjacent areas with typical alpine plants, including *Geum rossii* and *Salix reticulata*. Elevation 12,000 to 12,200 ft. Northeast-facing slope

Table 2 (cont.).

State / Heritage Occurrence Number	County	Location Name	Land ownership/ management	Last observed	Observers	Number of plants	Occurrence size information	Site description, habitat information
CO 9	Summit	Crystal Lake	Arapaho-Roosevelt National Forest, Dillon Ranger District	17-Jul-1997	Susan Spackman, Kim Fayette, Nancy Redner	636	636 plants in bloom counted in narrow strip along lakeshore	[Spackman and Fayette 1997:] The plants are mainly growing in wet, sandy soil covered by moss. The roots of the plants reach through the moss to the sandy soil. Most plants occur at the edge of the lake at the edge of the willows. Plants grow under the willow edge but do not continue into the stand. The surrounding parent material appears to be metamorphic rocks. [Redner 1994:] Total shrub cover 10%, total forb cover 10%, total graminoid cover 50%, total moss/lichen cover 30%. Associated plant community: mosses, *Salix brachycarpa*, *Salix glauca*, *Juncus drummondii*, *Ciminalis prostrata*, *Clementsia rhodantha*, *Psychrophila leptosepala*, *Deschampsia cespitosa*, and *Epilobium* sp. Habitat type: subalpine-moss community by lake. Flat slope in valley bottom at alpine glacial lake shore. Saturated soils saturated. 11,720 ft.
CO 10	Clear Creek	Naylor Lake	Arapaho-Roosevelt National Forest	02-Aug-2003	Erin Foley and Jill Torres, Bill Jennings, Linda Senser and others	100	100+ plants in an area 35 x 75 ft.	Linda Senser and others 1994: In damp moss; common associates include *Acomastylis rossii*, *Polemonium viscosum*, *Cirsium scopulorum*, *Cardamine cordifolia*, *Bistorta vivipara*, *Cerastium beeringianum*, and *Saxifraga* sp. Precambrian metamorphic substrate. On 30 degree slope. 11,883 feet. Erin Foley and Jill Torres 2003: Wet subalpine/ alpine, lakeside, and rocky coniferous slopes. Associated species: *Hymenoxys grandiflora*, *Dryas octopetala* var. *hookeriana*, *Geum rossii* var. *turbinatum*, and *Salix arctica* var. *petraea*. North aspect, 11,400 to 12,000 ft.

Table 2 (cont.).

State / Heritage Occurrence Number	County	Location Name	Land ownership/ management	Last observed	Observers	Number of plants	Occurrence size information	Site description, habitat information
CO 11	Clear Creek	Guanella Pass Road	Arapaho-Roosevelt National Forest	12-Aug-1996	Bill Jennings, Nan Lederer, Pat Murphy, and Ward Marotti	120	About 120 individuals counted in a few square m	Northeast aspect: NE, 40% slope in partial shade in an opening in spruce forest. Along a seasonal rivulet, moist all summer. Elevation: 11,000 ft. Glaciated mountain slope with highly organic soils. Total tree cover 40%, total shrub cover 10%, total forb cover 20%, total graminoid cover 5%, total moss/lichen cover 40%. Associated plants include *Picea engelmannii*, *Salix reticulata*, *Aquilegia coerulea*, *Swertia perennis*, *Carex norvegica*, and *Polygonum viviparum*
CO 12	Park	Horseshoe Cirque	Pike-San Isabel National Forest and/or private	10-Aug-1996	Tass Kelso	5	Estimated number of plants: 5	Associated plant community: streamside subalpine forbs (*Delphinium*, *Cardamine*, *Swertia*, *Gentianopsis barbellata*). Habitat type: moist stream bank. Forb cover: 100%. Partial shade below tall forbs. Topographic position: lower slope. Elevation: 12,400 ft.
CO 13	Garfield	Hooper Lake	White River National Forest, Flat Tops Wilderness	20-Jul-2000	Karen Vail	17	Estimated number of individuals: 17 counted in 5 $ft.^2$ in main area	Total shrub cover 40%, total forb cover 30%, total graminoid cover 20%, total moss/lichen cover 20%, total bare ground cover 5%. Associated plant community: *Salix arctica* ssp. *petraea* and *Acomastylis rossii* ssp. *turbinata*. Habitat type: tundra, aspect: east. Slope: 10 to 15%. Slope shape: straight to concave. Light exposure: open. Moisture: seasonally wet from snowmelt. Parent material: basalt. Geomorphic land form: glaciated slope. Soil texture: rocky with very little organic material. Elevation: 11,400 ft. rivulet above kettle pond and below snowfield
CO 14	Boulder	Upper Coney Lake	Arapaho-Roosevelt National Forest, Indian Peaks Wilderness	22-Jul-1972	V. Komarkova	10	None provided (assume at least 10 plants)	Above and around lake. 10,900 to 11,200 ft.
CO 15	Boulder	Red Deer Lake	Arapaho-Roosevelt National Forest, Indian Peaks Wilderness	07-Aug-1972	V. Komarkova	10	None provided (assume at least 10 plants)	Small cirque. 11,100 to 11,700 ft.

Table 2 (cont.).

State / Heritage Occurrence Number	County	Location Name	Land ownership/ management	Last observed	Observers	Number of plants	Occurrence size information	Site description, habitat information
CO 16	Boulder	Hutcheson Lakes	Rocky Mountain National Park	17-Jul-2000	Nan Lederer and Mike Figgs	50	50 plants counted in 1/4 acre or less	Glaciated subalpine/alpine valley. Most plants in fairly dense veg of forbs and grass, but some in bare mud or moss. Associated plant community: *Salix planifolia*, *S. brachycarpa*, *Trifolium parryi*, *Clementsia rhodantha*, moss, *Acomastylis rossii*, *Pedicularis scopulorum*, *P. groenlandica*, and *Swertia perennis*. Wet, steep, rocky, seepy alpine slope (outcrops not talus). Additional associated plants: *Carex scopulorum*, *C. capillaris*, and *Erigeron melanocephalus*. NNE aspect, 30 % slope. Moist to saturated. Metamorphic biotite schist. 11,400 ft.
WY NA	Johnson	Headwaters of Clear Creek and Crazy Woman Creek	Bighorn National Forest, Powder Ranger District, possibly within the Cloud Peak Wilderness	15-Aug-1900	F. Tweedy	10	None provided (assume at least 10 plants)	Elevation: 7,000 to 9,000 ft.
WY 1	Park	Gardner Lake	Shoshone National Forest, Clarks Fork Ranger District	23-Aug-983	Erwin Evert	10	None provided (assume at least 10 plants)	Dripping cliffs west of lake. 10,225 ft.
WY 2	Park	Beartooth Butte	Shoshone National Forest, Clarks Fork Ranger District, Absaroka Beartooth Wilderness	12-Aug-1984	Robert Dorn	10	None provided (assume at least 10 plants)	Rocky alpine slope. 10,000 ft.
WY 3	Park	Sleeping Giant Mountain	Shoshone National Forest, Wapiti Ranger District, North Absaroka Wilderness,	28-Jul-1981	Erwin Evert	10	None provided (assume at least 10 plants)	Above small lake on dripping cliffs. 10,300 ft. Collected with *Gentianella tenella*, *Erigeron humilis*, *Saxifraga cernua*, and *Carex incurviformis*
WY 4	Johnson	Lost Twin Lakes	Bighorn National Forest, Powder Ranger District, Cloud Peak Wilderness	06-Aug-1983	Erwin Evert	10	None provided (assume at least 10 plants)	Dripping cliffs. 10,200 ft.
WY 5	Johnson	Penrose Peak	Bighorn National Forest, Powder Ranger District, Cloud Peak Wilderness	20-Jul-1979	Ron Hartman	10	None provided (assume at least 10 plants)	Rocky alpine slopes. 10,200 ft.

Table 2 (cont.).

State / Heritage Occurrence Number	County	Location Name	Land ownership/ management	Last observed	Observers	Number of plants	Occurrence size information	Site description, habitat information
WY 9	Park	Cascade Creek	Shoshone National Forest, Greybull Ranger District	03-Aug-1989	Erwin Evert, R.S. Kirkpatrick, and R.E.B. Kirkpatrick	10	None provided (assume at least 10 plants)	Wet cliffs west of creek and wet meadows near timberline. 9,400-10,100 ft. With *Salix tweedyi* and *Saxifraga odontoloma*
WY 10	Park	Carter Mountain	Shoshone National Forest, Greybull Ranger District, Wapiti Ranger District	20-Aug-1983	Erwin Evert, R.S. Kirkpatrick, and R.E.B. Kirkpatrick	10	None provided (assume at least 10 plants)	Moist seep. 9,700 ft.
WY 14	Park	Chaos Mountain	Shoshone National Forest, Clarks Fork Ranger District	28-Jul-1980	Ron Hartman	10	None provided (assume at least 10 plants)	In moss in small rivulet. 10,200 ft. Associated with *Ranunculus pygmaeus*
WY 15	Park	Robbers Roost Creek	Shoshone National Forest, Clarks Fork Ranger District	02-Jul-1988	Erwin Evert	10	None provided (assume at least 10 plants)	Seepage areas along snowmelt channels. 10,200 ft. Associated with *Veronica wormskjoldii* and *Carex scopulorum*
WY 16	Park	Pat O'Hara Peak	Shoshone National Forest, Clarks Fork Ranger District	26-Jul-1988	Erwin Evert	10	None provided (assume at least 10 plants)	Around springs. 9,400 ft. Associated with *Carex scopulorum* and *Deschampsia caespitosa*
WY 17	Park	Whirlwind Peak	Shoshone National Forest, Clarks Fork Ranger District	08-Aug-1988	Erwin Evert	10	None provided (assume at least 10 plants)	Below late-melting snow banks. 10,400 ft. Associated with *Juncus mertensianus* and *Sedum rhodanthum*
TOTAL						**1135**		

habitat that remains to be searched in Region 2. Limited access to remote, high elevation areas and private land has made it difficult to search areas thoroughly within the known distribution of *P. kotzebuei*. While it is possible that the species is limited to the range as we know it, further inventories are necessary to verify this.

There has been no rigorous quantification of the total population of *Parnassia kotzebuei*. In Region 2, it is known from 27 occurrences, but very little is known about the total number of individuals (**Table 2**). Most of the occurrences in Region 2 have no information available documenting the total number of individuals. Based on the few occurrences in which population size is estimated (ranging from six to 636 individuals), it appears that many of the occurrences of *P. kotzebuei* are very small. Among the nine occurrences where abundance was reported, six reported fewer than 100 plants, and five of these reported fewer than 20 plants (**Table 2**). The largest occurrences are at Crystal Lake, Naylor Lake, and Guanella Pass in Colorado. However, these occurrences were never rigorously quantified. Nineteen of the 27 occurrences have not been visited in more than 15 years, and 17 do not report population size. For the purposes of this report, based on what we know about the population sizes for this species in Region 2 (**Table 2**), we estimate that each occurrence had at least 10 plants at the time it was observed, and therefore the total population size in Region 2 is at least 1,135 individuals.

Similarly, there has been no rigorous quantification of the total area occupied by *Parnassia kotzebuei*. While a few observers reported visual estimates of the total area of certain occurrences, 20 of 27 provide no information regarding the extent of occupied habitat (Colorado Natural Heritage Program 2004a, Wyoming Natural Diversity Database 2004). For the purposes of this assessment, based on what we know about occurrence extent in Region 2 (**Table 2**), we concluded that each occurrence probably occupies less than one acre, and that the total area of occupied habitat is therefore less than 27 acres.

Population trend

There are no quantitative data that could be used to infer the population trend of *Parnassia kotzebuei* in Region 2. Population estimates in **Table 2** are rough, and there have been few repeat observations and no population monitoring that could provide insight into population trend. In Region 2, recreational use, grazing, historical mining, and associated roads within *P. kotzebuei* habitat suggest that there may have been at least a slight downward trend since the region was settled.

Populations are likely to fluctuate naturally due to annual climatic variation. Drought probably reduces or eliminates recruitment of *Parnassia kotzebuei* seedlings, and juvenile plants may or may not be capable of surviving one or more bad years. Lyon (personal communication 2004) observed a very small population (six plants) at Burns Gulch on private land in San Juan County, and suggested that in a wetter year more plants would likely be present. Fluctuations such as this would make it more difficult to estimate the population accurately.

Habitat

Throughout its global range, *Parnassia kotzebuei* is found in mesic to wet meadows, in wet, sandy lakeshores (Porsild 1964), wet mossy areas (Polunin 1959), thickets, along creeks (Hultén 1968), on wet slopes, dripping cliffs, and moist tundra (Cronquist et al. 1997). The habitat is described by Duft and Moseley (1989) as "alpine meadows and tundra."

Habitat descriptions in Region 2 are documented through the work of botanists reporting to the Colorado Natural Heritage Program (Colorado Natural Heritage Program 2004a), or on labels of specimens deposited at the University of Colorado Herbarium and the Rocky Mountain Herbarium. Weber and Wittmann (2001) describe the habitat for *Parnassia kotzebuei* in Colorado as "rocky ledges and rills, subalpine, alpine." Spackman et al. (1997a) add that the species is found in "wet areas along streamlets and in moss mats." In Wyoming, Scott (1995) described the habitat as "tundra and moist to wet rocky places." *Parnassia kotzebuei* microhabitats have been described as the shores of lakes, ponds, streams, and creeks, dripping cliffs, rivulets, seeps, and seepage areas along snowmelt channels. Other habitat descriptions include tundra ledges, talus slopes, rocky alpine slopes, and meadows, in mossy areas, within fairly dense vegetation of forbs and grasses, and in bare mud or moss (Colorado Natural Heritage Program 2004a). *Parnassia kotzebuei* is found primarily above tree line, and also in subalpine forest openings, on rocky coniferous slopes, and in deep spruce forests. Occurrences are usually in remote, infrequently visited areas (Heidel and Laursen 2002, Colorado Natural Heritage Program 2004a). **Table 2** contains all of the information regarding habitat that has been provided for each occurrence within Region 2.

Parnassia kotzebuei is considered an obligate wetland species in western Colorado and western Wyoming, meaning that the species nearly always occurs in wetlands (U.S. Fish and Wildlife Service 1988). It is considered 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).

Parnassia kotzebuei grows where the parent material is described as sedimentary, metamorphic, or igneous. Horseshoe Cirque (in Colorado) is carved in sedimentary rocks (Olson personal communication 2004). The occurrences in the Bighorn National Forest are on granitic substrates (Vorhis personal communication 2004). Element occurrences records document parent materials of Precambrian metamorphic rocks, basalt, and granite (Colorado Natural Heritage Program 2004a). Fertig (personal communication 2004) reported that this species may have an affinity for alkaline soils. The few occurrences of *P. kotzebuei* that describe the soils report slightly or highly organic and sandy soils (Colorado Natural Heritage Program 2004a) or thin clay soils (Heidel and Laursen 2002). Our understanding of the distribution of *P. kotzebuei* in Region 2 would benefit from an investigation of this species' distribution patterns in relation to geologic and edaphic characteristics.

Parnassia kotzebuei is found across an approximately 3,000-foot elevation range in Region 2. Element occurrence records report elevations between 9,400 ft. in the Absaroka Mountains of Wyoming and 12,280 ft. in Horseshoe Cirque in Colorado (Colorado Natural Heritage Program 2004a, Wyoming Natural Diversity Database 2004). *Parnassia kotzebuei* is found on flat to steeply sloping terrain, and has been documented on cooler north, northeast, and east aspects (Colorado Natural Heritage Program 2004a). However, slope and aspect are not reported for most of the known locations (Colorado Natural Heritage Program 2004a, Wyoming Natural Diversity Database 2004).

Within Colorado, *Parnassia kotzebuei* occurs in the Southern Rocky Mountain Ecoregion, and in Wyoming, it occurs in the Utah-Wyoming Rocky Mountain Ecoregion in the ecoregional classification of Bailey (1995).

In characterizing the environment affecting *Parnassia kotzebuei* occurrences, we referred to climate 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 *P. kotzebuei* is Climax, Colorado, at approximately 11,500 feet in Summit County. The climate is typical of alpine regions, consisting of short, cool summers and long, cold winters. During the fall, winter, and spring months, the Climax weather station receives between 2 and 49 inches of snow. The ground is generally snow-free from July through mid-September. *Parnassia kotzebuei* probably grows most actively in July and August when rainfall totals exceed 2 inches per month and average maximum temperatures are at their highest. Average maximum temperatures are 64.5 °F in July and 62.4 °F in August.

The conditions that constitute high quality and marginal habitat for *Parnassia kotzebuei* are not clearly understood. Occurrences with natural vegetation that are minimally impacted by human activities and supporting dense populations probably constitute examples of high quality habitat.

Reproductive biology and autecology

Very little is known about the reproductive ecology and autecology of *Parnassia kotzebuei*. While the plants are probably 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 have both male and female sexual organs. *Parnassia kotzebuei* fruits are non-fleshy, dehiscent capsules (Polunin 1959, Watson and Dallwitz 1992, Aiken et al. 1999). Each fruit contains 100 to 120 seeds (Aiken et al. 1999). The life span and growth rate of *P. kotzebuei* have not been investigated. A close relative, *P. palustris*, has a "long" life span (exact length not indicated) and a moderate growth rate (USDA Natural Resources Conservation Service 2004).

Two cytodemes have been documented for *Parnassia kotzebuei*: a diploid (2n = 18) and a tetraploid (2n = 36). Diploid and tetraploid forms have been documented in other members of the Saxifragaceae (Ness et al. 1989). *Parnassia palustris* also has a diploid (2n = 18) and a tetraploid (2n = 36) cytodeme (Wentworth and Gornall 1996). *Parnassia palustris* tetraploids are known to be autopolyploids (Ness et al. 1989, Wentworth and Gornall 1996). Tetraploids of autoploid origin have greater genetic and biochemical versatility than diploid individuals (Borgen and Hultgard 2003). It is not known if a similar dynamic exists within populations of *P. kotzebuei*.

Pollinators and pollination ecology

The pollination ecology of *Parnassia kotzebuei* has not been investigated. Research on the pollination ecology of a close relative, *P. palustris* (e.g., Hultgard 1987, Bonnin et al. 2002, Sandvik and Totland 2003), showed that *P. palustris* is protandrous, meaning that the five stamens release their pollen before the stigma begins to mature, which enforces cross-pollination. Earlier studies reported that *P. palustris* was usually cross-pollinated and rarely autogamous (Hultgard 1987). However, Bonnin et al. (2002) found that *P. palustris* plants were self-compatible. Sandvik and Totland (2003) studied two populations of *P. palustris* in Norway (one at sea level and the other in the mountains) and found that the flowers in both populations were highly dependent on insect visitation for maximum seed set. However, for the population at sea level, the insects primarily cross-pollinated the flowers, while at the high elevation site, the pollinators facilitated self-pollination.

The most common insect visitors to *Parnassia palustris* are species of Diptera (flies), and Hymenoptera (bees and ants) (Sandvik and Totland 2003). Insect visitors to *P. kotzebuei* have not been documented.

Parnassia kotzebuei has five sterile stamens, or staminodes. In their research on *P. palustris*, Sandvik and Totland (2003) found that staminodes acted as both false and true nectaries. The conspicuous, shiny staminodes resemble nectaries and attract pollinators. While they offer no reward at the tips, they do produce nectar at their bases. The staminodes increase pollinator visitation rate and duration, which likely increases reproductive success (Sandvik and Totland 2003).

Phenology

Parnassia kotzebuei bears one flower on a short (usually less than 10 cm), leafless stem (Duft and Moseley 1989, Spackman et al. 1997a). As a subalpine/alpine plant species, it has a relatively short period of flowering. In Region 2, *P. kotzebuei* typically flowers in late June through August (USDA Forest Service 1989, Colorado Natural Heritage Program 2004a), but it is not likely to be in flower for the full length of time. By late August, most flowers have dried and produced fruits. Because *P. kotzebuei* occurs in mesic to wet sites, recruitment probably is confined to wet or otherwise favorable years during which seedlings can become established.

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 timing and rate of snowmelt (Billings and Bliss 1959, Walker et al. 1995). Billings and Bliss (1959) found that alpine plants can begin growth when the air and soil temperatures are still near the freezing point of water. In their study of 34 alpine plant species in the Medicine Bow Mountains of Wyoming, most species reached maximum flowering three weeks after initial growth; seed maturation and dispersal took seven to eight weeks. Overall, maximum plant productivity happened soon after release from snow cover and then tapered off erratically until the end of the growing season. Most of the early productivity evidently results from resources stored during the previous year. 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 below ground for the following summer (Walker et al. 1995). Although the specific growth habits of *Parnassia kotzebuei* are unknown, it is likely that this species follows a similar pattern.

Fertility and propagule viability

Seed germination requirements for *Parnassia kotzebuei* have not been investigated. Seed biology studies and germination trials were conducted on *P. asarifolia*, which is known from scattered locations from West Virginia to Alabama (Farmer 1980). This research was conducted on a high elevation population in the southern Appalachian Mountains and showed that while some seeds of *P. asarifolia* germinate immediately upon dispersal in the fall, most do not germinate until spring (Farmer 1980). The seeds evidently have a chilling requirement that prevents fall germination and promotes uniform low temperature germination in the spring. It is not known how *P. kotzebuei* would respond to similar treatments.

It is possible to grow *Parnassia palustris* from seed, but plants cannot be propagated from bare roots (USDA Natural Resources Conservation Service 2004). Seedling vigor of *P. palustris* is reported to be low (USDA Natural Resources Conservation Service 2004). *Parnassia palustris* grows in similar habitats as *P. kotzebuei*. Rook (2004) reported that the seeds of *P. palustris* should be sown as soon as they mature in autumn, and that the soil needs to remain continually moist. Research is needed to determine the factors most important to the germination and growth of *P. kotzebuei*.

Dispersal mechanisms

Dispersal mechanisms for *Parnassia kotzebuei* have not been investigated. Seeds of a close relative, *P. palustris*, are dispersed by water and wind (Hultgard 1987). The seeds of *P. kotzebuei* are probably also dispersed by water and wind, and by gravity. In addition, animals may incidentally distribute seeds. Although *P. kotzebuei* may have a limited ability to colonize new sites, suitable habitat also appears to be limited. The distribution of occurrences is likely to be caused by the lack of suitable habitat as well as by the inability to disperse over long distances.

Bonnin et al. (2002) found that on a regional scale, seed migration was less important to gene flow among populations of *Parnassia palustris* than was pollen migration. It is not known if this is also the case for *P. kotzebuei*.

Phenotypic plasticity

Parnassia kotzebuei does not exhibit a great degree of phenotypic plasticity. Plants may vary in size, stature, and reproductive effort, probably due to year-to-year variations in climate. There is some variation in the white to greenish coloring of the corolla (Colorado Natural Heritage Program 2004a). A broader range of phenotypic variation may exist for this species of *Parnassia* across its global range, but this has not been reported.

Mycorrhizal relationships

Roots of *Parnassia kotzebuei* have not been assayed for the presence of mycorrhizal symbionts. Arbuscular mycorrhizal (AM) fungi have been reported to form symbioses with *P. palustris* in grasslands in Norway (Eriksen et al. 2002). AM fungi belong to a group of nondescript soil fungi (Glomales) that are difficult to identify because they seldom sporulate (Fernando and Currah 1996). They are the most abundant type of soil fungi (Harley 1991) and infect up to 90 percent of all angiosperms (Law 1985). AM fungi are generally thought to have low host specificity, but there is increasing evidence for some 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 levels (Vandenkoornhuyse et al. 2002). As root endophytes, the hyphae of these fungi occupy plant roots, where water and nutrients are exchanged in specialized structures.

Hybridization

Hybridization has not been documented but is possible in *Parnassia kotzebuei*. Closely related species grow in the vicinity of most occurrences with which it could exchange pollen. Phillips (1982) suggests that closely related species in the *Parnassia* section of the genus *Parnassia*, found mostly in western North America, could hybridize. He postulates that the possibility of hybridization is sporadic throughout the range of species overlap. The phenomenon of polyploidy may encourage the formation of fertile hybrids (Phillips 1982). Hultgard (1987) also indicates that hybridization appears to be possible in populations of *P. palustris*.

The most closely related species to *Parnassia kotzebuei* are *P. palustris*, *P. parviflora*, *P. californica*, and *P. fimbriata* (Phillips 1982). *Parnassia parviflora* and *P. fimbriata* also grow in the alpine zone of Colorado and Wyoming.

Demography

The demographics of populations of *Parnassia kotzebuei* have not been investigated. Most occurrences in Region 2 do not report the total number of individuals, nor is there documentation on different age or size classes within occurrences. Based on information from occurrences whose populations have been estimated, it appears that many occurrences of *P. kotzebuei* are very small. Several occurrences appear to be small enough to be susceptible to inbreeding depression. Among the nine occurrences where abundance was reported, six report fewer than 100 individuals, and five of these report fewer than 20 individuals (**Table 2**).

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

Little is known about the population genetics of *Parnassia kotzebuei*. The degree of connectedness among populations in Region 2 is not known, but current knowledge of the distribution suggests that many of the occurrences are genetically isolated from each other. Known populations within Region 2 are separated by approximately one to several hundred miles (**Figure 4**). The occurrences in Wyoming are almost 300 miles from the closest occurrences in Colorado. The three occurrences on the Bighorn National Forest are separated by 10 to 20 miles. The nine occurrences on Shoshone National Forest are separated by 3 to 40 or more miles. The four occurrences in the Indian Peaks Wilderness (Arapaho-Roosevelt National Forest) are 1 to 2 miles apart, and they are only 2 and 6 miles from the two occurrences in Rocky Mountain National Park. The occurrences at Guanella Pass and Naylor Lake (Arapaho-Roosevelt National Forest) are 30 miles distant from other occurrences, and 1 to 2 miles apart from each other. The occurrence in the Flat Tops Wilderness (White River National Forest) is 78 miles from the next nearest occurrence of *P. kotzebuei*. The three occurrences on the Dillon Ranger District (White River National Forest) are 1 to 2 miles apart. The Horseshoe Cirque location on the Pike-San Isabel National Forest is 13 miles from the nearest occurrence. The two occurrences in the San Juan National Forest are 15 miles apart, and 116 miles distant from other occurrences of *P. kotzebuei*.

Gene flow is probably occurring among only a few populations of *Parnassia kotzebuei* in Region 2. Given our current understanding of the species' distribution, and the large distances between many of the occurrences within Region 2, some degree of inbreeding and local adaptation is probably occurring. However, inventories are needed to acquire more accurate distribution and abundance data. Studies of allele frequencies in the different population centers could help to clarify population connectivity and facilitate setting conservation targets.

Migration, extinction, and colonization rates are unknown for *Parnassia kotzebuei*. Baseline population dynamics and viability must first be assessed. Migration and colonization of *P. kotzebuei* are probably very limited in Region 2 because patches of suitable habitat are small, rare, and isolated. Migration among extant populations may be both good and bad (Bonnin et al. 2002). Migration may increase genetic variability and thereby improve a population's ability to adapt to stochastic events or to prevent inbreeding depression. On the other hand, migration of genetic material among populations may also interfere with a population's ability to adapt to local environmental conditions (Bonnin et al. 2002). In their research on *P. palustris*, Bonnin et al. (2002) found that seeds did not move very far and dispersed only very rarely among populations. Pollen, however, moved on a regional scale and contributed much more to gene flow among populations. The authors concluded that for *P. palustris*, colonization may occur if suitable sites are within hundreds of meters, but it is very unlikely if suitable sites are several kilometers distant (Bonnin et al. 2002). Similar patterns are likely to exist for *P. kotzebuei*.

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

The lifespan of *Parnassia kotzebuei* has not been determined, either through demographic studies or observations in the greenhouse. *Parnassia palustris* is long-lived (number of years not specified), and has a moderate growth rate (USDA Natural Resources Conservation Service 2004). There are no data regarding the proportion of individuals within a population that are reproducing in a given year. In favorable years, most of the adult plants probably set seed. The longevity and dormancy of the seeds of *P. kotzebuei* have not been studied.

Community ecology

There have been only limited observations of the community ecology and interspecific relationships of *Parnassia kotzebuei* in Region 2. Available information regarding community ecology of this species in Region 2 is limited to survey notes, herbarium specimens, observations, and inference from GIS data layers. While some effort has been devoted to documenting this species to achieve a basic understanding of its distribution and habitat, understanding of its interactions with other species remains poor and warrants further study.

In the few element occurrence records where plant community structure is reported, tree cover ranges from 0 to 40 percent, shrub cover ranges from 10 to 40 percent, forb cover ranges from 10 to 100 percent, graminoid cover ranges from 5 to 50 percent, and moss and lichen cover ranges from 20 to 40 percent. Bare ground cover is 5 percent at the one occurrence where this was recorded. **Table 3** is a list of all species that have been documented with *Parnassia kotzebuei*.

Table 3. Species that have been documented at least once with *Parnassia kotzebuei*. All are native species. Erigeron humilis, in bold type, is rare in Colorado and Wyoming.

Scientific name	Common name	Scientific name	Common name
Acomastylis rossii = Geum rossii var. *turbinatum*	Ross' avens	*Juncus mertensianus*	Mertens' rush
Anemone parviflora	smallflowered anemone	*Parnassia fimbriata*	fringed grass-of-Parnassus
Aquilegia coerulea	blue columbine	*Pedicularis groenlandica*	elephanthead lousewort
Bistorta vivipara = Polygonum viviparum	alpine bistort	*Pedicularis scopulorum*	sudetic lousewort
Cardamine cordifolia	heartleaf bittercress	*Picea engelmannii*	Engelmann spruce
Carex capillaris	hairlike sedge	*Polemonium viscosum*	sticky Jacob's-ladder
Carex incurviformis	coastal sand sedge	*Psychrophila leptosepala*	white marsh marigold
Carex norvegica	Norway sedge	*Ranunculus pygmaeus*	pygmy buttercup
Carex scopulorum	Rocky Mountain sedge	*Salix arctica var. petraea*	arctic willow
Cerastium beeringianum	Bering chickweed	*Salix brachycarpa*	shortfruit willow
Ciminalis prostrata	pygmy gentian	*Salix glauca*	grayleaf willow
Cirsium scopulorum	Rocky Mountain thistle	*Salix planifolia*	diamondleaf willow
Clementsia rhodantha = Sedum rhodanthum	Kings' crown	*Salix reticulata*	netleaf willow
Delphinium sp.	Monks' hood	*Salix tweedyi*	Tweedy's willow
Deschampsia cespitosa	Tufted hairgrass	*Saxifraga adscendens*	wedgeleaf saxifrage
Dryas octopetala var. *hookeriana*	eightpetal mountain-avens	*Saxifraga cernua*	nodding saxifrage
Erigeron humilis	**arctic alpine fleabane**	*Saxifraga odontoloma*	brook saxifrage
Erigeron melanocephalus	Blackheaded fleabane	*Saxifraga* sp.	saxifrage
Gentianopsis barbellata	perennial fringed gentian	*Swertia perennis*	felwort
Gentianella tenella	Dane's dwarf gentian	*Timmia norvegica*	moss
Hymenoxys grandiflora	Old man of the mountain	*Trifolium parryi*	Parry's clover
Juncus drummondii	Drummond's rush	*Veronica wormskjoldii*	American alpine speedwell

Herbivores

The specific response of *Parnassia kotzebuei* to browsing by herbivores has not been studied. It is possible that plants are browsed to some extent, but the plants are so small that they are unlikely to provide a significant food source, even for rodents. Stowe et al. (2000) present an overview of plant tolerance to consumer damage.

Competitors and symbioses

There has been no formal study of the community ecology or interspecific relationships of *Parnassia kotzebuei*. For a discussion of the threats to *P. kotzebuei* from exotic species, please see the ***Threats*** section. Herbarium specimens and occurrence records show no signs of parasites or disease. There have been no substantiated reports of symbiotic or mutualistic interactions between *P. kotzebuei* and other species.

CONSERVATION

Potential Threats

The severity and extent of threats to the persistence of *Parnassia kotzebuei* in Region 2 appear to be moderately low. In order of decreasing severity, potential threats include the effects of small population size, global climate change, motorized recreation, grazing, non-motorized recreation, exotic species invasion, mining, and pollution. These threats and the hierarchy ascribed to them are speculative, and more complete information on the biology and ecology of this species may reveal other threats. The scale and time frame within which these factors may affect occurrences of *P. kotzebuei* are unknown. Assessment of threats to this species will be an important component of inventories and monitoring protocols.

In general, impacts of various land uses within the habitat of *Parnassia kotzebuei* appear to be minimal. Many occurrences are in remote areas with few management concerns. However, alpine plants can be particularly vulnerable even to small alterations. 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).

Parnassia kotzebuei is very poorly understood, which is a liability because well-intended conservation actions are less effective when basic information is not available. A high percentage of occurrences have not been visited and assessed in more than 20 years. This adds a great deal of uncertainty to any discussion involving these data.

Small population size

With a total population of approximately 1,135 individuals, mostly distributed among four of the 27 known occurrences, *Parnassia kotzebuei* may be vulnerable in Region 2 because of its small population size (**Table 2**; Colorado Natural Heritage Program 2004a, Wyoming Natural Diversity Database 2004). Although more rigorous population estimates are needed, populations this small are likely to be affected by random events such as severe drought, disease or pest outbreak, or local surface disturbances. The degree to which *P. kotzebuei* can survive bad years will depend largely on how long individual plants can persist or remain dormant as seeds.

The small size of many *Parnassia kotzebuei* occurrences in Region 2 and its potential dependence on outcrossing makes 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 *P. kotzebuei*. The degree of connectedness among occurrences in Region 2 is not known, but current knowledge of the distribution suggests that many occurrences are genetically isolated from each other. Known occurrences within Region 2 are separated by 1 to 300 miles (**Figure 4**; see also the Demography section). Gene flow among occurrences in Region 2 is probably rare. However, the genetic system of *P. kotzebuei* may have adjusted to small populations, since the occurrences have probably been isolated for thousands of years (Barrett and Kohn 1991).

Small populations are particularly vulnerable to stochastic events (Huenneke 1991). Small populations 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 populations that are small and isolated, and genetic variability is lost even more quickly, which makes them more prone to extirpation (Barrett and Kohn 1991).

Global climate change

Anticipated increases in carbon dioxide and other "greenhouse" gases are predicted to warm the earth by several degrees Celsius during the 21st 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 in Colorado, average temperatures will increase while precipitation will decrease (Manabe and Wetherald 1986). This will have significant effects on soil moisture, nutrient cycling, vapor pressure gradients, plant growth, and phenology (Price and Waser 1998). Temperature increase could cause vegetation zones to climb 350 feet in elevation for every degree F of warming (U.S. Environmental Protection Agency 1997). Because *Parnassia kotzebuei* already grows at high elevations, it has few options for moving to more favorable habitats under warming and drying conditions. The long-term survival of this species could be affected by the habitat contraction induced by global climate change. Since *P. kotzebuei* relies on mesic to wet habitats, lower soil moistures in the growing season induced by decreased precipitation could have serious impacts.

At high elevations, global warming is likely to result in a longer snow-free period, affecting plant growth and reproduction. Spring snowmelt is a very strong environmental cue that causes many alpine plants to initiate growth and flowering (Billings and Bliss 1959, Price and Waser 1998). Research by Price and Waser (1998) showed that many plants respond to warming and earlier snowmelt with a phenological shift; they flower earlier, but not necessarily for a longer period of time. This shift may affect other aspects of the plant community and ecological relationships. For example, animal mutualists (pollinators, seed dispersers) and enemies (herbivores, seed predators) may or may not also shift their life stages (Price and Waser 1998). Community structure can also shift and influence how all species respond. For example, a

shift in phenology may bring *Parnassia kotzebuei* into competition with another plant species for pollinators (Price and Waser 1998).

Other climate change models predict increased winter snowfall (e.g., Giorgi et al. 1998), which also has implications for *Parnassia kotzebuei*. Increased snowfall could delay the onset of the growing season for *P. kotzebuei* if snow covers plants late into the spring, again causing potential problems with phonological shifts discussed above.

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 *Parnassia kotzebuei* in Region 2. Although motorized recreation has not been documented at any of the known occurrences of *P. kotzebuei* in Region 2, some occurrences are in areas open to this use, and the popularity of motorized recreation is increasing on public lands throughout Wyoming and Colorado. Fifteen of the occurrences in Region 2 are secure in this regard: 11 occurrences within wilderness areas (Baker personal communication 2004, Proctor personal communication 2004, Vorhis personal communication 2004); two occurrences in Rocky Mountain National Park; the Naylor Lake in Arapaho-Roosevelt National Forest, whose access trail is too narrow, steep, and rocky for off-road vehicles or snowmobiles (Jennings personal communication 2004); and Horseshoe Cirque on the Pike-San Isabel National Forest, where motorized recreation is not permitted (Olson personal communication 2004). Roads and motorized vehicles are not allowed in designated wilderness areas (San Juan Mountains Association 2004). Vehicle trails may be encroaching on occurrences outside of wilderness near existing roads (Baker personal communication 2004),

Off-road vehicle use is becoming an issue in the Shoshone National Forest (Wyoming), and resource managers are aware of potential problems (Houston personal communication 2004). This use could potentially affect seven occurrences on the Shoshone National Forest that are not in wilderness areas. The Summit County occurrences in Colorado (White River National Forest) also are vulnerable to motorized recreation (USDA Forest Service 2002, Colorado Natural Heritage Program 2004a). It is not known if motorized recreation poses a threat to other occurrences of *Parnassia kotzebuei* in Region 2.

Motorized recreation can affect individuals and populations directly and indirectly. Roads created by off-road vehicles could threaten occurrences of *Parnassia kotzebuei* directly by altering habitat and killing individuals and indirectly as sources of erosion and as dispersal corridors for exotic plant species. It is likely that *P. kotzebuei* can self-pollinate, but it may also be a primarily outcrossing species. Disturbed sites may support fewer species of pollinators for *P. kotzebuei* than natural sites. Roads can act as barriers to pollinators for *P. kotzebuei* and prevent effective gene flow by disrupting the trap lines of pollinators.

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

Researchers in Nova Scotia (Keddy et al. 1979) investigated the effects of snowmobiles making one to 25 passes over an area. 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 over a larger area. The authors concluded that limiting snowmobiles to trails causes less damage than dispersed use. They also found that areas covered with ice in the winter do not appear to be as damaged by snowmobiles, so it might help to divert snowmobile use to ice-covered areas (Keddy et al. 1979). More research is needed to determine the impacts of motorized recreation, including snowmobile use, on *Parnassia kotzebuei* in Region 2.

One occurrence is located near a road over Guanella Pass, in close proximity to recent road construction activities. However, the occurrence is about 150 feet from the new right of way, on a steep slope below the road, and is not likely to be impacted by the road, hydrologically or otherwise (Jennings personal communication 2004).

Grazing

Domestic cattle and sheep grazing potentially pose a threat to *Parnassia kotzebuei* in parts of 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 *P. kotzebuei* in Region 2 are probably located at elevations that are too high for cattle grazing. It is not known if *P. kotzebuei* is palatable to sheep or cattle. Plants that are not grazed are vulnerable to trampling and soil compaction resulting from grazing activity.

Currently, very few *Parnassia kotzebuei* sites are known to be experiencing any grazing activity. There is no evidence of grazing at Naylor Lake or at Guanella Pass (Jennings personal communication 2004). There is no grazing of cattle or sheep in the Indian Peaks Wilderness within the Arapaho-Roosevelt National Forest (Baker personal communication 2004, Sumerlin personal communication 2004), and there are no active grazing allotments at Horseshoe Cirque on the Pike-San Isabel National Forest (Olson personal communication 2004), or in Summit County, White River National Forest (USDA Forest Service 2002). There are very few active livestock grazing allotments in wilderness areas within the Bighorn National Forest. The areas on the Bighorn National Forest that are grazed are not likely to be near occurrences of *P. kotzebuei* (Vorhis personal communication 2004). Cattle are grazed in the Hooper Lake area of the White River National Forest, but sheep are not (Proctor personal communication 2004). Cattle probably do not access the steep location where *P. kotzebuei* occurs (Proctor personal communication 2004). There is no livestock grazing in Rocky Mountain National Park.

In the Beartooth and Greybull Ranger Districts of the Shoshone National Forest, cattle grazing is a primary concern (Houston personal communication 2004). Cows trample the wetlands where the *Parnassia kotzebuei* grows (Houston personal communication 2004). This activity could impact three or more occurrences of *P. kotzebuei* on the Shoshone National Forest.

Recreational livestock (horses and llamas) are grazed in the Indian Peaks Wilderness of the Arapaho-Roosevelt National Forest (Sumerlin personal communication 2004). Research is needed to determine the effects of current levels of grazing on populations of *Parnassia kotzebuei*.

Non-motorized recreation

Non-motorized recreation (e.g., hiking, camping, horse packing, mountain biking) has the potential to threaten some of the occurrences of *Parnassia kotzebuei* in Region 2. Although many of the occurrences are in remote locations that receive little human visitation, others are in areas that are popular for recreational use.

Non-motorized recreation, such as hiking and camping, is heavy in the Indian Peaks Wilderness Area in the Arapaho-Roosevelt National Forest (Baker personal communication 2004). The occurrence at Naylor Lake is located along a trail (Colorado Natural Heritage Program 2004a). Although it is possible that some plants were lost during the construction of this trail, the occurrence is located on a steep, rocky slope 30 to 40 feet above the trail where people probably would not walk (Jennings personal communication 2004). The occurrence at Guanella Pass is about 75 feet away from an informal campsite, but people are not likely to trample or otherwise affect the *Parnassia kotzebuei* occurrence (Jennings personal communication 2004). Specific issues posed by non-motorized recreation at the other occurrences of *P. kotzebuei* are not known.

The recreational uses discussed above could damage or kill individuals, change soil properties, or initiate erosion. If trampling is light or of short duration, the recovery time may be relatively short. Severe trampling over longer periods takes much longer to recover. Alpine areas may be particularly vulnerable. Willard and Marr (1971) studied an alpine area that been trampled for 38 years. Four years of observation following the end of the disturbance showed no improvement whatsoever. The authors estimated that tundra damaged for only a few seasons may require hundreds of years, possibly even a thousand years, to recover fully (Willard and Marr 1971). Trampling by recreation users has been shown to cause substantial declines in the numbers 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 *Parnassia kotzebuei* (Colorado Natural Heritage Program 2004a, Wyoming Natural Diversity Database 2004), several aggressive weeds have invaded high elevation native plant habitats in Colorado. These weeds 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 bibersteinii*), scentless chamomile (*Matricaria perforata*), Oxeye daisy (*Leucanthemum vulgare*), Shasta daisy (*L. maximum*), and Canada thistle (*Breea arvense*) (Lane personal communication 2003). These noxious weeds come into areas following disturbance, and they could be spread by grazing or recreation, including hiking and summer motorized recreation. Therefore, the occurrences of *P. kotzebuei* closest to roads areas with heavy recreational use are most vulnerable to this threat.

The best strategy for protecting *Parnassia kotzebuei* is to prevent the introduction of these non-native plants by carefully monitoring occurrences and implementing a weed management plan without delay if noxious weeds are detected.

Mining

The mountains of Wyoming and Colorado have been affected by historic mining, so it is possible that populations of *Parnassia kotzebuei* were impacted by this use. Occurrences at Horseshoe Cirque and Crystal Lake are close to historic mining districts.

Currently, there is no mining activity near any of the known occurrences of *Parnassia kotzebuei* (Hesch personal communication 2004, Houston personal communication 2004, Jennings personal communication 2004, Olson personal communication 2004, Proctor personal communication 2004, Vorhis personal communication 2004). However, mining could take place in the future, even in wilderness areas. Mining is unlikely to happen in the Flat Tops Wilderness (White River National Forest) because the basaltic geology is not conducive to economically valuable mineral deposits (Proctor personal communication 2004). Owners have the right to mine private inholdings in the Indian Peaks Wilderness, and owners may be able to reopen or build roads for access (Baker personal communication 2004). There is no known mining activity near *P. kotzebuei* occurrences at this time. The only occurrences of *P. kotzebuei* in Region 2 that are currently protected from mining are the two in Rocky Mountain National Park.

The effects of even small-scale mining could be severe, depending on the proximity of occurrences or potential habitat for *Parnassia kotzebuei*. Extraction activity, tailings ponds and piles, as well as associated roads could cause habitat degradation and destruction.

Pollution

Atmospheric nitrogen deposition (both organic and inorganic forms) is increasing worldwide. A recent analysis of data from 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 results from agricultural uses and burning fossil fuels. Nitrogen deposition is generally greater east of the Continental Divide in 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 *Parnassia kotzebuei* are responding to these changes.

Experimental nitrogen enrichment of alpine sites suggests that ecosystem processes are altered by enrichment, causing species turnover (Bowman et al. 1993, Bliss and Gold 1999). Relatively low levels of nitrogen enrichment help some species but are deleterious to others, making it difficult to predict species- and community-level responses. It is not known how *Parnassia kotzebuei* would respond to these changes.

Conservation Status of Parnassia kotzebuei 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 *Parnassia kotzebuei* over the last 100 years (e.g., mining, grazing, recreational uses), we can assume that in some places the distribution of this species has declined. Because the pre-settlement abundance of *P. kotzebuei* is unknown, it is difficult to quantify the effects of historic land use. While prolonged or constant disturbance, such as mining, over-grazing and heavy off-road vehicle use, is likely to extirpate populations, the species may tolerate occasional periodic light to moderate disturbance.

With many different land managers within the distribution of *Parnassia kotzebuei* in Region 2, it is likely that management of some properties is not compatible with the persistence of *P. kotzebuei*, but that other lands are managed appropriately. While the

net human impact on the distribution and abundance of *P. kotzebuei* is difficult and complicated to assess, the cumulative impact of historic mining, grazing, and recreation could be causing a decline of *P. kotzebuei*. Inventories and monitoring will help to determine the current population trend of this species.

Vulnerability due to life history and ecology

Assessing the vulnerability of *Parnassia kotzebuei* in Region 2 is complicated by the lack of information available about its life history and ecology. As a perennial plant, it is buffered somewhat from the effects of environmental stochasticity such as drought. Because it may have effective mechanisms for selfing, it may also be buffered from impacts that affect its pollinators. The degree to which populations can survive bad 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 populations of *Parnassia kotzebuei* in Region 2 are at risk from anthropogenic threats, further inventory and research on this species is warranted before conservation actions are taken.

Potential threats to *Parnassia kotzebuei* described above could put populations of this species in Region 2 at risk. However, *P. kotzebuei* is rare in Region 2 because it is on the edge of its natural range. More complete knowledge of the extent and abundance *P. kotzebuei* in Region 2 is needed to support conservation and management decisions. Ten of the 27 known occurrences in Region 2 are in areas with some protection, such as wilderness areas or national parks (see Distribution and abundance section). These areas prohibit off-road vehicle use, but mining and grazing are allowed uses of wilderness areas (San Juan Mountains Association 2004).

The total population size of *Parnassia kotzebuei* in Region 2 is very small, with an estimated 1,135 plants documented. These populations may be viable, and it is likely that additional plants will be found with further inventory.

Management of Parnassia kotzebuei in Region 2

Implications and potential conservation elements

Available data suggest that *Parnassia kotzebuei* is a peripheral species in Region 2. It is imperiled in this part of its range due to a small number of occurrences, small populations, and imminent climate change. Inventories are needed to determine if this species is as rare and imperiled 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 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 *Parnassia kotzebuei*. The autecology of *P. kotzebuei* is not understood well enough to decipher cause-effect relationships between *P. kotzebuei* density and natural processes (i.e., drought) or human-mediated changes to the environment (i.e., livestock grazing).

Desired environmental conditions for *Parnassia kotzebuei* include sufficiently large areas where the natural ecosystem processes on which *P. kotzebuei* depends can occur. The goal is to allow this species to persist unimpeded by human activities and their secondary effects such as weeds. This includes a satisfactory degree of ecological connectivity between populations to provide corridors and other nectar resources for pollinators. From a functional standpoint, ecosystem processes on which *P. kotzebuei* depends appear to remain intact to some extent. Whether this will remain true as the human population densities increase in the area is uncertain. Further research on the ecology and distribution of *P. kotzebuei* will help to develop effective approaches to management and conservation.

Tools and practices

Species inventory

Species inventory is among the highest priorities for *Parnassia kotzebuei* in Region 2. Collecting

baseline information and developing a detailed map of the species' distribution and abundance will provide a starting point from which population trend can be assessed, and will help to assign appropriate conservation priorities for this species. Species inventories are simple, inexpensive, and necessary for developing an understanding of the target species sufficient to design an effective monitoring program.

During the 1980s, 1990s and early 2000s, several botanists who were aware of the significance of *Parnassia kotzebuei* in Region 2 conducted botanical research in the alpine areas of Colorado (Spackman et al. 1995, Spackman et al. 1997b, Lyon and Sovell 2000, Spackman et al. 2001, Jennings personal communication 2004, Vorhis personal communication 2004, Yeatts personal communication 2004). During this time, eight new locations were documented in Colorado, including new records for Garfield, Park, Clear Creek, and Larimer counties.

Although *Parnassia kotzebuei* is a relatively inconspicuous species, it is not difficult to distinguish from other members of *Parnassia*. Field crews could be quickly taught to recognize it in the field. Areas with the highest probability of finding new occurrences are areas near known occurrences. Many areas within the known range of *P. kotzebuei* remain to be searched because of the difficulties in accessing remote areas. Searches could also target areas with similar habitats to the known occurrences, such as headwater streams, lakes, and other high elevation wetlands.

Habitat inventory

The Colorado Natural Heritage Program routinely uses aerial photography and topographic, soil, and geology maps to refine searches when conducting inventories of large areas. This approach has been highly effective in Colorado and elsewhere. It is most effective for species such as *Parnassia kotzebuei* about which we have basic knowledge of its substrate and habitat specificity from which distribution patterns and potential search areas can be deduced. Searches for *P. kotzebuei* 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 *P. kotzebuei*. This would be a valuable tool for guiding 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 are applicable to *P. kotzebuei*.

Population monitoring

The best time for inventory and monitoring of *Parnassia kotzebuei* in Colorado is from late June through early August when the plants are flowering. A monitoring program for *P. kotzebuei* would begin by targeting known occurrences, and other occurrences could be added to the program as they are discovered. Monitoring sites that are managed for a variety of purposes will help to identify appropriate management practices for *P. kotzebuei* and to understand its population dynamics and structure.

A demographic monitoring program that addresses recruitment, seed production, seed and plant longevity, population variability, and pollinators would generate data useful to managers and the scientific community. Suitable methods for monitoring pollinators are discussed in Kearns and Inouye (1993). Measuring seed production will require a visit later in the summer after fruit set. As in any monitoring study, it is important to define *a priori* the changes that the sampling regime intends to detect, and how management decisions will respond to the results (Schemske et al. 1994, Elzinga et al. 1998).

Because there could be a high annual variability in reproductive effort, re-sampling monitoring plots every year for a set period of five or ten years will be necessary to gain insight into the natural population dynamics of *Parnassia kotzebuei*.

A randomized design might be employed to establish the sampling units, particularly at locations where it is difficult to lay a transect due to the ruggedness of the terrain. Permanent plots could be selected within a habitat unit by randomly choosing X and Y UTM coordinates. The plots could then be located using a highly accurate GPS unit. Once established and marked, the plots could be relocated using a recreation grade GPS. If subsequent power analysis indicates that the sample size is inadequate, it is easy to add more sampling units to this design.

Elzinga et al. (1998) describe several methods of monumentation, depending on the site physiography and how conspicuous the site is to casual human visitors. This is an important consideration that will reap long-term benefits if done properly at the outset of the monitoring program.

Estimating cover and/or abundance of associated species within the plots described above could permit the investigation of interspecific relationships through ordination or other techniques. In very sparsely vegetated plots, this can be difficult, but it can be done accurately using appropriate cover classes or subdivided quadrat frames. Understanding environmental constraints on *Parnassia kotzebuei* would facilitate the management of this species. Gathering data on edaphic characteristics (e.g., soil moisture, texture, chemistry) from the permanent plots described above would permit the canonical analysis of species-environment relationships. These data would facilitate hypothesis generation for further studies of the ecology of this species.

Adding a photo point component to this work following recommendations in Elzinga et al. (1998) could facilitate the tracking of individuals and add valuable qualitative information. A handbook on photo point monitoring (Hall 2002) offers guidance 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.

Research priorities for *Parnassia kotzebuei* lie in gathering data on distribution and abundance. 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 *P. kotzebuei*.

Habitat monitoring

Habitat monitoring would be particularly beneficial to *Parnassia kotzebuei* and should be conducted concurrently with population monitoring. Documenting habitat attributes, disturbance regime, and associated species during all population monitoring will augment our understanding of its habitat requirements and management needs. These fields could be incorporated into the forms used for the population sampling described above. If carefully selected environmental variables are quantified during monitoring activities, then they will help to explain observations of population change. Habitat monitoring of known occurrences will alert managers of new impacts such as weed infestations and damage from human disturbance. Making note of signs of degradation from recreational uses may help managers to prevent serious damage by implementing changes in the management regime. Change in environmental variables might not cause observable demographic repercussions for several years, so re-sampling the chosen variables may help to identify underlying causes of population trends. Evidence of current land use and management are important to document while monitoring populations.

Observer bias can be a significant problem with habitat monitoring (Elzinga et al. 1998) unless field crews are trained in techniques of estimating plant cover accurately and consistently. Habitat monitoring is usually better at identifying new impacts than at tracking change in existing impacts. To assess trampling impacts, using photographs of impacts to train field crews will help them to rate the severity of the impact consistently.

The use of photo points for habitat monitoring is described in Elzinga et al. (1998). This is a useful 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 recreational uses and mining on populations of *Parnassia kotzebuei* are likely to contribute the most to the long-term survival of this species in Region 2. Excluding motorized recreation and limiting non-motorized recreation within all known occurrences will help protect *P. kotzebuei*. Implementing travel restrictions, signs, and fencing to reduce recreation impacts on populations and habitat may be the best course of action in some places.

Appropriate management of natural vegetation near populations of *Parnassia kotzebuei* is likely to benefit pollinators and may improve the likelihood of persistence for currently unknown occurrences. Avoiding activities that facilitate the invasion of noxious weeds and other non-native invasive plants will benefit *P. kotzebuei*.

Maintaining genetic integrity and eliminating inbreeding depression are important management considerations for *Parnassia kotzebuei*. This species could be vulnerable to inbreeding depression because of its small populations, possibly with limited pollinator activity. It is likely that *P. kotzebuei* can self-pollinate, but it may be a primarily outcrossing species. Developing an augmentation plan for populations whose existence appears to be threatened may be beneficial. This plan may include increasing the number

or size of *P. kotzebuei* populations by seeding, or by habitat management.

Seed banking

No seeds or genetic material are currently in storage for *Parnassia kotzebuei* 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 (Center for Plant Conservation 2002) although *P. caroliniana* is represented in the collection. Gathering seeds of *P. kotzebuei* for long-term storage will be useful if restoration is necessary. Seeds should be from populations representing the variability of the habitat.

Information Needs

Distribution

Inventories specifically targeting *Parnassia kotzebuei* are a high priority for this species in Region 2. Until we have a more complete picture of its distribution and abundance, it will not be possible to assess this species' conservation needs and priorities. Sometimes targeted searches for a rare species will reveal that it is not as rare as previously believed. Although *P. kotzebuei* has already been a target of several studies, habitat throughout its range in Region 2 has not been thoroughly inventoried. Places to focus searches include areas near known occurrences, areas with similar habitat to known occurrences, and other high elevation areas throughout Region 2.

If populations are large enough, specimens should be collected to document each new occurrence, as well as each repeat observation. When specimens are collected, the flowers should be pressed so that at least one petal is fully visible, in order to facilitate correct identification. Specimens are not available for Hutcheson Lakes and Horseshoe Cirque; collections are needed to confirm these locations.

Life cycle, habitat, and population trend

Little is known of the population ecology of *Parnassia kotzebuei*. Investigation of the species' lifespan and autecology would improve our ability to manage for its long-term survival.

The habitat for *Parnassia kotzebuei* has been roughly described, but the characteristics of its natural habitat and natural disturbance regime are poorly understood. The response of *P. kotzebuei* to particular environmental variables is unknown. Understanding its habitat and being able to identify suitable habitat is particularly important for the conservation and management of *P. kotzebuei*. 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 *Parnassia kotzebuei* is not known. Understanding its population biology is important for appropriate stewardship and management of this species.

Response to change

Reproduction and establishment rates and the effects of environmental variation on these parameters have not been investigated for *Parnassia kotzebuei*. The potential effects of various management options cannot be assessed during project planning without this information. Understanding the specific responses of *P. kotzebuei* to disturbance is important for determining appropriate management practices, but these are not clear and need further investigation.

Metapopulation dynamics

No studies have been done to determine the importance of metapopulation structure and dynamics to the long-term persistence of *Parnassia kotzebuei* at local or regional scales. Migration, extinction, and colonization rates are unknown. Baseline population dynamics and viability must first be assessed. Studies of allele frequencies among *P. kotzebuei* occurrences could clarify the degree of population connectivity and enable the setting of conservation priorities.

Demography

Only the broadest generalizations can be made regarding the demography of *Parnassia kotzebuei*. Abundance has not been assessed for most occurrences. Growth and survival rates are also unknown, and the reproduction rate is poorly understood. Our knowledge of the distribution of the species is incomplete. Many years of field data are needed before the species' potential for long-term persistence can be assessed with demographic modeling techniques. Short-term demographic studies can 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). However, the value of

demographic data for conservation planning and species management cannot be overstated.

Population trend monitoring methods

There has been no monitoring of *Parnassia kotzebuei* populations, but methods are available on which to base a monitoring protocol. Lesica (1987) described a technique for monitoring populations of non-rhizomatous perennial plant species that would be applicable to *P. kotzebuei*.

Restoration methods

There have been no known attempts to restore habitat or populations of *Parnassia kotzebuei*; therefore, there is no applied research from which to draw in developing a potential restoration program. It is possible that *P. kotzebuei* could be propagated in a greenhouse environment, but it may be difficult to transfer plants successfully into a natural or restored setting. Seed germination requirements are unknown.

Research priorities for Region 2

Additional inventories are needed to clarify the distribution and abundance of *Parnassia kotzebuei* in Region 2. Initial surveys should focus on expanding the boundaries of known occurrences and searching the vicinity of historic occurrences. Searches occurring between late June and early August in suitable habitat will help to confirm the distribution and abundance of *P. kotzebuei* and may identify opportunities for its conservation. Identifying robust populations 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 provide extremely useful information for management and conservation planning. Documentation of any threats or visible impacts to *P. kotzebuei* will help to develop protection strategies, and will help managers act to mitigate threats.

Demographic studies are needed for *Parnassia kotzebuei* in Region 2. Demographic data are far more useful for assessing status and developing recovery efforts than genetic information (Schemske et al. 1994). Determining critical life history stages of *P. kotzebuei* will allow managers to focus efforts on implementing management protocols that benefit those stages. A monitoring program that determines effective population sizes and investigates growth, survival, and reproduction of individuals within populations will have considerable practical value and will help determine the conservation status of *P. kotzebuei* in Region 2.

A better understanding of the influence of human activities on individuals and habitat of *Parnassia kotzebuei* in Region 2 will confer substantial practical benefits to land managers and planners. Identifying the life history and phenological stages in which *P. kotzebuei* is less sensitive to recreational impacts would help to guide management practices that are compatible with this species.

The role of disturbance in the autecology of *Parnassia kotzebuei* remains poorly understood. Specific tolerances of *P. kotzebuei* 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 affect the species negatively.

Information gained from studies of the physiological and community ecology of *Parnassia kotzebuei* 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 this species' survival. Understanding the plant-environment relationships of *P. kotzebuei* will assist in understanding the coping strategies employed by this species and in modeling its potential distribution.

Additional research and data resources

A forthcoming volume of the Flora of North America will include a treatment of *Parnassia* by Raymond Bruce Phillips that was not available for inclusion in this report. We were unable to contact Dr. Phillips by phone or email during this synthesis.

Definitions

50/500 rule – a generalized rule stating that isolated populations need a genetically effective population of about 50 individuals for short term persistence, and a genetically effective population of about 500 for long-term survival (Soulé 1980)

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

Autoploid – refers to an individual that has one or more exact duplications of the diploid set of chromosomes

Autopolyploid – a polyploid formed from the doubling of a single genome. Polyploidy in which all the chromosomes come from the same species

Diploid – having two similar complements of chromosomes

Ecoregions – large geographically defined areas that integrate various environmental conditions, such as climate and geology, and that support distinctive groupings of species and ecological communities

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

Genetic drift – random fluctuations in the frequency of the appearance of a gene in a small isolated population, presumably owing to chance rather than natural selection

Gland – a group of one or more cells whose main function is to secrete a specific chemical substance or substances

Heterozygosity – the presence of different alleles at one or more loci on homologous chromosomes

Inbreeding depression – a depression of vigor or yield due to inbreeding

Mesic – moist; between xeric (dry) and hydric (wet)

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

Monumentation – establishing permanent markers or boundaries

Outbreeding depression - a reduction in fitness that results from mating between unrelated or distantly related individuals

Polyploid – a cell or an organism having two or more sets of genes or chromosomes

Propagules – buds or shoots

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

Staminodia – a sterile stamen

Tetraploid – having four sets of chromosomes in each cell

Conservation 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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