Potentilla rupincola Osterhout (rock cinquefoil): A Technical Conservation Assessment

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

September 28, 2004

David G. Anderson
Colorado Natural Heritage Program
Colorado State University
Fort Collins, Colorado

Peer Review Administered by
Center for Plant Conservation

Anderson, D.G. (2004, September 28). *Potentilla rupincola* Osterhout (rock cinquefoil): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/potentillarupincola.pdf [date of access].

ACKNOWLEDGEMENTS

This research was facilitated by the helpfulness and generosity of many experts, particularly Ana Child, Dr. Barry Johnston, and Richard Scully. Their interest in the project and time spent answering questions were extremely valuable, and their insights into the distribution, habitat, genetics, and ecology of *Potentilla rupincola* were crucial to this project. Thanks also to Greg Hayward, Andy Kratz, and Joy Bartlett for assisting with questions and project management. Jane Nusbaum and Barbara Brayfield provided crucial financial oversight. Annette Miller provided information for the report on seed storage status. Fagan Johnston generated the distribution map. Alison Loar created an Access database to facilitate searches for element occurrence data. Nan Lederer and Tim Hogan provided valuable assistance and insights at the CU Herbarium, as did Janet Wingate and Loraine Yeatts at the Kalmbach Herbarium. Tara Santi assisted with literature acquisition. Special thanks to Dan Cariveau and the CNHP staff (Georgia Doyle, Michael Menefee, Ron Abbott, Jim Gionfriddo, and Jill Handwerk) who reviewed part or all of the first draft of this document. Thanks also to Jen Krafchick, Cleome Anderson, and Melia Anderson for their support during the synthesis of this document.

AUTHOR'S BIOGRAPHY

David G. Anderson is a botanist with the Colorado Natural Heritage Program (CNHP). Mr. Anderson's work at CNHP includes inventory and mapping of rare plants throughout Colorado, mapping weeds, maintaining and updating CNHP's database, and writing reports on the rare plants of Colorado. He has worked with CNHP since 1999. Much of Mr. Anderson's prior experience comes from five years of fieldwork studying the flora and ecosystem processes of the Alaskan and Canadian Arctic. Mr. Anderson also served in the Peace Corps as a science teacher in the Solomon Islands from 1996 to 1998. Mr. Anderson received his B.A. in Environmental, Populational, and Organismic Biology from the University of Colorado, Boulder (1991) and his M.S. in Botany from the University of Washington, Seattle (1996).

COVER PHOTO CREDIT

Potentilla rupincola (rock cinquefoil). Photograph by the author, from Virginia Dale on June 23, 2004.

What's in a name? That which we call a rose,
By any other name would smell as sweet

William Shakespeare
('Romeo and Juliet', ii, 4)

The order that our mind imagines is like a net, or like a ladder, built to attain something. But afterward you must throw the ladder away, because you discover that, even if it was useful, it was meaningless . . . The only truths that are useful are instruments to be thrown away.

Umberto Eco
(The Name of the Rose)

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *POTENTILLA RUPINCOLA*

Status

Potentilla rupincola (rock cinquefoil) is known from 23 occurrences in four counties in north-central Colorado. It is found primarily in cracks on granite rock outcrops between 6,500 and 10,900 feet in elevation. Eight occurrences are known from lands administrated by the USDA Forest Service (USFS) Region 2, including seven on the Roosevelt National Forest and one on the Pike National Forest. One occurrence is known from the Lone Pine Research Natural Area on the Roosevelt National Forest. Six occurrences are protected on lands owned by the National Park Service and The Nature Conservancy. The conservation status of 10 occurrences is uncertain. Seven occurrences are historic and their precise locations and land ownership status are uncertain. Three occurrences are known from private land where they are potentially threatened by impacts resulting from development. *Potentilla rupincola* element occurrence records indicate a total population size of approximately 36,000 individuals. *Potentilla rupincola* is ranked globally as imperiled (G2) by NatureServe, and is likewise considered imperiled (S2) in Colorado. It is considered sensitive by the USFS Region 2 (USDA Forest Service 2003). It is not listed as threatened or endangered under the Endangered Species Act (U.S.C. 1531-1536, 1538-1540).

Primary Threats

Observations and quantitative data have shown that there are several threats to the persistence of *Potentilla rupincola*. In order of decreasing priority, these are exotic species invasion, residential and commercial development, secondary impacts of grazing, right-of-way management, off-road vehicle use and other recreation, effects of small population size, global climate change, and pollution. Some threats are more urgent at some sites than at others; thus this hierarchy of threats is different for each site. In general, threats to *P. rupincola* resulting from human activities are minor due to the inaccessibility of its habitat, the lack of mineral resources at known occurrences, and the unsuitability of its habitat for development and grazing. Activities that would concentrate use in occurrences are likely to threaten *P. rupincola*.

Primary Conservation Elements, Management Implications and Considerations

Fourteen of the 23 occurrences are located in areas where they are unlikely to be impacted by some threats such as residential development, road construction, and resource extraction, due to protective land status (these are owned by the USFS, National Park Service, or The Nature Conservancy). *Potentilla rupincola* benefits from some degree of natural protection because its habitat is rugged, largely inaccessible, and unsuitable for development and most forms of resource extraction. Weeds have invaded limited portions of its habitat but do not appear to be having widespread impacts at present. Widespread grazing impacts to *P. rupincola* are unlikely because most of its habitat is inaccessible to cattle and horses.

Pursuing conservation easements on the private properties where three occurrences are found, or other protective land status changes would help to ensure the viability of occurrences on private land. Further species inventory work remains a high priority for *Potentilla rupincola* and is likely to identify other occurrences. Although considerable efforts have been made to find this species, the ruggedness of its habitat makes thorough surveys difficult. Conserving existing genetic diversity is important for *P. rupincola*. Research is needed to investigate the population biology and autecology of *P. rupincola* so that conservation efforts on its behalf can be most effective.

Table of Contents

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

List of Tables and Figures

Tables:

Figures:

Introduction

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). *Potentilla rupincola* is the focus of an assessment because it is a sensitive species in USFS Region 2. Within the National Forest System, sensitive species are plants and animals 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 a species distribution (FSM 2670.5(19)). Sensitive species require special management so knowledge of their biology and ecology is critical.

This assessment addresses the biology of *Potentilla rupincola* throughout its range in USFS Region 2. This introduction outlines the scope of the assessment and describes the process used in producing it.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation, and management status of certain species based on scientific knowledge accumulated prior to initiating the assessment. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations but provides the ecological backgrounds upon which management must be based. While the assessment does not provide management recommendations, it focuses on the consequences of changes in the environment that result from management (i.e. management implications).

Scope and Information Sources

The *Potentilla rupincola* assessment examines the biology, ecology, and management of this species with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. This assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *P. rupincola* in the context of the current environment rather than under historical conditions 200, 2000, or 2 million years ago. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. All known publications, reports, and element occurrence records for *Potentilla rupincola* in USFS Region 2 are referenced in this assessment, and all of the available experts on this species were consulted during its synthesis. All available specimens of *P. rupincola* were viewed to verify occurrences and incorporate specimen label data. Specimens were searched for at COLO (University of Colorado Herbarium), CS (CSU Herbarium), RM (Rocky Mountain Herbarium), SJNM (San Juan College Herbarium), KDH (Kalmbach Herbarium), CC (Carter Herbarium), GREE (University of Northern Colorado Herbarium), NMCR (New Mexico State University Range Science Herbarium), and UNM (University of New Mexico Herbarium). This assessment emphasizes refereed literature because this is the accepted standard in science. Nonrefereed publications or reports were regarded with greater skepticism. Some nonrefereed literature was used in the assessment, however, only when information was unavailable elsewhere. Unpublished data (e.g. state natural heritage program records) were important in estimating the geographic distribution, and contain the vast majority of the useful information known on *P. rupincola*. However, these data required special attention because of the diversity of persons and methods used to collect the data.

The motivation to produce species assessments rapidly, in order to make information available for forest plan revisions, lead to tight timelines. The goal to produce assessments rapidly limited the analysis of existing, unpublished data, or attempts to conduct meta-analysis to synthesize information from published literature. Ongoing research by Ana Child, a doctoral student at the University of Denver, is being conducted on the conservation genetics of *Potentilla rupincola*. Ana's research will yield valuable, relevant information for the conservation and management of this species, but this research is not yet completed.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and observations limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed in physics. The geologist, T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (experiments, modeling, logical inference). Ecological science is, in some ways, more similar to geology than physics because of the difficulty in conducting critical experiments and the reliance on observation, inference, good thinking, and models to guide understanding of the world (Hillborn and Mangel 1997). While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding and used in synthesis for this assessment. In this assessment, the strength of evidence for particular ideas is noted and alternative explanations described when appropriate.

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted and alternative explanations described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding.

Publication of Assessment on the World Wide Web

To facilitate use of species assessments in the Species Conservation Project, assessments are being published on the USFS Region 2 World Wide Web (WWW) site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publication as a book or report. More important, revision of the assessments will be facilitated. Revision will be accomplished based on guidelines established by USFS Region 2.

Peer Review

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

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Potentilla rupincola is a sensitive species in USFS Region 2 of the USFS. NatureServe considers *P. rupincola* to be globally imperiled (G2). Because it is only found in Colorado, it is also considered imperiled (S2) by the Colorado Natural Heritage Program (Colorado Natural Heritage Program 2004). It is considered imperiled because it is known from 23 occurrences, seven of which have not been relocated in more than 20 years despite efforts to find them. For explanations of NatureServe's ranking system, see the Definitions section of this document. It is not listed as threatened or endangered on the Federal Endangered Species List. *Potentilla rupincola* is a former Category 2 (C2) species. O'Kane (1988) recommended downgrading it to Category 3 (3C). However, the category program was eliminated by the USFWS in 1996, and those species are no longer being considered as candidate species (U.S. Fish and Wildlife Service 1996). *Potentilla rupincola* is not listed as threatened or endangered under the Endangered Species Act and therefore there are no federal or state laws concerned specifically with its conservation. It is listed on the sensitive species list in USFS Region 2 (USDA Forest Service 2003).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Adequacy of current laws and regulations

Potentilla rupincola has no known enforceable protective designations, conservation agreements, or approved management plans that would prevent the destruction of habitat or individuals. Because there are no laws in place that protect this species on private or public lands, current laws and regulations protecting this species are clearly inadequate to conserve the species throughout its native range. It is listed on the USFS Region 2 sensitive species list (USDA Forest Service 2003), which affords some protection of the species on Forest Service System lands. Because it is designated sensitive in USFS Region 2, the Regional Forester must give consideration to this species so as to maintain its habitat and occurrence persistence (see Forest Service Manual 2670). Issues regarding sensitive species must be addressed in all environmental assessments within suitable habitat. The collection of sensitive species is prohibited without a permit (see Forest Service Manual 2670). The USFS can modify allotment management plans and projects or contracts to give consideration to *P. rupincola* on a discretionary basis. Biological assessments and evaluations are conducted when applications for permits to drill are considered, and impacts to sensitive species can be mitigated. There is one occurrence of *P. rupincola* in the Lone Pine Research Natural Area (RNA). While *P. rupincola* is not the explicit object of any management objectives, the RNA does have a management objective to "protect native elements of biodiversity, including rare and endemic plant species" (Coles 2000). This should provide protection for the occurrence within the RNA.

Of the 23 occurrences of *Potentilla rupincola*, 14 are somewhat protected due to their location within special management areas (**Table 1**). Eight occurrences are known from National Forest System lands in Colorado, with seven on the Roosevelt National Forest (one of which is in the Lone Pine RNA) and one on the Pike National Forest. Four occurrences are known from Rocky Mountain National Park. Two occurrences are found within preserves owned by The Nature Conservancy.

The protection status of ten occurrences is uncertain. Three occurrences are known from private land. At least one landowner in the Virginia Dale area (EO 1) intends to subdivide and develop his property. While this would certainly result in ecological impacts at this location, it is unlikely that development will directly impact a large portion of this occurrence because the habitat of *Potentilla rupincola* is unsuitable for construction. The land ownership status of seven historic occurrences (not seen in more than 20 years) is unknown.

Most occurrences are in somewhat inaccessible, infrequently visited sites. *Potentilla rupincola* has not yet been subjected to many human impacts in which the adequacy of current laws would be tested.

Potentilla rupincola is a target in some conservation planning efforts. It is a conservation target for ecoregional planning in the Southern Rocky Mountain Ecoregion (Neely et al. 2001). *Potentilla rupincola* occurs in twelve Potential Conservation Areas (PCAs) defined by the Colorado Natural Heritage Program (Kettler et al. 1996, Colorado Natural Heritage Program 2004, Doyle et al. in prep). PCAs delineate the primary area that encompass the biological processes supporting the long-term survival of a targeted species and generally include an assessment of the management needs of the species.

Adequacy of current enforcement of laws and regulations

There have been no known cases in which an occurrence of *Potentilla rupincola* was extirpated due to human activities or the failure to enforce any existing regulations. However, this does not necessarily indicate that current regulations or their enforcement are adequate for its protection. Current legal protections that apply to this species pertain only to occurrences residing on land owned by the USFS. Thus there are

Table 1. Summary of land ownership status of the 23 known occurrences of *Potentilla rupincola* in USFS Region 2. Because some occurrences may be found on more than one land ownership type, the total number of occurrences is less than the sum of the rows in this table.

Land Ownership Status	Number of Occurrences	Subtotals
USDA Forest Service	8	
Pike NF		1
Roosevelt NF		7
National Park Service	4	
Unknown	6	
The Nature Conservancy	2	
Colorado Department of Transportation	1	
Private	3	
Total	23	

currently no enforceable laws or regulations that confer protection to occurrences of this species on private, state, or other federal lands.

Biology and Ecology

Classification and description

Potentilla rupincola is a member of the rose family (Rosaceae). The Rosaceae is a large family that includes approximately 100 genera and approximately 2,000 species, many of which are of great agricultural and economic significance (Heywood 1993). It is a cosmopolitan family and is distributed from the high arctic and subantarctic zones to the tropics. It is a diverse family that includes trees (among them important fruit trees such as apples, pears, and peaches), shrubs, and herbs. The Rosaceae is an ancient family and its members have many primitive (less specialized) characters such as actinomorphic flowers, large numbers of stamens and carpels, and unfixed numbers of floral parts (Heywood 1993 after Stebbins 1974).

The Rosaceae family is in the Dicot group, subclass Rosidae, and order Rosales (Cronquist 1988, Heywood 1993, USDA Natural Resources Conservation Service 2002). The Rosales is ancestral to Salicales and Leguminales (Scagel et al. 1966), and has many similarities to the Ranales from which it may have descended (Porter 1967). Rosidae is the largest angiosperm subclass.

Potentilla is in the subfamily Rosoideae (Porter 1967, National Center for Biotechnology Information 2002) and tribe Potentilleae (Morgan et al. 1994). The genus *Potentilla* includes 300 to 350 species (Eriksen 2002). Weber and Wittmann (2000, 2001a and 2001b) recognize 27 species of *Potentilla* in Colorado, as well as many taxa in other genera that have been segregated from *Potentilla* such as *Drymocallis*, *Pentaphylloides*, *Acomastylis*, and *Argentina*. Recent work suggests that the genus *Potentilla* is not monophyletic (Eriksson et al. 1998), so it may be split further in the future. *Potentilla rupincola* is in the section Multijugae of Wolf (1908). The Colorado Natural Heritage Program tracks three species of *Potentilla* (*P. rupincola*, *P. ambigens,* and *P. subviscosa*) as rare in Colorado (Colorado Natural Heritage Program 2004).

There are differing opinions on the appropriate taxonomic treatment of *Potentilla rupincola*. Most authors have treated it as a full species (e.g. Osterhout 1899, Rydberg 1906, Rydberg 1922, Harrington 1954, Kartesz 1999, Weber 1976, Weber and Wittmann 2000, 2001a), while others (e.g. Wolf 1908, Johnston 1980, Kartesz 1994) have treated it as a variety of *P. effusa* (as *P. effusa* var. *rupincola*). The rationale for both treatments is presented below.

Several observations suggest that *Potentilla rupincola* is best treated as a variety of *P. effusa*. These are best described in Johnston (1980, p. 188) thus:

"Except for the near lack of tomentum or other pubescence, var. *rupincola* greatly resembles in all other characters the typical form of *P. effusa* var. *effusa*; it represents the end of a series in pubescence density from the typical form through the light-green form [*P. coloradensis* Rydberg] to *rupincola*. However, the light-green form is found throughout the range of var. *effusa* with a southern flavor, whereas the glabrous-subglabrous plants are restricted to three counties along the Front Range in north central Colorado. It should also be noted that *rupincola* represents the end of a series leading to rockier, better-drained habitats."

Johnston (personal communication 2002) also pointed out that if *Potentilla rupincola* is to be recognized at the full species level, then so must many other entities in Colorado and elsewhere. The variation seen within many species of *Potentilla* is greater than the differences observed between *P. effusa* and *P. rupincola*. Gradual variation in the diagnostic characteristics between the true *P. rupincola* and *P. effusa* is seen in many occurrences. The only character separating these taxa is the vesture of the leaves, which is a dense tomentum in *P. effusa* and is almost absent (with a few strigose hairs on the leaf surface) in *P. rupincola*. Intermediate plants were described as *P. coloradensis* by P.A. Rydberg, but Johnston included this taxon within *P. effusa* in his revision of section Multijugae because of the observations cited above.

An observation by Richard Scully (personal communication 2002) also supports the treatment of *Potentilla rupincola* as a variety of *P. effusa*. In many occurrences of *P. effusa* on dry, rocky habitats, a small fraction of the individuals (less than one percent) are much less hairy than typical *P. effusa*, often nearly glabrous on the upper surface of the leaves. If they are collected and deposited in a herbarium these might pass for *P. rupincola* or the intermediate. This may be the case with the material collected from Boulder and Clear Creek counties. Whether these plants are an extreme phenotype within the normal range of variability of *P. effusa*, or truly equivalent to *P. rupincola* where it is found in larger numbers, is unknown. *Potentilla effusa* is highly plastic and grades into *P. hippiana*, with which it hybridizes (Johnston personal communication 2002). Other taxonomic treatments have even lumped *P. effusa* within *P. hippiana* (e.g. Hitchcock and Cronquist 1973).

Preliminary results from Ana Child's research suggest that *Potentilla rupincola* warrants treatment at the full species level (Child personal communication 2002). If *P. rupincola* is indeed a species rather than an extreme phenotype of *P. effusa*, then it is possible that the intermediate plants mentioned above are the products of hybridization between *P. effusa* and *P. rupincola*, or may even represent a third taxon (*P. coloradensis*) as described by Rydberg (1906, Child personal communication 2002). These hypotheses will be tested in the course of Ana's doctoral research. Ana has identified genetic markers in the large single copy region of the chloroplast genome that hold promise for determining the nature of the relationship between *P. effusa*, *P. rupincola*, and the intermediates.

Some field observations also lend credence to the treatment of *Potentilla rupincola* at the species level. Some populations are allopatric, containing only "pure *P. rupincola*," while other populations are sympatric and include *P. effusa*, *P. rupincola*, and intermediate plants. While this does not prove that *P. rupincola* is distinct enough to be treated as a species, Ana's hypothetical scenario makes some sense of this situation. Johnston (1980) offers what might be an equally parsimonious explanation- that the phenotype expressed in the rockiest, driest sites occupied by *P. effusa* is what we recognize as *rupincola*. However, tomentose *P. effusa* is also found infrequently in dry, rocky habitats, making it difficult to explain *P. rupincola* as an ecotype of *P. effusa* (Scully personal communication 2002).

The current taxonomic research by Child (2001, personal communication 2002) will shed light on the appropriate taxonomic treatment of *Potentilla rupincola*. In this report, *P. rupincola* is treated at the full species level to follow the treatment of Kartesz (1999) and USDA Natural Resources Conservation Service (2002), used as a taxonomic standard by NatureServe and the Colorado Natural Heritage Program (NatureServe 2002) and the USFS.

Potentilla rupincola was described in 1899 by George E. Osterhout from specimens collected from Dale Creek in the Virginia Dale area in northern Larimer County (Osterhout 1899). In the late 1800's and early 1900's, several specimens were collected in Larimer County, as were those collected in Clear Creek and Boulder counties (considered questionable by some experts- see the distribution section of this report for details). It was not discovered in Park County until 1979 by Pat Murphy. His specimen (79-50 at COLO) was annotated as *P. effusa* by Johnston in 1980, but was annotated as *P. rupincola* by Ertter in 1993 and appears to be a good specimen of *P. rupincola* although it is filed in the *P. effusa* folder (Scully personal communication 2002).

The most recent worldwide monograph of *Potentilla* was done in 1908 by T. Wolf. He divided *Potentilla* into subsections based on morphological characteristics of the achenes and styles, which is somewhat problematic and has resulted in many artificial groups (Johnston 1980). There have been many new species described and much systematic revision of the genus since, and a worldwide revision of the genus is wanting (Eriksen 1996, Eriksen 2002). Johnston (1980) revised *Potentilla* section Multijugae to which *P. rupincola* belongs based on morphometric analyses.

Extensive work in the 1990's by Kettler et al. (1996) and Richard Scully and MaryJane Howell (ongoing) contributed greatly to our understanding of the range, population size, and habitat of *Potentilla rupincola*. Current research by Ana Child holds great promise for understanding the taxonomy, demography, and breeding systems of *P. rupincola*.

Members of the subfamily Rosoideae are distinguished from other members of the Rosaceae family in having compound leaves, superior ovaries, and fruits that are aggregations of achenes (as in *Potentilla*) or drupelets (Cronquist 1981). As in all rosaceous flowers, there is an epicalyx of five bractlets below and alternating with the regular calyx in *Potentilla* (Eriksen 1996). These bractlets (or "bracteoles" in Weber and Wittmann 2001a) are diagnostic features for many *Potentilla* species and distinguish *P. effusa* and *P. rupincola* from *P. hippiana* (Weber and Wittmann 2001a, Scully personal communication 2002). In *P. effusa* and *P. rupincola*, the bractlets are darker and much smaller than the calyx lobes, while the bractlets are larger and the same color as the calyx in *P. hippiana* (Johnston 1980).

Potentilla rupincola is a low-growing perennial. It is usually caespitose (with a cushion plant growth form) (Child personal communication 2002, Scully personal communication 2002), but plants in sheltered sites may be taller and more erect, up to three dm tall (as described in Osterhout (1899) and Spackman et al. (1997)). Older plants have an extensive root system with branching, underground woody caudices (Osterhout 1899, Scully personal communication 2002). Weber (1976) states that the plants form massive tussocks with much dead leaf and stem material, and Spackman et al. (1997) and Weber and Wittmann (2001a) note the presence of marcescent leaf petioles. Scully (personal communication 2002) notes that herbarium specimens usually do not include this fragile, dried material from previous years' growth. *Potentilla rupincola* has numerous (seven to 30) small yellow flowers (**Figure 1**) borne on a branched cyme (Osterhout 1899, Johnston 1980).

The leaves and vesture are used in most keys to distinguish *Potentilla rupincola* from other species. The leaves have five to seven leaflets (rarely as many as nine to 13) and are bright shining green (Osterhout 1899, Spackman et al. 1997, Scully personal communication 2002). The leaflets are toothed mainly on the upper half, (Beidleman et al. 2000) but the number of teeth on the leaves reportedly varies, even between leaves of the same individual (Scully personal communication 2002). Weber and Wittmann (2001a) note that the primary pinnae are cuneate, broadest toward the apex, and toothed but undivided, while Harrington (1954) notes that the leaflets are sharply serrate, often almost incised except near the base. *Potentilla rupincola* is almost glabrous on the leaves and calyx, with strigose hairs on the leaf surfaces, veins, and margins (Osterhout 1899, Harrington 1954, Johnston 1980, Beidleman et al. 2000).

Potentilla rupincola is most easily confused with *P. effusa*, from which it can be difficult to distinguish. Both *P. effusa* and *P. rupincola* have strigose hairs on the leaves, but *P. rupincola* lacks a tomentum on both sides of the leaves, whereas *P. effusa* is often densely tomentose on both leaf surfaces. This is probably the most reliable characteristic for distinguishing *P. rupincola* from *P. effusa*, but the phenotypic plasticity of *P. effusa* can make identification difficult (**Figure 2**). Younger leaves are better for distinguishing these species, because the leaves of *P. rupincola* and intermediate plants become more hairy with age (Child personal communication 2004). The putative hybrids (intermediate plants) are typically tomentose on the undersides of the leaves but not above. The basal pair of leaflets is fairly consistently hairy in *P. effusa* even when young, while those of *P. rupincola* and intermediate plants are mostly glabrous (Child personal communication 2004). *Potentilla rupincola* tends to be, but is not always, more delicate in its overall "physique" than *P. effusa*, with thinner stems, a smaller calyx, and a smaller stature (Scully personal communication 2002). Osterhout (1899) describes it as "rather slender," while Johnston (1980) notes that the stems are brittle in *P. rupincola*.

Several published sources are available for technical descriptions of *Potentilla rupincola*. Several of those cited above (Osterhout 1899, Harrington 1954, Johnston 1980, Spackman et al. 1997, and Weber and Wittmann 2001a) are particularly useful and are relatively accessible. The only source with an illustration (**Figure 3**), rangemap, and photos of *P. rupincola* is Spackman et al. (1997). Scully (personal communication 2002)

Figure 1. The flower of *Potentilla rupincola*. Photograph by the author, from Virginia Dale on June 23, 2004.

Figure 2. Variation in the vesture of leaves observed and photographed by the author at Virginia Dale on June 23, 2004. The leaf on the left is almost completely glabrous and is characteristic of most plants at Virginia Dale. However, intermediate individuals (center leaves) and *Potentilla effusa* (silvery tomentose leaf at right) are also present.

and Child (personal communication 2002) noted that the drawing and photos in this source depict plants that appear much more robust than is typical of the species. Wolf (1908) also includes an illustration of *P. rupincola*. Please see **Figure 4**, **Figure 5**, **Figure 6**, and **Figure 7** for photos of *P. rupincola*.

Osterhout's type specimen of *Potentilla rupincola* is housed at the Rocky Mountain Herbarium in Laramie, Wyoming. An image of the isotype specimen housed at the New York Botanical Garden is available online (New York Botanical Garden 2002).

Distribution and abundance

The genus *Potentilla* is distributed from the subtropics to the arctic, but it is best represented on mountain ranges in the subalpine, alpine, and arctic (Johnston 1980).

The global distribution of *Potentilla rupincola* is limited to the Colorado Front Range (**Figure 8** and **Figure 9**). It has been reported from Larimer, Boulder, Clear Creek, and Park counties (Colorado Natural Heritage Program 2004) (**Table 2**). However, the only occurrences known to remain extant are in Larimer and Park Counties. The vast majority of the known occurrences and individuals are in Larimer County.

The Colorado Natural Heritage Program (2004) documents 23 element occurrences of *Potentilla rupincola* in its Biological Conservation Database. However, these do not equate directly to populations or patches; several of these records include two or more discrete patches that are included within a single record. For lack of better information, records of patches within one mile of each other are considered a single occurrence assuming that they are somewhat genetically connected and approximate a true panmictic population. Of the 23 known occurrences, seven are historic (not seen in 20 years or more). These occurrences were last observed between 1893 and 1931. Child visited 15 sites (in 12 element occurrences) in 2002, all of which were extant (Child personal communication 2002).

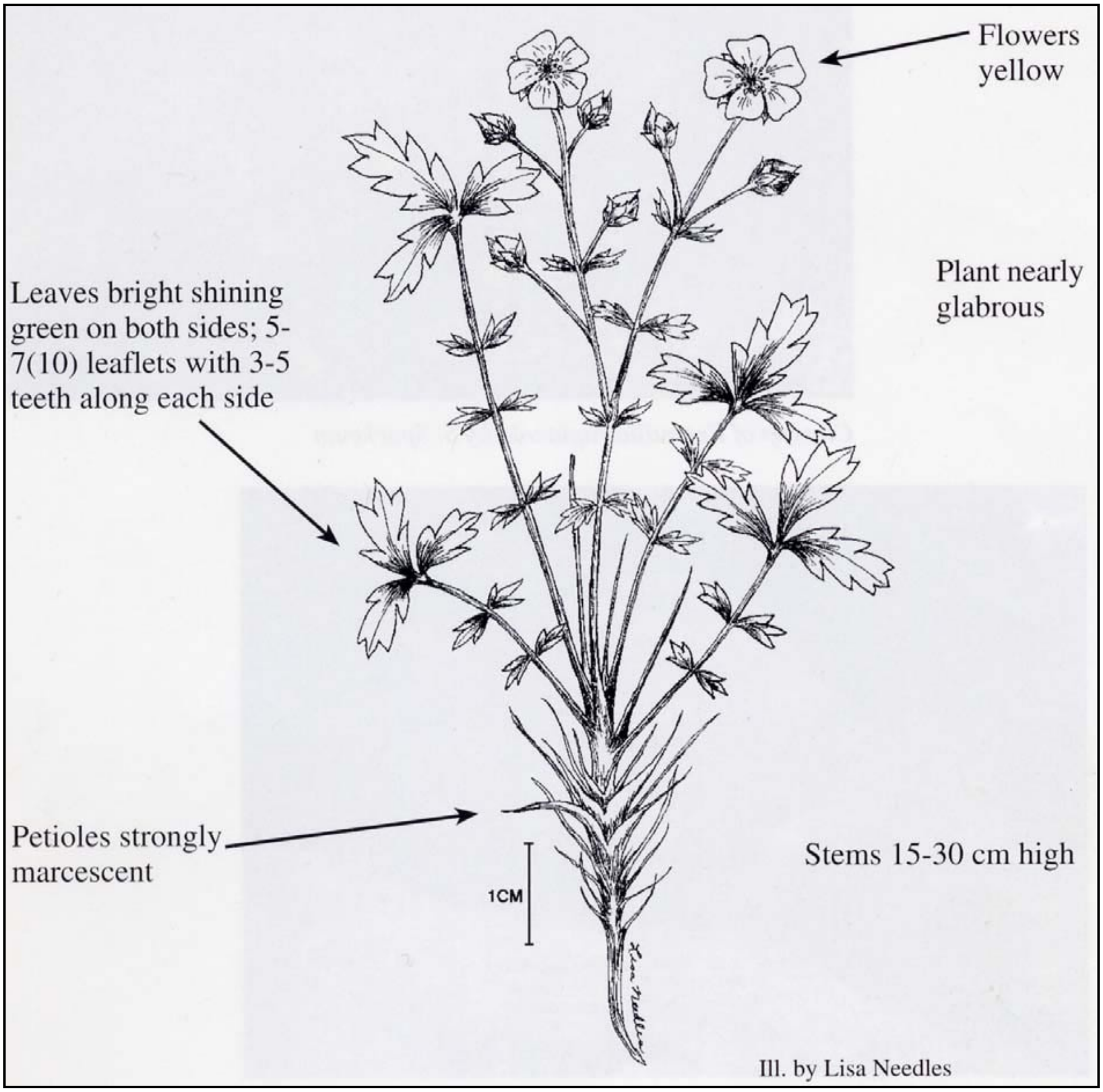

Figure 3. Illustration of *Potentilla rupincola* from Spackman et al. (1997), highlighting diagnostic characteristics.

Historic occurrences reported in Boulder and Clear Creek counties are very questionable. Nan Lederer (Curatorial Assistant with the University of Colorado Herbarium) and Richard Scully and MaryJane Howell (independent botanists who have discovered many occurrences of *Potentilla rupincola*) have tried to relocate the occurrences in Clear Creek and Boulder counties but could not find any *P. rupincola*. The specimens from Georgetown (collected in 1895), Empire (collected in 1903), and Eldora (collected in 1919), all have significant amounts of tomentum and are very likely *P. effusa* rather than *P. rupincola* (Nan Lederer as cited in Colorado Natural Heritage Program 2004). Due to the vague locational information on most of the historic specimens for this species, large areas of extremely steep terrain must be searched and it cannot be determined if locations found during the search are the same as those visited by the collector.

Further dedicated survey work is needed to search for *Potentilla rupincola* in Clear Creek and Boulder counties. Although the specimens from those counties are questionable, this area contains large amounts of apparently suitable habitat for *P. rupincola*, and is between occurrences that are currently known to be extant. More survey work is warranted also in Jefferson and Park Counties.

Figure 4. *Potentilla rupincola* (Child 2002). Note the shiny, green, hairless leaves and caespitose habit. This form is most characteristic of *P. rupincola*.

Figure 5. Typical individual at Virginia Dale. Plants at Virginia Dale tend to be larger and less caespitose than is seen at other sites. Photograph by the author.

Figure 6. *Potentilla rupincola* on rock exposed on a roadcut at Virginia Dale. Photograph taken by the author June 23, 2004.

Some of the Larimer County occurrences may also turn out to be extirpated or misidentified. Preliminary results suggest that the Phantom Canyon Preserve occurrence (EO 14) is intermediate between *Potentilla effusa* and *P. rupincola* (Child personal communication 2002). All plants observed thus far at Lily Mountain (EO 21 – Roosevelt National Forest) and the specimen from Chambers Lake (EO 10) also appear to be intermediate (Scully personal communication 2002, Colorado Natural Heritage Program 2004). Plants at Turkey Roost (EO 3, Roosevelt National Forest) are also intermediate (Child personal communication 2004).

The population size of *Potentilla rupincola* has not been rigorously quantified, but Colorado Natural Heritage Program element occurrence records support a total population size estimate of 36,000 individuals (Colorado Natural Heritage Program 2004). Scully (personal communication 2002) estimates that the total population size may approach 100,000 individuals. A single occurrence at Stewart Hole (EO 13, Roosevelt National Forest) may contain 10,000 plants (Scully personal communication 2002), while most other occurrences have population size counts or estimates ranging from nine to 2,000 plants (Colorado Natural Heritage Program 2004). Several large occurrences

Figure 7. Variation in *Potentilla rupincola* seen and photographed by the author at the Abbey of St. Walburga (in the Virginia Dale area) on June 23, 2004.

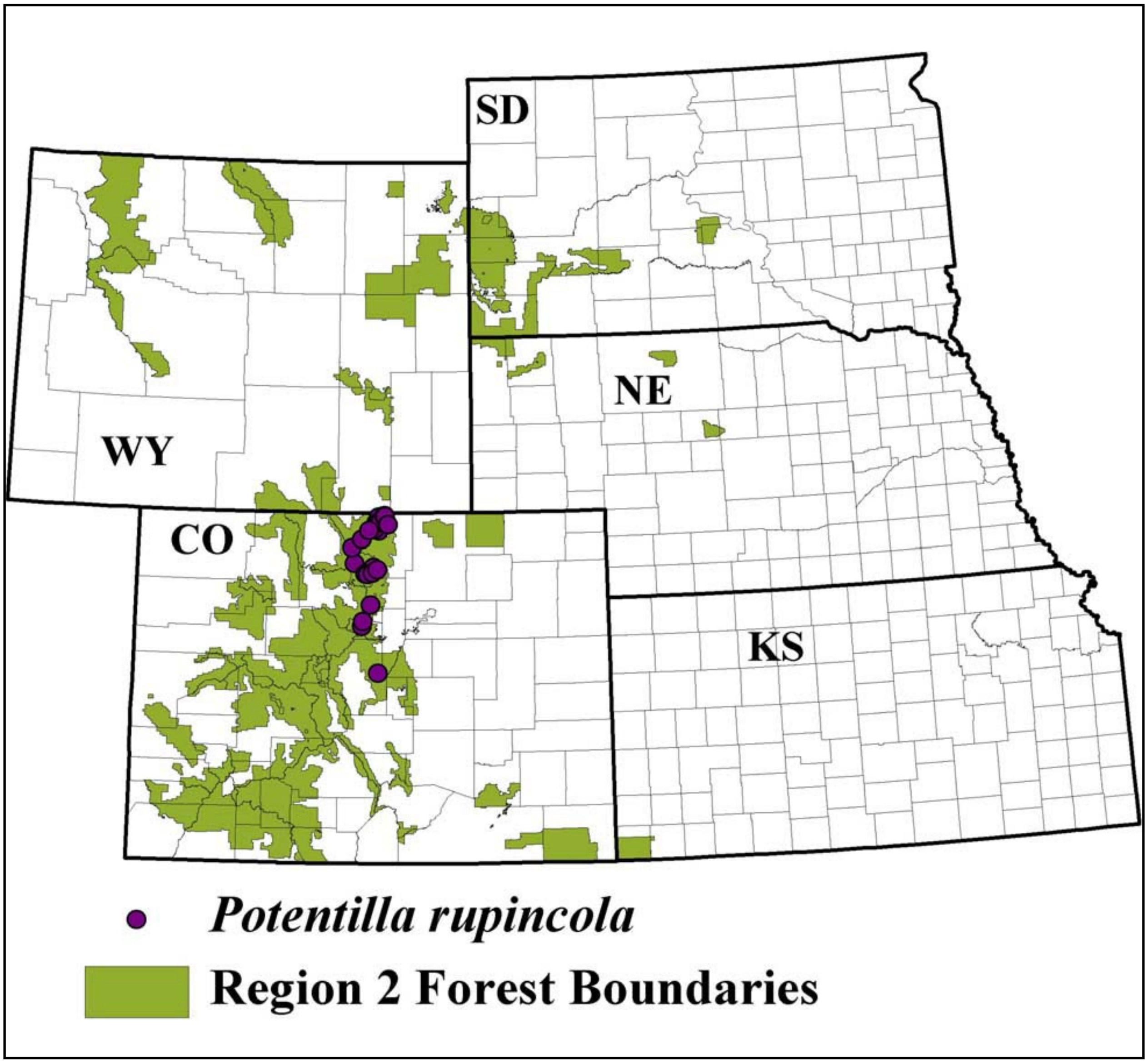

Figure 8. Distribution of *Potentilla rupincola* in the states of Region 2.

have also been documented in Rocky Mountain National Park. See **Table 2** for population size estimates for each occurrence.

Potentilla rupincola is found at the southern extent of the larger range of *P. effusa* (Johnston 1980, USDA Natural Resources Conservation Service 2002) (**Figure 10**). Although the vast majority of the known occurrences are found in Larimer County, another disjunct occurrence is known from Park County. However, it is possible that there is more connectivity between the known occurrences if the Boulder and Clear Creek county occurrences (EO 6, EO 8, EO 9) are extant and include *P. rupincola*. At finer scales, occurrences are also disjunct due to the limited availability of habitat. No occurrence is particularly large or extensive. No occurrence occupies more than 300 acres, and most are one to ten acres in size.

Very few of the known occurrences of *Potentilla rupincola* do not co-occur with *P. effusa* and intermediate plants. **Table 2** notes which occurrences are sympatric (include one or more entities), allopatric (include *P. rupincola* or the intermediate only), or parapatric (include the three entities mixed together). This information is based on survey work by Kettler et al. (1996), Child (2001), and Scully and Howell (Scully personal communication 2002, Colorado Natural

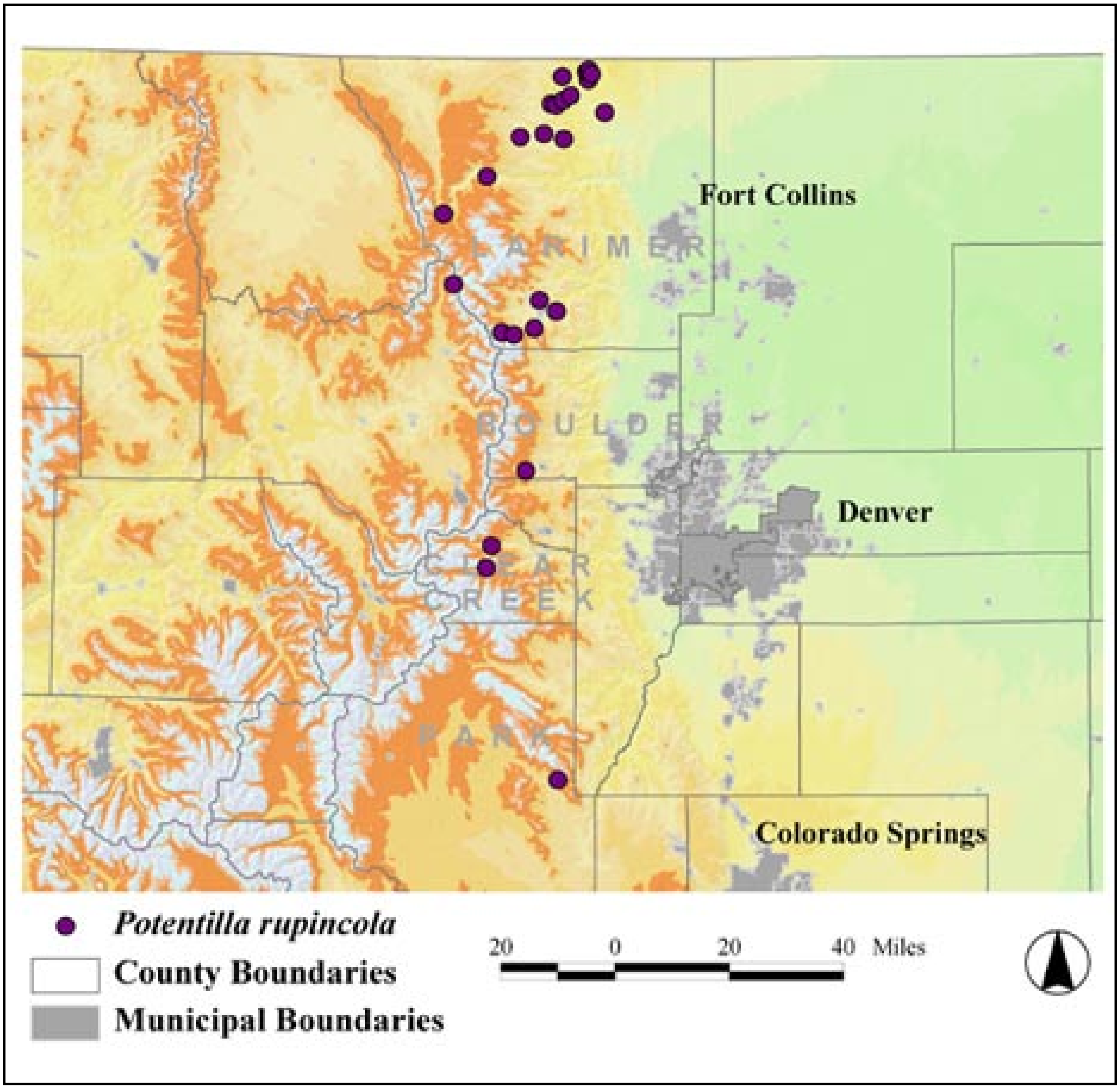

Figure 9. Extent of the known global range of *Potentilla rupincola* with respect to major physiographic features and population centers. Map extent is north-central Colorado.

Heritage Program 2004). The only allopatric occurrences of *P. rupincola* are in Larimer County (four in Rocky Mountain National Park (EO 11, EO 12, EO 22, EO 27), and one occurrence east of Mount Margaret (EO 15, Roosevelt National Forest). Populations at Bull Garden (EO 23, Roosevelt National Forest), Steep Mountain (EO 27), and Virginia Dale (EO 1) are parapatric occurrences, although all of the sympatric occurrences are also mixed to some degree. However, Bull Garden (EO 23, Roosevelt National Forest) is unusual because all three entities occur together on similar substrates (Child personal communication 2002).

Population trend

There are no quantitative population trend data for *Potentilla rupincola*. There has been no population monitoring that could provide insight into population trend, and population size is not known for many of the known locations in USFS Region 2. A small portion of the occurrence at Virginia Dale (EO 1) appears to be imperiled by cheatgrass (*Bromus tectorum*) invasion on a roadcut, where casual observations suggest that the species has declined (Child personal communication 2002). However, most of the occurrence in this

Table 2. Summary information for all Element Occurrences of *Potentilla rupincola* by area.

Area (from north to south)	Location	County	CNHP EO#	Last Observed	*P. effusa*	Intermediate	*P. rupincola*	N (est.)	Est./ Count[a]	Source of N[b]	Notes[c]	Land Ownership	Elevation (feet)	Habitat and Notes
Virginia Dale	Lover's Leap, Dale Creek, Abbey of St. Walburga	Larimer	1	2004	x	x	x	5,000	e	1	parapatric?	Private (including Abbey of St. Walburga), Colorado Department of Transportation	6,860 to 7,240	Reddish granite outcrop of Sherman Granite with broken boulders and cracked cliff faces; also on a steep north-facing road cut on granite. Also on shallow granitic soil and in soil filled depressions of sandstone outcrop. Soil is shallow, granitic, and gravelly. Plants occur on all aspects, mostly in full sun, but also in the shade of trees and shrubs. Slope is flat to nearly vertical. *Potentilla effusa* is also present, though not as abundant as *P. rupincola*. Mostly found in open ponderosa pine; less dense among shrubs. Size classes range from 4 inches in diameter to 1.5 feet. Plants occur in patches. *Bromus tectorum* has invaded some occupied habitat; very dense in places where *P. rupincola* is not found. Horse and cattle grazing in the area has limited impacts; most habitat is rocky and not accessible to grazing. With *Ribes cereum*, *Bouteloua gracilis*, *Eriogonum umbellatum*, *Geranium caespitosum* ssp. *caespitosum*, *Juniperus scopulorum*, *Penstemon virens*, *Aletes humilis*, *Pinus ponderosa*, *Selaginella* spp., *Opuntia polyacantha*, *Cercocarpus montanus*, and other species.
Phantom Canyon	Phantom Canyon	Larimer	14	2002		x		500	e	2	allopatric?	The Nature Conservancy	6,500 to 6,700	On side and top of cliff, NW-to N-facing slopes. Unforested. Here *Potentilla rupincola* occupies the habitat niche that elsewhere is occupied by *aletes humilis*.
Between Prairie Divide and Turkey Roost	Bull Garden	Larimer	23	2002	x	x	x	5,000	e	2	parapatric	Roosevelt National Forest, possibly private	7,400 to 7,800	Growing in thin sandy soil and in crevices of granite on upland with level to moderate slopes, of all aspects. Associated species: *Pinus ponderosa*, *Pseudotsuga menziesii*, *Drymocallis fissa*, *Potentilla effusa*, *Sedum* spp., *Heuchera* spp., *Ranunculus ranunculinus*, *Purshia* spp., *Achillea*, *Senecio*, *Artemisia* spp., *Ribes* spp., *Rubus* spp., *Penstemon virens*, grasses, *Aletes humilis*. Extensive population of shiny green *Potentilla effusa* var. *rupincola*. Some plants intergrading with *P. effusa* var. *effusa*. *Potentilla rupincola* just beginning to flower at this time.
	Turkey Roost	Larimer	3	2004	x	x		9	c	1	sympatric	Roosevelt National Forest	7,700	Geology: granite outcropping. Aspect: top hill. Soil: granite and gravelly soils. Slope: flat. Associated taxa: *Pinus ponderosa*, *Aletes humilis*. Area is protected for wildlife; no grazing is occurring.
	West of Turkey Roost	Larimer	17	1994			x	2,000	e	2	unknown	Roosevelt National Forest	7,100 to 7,400	Moderate north and west- facing slopes on granitic soil and on roadcuts. Associated taxa: *Potentilla effusa*, grasses, *Geranium* spp. Plant forms transitional to *P. effusa* are common. This site visit observed several small populations, but extent may be larger.
	Cap Rock	Larimer	25	1996	x	x	x	23	c	1	sympatric	The Nature Conservancy	7,360	Open ponderosa pine and Douglas fir forest. With *Jamesia americana*, *Physocarpus monogynus*, *Sedum lanceolatum*, *Leucopoa kingii*, *Poa fendleriana*. On old overgrown trail. In area with 25 percent cover of rocks/ boulders. Flat to 10 degree slope, south facing. 23 individuals counted with sparce pubescence. 11 individuals of *Potentilla effusa* also counted with more silvery/grey green pubescence. All individuals very small approximately 5 cm. across.
	Prairie Divide Road	Larimer	18	2002	x	x	x	5,000	e	2	sympatric	Private: Elk Meadows Road Association	7,640 to 7,680	On gently rolling upland, growing in shallow soil and granite crevices in open montane forest; Growing in thin sandy soil and in crevices of granite on upland with level to moderate slopes, of all aspects. Also on gentle north-facing slope, with shallow granitic soil and in roadcut. Associated taxa: *Pinus ponderosa*, *Pseudotsuga menziesii*, *Drymocallis fissa*, *Potentilla effusa*, *Sedum* spp., *Heuchera* spp., *Ranunculus ranunculinus*, *Purshia* spp., *Achillea* spp., *Senecio* spp., *Artemisia* spp., *Ribes* spp., *Rubus* spp., *Penstemon virens*, grasses, *Aletes humilis*, *Antennaria* spp., *Potentilla* spp., *Geranium* spp.

Table 2 (cont.).

Area (from north to south)	Location	County	CNHP EO#	Last Observed	*P. effusa*	Intermediate	*P. rupincola*	N (est.)	Est./ Count[a]	Source of N[b]	Notes[c]	Land Ownership	Elevation (feet)	Habitat and Notes
Lone Pine Research Natural Area and surrounding area	Mount Margaret	Larimer	15	1994			x	100	c	2	allopatric	Roosevelt National Forest	7,800	On gentle slopes and moderate west-facing slopes of low ridges with shallow granitic soil. Associated taxa: grasses, *Potentilla fissa*, *Purshia* spp., *Penstemon* spp., *Juniperus communis*, *Pinus ponderosa*, *Artemisia* spp. Plants appear to reproduce best in areas disturbed by old road, providing that there is little traffic. Road is closed Dec. 1 to Sept 15.
	Red Feather Lakes	Larimer	26	2001	?	?	x	unknown	—	—	unknown	Roosevelt National Forest	7,600 to 8,000	Steep canyon walls in narrow, damp canyon, with rock ledges. Associated species: *Jamesia americana*, *Cornus sericea*.
	Stuart Hole/ Sheep Mountain	Larimer	13	2002	x	x	x	10,000	e	2	sympatric, allopatric	Roosevelt National Forest, Lone Pine Research Natural Area	7,200 to 8,050	Widespread on gravelly woodland slopes. Associated plant community: ponderosa pine woodland with *Purshia tridentata*, *Leucopoa kingii*, *Physocarpus monogynus*, *Ribes cereum*, *Artemisia frigida*, *Jamesia americana*, *Pinus ponderosa*, *Aletes humilis*, *Pseudotsuga menziesii*. Habitat type: growing in bare gravel or between rocks. Additional associated plant species: *Leptodactylon pungens*, *Drymocallis fissa*, *Harbouria* spp., *Geranium* spp., *Potentilla* spp. Geomorphic landform: colluvial foothill slopes and rock outcrops. Soil texture: coarse gravelly soil. Total tree cover: 15-30 percent. Total forb cover: 10 percent. Total shrub Cover: 10 percent. Total graminoid cover: 10 percent. Total bare ground cover: 50 percent. Aspect: SW to NW. Slope: 0 to 40 percent. Slope shape: convex. Light exposure: mostly open. Topographic position: varied, lower slope to crest. Moisture: dry. Parent material: granite. Size of area covered by population: 15 acres (may be much more extensive). Exposed to west winds. The population appears to be on more easterly aspects of ridge. Valley bottom outside the RNA is dominated by exotic plant species, especially hay grasses, but there are few weeds within the site besides a few patches of *Bromus tectorum*. On shallow granitic soils and in cracks of rock outcrops on steep northwest-facing slopes and on moderate to gentle slopes of all aspects. Silver plume granite bedrock. On shallow soil near granite outcrop. Clumped habit, numerous marcescent stems, subglabarous glossy bright green leaves. Reproductive status: vegetative. Lone Pine Creek valley bottom apparently grazed/hayed in past, probably homesteaded. Upper slopes have been grazed by livestock in past. Very little connectivity to other FS land; surrounded by private property and State Wildlife Area. No access to site except Lone Pine Creek corridor, without permission from private landowners.
South of Estes Park	Lily Mountain	Larimer	21	2002		x		1,000	e	2	allopatric?	Roosevelt National Forest	8,600 to 9,600	Upper montane forest. Aspect: E and S. slope: 50 percent. Slope shape: straight. Light exposure: open woodland. Moisture: dry. Parent material: silver plume granite. Land form: unglaciated mountainside. Soil: gravelly loamy sand (grus). Reproductive success: widespread on east side of mountain. Associated species: *Pseudotsuga* spp., *Ciliaria* spp., *Drymocallis fissa*, *Geranium* spp., *Penstemon virens*, *Erigeron* spp., *Artemisia* spp., *Senecio* spp., *Juniperus communis*, *Pinus flexilis*, *Purshi* spp., *Jamesia* spp., *Draba streptocarpa*, *Potentilla effusa* or *hippiana*.
	Hermit Park	Larimer	24	1996	x		x	300	e	1	sympatric	Private: Hewlett Packard	8,440 to 8,560	Ponderosa pine open woodland with steep granite outcrop cliffs, also in thin forested soil and in granite exposed on the north-facing roadcut. Plants were found in open understory with pine needle litter. Gravel soil. Slope: 0 to 10 degrees. Not found on top of the granite outcrops but below them. Associated Species: *Arctostaphylos* spp., *Geranium* spp., *Jamesia* spp., Rocky Mountain maple, grasses. No exotics noted. Only light recreation use. Quality and viability of population unknown at this time. Only used for recreation. Mostly camping but little hiking. Several glabrous plants among a population of *Potentilla effusa* var. *effusa*.

Table 2 (cont.).

Area (from north to south)	Location	County	CNHP EO#	Last Observed	*P. effusa*	Intermediate	*P. rupincola*	N (est.)	Est./ Count[a]	Source of N[b]	Notes[c]	Land Ownership	Elevation (feet)	Habitat and Notes
Rocky Mountain National Park-Glacier Basin	Steep Mountain	Larimer	27	2002	x	x	x	50	e	2	sympatric	Rocky Mountain National Park	9,480	On top of windswept cliff on open gravelly area and rock outcrop at the edge of wind forest. Aspect: NW. Light exposure: open. Moisture: well drained. Parent Material: Silver Plume Granite.
	Glacier Knobs/ Battle Mountain	Larimer	12, 22	2002			x	6,000	e	2	allopatric	Rocky Mountain National Park	9,750 to 10,900	On broad shelves of a west-facing cliff of granite. Total tree cover: 0 to 50 percent. Aspect: all. Percent slope: 0-20. Slope shape: convex. Light exposure: open to partially shaded. Topographic position: hilltop and benches. Moisture: dry. Parent material: massive biotite schist. Geomorphic land form: Glaciated rock knob. Soil texture: the little soil is loamy sand. Many are in rock crevices. Associated taxa are *Pinus flexilis*, *Populus tremuloides*, *Potentilla fruticosa*, *Heuchera* spp., *Ciliaria* spp., *Erigeron* spp., *Trifolium* spp., *Juniperus communis*, *Senecio* spp. Relatively small and apparently isolated population, with many individuals that are not flowering. The old trail receives some use but the impact is minor. Slope shape: convex. Slope: 0 to 20 percent. On all aspects. Light exposure: Open. Topographic position: top of ridge. Moisture: dry. Parent material: biotite schist and silver plume granite. Landform: residual soils on mountain top. Soil texture: gravelly loamy sand and rock crevices. Associated species: *Pinus flexilis*, *Polemonium* spp., *Erigeron* spp., *Dasiphora floribunda*, *Trifolium* spp., *Hymenoxys acaulis* var. *caespitosa*, *Antennaria* spp., *Ciliaria* spp., *Abies lasiocarpa*, *Heuchera* spp., *Achillea* spp., *Oreoxis humilis*. Leaves are entirely glabrous (without tomentum), although strigose hairs are present.
West Side of Tarryall Mountains	Hankins Pass Trail	Park	20	2002		x	x	250	e	2	sympatric?	Pike National Forest	8,680 to 9,260	Hillslope below cliffs; granitic soil derived from Pikes Peak granite. Habitat varies from open to wooded. Aspect: NW. Slope: 20+ percent. Slope shape: Convex. Light exposure: open and partial shade. Topographic position: crest and lowerslope. Moisture: extremely well drained. Parent material: Pikes Peak granite. Geomorphic land form: granite tors. Soil texture: coarse sandy. Associated taxa include *Pinus ponderosa*, *Populus tremuloides*, *Pinus flexilis*, *Potentilla fissa*, *Artemisia* spp., *Geranium* spp., *Arctostaphylos*, *scattered Pinus aristata*, *Telesonix jamesii*, *Erigeron vetensis* and *E. compositus*, *Artemisia frigida*, *Ciliaria austromontana*, *Heuchera bracteata*, *Pseudotsuga menziesii*, *Delphinium nuttallianum*, grasses.
	Brookside-McCurdy Trail	Park	20	2002			x	600	e	2	allopatric?	Pike National Forest	8,680 to 9,260	Hillslope below cliffs; granitic soil derived from Pikes Peak granite. Habitat varies from open to wooded. Aspect: NW. Slope: 20+ percent. Slope shape: Convex. Light exposure: open and partial shade. Topographic position: crest and lowerslope. Moisture: extremely well drained. Parent material: Pikes Peak granite. Geomorphic land form: granite tors. Soil texture: coarse sandy. Associated taxa include *Pinus ponderosa*, *Populus tremuloides*, *Pinus flexilis*, *Potentilla fissa*, *Artemisia* spp., *Geranium* spp., *Arctostaphylos*, scattered *Pinus aristata*, *Telesonix jamesii*, *Erigeron vetensis* and *E. compositus*, *Artemisia frigida*, *Ciliaria austromontana*, *Heuchera bracteata*, *Pseudotsuga menziesii*, *Delphinium nuttallianum*, grasses.
Historic Records	Fall River Pass	Larimer	11	1931			x	unknown			unknown	Rocky Mountain National Park	10,760	Subalpine meadows.
	Estes Park	Larimer	19	1897			x	unknown			unknown	Unknown	~7,600	Not reported
	Chambers Lake	Larimer	10	1896			?	unknown			unknown	Unknown	9,500	Not reported
	Upper Cache la Poudre	Larimer	2	1893			?	unknown			unknown	Unknown	not reported	Not reported

Table 2 (concluded).

Area (from north to south)	Location	County	CNHP EO#	Last Observed	*P. effusa*	Intermediate	*P. rupincola*	N (est.)	Est./ Count[a]	Source of N[b]	Notes[c]	Land Ownership	Elevation (feet)	Habitat and Notes
	Eldora	Boulder	6	1919			x	unknown			unknown	Unknown	~8,800	Rocks.
	Georgetown	Clear Creek	8	1895			x	unknown			unknown	Unknown	~8,700	Stony places; mountainsides.
	Empire	Clear Creek	9	1903			x	unknown			unknown	Unknown	8,600	Mountainsides.

[a] Nature of population size estimate (N). c = count, e = estimate.

[b] Source of estimate of population size. 1 = Colorado Natural Heritage Program Element Occurrence Data, 2 = Scully personal communication 2002.

[c] Assessment of allopatry, sympatry, and parapatry in populations provided by Ana Child (Child 2001, Child personal communication 2002).

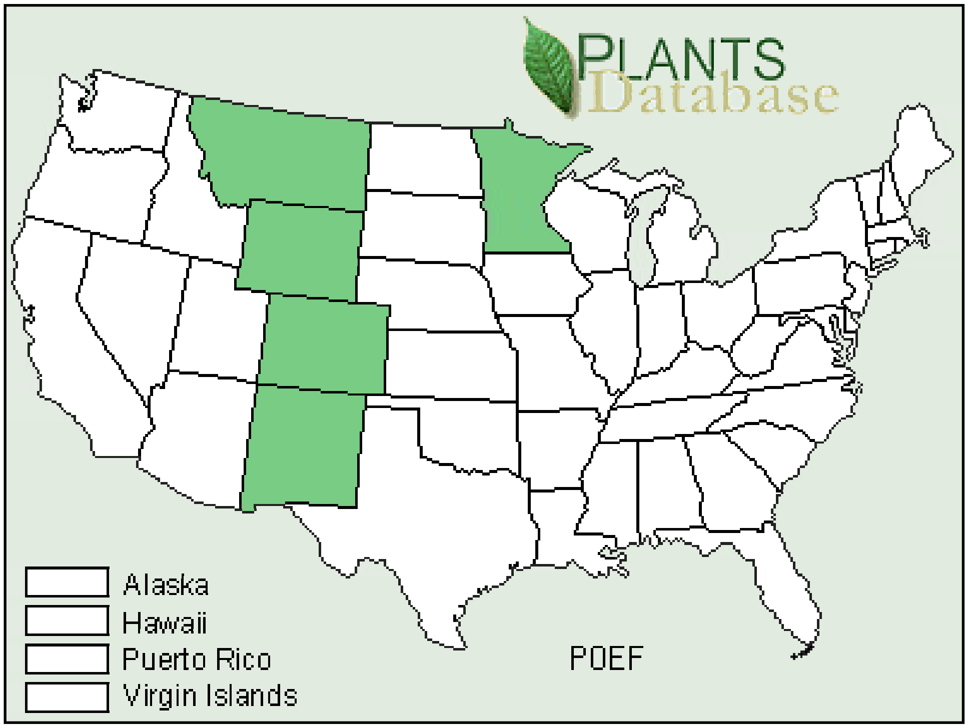

Figure 10. States in which *Potentilla effusa* is found (USDA, Natural Resources Conservation Service 2002).

area remains largely unaffected by non-native species (Scully personal communication 2002). The occurrences in Boulder and Clear Creek counties (EO 6, EO 8, EO 9) have not been seen for several decades, and it is possible, though not particularly likely, that this is due to extirpation. With the exception of a portion of the occurrence at Virginia Dale (EO 1), the currently known occurrences appear healthy and stable, and given current data, there is no reason to believe that other occurrences are declining. As a fairly long-lived polycarpic perennial that does not exhibit prolonged dormancy, occurrences of *P. rupincola* are unlikely to fluctuate greatly from year to year.

Habitat

The habitat for *Potentilla rupincola* has been relatively thoroughly documented, largely through the work of Barry Johnston, Richard Scully, and Kettler et al. (1996). It is generally found on granite shelves or niches on cliffs (Johnston 1980) (**Figure 11**, **Figure 12**, **Figure 13**, and **Figure 14**). Numerous records document plants in rock crevices on granite rock outcrops and on cliff faces. Occupied habitats have been variously described as "granite outcrops," "glaciated rock knob," "granite tors," and "on gentle slopes and low ridges." *Potentilla rupincola* is also sometimes found in sparsely forested sites with thin soil, and in gravelly soils within and adjacent to rock outcrops (**Figure 14**). It is more often found on the margin of forests in areas too rocky to support trees than in sites within forest. A historic specimen documents it from "subalpine meadows" in Rocky Mountain National Park but this location has not been revisited recently. It is also documented on roadcuts (Virginia Dale (EO 1), Turkey Roost (EO 3, Roosevelt National Forest), and Prairie Divide Road (EO 18), and in one case on an infrequently used road (Mount Margaret, EO 15, Roosevelt National Forest). At the latter site, individuals in the road were more robust and were flowering more profusely than those adjacent to the road. Please see **Table 2** for a summary of habitat descriptions at all known occurrences.

Potentilla rupincola is found almost exclusively on granite or on metamorphic rocks that are mineralogically similar to granite, such as schist, or in soils derived from them. Many occurrences are found on Silver Plume granite, such as some in Rocky Mountain National Park and at Sheep Mountain (EO 13, Roosevelt National Forest). Others, such as the Virginia Dale occurrences (EO 1), are on Sherman Granite. The disjunct occurrence in Park County (EO 20, Pike National Forest) is on Pikes Peak Granite. Other occurrences in Rocky Mountain National Park are found on massive biotite schist. One record in the Virginia Dale area (EO 1) documents it on sandstone, but this needs verification (Scully personal communication 2002).

Figure 11. Suitable habitat for *Potentilla rupincola* at Dale Creek, near Virginia Dale (August 15, 1994). Suitable habitat is abundant in this area and areas remain to be searched. Photo provided by Richard Scully.

Potentilla rupincola is invariably found in sites with coarse, shallow soil (probably less than 10 inches deep). These include sites with scattered rock outcrops overlain in places by a thin soil veneer. It is often found in crevices and small soil patches within a rock outcrop, or in thin soil adjacent to rock outcrops. Soil texture is loamy sand or sandy loam, often gravelly, and derived from granitic parent material. These soils are dry and excessively drained, and are probably droughty and often desiccated, particularly in highly exposed sites. Future research will investigate distribution patterns of *P. rupincola* in relation to edaphic characteristics (Child personal communication 2002).

Potentilla rupincola is found across a fairly wide elevational range, including sites in the lower montane foothills to subalpine sites near treeline. According to one source (Beidleman et al. 2000) it also grows in the low tundra, but there are currently no records of occurrences at that elevation. The range of elevation documented in Element Occurrence Records of the Colorado Natural Heritage Program (2004) is 6,500 feet (at Phantom Canyon, EO 14) to 10,900 feet (at Battle Mountain, EO 22).

Sites occupied by *Potentilla rupincola* are typically exposed and windswept. These areas may support open forests or parklands of *Pinus flexilis* (limber pine), *P. ponderosa* (ponderosa pine), or *P. aristata* (bristlecone pine) in southern occurrences (EO 20, Pike National Forest). *Potentilla rupincola* most often grows in open sites accompanied by few other species of vascular plants, but is also found in the shade of trees and shrubs.

Potentilla rupincola is often found on sites with west or north exposure (Spackman et al. 1997). Scully (personal communication 2002) has found *P. rupincola* on all aspects and flat sites, but has seen it least frequently on east aspects. This might be correlated with the affinity of the species for windy sites. Throughout the distribution of *P. rupincola*, the prevailing winds come from the west, so east-facing slopes are often in the lee. Plants on south-facing slopes are sometimes larger and more robust (Child personal communication 2002).

Granite outcrops are common throughout the Colorado Front Range. The more easily-eroded upper strata of ancient mountains have long eroded away in this range, leaving mainly their resilient granite "cores" at the surface. Granite and schist outcrops are stable and erode very slowly, so the habitat for *Potentilla rupincola* is not particularly facile. In historic times there has been

Figure 12. Typical habitat of *Potentilla rupincola* (Child 2002).

Figure 13. Battle Mountain, Rocky Mountain National Park (July 16, 1995). At 10,700 to 10,900 feet, this is the highest elevation at which *Potentilla rupincola* is found. Photo provided by Richard Scully.

Figure 14. *Potentilla rupincola* growing in a thin veneer of granitic soil at Prairie Divide Road (July 24, 1994). Photo provided by Richard Scully.

very little loss of habitat for *P. rupincola* because these areas don't lend themselves readily to human use. Road construction has had the greatest impact on habitat and has probably caused the loss of some occupied habitat.

There is a general consensus among experts that there is much potential habitat for *Potentilla rupincola* (Child personal communication 2002, Johnston personal communication 2002, Scully personal communication 2002). *Potentilla rupincola* is inexplicably absent from many locations with abundant amounts of apparently suitable habitat. Currently we do not know how to predict whether habitat is occupied or not. There may be unidentified environmental variables involved such as soil chemistry or microclimate that *P. rupincola* responds to, but this is unlikely. Its absence is more likely due to limitations in its ability to colonize new sites caused by poor dispersal, germination requirements, or other factors.

Reproductive biology and autecology

In the CSR (Competitive/Stress-Tolerant/Ruderal) model of Grime (2001), characteristics of *Potentilla rupincola* most closely approximate those of stress-tolerant species. Stress-tolerant attributes of

P. rupincola include long lifespan, adaptations to xeric and windy conditions, and low reproductive output. Its caespitose growth form with a sturdy taproot and slow growth are also typical of stress-tolerators under this model.

Although its characteristics are primarily those of a stress-tolerator, *P. rupincola* may tolerate disturbance to some degree as well. The specific tolerance of *P. rupincola* to disturbance is not known, and many observations indicate that it favors stable habitats with little disturbance. Most occurrences are on rock outcrops or on sites where erosion or other potential disturbance is minimal. However, it has colonized roadcuts, and appears to favor areas disturbed by an old road at Mount Margaret (EO 15, Roosevelt National Forest) (Colorado Natural Heritage Program 2004). *Potentilla effusa* is tolerant of light to moderate disturbance such as grazing, so *P. rupincola* probably is, too (Johnston personal communication 2002). Many species of *Potentilla* that are adapted to highly disturbed habitats, such as *P. anserina*, employ the use of stolons to propagate clonally (Stuefer and Huber 1999). However, *P. rupincola* does not produce stolons, suggesting that at least with respect to this character it is not displaying morphological adaptations to disturbance. The tolerance of *P. rupincola* to various types of disturbance is a key question to answer for its appropriate management and stewardship.

Because it allocates relatively little biomass to the production of its relatively large propagules, has a low reproductive rate, and occurs primarily in stable habitats, the life history pattern of *Potentilla rupincola* is best classified as *K*-selected (using the classification scheme of MacArthur and Wilson 1967).

Many different reproductive strategies and mating systems are employed by members of the genus *Potentilla*. These are explained well for *Potentilla* in general by Eriksen (1996). Please also see the definitions section of this document. While many species of *Potentilla* are obligate outcrossers, others are facultatively apomictic (Eriksen 1996, Hansen et al. 2000). Apomixis is a common phenomenon among members of the genus *Potentilla* (Acharya Goswami and Matfield 1974, Eriksen 1996, Holm and Ghatnekar 1996). The particular type of apomixis employed by *Potentilla* species is pseudogamous agamospermy (Asker 1977). In some species, more than 90 percent of the seed is of maternal origin (Johnston personal communication 2002). *Potentilla ambigens*, another rare endemic from Colorado, is possibly pseudogamous (Acharya Goswami and Matfield 1978). Other Colorado species are obligate outcrossers, including *P. anserina* (Saikkonen et al. 1998) and *Dasiphora floribunda*, which is also self-incompatible (Innes and Lenz 1990). The mating systems employed by *P. rupincola* have not been investigated, but ongoing research is addressing this issue (Child personal communication 2002).

Clonal growth is also common in many species in *Potentilla*, and is best developed in stoloniferous species such as *P. anserina* (Stuefer and Huber 1999). Apparently *P. rupincola* reproduces only by seed.

The base chromosome number is seven for *Potentilla*, and the chromosomes are small (Johnston 1980, Asker 1985, Delgado et al. 2000). However, polyploidy and aneuploidy are common (Holm and Ghatnekar 1996, Johnston personal communication 2002). There are many high polyploids, such as *P. ambigens* (2n=82) (Acharya Goswami and Matfield 1978). Apomixis is strongly related to polyploidy in angiosperms (Asker and Jerling 1992). In members of the genus *Potentilla* this correlation has also been observed (Holm and Ghatnekar 1996). Thus, a cytological investigation of *P. rupincola* could help to understand its mating system, since almost all gametophytically apomictic species are polyploid (Asker and Jerling 1992). The cytology of *P. rupincola* is currently being investigated (Child 2001).

The floral biology of some *Potentilla* species has been at least cursorily investigated, revealing much diversity in strategies for pollen transfer. There has been no research regarding the pollinators and pollination ecology of *P. rupincola*. Smaller-flowered members of the Rosaceae such as *Potentilla* are typically visited by flies and short-tongued bees (Zomlefer 1994). *Potentilla rivalis* is apparently partially reliant on thrips, which mediate self-pollination by moving pollen from the stamens to the stigma of the same flower (Baker and Cruden 1991). *Amecocerus senilis* LeConte, a Dasytinid beetle, is found abundantly on flowers in ponderosa pine forests of Colorado, including the flowers of *P. gracilis* (Mawdsley 1999, Mawdsley 2003). This species feeds on both nectar and pollen, and is thus a potential pollinator for species of *Potentilla*.

Child (personal communication 2002) has frequently observed flies visiting the flowers of *Potentilla rupincola*. In the summer of 2002, she also noted a profusion of ants on many *P. rupincola* individuals. They were seen on vegetative parts as well as flowers, raising the question of a possible role for them in the floral biology of *P. rupincola*. Johnston (personal communication 2002) commented that ants were exhibiting unusual behavior in 2002 in response to a severe drought. Thus, observations will be needed in more typical years to gather insect visitation data for *P. rupincola*. Johnston (personal communication 2002) has seen bumblebees visiting *P. rupincola*, but never specialists such as wasps. A small beetle, possibly a Dasytinid, was observed visiting the flowers of *P. rupincola* and *Drymocallis fissa* at Virginia Dale (EO 1) (**Figure 15**).

Potentilla rupincola flowers from mid June to August (Spackman et al. 1997).

Seeds are dispersed in late summer, fall, and presumably through the winter months.

Seeds will germinate readily without any special treatments, but without stratification the seeds produce plants that will not flower (Child personal communication 2002).

Potentilla rupincola produces about 10 to 20 achenes (each containing one seed) per flower. Approximately 80 percent of *P. rupincola* seeds collected from study sites were viable and germinated readily in a greenhouse in 2002 (Child personal communication 2002). Seeds of *P. rupincola* are viable for at least two years (Child personal communication 2002). Three percent of unscarified seeds of *P. norvegica* were still viable after 9.7 years of burial in a study of seed viability and dormancy (Conn and Deck 1995). Child will conduct further research on the fertility and propagule viability of *P. rupincola*.

Seeds from plants growing on exposed sites are probably dispersed effectively by wind. Disseminules of numerous taxa were found in snow samples from St. Mary's Glacier, Colorado, exhibiting the efficacy of wind as a dispersal agent in the alpine (Bonde 1969). Ants may also be involved in seed dispersal of *Potentilla rupincola* (Child personal communication 2002).

Understanding the range of phenotypic plasticity expressed in *Potentilla rupincola* is a key step in understanding the range of morphological attributes possible within the taxon. There are differing opinions among botanists regarding the limits of key characteristics allowed for this species. Some descriptions of *P. rupincola* state that it completely lacks a tomentum on the leaves and calyx, and has only a few strigose hairs on the margins. Other descriptions (e.g. Johnston 1980) allow a small amount of tomentum. A morphometric analysis of *P. rupincola* and *P. effusa* is needed to resolve this question. A morphometric

Figure 15. A small beetle visiting the flower of *Potentilla rupincola* at Virginia Dale, photographed by the author on June 23, 2004. This species was also observed on *Drymocallis fissa* at this location.

analysis of these taxa similar to that of Eriksen (1997) for *Potentilla* sect. Niveae would be useful following the current work of Child (2001).

Members of the genus *Potentilla* have been shown to have a morphological response to light quantity and quality. A study of the effects of shade (characterized by decreased light quantity and quality) on *P. anserina* and *P. reptans* observed significant responses in both species from both treatments in morphological and production parameters (Stuefer and Huber 1998).

When grown in a greenhouse, *Potentilla rupincola* appears larger and taller than typical wild plants. Thus the caespitose, compact growth form of *P. rupincola* may be an ecophenic response to wind and low soil moisture. This might explain observations made by Child (personal communication 2002) that plants are taller in protected microsites such as adjacent to boulders. This is exemplified at Virginia Dale (EO 1), where plants tend to be larger than usually seen elsewhere. It is also apparent at Glacier Knobs (EO 12), where large individuals have been seen in protected sites (Child personal communication 2004).

Virtually all members of the family Rosaceae have strong arbuscular mycorrhizal (AM) relationships (St. John 1996). 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 (Vandenkoornhuyse et al. 2002) levels. As root endophytes, the hyphae of these fungi enter the cells of the plant roots where water and nutrients are exchanged in specialized structures.

There has been no investigation of the mycorrhizal symbionts of *Potentilla rupincola* but studies of other taxa suggest that it forms mycorrhizal relationships. Axenically reared *P. fruticosa* (*Dasiphora floribunda*) seedlings grown in culture with *Phialocephala fortinii*, a common root endophyte, showed significant increases in shoot weight when compared with seedlings grown in monoculture (Fernando and Currah 1996).

There are many known and putative hybrids in the genus *Potentilla* (Eriksen 1997). Moore (1979, p. 134) aptly described the genus *Potentilla* as "a botanist's nightmare of crossbreeding." Hansen et al. (2000, p. 1466) note that "Extensive reticulate evolution via hybridization and polyploidy, combined with facultative, pseudogamous agamospermy, have probably caused many of the taxonomic problems in the genus." Although hybrids are often not highly fertile, apomixis allows them to persist for indefinite periods, during which they may backcross or hybridize again (Eriksen 1996). Thus the patterns of morphological variation among many related species of *Potentilla* are very complex (Asker 1977). Other studies have addressed these issues for certain groups within *Potentilla* (e.g. Hansen et al. 2000), and the current work of Child (2001) is using a similar approach. Currently there are not enough preliminary data to determine the role of hybridization in *P. rupincola*, *P. effusa*, and intermediate plants. However, Child will investigate hypotheses regarding a hybrid origin for the intermediate plants, with *P. effusa* and *P. rupincola* as the putative parent taxa. If her research supports the treatment of *P. rupincola* as a full species, she will investigate the intermediate taxa to determine if they are hybrids, phenotypes, or another distinct taxon. If they are hybrids, she will investigate their fertility.

Hybrid swarms are common among *Potentilla* species. *Potentilla effusa* forms hybrid swarms with many species including *P. hippiana* (Johnston personal communication 2002). *Potentilla hippiana* and *P. pulcherrima* also frequently hybridize (Weber and Wittmann 2001a). Throughout most of its range, *P. effusa* is clearly distinct, but where its range overlaps that of another species with which it can hybridize, it forms hybrid swarms. These are confusing since they are difficult to identify.

Demography

There have been no demographic studies of *Potentilla rupincola*, but there have been many studies of other members of this genus that have some inferential value. Also, research is currently underway to address genetic characteristics and concerns for *P. rupincola* (Child 2001). This research will help greatly to explain many demographic parameters for *P. rupincola*. The inbreeding coefficient for study occurrences of *P. rupincola* will be determined. Evidence of gene flow within and between occurrences of *P. rupincola* and *P. effusa* will also be sought. Pollen viability will be investigated, since it can provide an indication of the degree to which *P. rupincola* reproduces through apomixis. The status of morphologically intermediate plants and their relationship with *P. rupincola* and *P. effusa* will be assessed with the intent of resolving their taxonomic status.

Maintaining genetic integrity and eliminating inbreeding and outbreeding depression are important management considerations for *Potentilla rupincola*. *Potentilla rupincola* is more vulnerable to genetic concerns if it is heavily dependent on outcrossing. Preliminary molecular data suggest that genetic variation between occurrences in Rocky Mountain National Park is high (Child personal communication 2002). Thus, using on-site material for restoration will reduce the negative effects of outbreeding depression. Maintaining genetic integrity and natural levels of gene flow are also important for its conservation.

The lifespan of *Potentilla rupincola* has not been determined. Based on other plant species with similar life history characteristics, Johnston (personal communication 2002) estimates that the average lifespan for *P. rupincola* is 30 to 40 years, perhaps reaching 50 to 70 years. Plants need to overwinter before they can flower, and probably take two to three years to flower (Child personal communication 2002). Most plants produce some flowers every year, even in 2002 during a severe drought (Child personal communication 2002). See **Figure 16** for a diagrammatic representation of the life cycle of *P. rupincola*, **Figure 17** for a life cycle graph for *P. rupincola*.

No Population Viability Analysis (PVA) has been performed for *Potentilla rupincola*. Apparently there has never been a PVA of any member of the genus

Potentilla from which inferences could be drawn for this report. Two species of *Potentilla* (*P. hickmanii* and *P. robbinsiana*) are currently listed endangered (U.S. Fish and Wildlife Service 1999) but there has been no PVA of these species to date.

Many life history parameters remain unknown in *Potentilla rupincola*. Of particular value would be information on seeds and recruitment. Seed production, seed longevity, seed dormancy, and variables controlling these parameters would help reveal potential bottlenecks in the survival of *P. rupincola* (Colorado Natural Heritage Program 2004). Recruitment and longevity are also unknown, yet critical for understanding the demography of this species.

Metapopulation issues for *Potentilla rupincola* are under study (Child 2001). This work will detect the amount of gene flow between sampled sites, and will determine the relative genetic distinctness of sampled occurrences.

The probability of dispersal of seeds and other propagules decreases rapidly with increasing distance from the source (Barbour et al. 1987). Thus, long distance dispersal events are rare. Pollinator-mediated pollen dispersal is largely limited to the flight distances of pollinators (Kearns and Inouye 1993). Due to the formidable physical limitations to dispersal of seeds and pollen, the rate of geneflow between occurrences of *Potentilla rupincola* is probably quite low. Preliminary molecular data from occurrences in Rocky Mountain National Park show that some occurrences have unique haplotypes, while other occurrences are mixed (Child personal communication 2002). This suggests that there is some incidence of geneflow between the occurrences, but the importance of this for maintaining healthy levels of heterozygosity is not known.

As a habitat specialist, population sizes of *Potentilla rupincola* are naturally limited to available habitat. The granite and schist rock outcrops on which *P. rupincola* lives are often small and insular. Within an area of suitable habitat, the availability of microsites suitable for *P. rupincola* is also limited, in most places precluding the development of a large population. Thus, the distribution and physiognomy of habitat for *P. rupincola* imposes constraints on population growth at a variety of scales. However, granite rock outcrops that appear suitable for *P. rupincola* are fairly common and widespread throughout its known range. Surveys (e.g., Spackman et al. 1999) have shown *P. rupincola* to be absent in many areas containing apparently suitable habitat. Although *P. rupincola* is likely to be capable of surviving in many locations, its lack of competitive ability probably precludes the growth of populations where other, more competitive species can survive.

Community ecology

Associated species that have been documented in Element Occurrence Records are presented in **Table 3** (Colorado Natural Heritage Program 2004). In some sites there are few if any plant species associated with *Potentilla rupincola*, suggesting that it possesses adaptations to its habitat that other species do not have.

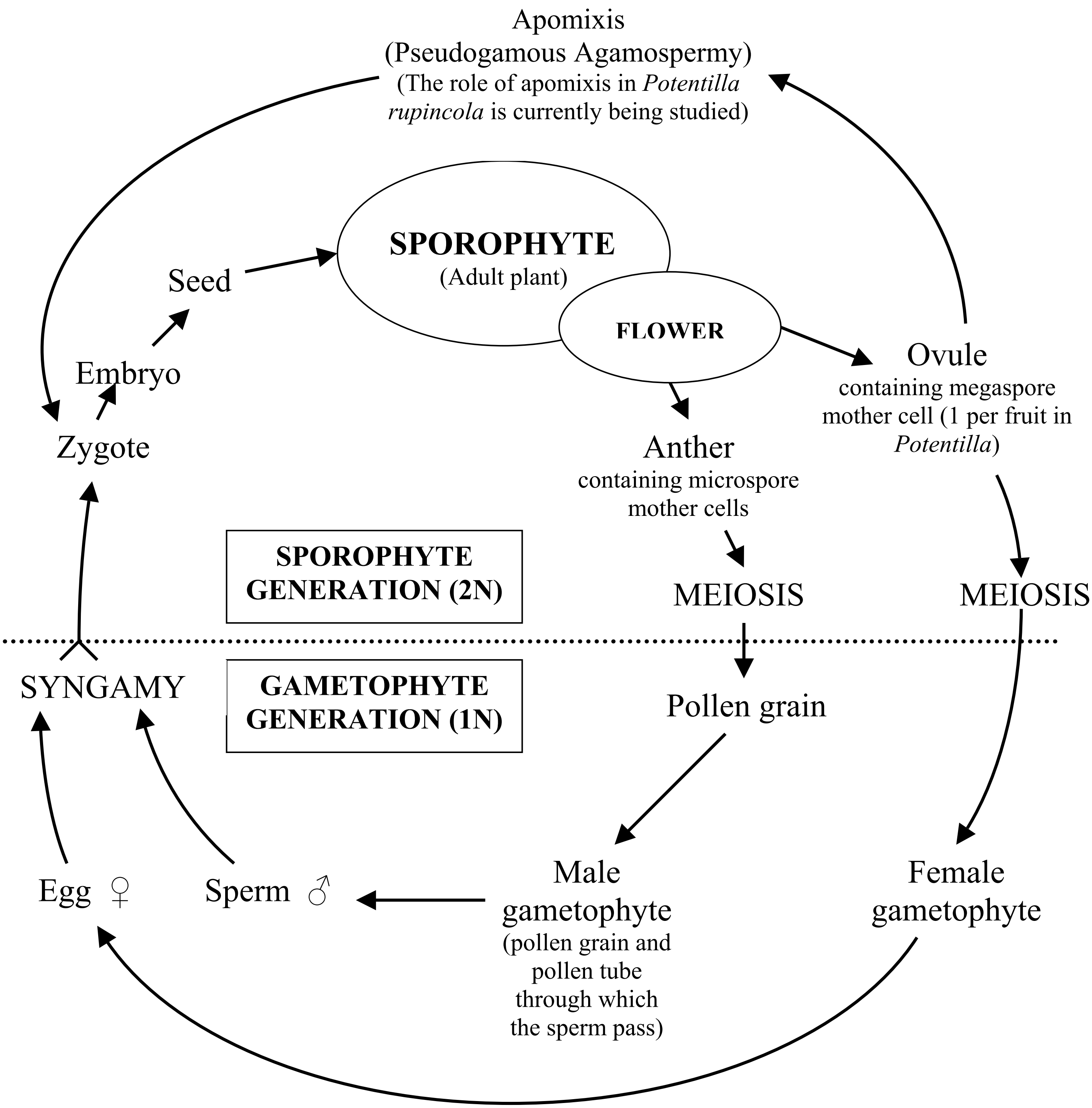

Figure 16. Life cycle diagram for *Potentilla rupincola* (after Stern 1994).

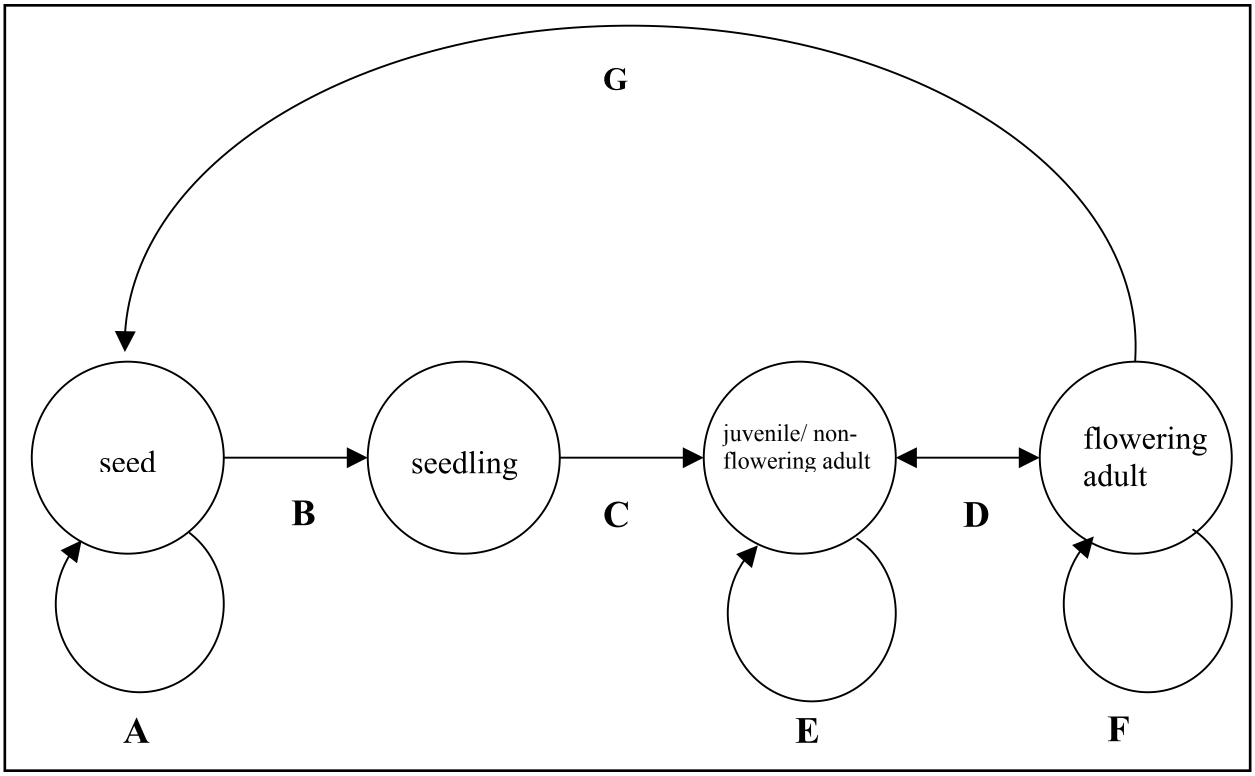

Figure 17. Hypothetical life cycle graph (after Caswell 2001) for *Potentilla rupincola*. There has been no investigation of the life history stages of this species. No transition probabilities are known for *P. rupincola*, and there has been no demographic monitoring of other species of *Potentilla* from which valuable inferences can be drawn. The values of A through G probably vary from year to year depending on climatic variables. No seedlings have ever been observed, so there are no data from which to infer B and C. The duration of the juvenile stage is not known (E), and it is not known how long it takes juvenile plants to become capable of flowering (D). It is likely that plants remain vegetative in poor years. Seed production per plant (G) has not been quantified.

At low elevations such as the Virginia Dale sites (EO 1), *Potentilla rupincola* has been documented with *Opuntia* spp., *Bouteloua gracilis*, *Cercocarpus montanus*, *Ribes cereum*, and other common foothills shrubland species. At the highest elevation sites, it occurs with *Abies bifolia*, *Dasiphora floribunda*, and other upper montane and subalpine species.

Potentilla rupincola occurs in habitats that are very similar to those occupied by *Aletes humilis*, another rare Colorado endemic (Scully personal communication 2002, Colorado Natural Heritage Program 2004). These species are both found at Phantom Canyon (EO 14), Cap Rock Preserve (EO 25), Bull Garden (EO 23, Roosevelt National Forest), and Turkey Roost (EO 3, Roosevelt National Forest).

An envirogram showing resources, reproduction, predators/herbivores, and malentities is provided in **Figure 18**. Herbivory probably plays a very minor role in the ecology of *Potentilla rupincola*. Many occurrences are not accessible to large herbivores, or have very low forage value and are thus not attractive to them. Deer and elk can get to many occurrences but do not appear interested (Johnston personal communication 2002). Utilization by small mammals and insects is possible but there have been no observations of this.

There is no information on competitors for biotic and abiotic resources with *Potentilla rupincola*. If competitive interactions are important in the autecology of *P. rupincola*, some of the associated species cited in **Table 3** are the most probable competitors. However, stress tolerant species sensu Grime (2001) do not typically need to be good competitors, since highly competitive species are not capable of withstanding the chronic stress regime to which stress tolerators are supremely adapted. Thus, they typically do not share the same resource pool with species such as *P. rupincola*.

There have been no reports in the literature or other observations of parasite or disease attack on *Potentilla rupincola*. Some winter mortality of plants growing in crevices of an exposed rock outcrop was observed at a

Table 3. Associated species with *Potentilla rupincola* from Element Occurrence Records (Colorado Natural Heritage Program 2004). R = Rare plant tracked by the Colorado Natural Heritage Program; * = Frequent associate with *P. rupincola*; and E = Exotic species.

	Scientific Name		Scientific Name
	Abies bifolia		*Leucopoa kingii*
	Acer glabrum		*Leymus ambiguus*
R	*Aletes humilis*		*Mentzelia sinuata*
	Antennaria spp.		*Muhlenbergia montana*
*	*Artemisia frigida*		*Opuntia macrorhiza*
	Aster spp.		*Opuntia polyacantha*
E	*Bromus inermis*		*Oreoxis humilis*
E	*Bromus tectorum*		*Penstemon strictus*
	Cercocarpus montanus		*Penstemon virens*
	Chondrosum gracile		*Phacelia heterophylla*
	Ciliaria austromontana		*Physocarpus monogynus*
	Collomia linearis		*Pinus aristata*
E	*Convolvulus arvensis*	*	*Pinus flexilis*
	Cornus sericea	*	*Pinus ponderosa*
E	*Cynoglossum officinale*		*Poa fendleriana*
	Dasiphora floribunda		*Polemonium brandegei*
	Delphinium nuttallianum		*Populus tremuloides*
	Draba streptocarpa		*Potentilla c.f. hippiana*
	Drymocallis fissa		*Potentilla effusa*
*	*Erigeron compositus*		*Pseudotsuga menziesii*
*	*Erigeron vetensis*		*Purshia tridentata*
	Eriogonum umbellatum		*Ranunculus ranunculina*
	Geranium caespitosum ssp. *caespitosum*		*Ribes cereum*
	Geranium viscosum		*Rubus idaeus*
	Harbouria trachypleura		*Scutellaria brittonii*
	Heterotheca villosa		*Sedum lanceolatum*
	Heuchera bracteata		*Selaginella* spp.
	Hymenoxys acaulis var. *caespitosa*		*Shepherdia canadensis*
	Jamesia americana	R	*Telesonix jamesii*
	Juniperus communis		*Trifolium* spp.
	Koeleria macrantha		

high subalpine occurrence in Rocky Mountain National Park (Scully personal communication 2002).

Conservation

Threats

Numerous reports, observations, and opinions of experts show that there are threats to the persistence of *Potentilla rupincola*. In order of decreasing priority these are exotic species invasion, residential and commercial development, secondary impacts of grazing, right-of-way management, off-road vehicle use and other recreation, effects of small population size, global climate change, and pollution. These threats and the hierarchy ascribed to them are somewhat speculative, and more complete information on the biology and ecology of this species may elucidate other threats. In general, threats to *P. rupincola* resulting from human activities are minor due to the inaccessibility of its habitat, the lack of mineral resources at known occurrences, and the unsuitability of its habitat for development and grazing. Activities

INDIRECT ENVIRONMENT 2	INDIRECT ENVIRONMENT 1	DIRECT ENVIRONMENT	
		RESOURCES	
	Canopy openness	Light energy	
	Slope, aspect, albedo	Thermal energy (climate)	
Local geology	Soil texture	Soil moisture	
	Climate		
		Oxygen, carbon dioxide	
		Nutrients	
		REPRODUCTION	
	Other plant resources	Pollinators	
	nest sites		
	Other *P. rupincola* inds.	Genetic diversity (?)	*Potentilla rupincola*
	Rock crevices	Safe sites	
	Wind		
	Seed dispersers		
		PREDATORS/ HERBIVORES	
	Other food resources	Herbivores (?)	
	Site accessibility	Humans (collectors)	
		Seed predators	
		MALENTITIES	
	Industrial complex	Airborne pollutants	
		Thermal energy (climate)	
Economic variables	Human population density	Humans (off-road vehicle users, development)	
	Site/microsite attributes	Competitors	
	Drought	Soil moisture	

Figure 18. Envirogram for *Potentilla rupincola*, showing resources, reproduction, predators/ herbivores, and malentities (after Niven and Liddle 1994).

that would concentrate use in occurrences are likely to threaten *P. rupincola*. Assessment of threats to this species will be an important component of future inventory and monitoring work. Please see the following sections for specific treatments of these threats to habitat and individuals, and from exotic species and over-utilization.

Influence of management activities or natural disturbances on habitat quality

Although there has been no analysis of the effects of various management practices on the habitat of *Potentilla rupincola*, some inferences can be made based on the nature of these habitats. In general, habitat for *P. rupincola* is probably somewhat resilient to impacts that might cause light or moderate disturbance. The rock outcrops can probably withstand occasional human visitation without severe effects, although frequent use by hikers and rock climbers would probably degrade these sites. Plants growing in footholds or handholds would be particularly imperiled by this sort of usage pattern. In most areas occupied by *P. rupincola*, current management appears sufficient for the long-term viability of these occurrences and their habitat, but management changes might be necessary if human use of areas supporting occurrences of *P. rupincola* increases or changes.

Resource extraction is a potential threat to *Potentilla rupincola*. However, forests in occurrences of *P. rupincola* are sparse and unlikely to yield valuable timber. Increased erosion from logging operations upslope of an occurrence could result in soil deposition that would permit other more competitive species, including exotic species, to invade. However, this scenario is unlikely to occur in any of the known occurrences given the topography of these sites. Impacts to *P. rupincola* resulting from mining are unlikely because areas where it is known to occur are not heavily mineralized. Gathering rocks for use as "mossrocks" in home construction would threaten *P. rupincola* locally should this practice become commonplace in *P. rupincola* occurrences.

The effects of fire suppression on habitat quality are unknown. Given the sparse vegetation in sites occupied by *Potentilla rupincola*, the role of fire in these habitats is certainly minor. However, ecosystem processes in the surrounding grasslands and forests probably directly or indirectly affect *P. rupincola* and its habitat quality, and fire might be important in the maintenance of these processes.

Roads run through or adjacent to five occurrences of *Potentilla rupincola*. Roads threaten occurrences of *P. rupincola* largely through indirect effects as dispersal corridors for weeds and as sources of erosion. In highly outcrossing species, roads and trails might act as barriers to pollinators and prevent effective geneflow by disrupting their traplines. Right-of-way management and road widening projects are potential threats to occurrences at Virginia Dale (EO 1), Prairie Divide Road (EO 18), West Turkey Roost (EO 17, Roosevelt National Forest), and Mount Margaret (EO 15, Roosevelt National Forest). New road construction threatens occurrences if it involves occupied habitat. Road building has apparently created small amounts of suitable habitat at Virginia Dale (EO 1), West Turkey Roost (EO 17, Roosevelt National Forest), Prairie Divide Road (EO 18), and Mount Margaret (EO 15, Roosevelt National Forest), but probably also destroyed habitat and individuals in the process. The benefits of disturbance from human activities are almost certainly outweighed by their detrimental effects on the habitat and individuals of *P. rupincola*.

Residential development is a significant potential threat to occurrences of *Potentilla rupincola* found on private land. While development is not currently occurring in close proximity to any known occurrences, at least one landowner at Virginia Dale (EO 1) plans to subdivide for residential development. Exurban development in the mountains of the Front Range is advancing rapidly in counties where *P. rupincola* occurs, and given current population growth estimates for the northern Front Range, development near some occurrences of *P. rupincola* is likely. However, the bedrock substrate where *P. rupincola* is found is unsuitable for foundations, septic tanks, and other infrastructure. Thus, the threat from direct impacts from development is low even for the three occurrences known from private land. The specific effects of development on *P. rupincola* are not known but it is plausible to speculate that it will impact this species at many different scales.

Because it is not naturally disturbed, it is likely that habitat quality would be negatively impacted by activities that directly affect it, such as mining and residential development. Indirect effects on habitat quality for *Potentilla rupincola* caused by fragmentation are less clear. The impact of these actions on habitat quality for *P. rupincola* depends largely on the importance of ecological connectivity between occurrences, which is not known.

Global climate change is likely to have wide-ranging effects in the near future. Projections based on current atmospheric CO_2 trends suggest that average temperatures will increase while precipitation will decrease in Colorado (Manabe and Wetherald 1986). This will have significant effects on nutrient cycling, vapor pressure gradients, and a suite of other environmental variables. Temperature increase could cause vegetation zones to climb 350 feet in elevation for every degree Fahrenheit of warming (US Environmental Protection Agency 1997). Effects on *Potentilla rupincola* and its mountain habitats are difficult to project given this scenario. In a study of *P. gracilis* in Colorado, surprisingly high tolerance of elevated leaf temperatures were observed in an experimental manipulation to investigate the possible effects of global warming (Loik and Harte 1996). In the same study, *P. gracilis* also responded well to drought stress induced by infrared heating of plots (Loik and Harte 1997). Like *P. rupincola*, *P. gracilis* often occurs in somewhat dry sites (Allen-Diaz 1991), so there may be valid inferences to be drawn from these studies. Through genetic drift, high elevation, isolated occurrences of *P. rupincola* may have lost alleles that could increase their fitness under warmer conditions.

Atmospheric nitrogen deposition (of both organic and inorganic forms) is increasing worldwide. Experimental nitrogen enrichment of alpine sites suggests that ecosystem processes will be altered and result in species turnover (Bowman et al. 1993, Gold 2000). Relatively low levels of nitrogen enrichment are advantageous to some species but deleterious to others, making it difficult to predict species- and community-level responses.

The proximity of all occurrences of *Potentilla rupincola* to major metropolitan areas of the Front Range leaves them vulnerable to effects of atmospheric pollution. Plant growth was limited and resource allocation was altered in *P. anserina* grown in high concentrations of copper and nickel (Saikkonen et al. 1998). The tolerance of *P. rupincola* to heavy metals and other pollutants has not been investigated.

Influence of management activities or natural disturbances on individuals

Impacts to individuals and occurrences of *Potentilla rupincola* resulting from various management activities have not been investigated. However, observations suggest that *P. rupincola* is vulnerable to certain kinds of ongoing impacts. Road construction has probably resulted in mortality of plants at one to four locations. Plants growing in roadcuts are vulnerable to right-of-way management activities and road widening projects. Although the plants have exploited habitat created by the construction of roads, the indirect impacts of the roads including weed invasion are likely to have long-term detrimental effects. Road building probably directly impacted a Virginia Dale occurrence, and may be indirectly impacting it by spurring the invasion of cheat grass.

Hiking and motorized recreation are unlikely to have significant impacts on *Potentilla rupincola*. Most occurrences are remote, and the physiography of most occupied sites does not lend itself well to exploitation for motorized recreation. One large occurrence in Rocky Mountain National Park, originally discovered in 1930, is bisected by a heavily-used hiking trail and has persisted nonetheless. Johnston (personal communication 2002) notes that trail impacts have a greater potential effect on *P. rupincola* if the species is heavily reliant on pollinators as a frequent or obligate outcrosser, since visitor disturbance of pollinators might reduce their effectiveness. If *P. rupincola* is largely apomictic with very little outcrossing then the importance of maintaining pollinator occurrences is diminished. Plants growing in potential foot- or handholds are likely to be damaged if they are on a popular or easily accessible climbing or scrambling route, although there are currently no known occurrences on climbing routes. Trampling impacts were among those that contributed to the listing of both *P. robbinsii* (NatureServe 2002) and *P. hickmanii* (U.S. Fish and Wildlife Service 1998) as endangered species.

Livestock grazing may threaten portions of occurrences that are accessible to cattle and horses. However, very few occurrences are accessible, and grazing is not occurring at many locations for this species. Grazing has occurred at Bull Garden (EO 23, Roosevelt National Forest; the only occurrence in an active grazing allotment), and is ongoing at Virginia Dale (EO 1). Impacts to plants near the base of rock outcrops resulting from grazing have been observed at Virginia Dale (EO 1) (**Figure 19** and **Figure 20**). Most *Potentilla* species, including *P. effusa*, are somewhat tolerant of grazing (Johnston personal communication 2002). It is not known to what extent *P. rupincola* tolerates grazing and trampling.

Because occurrences of *Potentilla rupincola* probably remain to be discovered and documented, surveys are needed before management actions within potential habitat. Although many occurrences are in

Figure 19. A portion of the population of *Potentilla rupincola* at Virginia Dale on a toeslope that has been disturbed by the hooves of cattle. Photograph by the author.

Figure 20. A *Potentilla rupincola* individual (seen at lower right of **Figure 19**) at Virginia Dale with a portion of its canopy removed by cattle (photograph by the author). Impacts of this sort are impossible for the majority of the occurrence but are likely where cattle and horses can gain access.

remote locations, some of these areas are also accessible by popular hiking trails and receive fairly heavy recreational use. There has been no documentation of recreational impacts to the species. Because *P. rupincola* is a long-lived, stress tolerant, slow-growing perennial, it is likely that it would respond poorly to disturbance from heavy recreational use.

Interaction of the species with exotic species

Exotic plant species may represent a significant threat to *Potentilla rupincola*, although they are not currently common in its habitat. Four exotic species have been documented with *P. rupincola* (**Table 3**). Among these species, *Bromus tectorum* is most widespread in habitat for *P. rupincola*. This species has been documented at Virginia Dale (EO 1) (**Figure 21**), where it has reportedly encroached into areas adjacent to highways, possibly reducing the density of *P. rupincola* (Child personal communication 2002). However, it is uncommon throughout most of this occurrence and is probably not currently having significant impacts on the viability of this occurrence. *Bromus tectorum* has also been documented at Sheep Mountain (EO 13) (Colorado Natural Heritage Program 2004).

Because new exotic species are arriving all the time, vigilance in monitoring for their impacts is crucial. It is possible that an incipient weed could favor the habitat for *Potentilla rupincola* when it arrives, and require costly management efforts for its control. Impacts from weeds contributed to the listing of another species of *Potentilla*, *P. hickmanii*, as an endangered species (U.S. Fish and Wildlife Service 1998).

Use of herbicides for right-of-way weed management and for range management threatens *Potentilla rupincola* where it occurs on roadcuts or roadsides. Care must be taken with the application of herbicides in habitat for *P. rupincola*, and use of herbicides within known occurrences should be limited to hand application to the target species.

Figure 21. *Potentilla rupincola* with dense *Bromus tectorum* at Virginia Dale (photograph by the author). Areas near roadsides and near a ditch appear most heavily infested.

Threats from over-utilization

There are no known commercial uses for *Potentilla rupincola*. However, other species of *Potentilla* are widely used for medicinal purposes, and members of this genus have a long history of human use as remedies for various maladies. Gerard (1633, pp. 991-992) lists numerous ailments cured by cinquefoil ('Cinkfoile') including excessive bleeding, diseases of the liver and lungs, poisoning, and hernias ('guts falling into the cods'). Modern medicinal uses are principally as an astringent and for reducing inflammations (Moore 1979). *Potentilla* species are also an ingredient in anti-wrinkle cream (Shelton 2002), and many species are actively sought for use in the herb trade. Many members of the family Rosaceae are highly toxic, and many produce cyanogenic compounds. However, no members of the subfamily Rosoideae (which includes the genus *Potentilla*) are cited for any particular toxicity issues (Burrows and Tyrl 2001). For members of the genus *Potentilla*, the whole plant is consumable (Moore 1979). Due to its small population size, *P. rupincola* is vulnerable to potential impacts from harvesting wild occurrences if for some reason it became sought after as a medicinal herb. Over-collection for scientific purposes, particularly in small occurrences, is also a potential, though unlikely, threat. Heavy collection for herbarium specimens of the federally endangered *P. robbinsiana* contributed greatly to its imperilment (NatureServe 2002). Collection of plants from occurrences of fewer than 50 plants is ill-advised.

Conservation Status of the Species in USFS Region 2

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

Most occurrences of *Potentilla rupincola* appear healthy and show no signs of decline. Child (personal communication 2002) noted declining numbers in a limited portion of the roadside occurrence at Virginia Dale (EO 1). However, most of this occurrence appears healthy and unimpacted by human activities. Four other occurrences are also close to a road but no resulting decrease in abundance has been observed. Although some fairly rigorous data on distribution have been amassed, these are largely qualitative or include rough population estimates.

Do habitats vary in their capacity to support this species?

The high variation in population size and density documented thus far in occurrences suggests that habitats vary greatly in their capacity to support *Potentilla rupincola*. However, the underlying ecological reasons for this variation are unknown and difficult to speculate on until research is conducted to clarify the relationships between *P. rupincola* and its habitat. It is possible that failure to disperse widely is responsible for the current limited and sporadic distribution of *P. rupincola* (Scully personal communication 2002).

As a poor competitor, marginal habitats for *Potentilla rupincola* are those with a greater abundance and richness of soil, where other more competitive species can be found (Child personal communication 2002). This is a typical distribution pattern for a stress-tolerant species (Grime 2001). Large granite outcrops can support larger occurrences of *P. rupincola* than small ones, particularly if there are numerous cracks in the rock (Child personal communication 2002). *Potentilla effusa* tends to occur more often on sites with soil. Sites with mixed occurrences typically have much soil, and tend to occur at the low end of the elevation range for *P. rupincola*. In general, richer, warmer sites tend to have sympatric occurrences while very rocky sites and high elevation sites are more likely to support allopatric occurrences of *P. rupincola*. Future work by Child will investigate the relationship of edaphic characteristics with the incidence of sympatry (Child personal communication 2002).

Vulnerability due to life history and ecology

Potentilla rupincola may be considered vulnerable due to its specific habitat requirements. However, suitable granite rock outcrop habitat is abundant in Colorado, suggesting that the potential range and abundance of *P. rupincola* is larger and may be limited mainly by its dispersal ability (Scully personal communication 2002). If *P. rupincola* is an obligate outcrosser it may be vulnerable to impacts that affect its pollinators. As a stress-tolerator it may not tolerate invasion of its habitat by more competitive species.

Other observations suggest that *Potentilla rupincola* is not vulnerable to habitat change and change to its environment. As a long-lived, stress-tolerant perennial, *P. rupincola* is buffered somewhat from the effects of environmental stochasticity such as drought. If it relies heavily on apomixis for reproduction, it may also be buffered from impacts that affect its pollinators. The wide elevation range of *P. rupincola* may buffer it somewhat from climate change impacts that are most likely to affect low elevation occurrences first. Recent studies of *P. gracilis* in Colorado (Loik and Harte 1996, 1997) suggest that it, and perhaps other species of *Potentilla* such as *P. rupincola*, might be tolerant of elevated leaf temperatures and water stress that will occur if global climate change predictions are true.

The minimum viable population size is not known for *Potentilla rupincola*, but even small populations by the standards of the 50/500 rule of Soulé (1980) may still be viable and of conservation importance. Somewhat arbitrarily, the Colorado Natural Heritage Program considers occurrences of *P. rupincola* containing ten or more plants as viable, but this threshold will be revised when a minimum viable population size is determined.

Like all rare plants, *Potentilla rupincola* is vulnerable to unforeseen impacts from noxious weeds. New exotic species are arriving constantly, and it may be only a matter of luck that the habitat for *P. rupincola* has not already been substantially invaded by exotics.

Evidence of occurrences in USFS Region 2 at risk

Some occurrences of *Potentilla rupincola* are at risk as a consequence of human activities that have persisted for many years. Prairie Divide Road (EO 18), Mount Margaret (EO 15, Roosevelt National Forest), Turkey Roost (EO 3, Roosevelt National Forest), and Virginia Dale (EO 1) are arguably the most imperiled occurrences, since they are all in close proximity to roads. Portions of occurrences at Virginia Dale (EO 1), Prairie Divide Road (EO 18), and Hermit Park (EO 24) are at risk due to the potential for future development. A larger proportion of the occurrence at Prairie Divide Road (EO 18) is vulnerable to impacts from roads and development than at Virginia Dale (EO 1). An occurrence near a popular hiking trail in Rocky Mountain National Park may also be imperiled by the effects of recreation despite the excellent protection and stewardship offered it. Occurrences at Sheep Mountain (EO 13, Roosevelt National Forest) and Virginia Dale (EO 1), and all occurrences adjacent to roads, are at risk of invasion by exotic species, particularly *Bromus tectorum*.

Although some occurrences of *Potentilla rupincola* are at risk, most occurrences are relatively secure, either because they are in protected locations or because they are in remote, infrequently visited areas. The habitat for *P. rupincola* is not vulnerable to activities that threaten many other rare plant species of the Colorado Front Range. The rock outcrops on which it typically grows are not sought after for recreation activities and are not favorable sites for residential development. They are not heavily mineralized and thus are not eminently threatened by the possibility of mining.

Although habitats occupied by *Potentilla rupincola* are not well suited to many human uses, increasing population density, proliferation of low-density residential development, and rapid subdivision of the Front Range are significant threats to this species and may place occurrences at risk in the future. Increased human visitation to occurrences of *P. rupincola* is inevitable given the current population growth projections for the Colorado Front Range, and the effects this will have on *P. rupincola* are difficult to ascertain. Development might also negatively impact some of the pollinator species on which *P. rupincola* depends by reducing nectar resources in the area.

Seven occurrences have not been visited and assessed in more than 20 years (EO 2, EO 6, EO 8, EO 9, EO 10, EO 11, EO 19), although some of these records are probably better classified as *Potentilla effusa* rather than *P. rupincola*. However, if these records represent occurrences that remain extant today, they cannot benefit substantially from any conservation actions on behalf of the species until they are relocated. Thus these occurrences are at risk simply as a result of our ignorance of them. Some occurrences, particularly those on private land, are at risk from future development.

Management of the Species in USFS Region 2

Implications and potential conservation elements

The most current data available suggest that *Potentilla rupincola* is imperiled due to small population sizes and a small number of occurrences. Thus, the loss of any occurrence is significant and will probably result in the loss of important components of the genetic diversity of the species. It is likely that the disjunct populations and populations in more extreme habitats have many alleles not present in other populations, so loss of these populations will result in a significant loss of genetic diversity.

Maintaining the genetic integrity of populations of *Potentilla rupincola* is an important management consideration. Preliminary molecular data suggest that genetic variation between occurrences in Rocky Mountain National Park is high (Child personal communication 2002). Thus, using on-site material for restoration will reduce the negative effects of outbreeding depression. Forthcoming genetic data will help greatly with developing restoration policy.

Desired environmental conditions for *Potentilla rupincola* include sufficiently large areas where the natural ecosystem processes on which *P. rupincola* depends can occur, permitting it to persist unimpeded by human activities and their secondary effects, such as weeds. This includes a satisfactory degree of ecological connectivity between occurrences to provide corridors and other nectar resources for pollinators if necessary. Given the current paucity of detailed information on this species, it is unknown how far this ideal is from being achieved. It is possible that most or all of the ecosystem processes on which *P. rupincola* depends are functioning properly at many or most of the occurrences of this species. Further research on the ecology and distribution of *P. rupincola* will help develop effective approaches to management and conservation. Until a more complete picture of the distribution and ecology of this species is obtained, priorities lie with conserving the known occurrences, particularly those that support large occurrences, are in excellent condition, and in which the surrounding landscape remains largely intact.

Within the last 15,000 years, the climate in the southern Rocky Mountains has been both warmer and colder than it is at present. There is much evidence to suggest that the elevational and latitudinal distributions of many plant species were much different in these periods than they are today. Given the changes predicted in the global climate for the next 100 years, incorporation of higher elevation refugia for *Potentilla rupincola* into preserve designs and conservation plans will help to ensure its long-term viability.

Tools and practices

Species and habitat inventory

It is likely that occurrences of *Potentilla rupincola* remain to be discovered. *Potentilla rupincola* is best sought from mid-June into August when plants are in flower.

Potentilla rupincola could benefit greatly from inventory and mapping using GPS to precisely mark occurrence boundaries. This would provide land managers with useful data for generating land use plans and permitting, for example. The value of such a project would be greatly augmented by the collection of quantitative census data with ecological data.

Aerial photography, topographic maps, soil maps, and geology maps can be used to refine surveys of large areas, and could be highly effective for refining survey areas for *Potentilla rupincola*. It is most effective for species about which we have basic knowledge of its substrate and habitat specificity from which distribution patterns and potential search areas can be deduced. While habitat affinities of *P. rupincola* are well known, it is difficult to refine search areas using habitat since there is apparently abundant habitat that is suitable but unoccupied. Searching apparently suitable habitat in the vicinity of known occurrences is an effective starting point for species inventory work. This approach led to discoveries of additional suboccurrences at Virginia Dale (EO 1) in 2004 (Doyle et al. in prep.)

Species inventories for *Potentilla rupincola* are complicated by the difficulty of field identification, taxonomic questions, possible hybridization, and possible phenotypic plasticity of the species. Recent searches by botanists in suitable habitat areas have found previously unknown occurrences in the last ten years, contributing the vast majority of our basic knowledge of the distribution and habitat for species. This approach is simple, inexpensive, and effective. Contracting experts on this species to search for more occurrences and update historic records would contribute greatly to our knowledge of *P. rupincola*.

Searches for *Potentilla rupincola* 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. rupincola* in given locations. This would be a valuable tool for guiding and focusing future searches. Techniques for predicting species occurrences are reviewed extensively by Scott et al. (2002). Habitat modeling has been done for other sensitive plant species in Wyoming (Fertig and Thurston 2003) and these methods are applicable to *P. rupincola* as well. However, this approach might be complicated by the extent of habitat that is apparently suitable but unoccupied.

Population monitoring

A 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. Population monitoring would also be a useful means of detecting population trends under different management and human use scenarios. A monitoring program for *Potentilla rupincola* targeting robust occurrences in both natural and disturbed settings could incorporate an investigation of human impacts such as recreation and grazing. Monitoring sites under a variety of land use scenarios will help identify appropriate management practices for *P. rupincola* and will help to understand its population dynamics and structure.

Suitable methods for monitoring pollinators are discussed in Kearns and Inouye (1993). It will be important to define a priori the changes the sampling regime intends to detect, and the management actions that will follow from the results (Schemske et al. 1994, Elzinga et al. 1998).

Resampling of monitoring plots will be necessary every year at first to gain insight into the population dynamics of *Potentilla rupincola*. To document important demographic parameters (mainly seedlings and fruitset), two trips per growing season may be required, one in early spring to observe seedlings and one in mid August to observe seed set. The most sensitive measure of population change will be gleaned from recruitment success.

A commonly used method involves tracking marked individuals over several years. One possible approach that is suitable for non-rhizomatous perennials such as *Potentilla rupincola* is described in Lesica (1987). Ideally, a discrete subset of the occurrence would be selected randomly and individuals within quadrats or transects are marked using aluminum tags or other field markers. It is important that plots be large enough and contain a reasonable sample size (perhaps 100 to 200 individuals). This will help ensure that changes within plots resulting from death and recruitment do not eventually result in the obsolescence of the plot. Elzinga et al. (1998) offers additional suggestions regarding sampling design and protocol.

Monumentation is difficult in many sites occupied by *Potentilla rupincola*. Child (2001) has marked plots with big, spray-painted nails that are pounded into a crack in the rock and marked with a metal identification tag. These are semi-permanent to permanent, and are fairly easy to relocate on rock outcrops using a recreation-grade GPS. So far these have not been vandalized or removed, but for frequently visited areas less conspicuous methods are offered in Elzinga et al. (1998).

Estimating cover and/or abundance of associated species within the plots described above could permit the investigation of interspecific relationships through ordination or other statistical techniques. In very sparsely vegetated plots this can be difficult, but can be done accurately using appropriate cover classes or subdivided quadrat frames. Understanding environmental constraints on *Potentilla rupincola* would facilitate the development of beneficial management practices for this species. Gathering data on slope, aspect, and edaphic characteristics (if possible) 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 offered in Elzinga et al. (1998) could facilitate the tracking of individuals and add valuable qualitative information. A handbook on photo point monitoring (Hall 2002) is available that offers excellent instructions on establishing photo point monitoring plots. Monitoring sites should be selected carefully, and a sufficient number of sites selected if the data are intended to detect overall population trends.

To address the metapopulation structure of *Potentilla rupincola*, one approach might be to select highly suitable but unoccupied sites, such as those cited in the Distribution and abundance section of this document, and attempt to observe colonization events through presence/absence monitoring. However, this approach could be particularly difficult for *P. rupincola*. Given the life history characteristics of *P. rupincola*, it is possible that many years of data would be needed before meaningful inferences could be made about its metapopulation structure using this method. Concurrent observations of local extirpations (which are fairly likely to occur in the smaller known occurrences) would also add to our understanding of the metapopulation structure of *P. rupincola*. Even for plants in which metapopulation dynamics can be successfully inferred from regional extinction and colonization data, focusing efforts on monitoring of individual occurrences is more likely to provide an accurate assessment of the species (Harrison and Ray 2002).

If resources permit, all the known occurrences of *Potentilla rupincola* could be monitored, doing half of them each year. Meaningful population trend data could probably be obtained from a subset of these occurrences. Selecting monitoring sites throughout the range of *P. rupincola* at a variety of substrates, elevations, and human usage patterns is needed to assess the relative performance of occurrences in these scenarios.

Visiting occurrences in mid-summer while the plants are flowering would allow researchers to observe insect visitors if it is determined that they play a crucial role in the breeding biology of *Potentilla rupincola*. It may also be possible to count seedlings at this time. Measuring seed production will require another visit later in the summer.

At present the priorities lie in gathering baseline data on distribution and population sizes for *Potentilla rupincola*. Gathering population size data can be done rapidly and requires only a small amount of additional time and effort (Elzinga et al. 1998), although this is complicated somewhat by the difficulty in distinguishing *P. rupincola* from *P. effusa* and intermediate plants. However, presence/absence monitoring is not recommended for *P. rupincola*. Further rationale for this is that it is time consuming and difficult to reach many of these occurrences, so the additional time investment of gathering population size and other data is worthwhile to maximize the information gleaned during each visit.

Habitat monitoring

Habitat monitoring in the absence of *Potentilla rupincola* individuals could be conducted on sites within the known distribution with suitable soils, geologic substrate, and vegetation. For sites that are occupied by *P. rupincola*, habitat monitoring could be conducted concurrently with population monitoring if population monitoring is conducted. Documenting habitat attributes, disturbance regime, and associated species during all population monitoring efforts will greatly augment our present understanding of its habitat requirements and management needs. This could be incorporated into the field forms used for the quantitative sampling regimen described above. If carefully selected environmental variables are quantified during monitoring activities, they may help 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 and grazing. Change in environmental variables might not cause observable demographic repercussions for several years, so resampling the chosen variables may help to identify underlying causes of population trends. Evidence of current land use practices and management are important to document while monitoring occurrences. Monitoring all the known extant occurrences of *P. rupincola* with a visit every third year is feasible given the small number of occurrences.

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

Beneficial management actions

Management actions that reduce impacts to *Potentilla rupincola* and its habitat are likely to procure significant benefits for the species. Most occurrences are not in need of changes in management at this time.

Surveys prior to management actions within potential habitat on public lands would help alleviate threats to this species from human impacts to individuals. Complete and detailed surveys are needed wherever there is the potential for impact to *Potentilla rupincola*. This will help to identify new occurrences and avert impacts to occurrences from development activities. Incorporating the needs of *P. rupincola* into management plans and land use decisions is needed to ensure its needs are accounted for in project planning.

Management of exotic species at Virginia Dale (EO 1) and Sheep Mountain (EO 13) would help to ensure the long-term viability of these occurrences. Weed management is needed primarily where roads pass through occurrences of *Potentilla rupincola*. Where it occurs with *P. rupincola*, managing *Bromus tectorum* without impacting *P. rupincola* might be difficult. Proactive management that works towards the prevention of the spread of *B. tectorum* and other weeds into native habitat is most likely to procure significant benefits. Minimizing ground-disturbing activities and actively managing roadside weeds in and near occurrences of *P. rupincola* are most likely to be successful.

Livestock management practices that limit or prohibit grazing within accessible portions of occurrences of *Potentilla rupincola* will probably have minor benefits. The primary threat to *P. rupincola* from grazing is probably the spread of weeds. Active weed management in grazing allotments near *P. rupincola* occurrences is advisable to prevent infestations that impact *P. rupincola*. Livestock exclosures could be used to prevent horse and cattle grazing in occupied habitat they can access if such locations are later identified. Since habitat for *P. rupincola* is inaccessible and of very low forage value it is unlikely that actions on behalf of *P. rupincola* will affect the grazing regime or have economic impacts.

Mitigation of impacts to roadside occurrences is needed to improve the likelihood of the long-term viability of these sites. The roadside plants at Virginia Dale (EO 1) are susceptible to impacts from right-of-way management practices that may or may not benefit it. Well-intentioned use of herbicides might do more harm than good if their use kills *Potentilla rupincola* too. Thus, use of herbicides within roadside occurrences should be limited to direct application to weeds.

Routing new trails and rerouting any existing trails around known occurrences are probably the best ways to reduce direct human impacts to *Potentilla rupincola*. Rocky Mountain National Park has installed trailside barriers to prevent accidental trampling by hikers where a trail bisects an occurrence. Such barriers have also been installed to protect occurrences of the federally endangered *P. robbinsiana* from trampling, and have been successful. However, the construction of a stone wall in its habitat may also be acting as a barrier to the natural spread of the occurrence (NatureServe 2002). Imposing regulations prohibiting rock climbing and scrambling at occurrences of *P. rupincola* will help to reduce visitor impacts. Such regulations are proposed for the Eagle's Nest Open Space in Larimer County to prevent impacts to *P. rupincola* habitat (Larimer County Parks and Open Lands 2002).

Most of the known occurrences (12 of 23) of *Potentilla rupincola* in the states of USFS Region 2 are found on federal public lands (**Table 1**). However, there are four significant occurrences (EO 1, EO 18, EO 23, EO 24) that are known (at least in part) from private lands where they are at some risk from development. The purchase of conservation easements and other land trust activities is a useful conservation tool to protect occurrences on private land. Purchasing conservation easements even on small properties may confer significant benefits to the conservation of *P. rupincola*, since its occurrences tend to be isolated and limited in size anyway. Purchase of conservation easements in the Virginia Dale (EO 1) area would help to broaden the elevation range and habitat types protected for this species, which in turn will very likely help maintain the genetic diversity of *P. rupincola*. Bringing sites on private land into public ownership through land exchange or purchase could also protect occurrences from residential development. Similarly, consideration of land exchanges involving sites that are currently on public land would not be beneficial to *P. rupincola*. The conservation of *P. rupincola* would be an appropriate goal to include in county and city planning efforts. Purchase of land or conservation easements by Open Space Programs is also a useful conservation tool.

Seed banking

No seeds or genetic material are currently in storage for *Potentilla rupincola* at the National Center for Genetic Resource Preservation (Miller personal communication 2002). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2002). Collection of seeds for long-term storage will be useful if future restoration work is necessary.

Information Needs

Distribution

Further species inventory work is among the top priorities for research on *Potentilla rupincola*. Until we have a better picture of its distribution and population size it will not be possible to accurately assess the conservation needs and priorities for this species.

Although the entire global range of *Potentilla rupincola* is near Denver and Fort Collins, Colorado, much suitable habitat between known occurrences remains to be searched. There is a great deal of apparently suitable habitat along the Front Range, and much of it is rugged and difficult to reach. Complex land ownership patterns, particularly in subdivided areas, can thwart search efforts due to the need for permission to access these sites. However, recent search efforts have been rewarding, particularly those of Nan Lederer and Marion Reid (1994), Kettler et al. (1996) and Richard Scully and MaryJane Howell (ongoing). Kettler et al. (1996) searched Larimer County for *P. rupincola*, but time and funding constraints limited the intensity of this inventory. Further focused searching in areas not searched during this inventory is warranted. Revisiting and assessing the historic occurrences is also needed. More detailed habitat specificity information will help to refine future search efforts.

Lifecycle, habitat, and population trend

Very little is known about the population ecology of *Potentilla rupincola*. Baseline population size data are available for many occurrences but there are no monitoring data with which to determine the population trend. Basic life history parameters need to be determined from which the viability of occurrences can be inferred.

Fortunately there has been much work in the past ten years (cited above) to provide basic information on population size and habitat of *P. rupincola*. Further work is needed to more rigorously quantify population size and to attempt to observe population trend.

Autecological research is needed for *Potentilla rupincola*. Such research will help refine our definition of appropriate habitat and to understand why many sites are not occupied. Information on soil chemistry and nutrient relations might yield valuable insights into the ecological requirements of *P. rupincola*, which would facilitate effective habitat monitoring and conservation stewardship of this species. Physiological ecology studies will help determine what substrate characteristics are required by *P. rupincola*, which will be valuable information in the event that an occurrence needs to be restored, and will help to model the potential distribution of the species.

Response to change

Rates of reproduction, dispersal, and establishment and the effects of environmental variation on these parameters have not been investigated in *Potentilla rupincola*. Thus, the effects of various management options cannot be assessed during project planning.

Understanding the breeding systems employed by *Potentilla rupincola* will assist managers by determining the importance of pollinators for reproduction and population genetics. At this time, it is not known how management changes that affect insect visitors will affect *P. rupincola*.

The importance of herbivory in the ecology of *Potentilla rupincola* is not understood. Observations made thus far do not suggest that it has a significant impact on biomass reduction and disturbance of the species but this has not been assessed.

It can be assumed that any management change that promotes the spread and abundance of *Bromus tectorum* in the vicinity of *Potentilla rupincola* occurrences will be detrimental. A more rigorous study of the impact on *P. rupincola* of exotic species, particularly *Bromus tectorum*, is needed. Population monitoring efforts are needed to better understand the relationship between *B. tectorum* and *P. rupincola*, which will contribute valuable insight into appropriate management strategies.

Metapopulation dynamics

Research on the population ecology of *Potentilla rupincola* has not been done to determine the importance of metapopulation structure and dynamics to the long-term persistence of *P. rupincola* at local or regional scales. Migration, extinction, and colonization rates are unknown for *P. rupincola*. Thus, analyses of local or regional population viability must rely on observable trends in individual occurrences. However, this approach can provide reliable assessments of species status in the absence of metapopulation structure information (Harrison and Ray 2002).

Demography

Population size has been estimated but not rigorously quantified for occurrences of *Potentilla rupincola*. Growth, survival, and reproduction rates are also unknown. Our knowledge of the distribution of the species is probably incomplete. Therefore much work is needed in the field before local and range-wide persistence can be assessed with demographic modeling techniques. Short term demographic studies often provide misleading guidance for conservation purposes, so complementary information, such as historical data and experimental manipulations should be included whenever possible (Lindborg and Ehrlén 2002).

Population trend monitoring methods

There has been no monitoring of occurrences of *Potentilla rupincola*, but methods are available to begin a monitoring program. Lesica (1987) described a technique for monitoring occurrences of non-rhizomatous perennial plant species that would be applicable to *P. rupincola*. Measuring transitions between life history stages can provide more reliable data for slow-growing, long-lived species such as *P. rupincola* (Schemske et al. 1994).

Restoration methods

Potentilla species are generally not difficult to propagate, and *P. rupincola* grows readily from seed in a greenhouse in a standard soil mixture (Child personal communication 2002). Clonal propagation might also be feasible for *P. rupincola*. Plants could be readily propagated in a greenhouse environment, but they would probably be very difficult to transfer successfully into a natural or quasi-natural (restored) setting. *Potentilla subjuga* increased in relative cover in plots in a study using turf transplants to restore alpine communities in Colorado (Conlin and Ebersole 2001). However, the utility of these methods is dubious given the paucity of soil and turf in most occurrences of *P. rupincola*.

Using an appropriate inoculum might facilitate biomass accumulation in young *Potentilla rupincola* plants (Fernando and Currah 1996, St. John 1996). Because no attempts have been made to restore occurrences of *P. rupincola*, there is no applied research to draw from in developing a potential restoration program.

Research priorities for USFS Region 2

Understanding the genetic structure and demographics of *Potentilla rupincola* are among the top research priorities for this species. Demographic research will have great value for management and conservation purposes. If occurrences are robust and contain healthy levels of genetic diversity, demographic studies will help determine how to keep them that way by way of management. If they are not, we can become aware of the problem though demographic research and develop management guidelines to address genetic concerns. Some key questions to address are: Are occurrences stable? Do peripheral occurrences (such as those in Park County) contain unique alleles? What is the minimum viable population size for *P. rupincola*? Forthcoming molecular data will reveal much about the population genetics of individual occurrences as well.

Understanding the breeding systems employed by *Potentilla rupincola* is another research priority for this species due to the practical and scientific value of such studies. Answers to questions about whether *P. rupincola* is apomictic or an obligate or frequent outcrosser will provide needed guidance for developing appropriate management practices. If *P. rupincola* reproduces predominantly through apomixis, the genetic population structure is more stable then if the species is an obligate outcrosser. Thus, a trail through an apomictic occurrence will not be as detrimental as one through a occurrence of obligate outcrossers.

The extent to which *Potentilla rupincola* hybridizes, or is itself the product of hybridization, is another important question. Some key questions relating to this topic are: What is going on in mixed occurrences? Are intermediates the product of hybridization, a new species, or merely expressions of phenotypic plasticity within one or more variable taxa? If the intermediate plants are the result of hybridization between *P. rupincola* and *P. effusa*, research will need to address whether these hybrids are fertile, stable, or perhaps still undergoing further hybridization. These issues also have management and conservation implications. The parapatric occurrence at Bull Garden (EO 23, Roosevelt National Forest) will be particularly interesting to compare with sympatric and allopatric occurrences of *P. rupincola* at other locations.

The conservation priority for *Potentilla rupincola* depends largely on its taxonomic status. If *P. rupincola* represents a distinct taxon, then it represents an element of Colorado's flora that warrants the attention deserved by a globally imperiled species. However, if *P. rupincola* is an ecotype of *P. effusa*, it remains important mainly for scientific study as an extreme expression of the phenotypic range of *P. effusa*. Although the latter is probably not the case, *P. rupincola* is of higher conservation priority with full species status as opposed to infraspecific status (e.g., as a variety of *P. effusa*). Thus, the issue of taxonomic status has practical implications for management and conservation.

The response of *Potentilla rupincola* to human impacts and disturbance has not been studied. Gaining practical knowledge of how to best manage occurrences of this species is of considerable importance given the rapid change in land use patterns, increasing recreational use, and increasing human population density of the Front Range.

Although *Potentilla rupincola* has been relatively well documented, more species inventory work is needed throughout the range of the species. Further attempts to locate occurrences in Clear Creek and Boulder counties are warranted, mainly because extant occurrences are known to the north and south, and they contain much apparently suitable habitat. Historic collections, though questionable, have also documented the species in Clear Creek and Boulder counties (EO 2, EO 6, EO 8, EO 9, EO 10, EO 11, EO 19) and are worthy of further attempts to find them. Potential habitat remains to be searched in Park and Larimer counties, where extant occurrences are located. Other neighboring counties where *P. rupincola* has not yet been found (e.g. Gilpin and Jefferson counties) are also worthy of species inventory work.

Additional research and data resources

Research is in progress on this species that will clarify many points of *Potentilla rupincola* biology and ecology. Ana Child, a doctoral student at the University of Denver, is conducting this research with Dr. Tom Quinn. The results of Child's research presented herein are preliminary and tentative until her research is complete. When her results are published, relevant sections of this assessment will warrant revision and update. She is studying the systematics, demography, conservation genetics, breeding system, pollen cytology, molecular cytogenetics, ploidy, possible hybridization, floral biology, seed viability, and species-environment relationships of *P. rupincola* and plants that are intermediate between *P. rupincola* and *P. effusa* in 15 study sites. Her results will have significant relevance to the conservation and management of this species.

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).

Actinomorphic: Radially symmetrical (Harris and Harris 1999).

Agamospermy: Apomictic reproduction involving seed production without fusion of gametes (Gould and Shaw 1983).

Allopatric: Species or populations that do not grow in or inhabit overlapping geographical ranges (Art 1993).

Aneuploid: An organism whose nuclei possess a chromosome number that is greater by a small number than the normal chromosome number for that species (Allaby 1998).

Apomixis: Reproduction which involves structures commonly concerned in sexual reproduction but in which there is no actual fusion of male and female gametes (Gould and Shaw 1983).

Autopolyploid: An organism with three or more sets of chromosomes that come from the same species (Art 1993). May arise through the spontaneous doubling of the chromosomal complement as observed by Müntzing and Müntzing (1943) in *Potentilla*.

Axenically: A culture of a single type of organism only (Allaby 1998).

CSR (Competive/Stress-tolerant/ruderal) model: A model developed by J.P. Grime in 1977 in which plants are characterized as Competitive, Stress-tolerant, or Ruderal, based on their allocation of resources. Competitive species allocate resources primarily to growth, stress-tolerant species allocate resources primarily to maintenance, and ruderal species allocate resources primarily to reproduction. A suite of other adaptive patterns also characterize species under this model. Some species show characteristics of more than one strategy (Barbour et al. 1987).

Ecophenic: The morphological response of a phenotypically plastic species to environmental variation (after Cole 1967).

Ecotype: The mophological expression of a unique genotype that is adapted to particular habitat attributes (after Allaby 1998).

Edaphic: Of the soil, or influenced by the soil (Allaby 1998).

Haplotype: One of the alternative forms of the genotype of a gene complex. This term is applied to gene complexes rather than the term allele, which refers to one of the forms of a single gene.

Hybrid Swarm: A continuous series of morphologically distinct hybrids resulting from interspecific crosses followed by back crosses in subsequent generations (Art 1993).

Marcescent: Withering but persistent, as in the leaves at the base of some plants including *Potentilla rupincola* (Harris and Harris 1999).

Panmictic: A population in which random crossing is occurring (Art 1993).

Parapatric: Describes adjacent taxa whose ranges overlap slightly (Art 1993).

Polyploid: Having three or more sets of chromosomes (Art 1993). This condition is common in the genus *Potentilla*.

Potential Conservation Area: A best estimate of the primary area supporting the long-term survival of targeted species or natural communities. PCAs are circumscribed for planning purposes only (Colorado Natural Heritage Program Site Committee 2001). They are ranked as follows based on their biodiversity significance:

- **B1** Outstanding Significance: only location known for an element or an excellent occurrence of a G1 species.
- **B2** Very High Significance: one of the best examples of a community type, good occurrence of a G1 species, or excellent occurrence of a G2 or G3 species.
- **B3** High Significance: excellent example of any community type, good occurrence of a G3 species, fair occurrence of a G2 species, or a large concentration of good occurrences of state-rare species.
- **B4** Moderate or Regional Significance: good example of a community type, fair occurrences of a G3 species, excellent or good occurrence of state-rare species.
- **B5** General or State-wide Biodiversity Significance: good or marginal occurrence of a community type, S1, or S2 species.

Pseudogamous: Characteristic of a type of agamospermy where pollination takes place and a pollen nucleus fuses with the polar nuclei of the embryo sac to form endosperm, while the embryo develops without fertilization from an unreduced egg. Thus, pseudogamous plants require the pollen from another individual even though fertilization does not occur. This is common in members of the genus *Potentilla* (Eriksen 1996).

Pubescence: Short, soft hairs (Harris and Harris 1999).

Strigose: Bearing straight, stiff, sharp, appressed hairs (Harris and Harris 1999).

Sympatric: Describes two populations or species that live in the same region without merging into one population through interbreeding (Art 1993).

Tomentose: With a covering of short, matted or tangled, soft, wooly hairs (Harris and Harris 1999).

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

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

G/S1 Critically imperiled globally/state-province because of rarity (5 or fewer occurrences in the world/state; or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction.

G/S2 Imperiled globally/state-province because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.

G/S3 Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences).

G/S4 Apparently secure globally/state-province, though it might be quite rare in parts of its range, especially at the periphery.

G/S5 Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.

GX Presumed extinct.

G#? Indicates uncertainty about an assigned global rank.

G/SU Unable to assign rank due to lack of available information.

GQ Indicates uncertainty about taxonomic status.

G/SH Historically known, but not verified for an extended period, usually.

G#T# Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1 to 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.

References

Acharya Goswami, D. and B. Matfield. 1974. Pseudogamy in the genus *Potentilla* L. New Phytologist 73:1243-1247.

Acharya Goswami, D. and B. Matfield. 1978. Meiotic Studies on 2 Polyploid *Potentillas*, *P. ambigens* Greene and *P. atrisanguinea* Lodd. Caryologia 31:109-115.

Allaby, M. 1998. A Dictionary of Plant Sciences. New York, NY: Oxford University Press.

Allen-Diaz, B.H. 1991. Water Table and Plant Species Relationships in Sierra Nevada Meadows. American Midland Naturalist 126:30-43.

Art, H.W. 1993. The Dictionary of Ecology and Environmental Science. New York, NY: Henry Holt and Company.

Asker, S. 1977. Pseudogamy, Hybridization and Evolution in *Potentilla*. Hereditas 87:179-183.

Asker, S. 1985. Chromosome Studies in *Potentilla*. Hereditas 102:289-292.

Asker, S. and L. Jerling. 1992. Apomixis in Plants. Boca Raton, FL: CRC Press.

Baker, J.D. and R.W. Cruden. 1991. Thrips-Mediated Self-Pollination of two Facultatively Xenogamous Wetland Species. American Journal of Botany 78:959-963.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial Plant Ecology. Menlo Park, CA: Benjamin/Cummings Publishing Company, Inc.

Beidleman, L.H., R.G. Beidleman, and B.E. Willard. 2000. Plants of Rocky Mountain National Park. Helena, MT: Rocky Mountain Nature Association and Falcon Publishing, Inc.

Bonde, E.K. 1969. Plant disseminules in wind-blown debris from a glacier in Colorado. Arctic and Alpine Research 1:135-140.

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

Burrows, G.E. and R.J. Tyrl. 2001. Toxic Plants of North America. Ames: Iowa State University Press.

Caswell, H. 2001. Matrix Population Models. Second Edition. Sunderland, MA: Sinauer Associates, Inc

Center for Plant Conservation. 2002. National Collection of Endangered Plants. Accessed via the world wide web at http://www.mobot.org/CPC/NC_Choice.html.

Chamberlain, T.C. 1897. The method of multiple working hypotheses. Journal of Geology 5:837-848 (Reprinted in Science 148:754-759).

Child, A.L. 2001. Conservation Genetics of the Rare Plant *Potentilla rupincola* (Rosaceae): Assessing Genetic Diversity and Taxonomic Resolution. Proposal for Dissertation Research presented to Department of Biological Sciences at the University of Denver and the U.S. Geological Survey.

Child, A.L. 2002. Conservation genetics of the rare plant *Potentilla rupincola* (Rosaceae): An assessment of genetic diversity and taxonomy. In: Rocky Mountain National Park Research Conference; 2002 Apr 9-11; Estes Park, CO: Rocky Mountain National Park and Continental Divide Research and Learning Center; 2002. Pg 14.

Child, A.L. 2004. Personal communications with doctoral student researching *Potentilla rupincola*.

Cole, N.H.A. 1967. Comparative Physiological Ecology of Genus *Eriogonum* in Santa Monica Mountains Southern California. Ecological Monographs 37:1-&.

Colorado Natural Heritage Program. 2004. Biodiversity Tracking and Conservation System. Colorado State University, Fort Collins, CO, USA.

Colorado Natural Heritage Program Site Committee. 2001. Recommendations for Development and Standardization of Potential Conservation Areas and Network of Conservation Areas. Fort Collins, CO: Colorado Natural Heritage Program.

Conlin, D.B. and J.J. Ebersole. 2001. Restoration of an Alpine Disturbance: Differential Success of Species in Turf Transplants, Colorado, USA. Arctic, Antarctic, and Alpine Research 33:340-347.

Conn, J.S. and R.E. Deck. 1995. Seed Viability and Dormancy of 17 Weed Species After 9.7 Years of Burial in Alaska. Weed Science 43:583-585.

Cronquist, A. 1981. An Integrated System of Classification of Flowering Plants. New York, NY.

Cronquist, A. 1988. The Evolution and Classification of Flowering Plants. Second Edition. Bronx, NY: New York Botanical Garden.

Delgado, L., F. Gallego, and E. Rico. 2000. Karyosystematic Study of *Potentilla* L. Subgenus *Potentilla* (Rosaceae) in the Iberian Peninsula. Botanical Journal of the Linnean Society 132:263-280.

Doyle, G., S. Neid, and B. Drummond. In Prep. Biological Inventory of Larimer County. Unpublished report prepared for Larimer County and others.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM Technical Reference 1730-1.

Eriksen, B. 1996. Mating Systems in Two Species of *Potentilla* From Alaska. Folia Geobotanica and Phytotaxonomica 31:333-344.

Eriksen, B. 1997. Morphometric Analysis of Alaskan Members of the Genus *Potentilla* Sect. Niveae (Rosaceae). Nordic Journal of Botany 17:621-630.

Eriksen, B. 2002. Potentilla Society Homepage. Accessed via the internet at: http://www.systbot.gu.se/staff/beneri/potsoc.html.

Eriksson, T., M.J. Donoghue, and M.S. Hibbs. 1998. Phylogenetic Analysis of *Potentilla* Using DNA Sequences of Nuclear Ribosomal Internal Transcribed Spacers (Its), and Implications for the Classification of Rosoideae (Rosaceae). Plant Systematics and Evolution 211:155-179.

Fernando, A.A. and R.S. Currah. 1996. A Comparative Study of the Effects of the Root Endophytes *Leptodontidium orchidicola* and *Phialocephala fortinii* (Fungi Imperfecti) on the Growth of Some Subalpine Plants in Culture. Canadian Journal of Botany 74:1071-1078.

Fertig, W. and R. Thurston. 2003. Modeling the Potential Distribution of BLM sensitive and USFWS Threatened and Endangered Plant Species. Laramie, WY: Wyoming Natural Diversity Database.

Gerard, J. 1633. The Herbal or General History of Plants. 1633 Edition as Revised and Enlarged by T. Johnson. New York, NY: Dover Publications Inc. Reprinted in 1975.

Gold, W.G. 2000. Nutrient relations and photosynthesis of plants in a high arctic polar desert, Devon Island, N.W.T., Canada: effects of fertilization and cryptogamic crusts. Canadian Journal of Botany.

Gould, F.W. and R.B. Shaw. 1983. Grass Systematics. Second Edition. College Station, TX: Texas A&M University Press.

Grime, J.P. 2001. Plant Strategies, Vegetation Processes, and Ecosystem Properties. 2nd ed. Chichester, West Sussex, England: John Wiley & Sons.

Hall, F.C. 2002. Photo Point Monitoring Handbook- Parts A and B. General Technical Report PNW-GTR 526. Portland, OR: USFS Pacific Northwest Research Station.

Hansen, K.T., R. Elven, and C. Brochmann. 2000. Molecules and Morphology in Concert: Tests of Some Hypotheses in Arctic *Potentilla* (Rosaceae). American Journal of Botany 87:1466-1479.

Harley, J.L. 1991. Introduction: The state of the art. In: Norris, J.R., D.J. Read, and A.K. Varma (eds) Methods in Microbiology, Vol. 23. London. pp 1-24: Academic Press.

Harrington, H.D. 1954. Manual of the Plants of Colorado. Denver: Sage Books.

Harris, J.G. and M.W. Harris. 1999. Plant Identification Terminology- an Illustrated Glossary. Spring Lake, UT: Spring Lake Publishing.

Harrison, S. and C. Ray. 2002. Plant population viability and metapopulation-level processes. In: Population Viability Analysis (S.R. Beissinger and D.R. McCullough, Eds). Chicago, IL: The University of Chicago Press.

Heywood, V.H. 1993. Flowering Plants of the World. New York: Oxford University Press.

Hillborn, R. and M. Mangel. 1997. The Ecological Detective: Confronting Models with Data. Princeton, NJ: Princeton University Press.

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

Holm, S. and L. Ghatnekar. 1996. Apomixis and Sexuality in Hexaploid *Potentilla argentea*. Hereditas 125:53-60.

Innes, R.L. and L.M. Lenz. 1990. A Genetic Analysis of Self-Incompatibility and Double Flowers in *Potentilla fruticosa* L. Euphytica 51:241-248.

Johnston, B.C. 1980. Studies of Population Variability Leading to a New Classification of *Potentilla* section Multijugae (Rosaceae). Dissertation. Boulder, CO: University of Colorado.

Johnston, B.C. 2002. Personal communication with USFS Botanist regarding *Potentilla rupincola*.

Kartesz, J.T. 1994. A Synonymized Checklist of the Vascular Flora of the United Stated, Canada, and Greenland. Second Edition (2 Volumes). Portland, OR: Timber Press.

Kartesz, J.T. 1999. A Synonymized Checklist and Atlas with Biological Attributes for the Vascular Flora of the United States, Canada, and Greenland. First Edition. In: Kartesz, J.T. and C.A. Meacham. Synthesis of the North American Flora [computer program]. Version 1.0 . Chapel Hill, NC: North Carolina Botanical Garden.

Kearns, C.A. and D.W. Inouye. 1993. Techniques for Pollination Biologists. Niwot, CO: University Press of Colorado.

Kettler, S., J. Sanderson, S. Spackman, K. Fayette, C. Pague, D. Clark, and A. Hicks. 1996. Significant Plant, Animal, and Wetland Resources of Larimer County and Their Conservation. Colorado Natural Heritage Program Research Report #41. Unpublished report prepared for Larimer County, CO. 293 pp.

Larimer County Parks and Open Lands. 2002. Resource Management Plan for the Eagle's Nest Open Space.

Law, R. 1985. Evolution in a mutualistic environment. *In*: Boucher, D.H. (ed) The Biology of Mutualism, Ecology and Evolution. New York, NY. Pp 145-170: Oxford University Press.

Lesica, P. 1987. A technique for monitoring nonrhizomatous, perennial plant species in permanent belt transects. Natural Areas Journal 7(2):65-8.

Lindborg, R. and J. Ehrlén. 2002. Evaluating the extinction risk of a perennial herb: demographic data versus historical records. Conservation Biology 16:683-690.

Loik, M.E. and J. Harte. 1996. High-Temperature Tolerance of *Artemisia tridentata* and *Potentilla gracilis* Under a Climate Change Manipulation. Oecologia 108:224-231.

Loik, M.E. and J. Harte. 1997. Changes in Water Relations for Leaves Exposed to a Climate- Warming Manipulation in the Rocky Mountains of Colorado. Environmental and Experimental Botany 37:115-123.

MacArthur, R.H. and E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton, NJ: Princeton University Press.

Manabe, S. and R.T. Wetherald. 1986. Reduction in summer soil wetness induced by an increase in atmospheric carbon dioxide. Science 232:626-628.

Mawdsley, J.R. 1999. Redescription and Notes on the Biology of *Amecocerus senilis* (Leconte) (Coleoptera: Meyridae: Dasytinae). Journal of the New York Entomological Society 107:68-72.

Mawdsley, J.R. 2003. The Importance of Species of Dasytinae (Coleoptera: Melyridae) as Pollinators in Western North America. The Coleopterists Bulletin 57(2):154-160.

Miller, A. 2002. Personal communication with National Center for Genetic Resource Preservation Seed Analyst regarding *Potentilla rupincola*.

Moore, M. 1979. Medicinal Plants of the Mountain West. Santa Fe, NM: The Museum of New Mexico Press.

Morgan, D.R., D.E. Soltis, and K.R. Robertson . 1994. Systematic and evolutionary implications of rbcL sequence variation in Rosaceae. American Journal of Botany 81:890-903.

Müntzing, A. and G. Müntzing. 1943. Spontaneous changes in the chromosome number in apomictic *Potentilla collina*. Hereditas 29:451-460.

National Center for Biotechnology Information. 2002. Taxonomy Browser. Accessed on the web at http://www.ncbi.nlm.nih.gov/Taxonomy/tax.html/.

NatureServe Explorer. 2002. NatureServe Explorer: an online encyclopedia of life [web application]. Accessed via the web at: http://www.natureserve.org/explorer/

Neely, B., P. Comer, C. Moritz, M. Lammert, R. Rondeau, C. Pague, G. Bell, H. Copeland, J. Humke, S. Spackman, T. Schulz, D. Theobald, and L. Valutis. 2001. Southern Rocky Mountains: An Ecoregional Assessment and Conservation Blueprint. Prepared by the Nature Conservancy with support from the USDA. Forest Service, Rocky Mountain Region, Colorado Division of Wildlife, and Bureau of Land Management.

New York Botanical Garden. 2002. Vascular Plant Type Catalog. Image of *Potentilla rupincola* isotype specimen. Accessed on the world wide web at http://www.nybg.org/bsci/hcol/vasc/.

O'Kane, S.L. 1988. Colorado's rare flora. Great Basin Naturalist 48(4):434-84.

Osterhout, G.E. 1899. New Plants from Colorado. Bulletin of the Torrey Botanical Club 26:256-257.

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

Porter, C.L. 1967. Taxonomy of Flowering Plants. 2nd ed. San Francisco, CA: W.H. Freeman and Co.

Rosendahl, S., C.N. Rosendahl, and U. Sochting. 1992. Distribution of VA mycorrhizal endophytes amongst plants from a Danish grassland community. Agric Ecosystem and Environment 29:329-335.

Rydberg, P.A. 1906. Flora of Colorado. Fort Collins, CO: Agricultural Experiment Station.

Rydberg, P.A. 1922. Flora of the Rocky Mountains and Adjacent Plains. New York, NY: Hafner Publishing Co.

Saikkonen, K., S. Koivunen, T. Vuorisalo, and P. Mutikainen. 1998. Interactive Effects of Pollination and Heavy Metals on Resource Allocation in *Potentilla anserina* L. Ecology 79:1620-1629.

Sanders, I.R., J.P. Clapp, and A. Wiemken. 1996. The genetic diversity of arbuscular mycorrhizal fungi in natural ecosystems - a key to understanding the ecology and functioning of the mycorrhizal symbiosis. New Phytologist 133:123-134.

Scagel, R.F., R.J. Bandoni, G.L. Rouse, W.B. Schofield, J.R. Stein, and T.M. Taylor. 1966. An evolutionary survey of the plant kingdom. Belmont, CA: Wadsworth Publishing Co.

Scott, M.J., P.J. Heglund, M.L. Morrison, J.B. Haufler, M.G. Raphael, W.A. Wall, and F.B. Samson. 2002. Predicting Species Occurrences- Issues of Accuracy and Scale. Washington, D.C.: Island Press.

Schemske, D.W., B.C. Husband, M.H. Ruckelshaus, C. Goodwillie, I.M. Parker, and J.G. Bishop. 1994. Evaluating approaches to the conservation of rare and endangered plants. Ecology 75:584-606.

Scully, R. 2002. Personal communication with local botanist and expert on *Potentilla rupincola*.

Shelton, K. Cinquefoil (*Potentilla simplex*). Information on medicinal uses by Alternative Nature. Accessed on the web at http://altnature.com/gallery/Cinquefoil.htm. 2002.

Soulé, M.E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-169 in: M. E. Soulé and B. A. Wilcox (Ed.) Conservation Biology: an Evolutionary Perspective. Sunderland, MA: Sinauer Associates.

Spackman, S., D. Anderson, J. Siemers, P. Pineda, and J. Handwerk. 1999. Staunton State Park Biological Inventory. Unpublished report prepared for Colorado State Parks by the Colorado Natural Heritage Program.

Spackman, S., B. Jennings, J. Coles, C. Dawson, M. Minton, A. Kratz, and C. Spurrier. 1997. Colorado rare plant field guide. Prepared for the Bureau of Land Management, the U.S. forest Service and the U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program.

St. John, T. 1996. Mycorrhizal inoculation: advice for growers and restorationists. Hortus West 7:1-4.

Stebbins, G.L. 1974. Flowering Plants- Evolution above the Species Level. London.

Stuefer, J.F. and H. Huber. 1998. Differential Effects of Light Quantity and Spectral Light Quality on Growth, Morphology and Development of Two Stoloniferous *Potentilla* Species. Oecologia 117:1-8.

Stuefer, J.F. and H. Huber. 1999. The Role of Stolon Internodes for Ramet Survival After Clone Fragmentation in *Potentilla anserina*. Ecology Letters 2:135-139.

U.S. Fish and Wildlife Service. 1996. Endangered and Threatened Wildlife and Plants: Review of Plant and Animal Taxa that are Candidates for Listing as Endangered or Threatened Species; Notice of Review; Proposed Rule. Federal Register 61(40):7596-7613.

U.S. Fish and Wildlife Service. 1998. Final Rule Listing Five Plants From Monterey County, CA, as Endangered or Threatened . Federal Register 63:43100-43116.

U.S. Fish and Wildlife Service. 1999. List of endangered and threatened plants. Federal Register Section 17.12:38-55.

USDA Forest Service. 2003. Forest Service Manual Rocky Mountain Region. Chapter 2670. Threatened, Endangered, and Sensitive Plants and Animals. Lakewood, CO: USFS Region 2.

US Environmental Protection Agency. 1997. Climate Change and Colorado. EPA 230-F-97-008f. Washington D.C.: Office of Policy, Planning, and Evaluation, Climate and Policy Assessment Division.

USDA Natural Resources Conservation Service. 2002. The PLANTS Database, Version 3.5 (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Vandenkoornhuyse, P., S.L. Baldauf, C. Leyval, J. Straczek, and J.P.W. Young. 2002. Extensive fungal diversity in plant roots. Science 2051-2052.

Varma, A. 1999. Functions and application of arbuscular mycorrhizal fungi in arid and semi-arid soils. In: Varma, A. and B. Hock (eds) Mycorrhiza, 2nd Ed. Berlin: Springer-Verlag. Pp. 521-556.

Weber, W.A. 1976. Rocky Mountain Flora. Boulder, CO: Colorado Associated University Press.

Weber, W.A. and R.C. Wittmann. 2000. Catalog of the Colorado Flora: A Biodiversity Baseline. Electronic version, revised March 11, 2000. Boulder, CO: University of Colorado Museum.

Weber, W.A. and R.C. Wittmann. 2001a. Colorado Flora: Eastern Slope. Third ed. Boulder, CO: University Press of Colorado.

Weber, W.A. and R.C. Wittmann. 2001b. Colorado Flora: Western Slope. Third ed. Boulder, CO: University Press of Colorado.

Wolf, T. 1908. Mongraphie der Gattung *Potentilla*. Bibliotheca Botanica 16:1-714.

Zomlefer, W. 1994. Guide to Flowering Plant Families. Chapel Hill, NC: University of North Carolina Press.