Mimulus gemmiparus W.A. Weber (Rocky Mountain monkeyflower): A Technical Conservation Assessment

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COVER PHOTO CREDIT

Mimulus gemmiparus photograph taken by William Jennings. Reprinted with permission from the photographer.

Summary of Key Components for Conservation of *Mimulus gemmiparus*

Status

Mimulus gemmiparus (Rocky Mountain monkeyflower) is a regional endemic species occurring from 2560 to 3390 meters [m] (8,400 to 11,120 feet [ft]) in montane environments along both sides of the Front Range of Colorado. *Mimulus gemmiparus* is a unique annual species because it reproduces predominantly with asexual propagules. This species most often grows in moist, seepy habitats on cliff ledges or under rocky overhangs. Currently, there are eight known occurrences of this species, and three of those occurrences are on U.S. Forest Service (USFS) National Forest System lands. Few studies have elucidated the basic biology of *M. gemmiparus*, and little is known about the ecological requirements, current abundance, or long-term persistence of this species. Not enough abundance data or demographic information are available to conclude if populations of *M. gemmiparus* are increasing, decreasing, or remaining stable.

Mimulus gemmiparus is currently on the USFS Rocky Mountain Region (Region 2) sensitive species list (U.S. Forest Service 2003). This species is not listed on the U.S. Fish and Wildlife Service threatened or endangered species list or the Colorado Bureau of Land Management sensitive species list (U.S. Bureau of Land Management 2000). The Global Heritage status rank for *M. gemmiparus* is G1 (critically imperiled globally) and the Colorado Natural Heritage Program status rank is S1 (critically imperiled in state) (D. Anderson personal communication 2003).

Primary Threats

The primary threats to *Mimulus gemmiparus* include both human-related and ecological factors. Most of the *M. gemmiparus* locations occur in proximity to trails or roads. As a result, the dense clusters of *M. gemmiparus* could be impacted or trampled by off-trail activity by tourists, hikers, and horses or trail maintenance activities. Existing *M. gemmiparus* populations are also susceptible to ecological or human-related disturbances that could alter soil conditions, affect hydrology, or increase competition with other species. Ecological disturbances could include succession, wildfire, drought, rock fall, flash flood, erosion, global warming, tree blowdown, and invasion of exotic plants.

Primary Conservation Elements, Management Implications and Considerations

Mimulus gemmiparus grows in only a few, small, geographically isolated locations with specialized habitats and is highly susceptible to population extirpation by trail-related activities or natural disturbances. There are only eight documented occurrences of *M. gemmiparus*, and the persistence of several of those populations is unknown as a result of drought conditions, wildfires, and succession since last observation. This monkeyflower is not at immediate risk as a result of management activities, but its long-term persistence relies on adequate management to reduce potential threats (M. Beardsley personal communication 2003). Features of *M. gemmiparus* biology that would affect conservation of this species include its small size, specialized habitat needs, reliance on an adequate water supply, discontinuous distribution, annual life history, unique asexual reproduction, and lack of interspecific competitive ability. Protecting existing populations of *M. gemmiparus* from damage, surveying for new populations, studying the ability of this species to persist in stochastic conditions, and exploring the potential for restoration are important conservation tools.

Critical components of future studies would include:

- ❖ Habitat characterizations for existing populations and surveys to locate additional populations within USFS Region 2
- ❖ Multi-year measurements of population area, size, and density
- ❖ Determination of demographic parameters (e.g., fecundity, propagule longevity, survival)

- Investigation of metapopulation dynamics; minimum number of plants necessary to perpetuate the species
- Studies on biological and ecological limitations (e.g., moisture requirements, germination requirements, dispersal abilities)
- Analyses of threats affecting population establishment, growth, and reproduction (e.g., effects of non-native plant invasions, trail activity)
- Genetic analyses to assess variability (e.g., inbreeding depression)
- Research into restoration techniques (e.g., storage of propagules and reintroduction of plants)

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), U.S. Forest Service (USFS). *Mimulus gemmiparus* is the focus of an assessment because it is listed as a sensitive species in Region 2 (U.S. Forest Service 2003) (**Table 1**). Within the National Forest system, a sensitive species is a plant or animal whose population viability is identified as a concern by a regional forester because of significant current or predicted downward trends in population numbers, density, or habitat capability that would reduce its existing distribution (U.S. Forest Service 1995). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Mimulus gemmiparus* throughout its range in Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge.

Table 1. Conservation and management status of *Mimulus gemmiparus* as ranked by the U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, NatureServe, and Natural Heritage Programs in Region 2 states.

Listing	Rank
U.S. Forest Service Region 2 Sensitive Species List[1]	Sensitive
U.S. Fish and Wildlife Service Endangered Species Act	Not listed
U.S. Bureau of Land Management	Not listed
NatureServe Global Ranking[2]	Critically imperiled (G1)
Colorado Natural Heritage Program[2]	Critically imperiled (S1)
Kansas, Nebraska, South Dakota, Wyoming Natural Heritage Programs	Not listed; Not known in state

[1]As designated by a USFS Regional Forester; population viability is a concern due to downward trends in population numbers, density, or habitat capability.

[2]Key to rankings: G = Global rank based on rangewide status, S= State rank based on status of a species in an individual state.

G1 Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction.

G2 Imperiled globally because of rarity (six to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction.

G3 Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences) or because of other factors making it vulnerable to extinction.

G4 Apparently secure, though it may be quite rare in parts of its range, especially at the periphery.

G5 Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.

S1 Critically imperiled in the state because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction.

S2 Imperiled in the state because of rarity (six to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction.

S3 Vulnerable throughout its statewide range or found locally in a restricted statewide range (21 to 100 occurrences) or because of other factors making it vulnerable to extinction.

S4 Apparently secure, though it may be quite rare in parts of its statewide range, especially at the periphery.

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

The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussions of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations but provides the ecological background upon which management must be based. However, it does focus on the consequences of changes in the environment that result from management (i.e., management implications). Additionally, the assessment cites management recommendations proposed elsewhere, and, when management recommendations have been implemented, the assessment examines their success.

Scope and Information Sources

The *Mimulus gemmiparus* species assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. In addition, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *M. gemmiparus* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis but within a current context.

In producing the assessment, we performed an extensive literature search to obtain material focusing on *Mimulus gemmiparus*, as well as related information on the geographical and environmental contexts of this species. We reviewed refereed literature (e.g., published journal articles), non-refereed publications (e.g., unpublished status reports), theses and dissertations, data accumulated by resources management agencies (e.g., Natural Heritage Program [NHP] element occurrence records), and regulatory guidelines (e.g., USFS Forest Service Manual). We did not visit every herbarium with specimens of this species but did incorporate specimen label information provided by herbarium staff and available in NHP element occurrence records (University of Colorado Herbarium 2002, Colorado Natural Heritage Program 2003). While the assessment emphasizes refereed literature because this is the accepted standard in science, non-refereed publications, theses, and reports are used extensively in this assessment because they provide information unavailable elsewhere. These unpublished, non-refereed reports were regarded with greater skepticism, and we treated all information with appropriate uncertainty. In addition, we highlighted areas of current research with this species and cited if these studies were in progress, preparation, or press.

Treatment of Uncertainty

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

Much of the existing information concerning details of *Mimulus gemmiparus* in USFS Region 2 is based on the research and personal observations of USFS biologists, NHP botanists, and independent scientists. When information presented in this assessment is based on our personal communications with a specialist, we cite those sources as "personal communication". Unpublished data (e.g., NHP records) were important in estimating the geographic distribution and describing habitat. These data required special attention because of the diversity of persons and methods used to collect the data. Also, much of the knowledge about the biology and ecology of *M. gemmiparus* is based solely on the thesis of M. Beardsley (1997) and evolutionary analyses by Moody et al. (1999). These works currently provide the only source of experimental data about *M. gemmiparus*. Because there is a paucity of information about this rare plant species, we also incorporated information from closely related species within and outside the region to formulate this assessment. We clearly noted when we were making inferences based on the available knowledge to inform our understanding of *M. gemmiparus* within Region 2.

Publication of Assessment on the World Wide Web

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

Peer Review

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

MANAGEMENT STATUS AND NATURAL HISTORY

Mimulus gemmiparus is an endemic species found within one state of USFS Region 2, Colorado (**Figure 1**). This section discusses the special management status, existing regulatory mechanisms, and biological characteristics of this species.

Management and Conservation Status

Federal status

The Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531-1536, 1538-1540) was passed to protect plant and animal species placed on the threatened or endangered list. The listing process is based on population data and is maintained and enforced by the U.S. Fish and Wildlife Service (USFWS). In 1980, *Mimulus gemmiparus* was ranked as a Category 2 species, a taxa for which proposal as endangered or threatened is appropriate, but conclusive data on biological vulnerability and threats are not currently available (U.S. Fish and Wildlife Service 1980). 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). Therefore, *M. gemmiparus* is not currently ranked under ESA (**Table 1**).

Mimulus gemmiparus is currently listed as a sensitive species within USFS Region 2, Rocky Mountain Region (U.S. Forest Service 2003) (**Table 1**). Within the National Forest system, a sensitive species is a plant or animal whose population viability is identified as a concern by a regional forester because of a significant current or predicted downward trend in population numbers, density, or habitat capability that would reduce its existing distribution (U.S. Forest Service 1995).

Mimulus gemmiparus is not known to occur on Bureau of Land Management (BLM) land, and therefore it is not listed on the Colorado BLM sensitive species list (U.S. Bureau of Land Management 2000).

Heritage program ranks

Natural Heritage Programs collect information about the biological diversity of their respective states and maintain databases of plant species of concern. The Global Heritage status rank for *Mimulus gemmiparus* is G1 (critically imperiled globally), and within USFS Region 2, the Colorado NHP status rank for this species is S1 (critically imperiled in state) (D. Anderson personal communication 2003). This species was previously ranked as imperiled (G2, S2), but these rankings were updated to reflect the small, geographically isolated populations and the high vulnerability of *M. gemmiparus* (D. Anderson personal communication 2003). As of September 2003, the NatureServe Web site listed this species as G2/S2 but those rankings were to be updated shortly (D. Anderson personal communication 2003, NatureServe 2003).

Mimulus gemmiparus is currently known from eight occurrences in Colorado (Colorado Natural Heritage Program 2003). This species is not known to occur in the other states within USFS Region 2 (i.e., Kansas, Nebraska, South Dakota, or Wyoming) and is thus not currently listed or ranked in those states (Kansas Natural Heritage Inventory 2000, Nebraska Natural Heritage Program 2001, Fertig and Heidel 2002, South Dakota Natural Heritage Program 2002).

Existing Regulatory Mechanisms, Management Plans, and Conservation Practices

Existing laws and regulations seem inadequate to conserve *Mimulus gemmiparus* over the long term. Although this species has been identified as a species of special concern, there are few regulatory mechanisms at the federal or state level to ensure its continued existence. This section details regulatory mechanisms, management plans, and conservation strategies that currently exist for *M. gemmiparus*.

Known populations of *Mimulus gemmiparus* occur in a variety of land ownership and management contexts, including two USFS Region 2 National

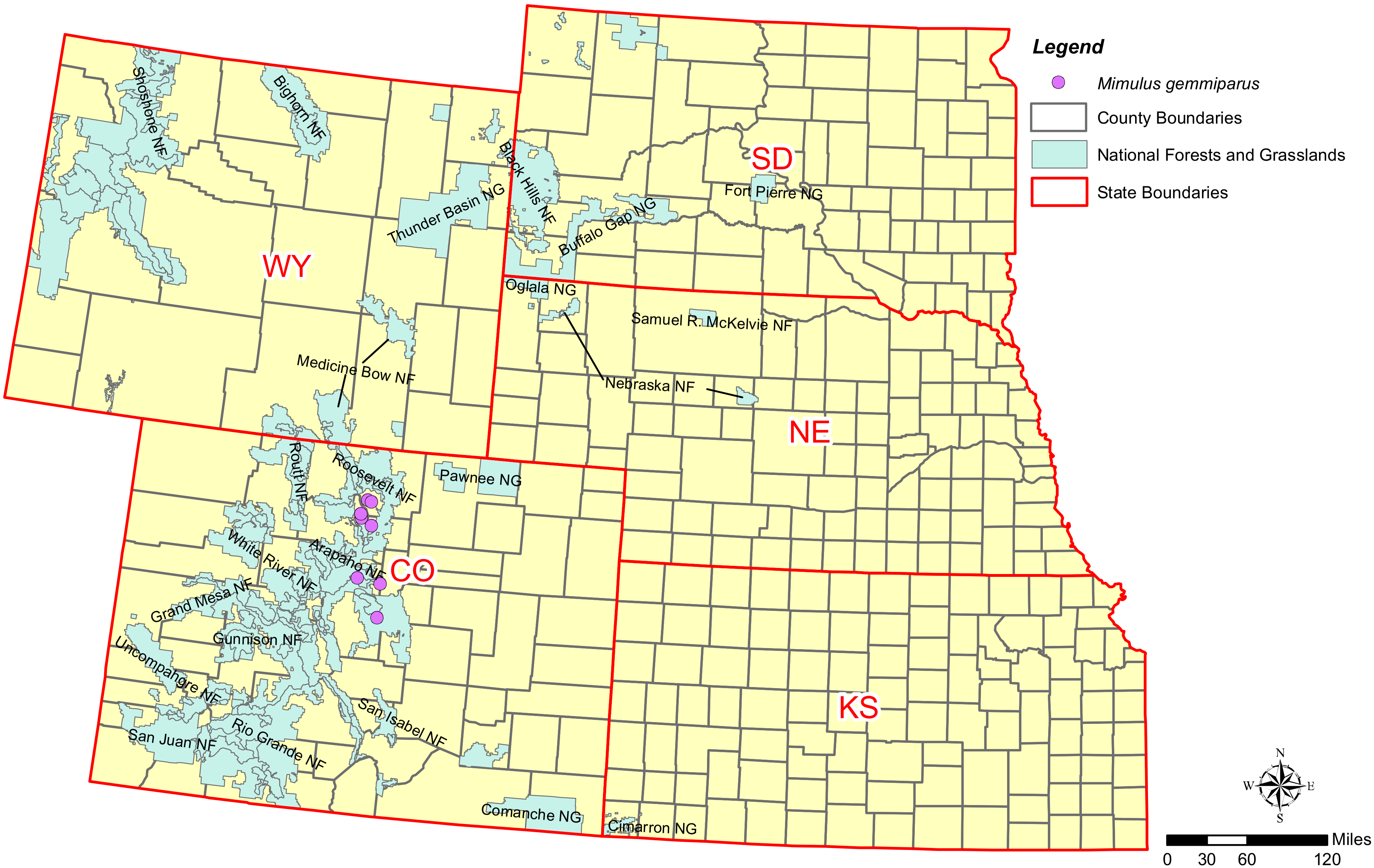

Figure 1. Map of U.S. Forest Service Region 2 illustrating distribution of eight *Mimulus gemmiparus* occurrences in Boulder, Clear Creek, Grand, Jefferson, and Larimer counties, Colorado. Each occurrence may include one to several populations. Refer to document for abundance and distribution information. Source: Colorado Natural Heritage Program, Fort Collins, Colorado (2003).

Forests in Colorado (USFS Pike-San Isabel National Forest, USFS Arapahoe-Roosevelt National Forest), National Park Service (NPS) lands (Rocky Mountain National Park), and Colorado Division of Parks and Recreation lands (Staunton State Park).

At the federal level, there are no specific regulatory mechanisms or conservation strategies currently established for *Mimulus gemmiparus*. This species was formerly considered a USFWS Category 2 plant (U.S. Fish and Wildlife Service 1980), but this category no longer exists (U.S. Fish and Wildlife Service 1996). Therefore this species is not currently listed under the ESA. *Mimulus gemmiparus* is designated as a USFS Region 2 sensitive species. As a result, *M. gemmiparus* may obtain some protection under various conservation strategies designed to protect plants and animals within federal lands, such as those discussed in the following sentences. The National Environmental Policy Act (U.S. Congress 1982) requires an assessment to evaluate the impacts of any federal projects to the environment. U.S. Forest Service policies require a Biological Evaluation to assess project impacts to sensitive species (U.S. Forest Service 1995). U.S. Forest Service travel management plans may protect rare species by restricting vehicle use to established roads only (U.S. Forest Service/Bureau of Land Management 2000), and wilderness areas have restrictions on motorized travel (Office of the Secretary of the Interior 1964). In addition, the NPS prohibits the collection of any native plants without a permit (U.S. National Park Service 2002a) and the USFS prohibits the collection of sensitive plants without a permit (U.S. Forest Service 1995).

The presence of *Mimulus gemmiparus* was considered during several recent impact assessments, including an environmental impact statement for proposed improvements on Guanella Pass Road on USFS Pike-San Isabel National Forest (Federal Highway Administration 1999, 2002), an environmental assessment of relocation of Twin Owls and Gem Lake Trailheads in Rocky Mountain National Park (U.S. National Park Service 2002b), and a pre-development field survey for Staunton State Park (Spackman and Anderson 1999). The *M. gemmiparus* population on Guanella Pass Road is located on a cliff adjacent to the road. Potential damage to the cliff habitat and detrimental impact to this species would be avoided by using retaining walls to protect cliffs during blasting and excavation (Federal Highway Administration 1999, 2002). As of August 2002, author W. Jennings noted that the proposed road improvement work had not been started, and the cliff habitat had not been visibly changed or damaged by work on buried utilities lines. *Mimulus gemmiparus* was not found on lands that will be directly affected by the Twin Owls and Gem Lake Trailhead relocations, but the area encompasses suitable habitat for this species and future surveys will be conducted if current land management changes (U.S. National Park Service 2002b). Staunton State Park is not currently open to the public, and Colorado Division of Parks and Recreation is developing a master plan to address recreation and resource management needs (Colorado Mountain Club 1999). The Colorado NHP performed a field survey of the park to inventory plant resources and identified the location of a *M. gemmiparus* population (Spackman and Anderson 1999). As a result, park managers will consider the presence of this species when creating land use plans (D. Anderson personal communication 2003).

The Colorado NHP has classified this species as a critically imperiled (S1) species of concern due to its regional endemic status and small populations (**Table 1**). Natural Heritage Program databases draw attention to species potentially requiring conservation strategies for future success. However, these lists are not associated with specific legal constraints, such as limits to plant harvesting or damage to habitats supporting these plants. The Colorado NHP maintains occurrence records for *M. gemmiparus*, which include repeated observations of individual populations (Colorado Natural Heritage Program 2003), and that information is presented in this report. These data often lack detailed demographic or abundance information, especially for historical records. This species assessment report also presents recent observations of *M. gemmiparus* populations, although those observations have not yet been submitted and added to the Colorado NHP database (D. Anderson personal communication 2003). For example, D. Steingraeber and P. Beardsley recently observed five of the eight populations in August and September 2003 while sampling propagules for genetic research (D. Steingraeber personal communication 2003). In addition, the NPS is currently working with the Denver Botanic Gardens to inventory the status and abundance of rare species in Rocky Mountain National Park, and the available preliminary results concerning *M. gemmiparus* (J. Connor personal communication 2002, 2003) are also presented in this report. We have also included personal communications from forest botanists in the USFS Pike-San Isabel National Forest regarding recent surveys of *M. gemmiparus* populations potentially impacted by wildfires in 2002 (B. Madsen personal communication 2002, S. Olsen personal communication 2003).

Biology and Ecology

Classification and description

Systematics and synonymy

Mimulus gemmiparus W.A. Weber is a member of the genus *Mimulus* within the tribe Mimuleae of the family Scrophulariaceae (Figwort or Snapdragon Family), order Scrophulariales, and group Dicotyledonae (dicots) of phylum Anthophyta (flowering plants) (Weber 1972, NatureServe 2003, U.S. Department of Agriculture and Natural Resources Conservation Service 2003). With over 100 species, *Mimulus* is one of the largest and most variable genera of the Scrophulariaceae in North America (Grant 1924, Zomlefer 1994, U.S. Department of Agriculture and Natural Resources Conservation Service 2003). Recently, researchers have extensively revised the phylogyny of the family Scrophulariaceae based on molecular and morphological work and have proposed placing the entire genus *Mimulus* into the family Phrymaceae (Beardsley 2002, Beardsley and Olmstead 2002, P. Beardsley personal communication 2003).

Grant produced a monograph of Scrophulariaceae in 1924 and other researchers have contributed to the body of knowledge about the taxonomy and biology of *Mimulus* species since then (Grant 1924, Vickery 1978, Sutherland and Vickery 1988, Sutherland and Vickery 1993, Willis 1993, Karron et al. 1995, Beardsley 1997, Moody et al. 1999, Vickery 1999, Beardsley 2002, Beardsley and Olmstead 2002, Carr and Eubanks 2002). The phylogeny of all *Mimulus* species in western North America based on molecular and morphological evidence was the subject of recent dissertation work by P. Beardsley (Beardsley 2002, P. Beardsley personal communication 2002). Although previous work has suggested that *M. gemmiparus* may be related to *M. glabratus*, *M. guttatus*, or *M. alsinoides* (Weber 1972, Moody et al. 1999, Beardsley 1997, P. Beardsley personal communication 2003), current work by P. Beardsley et al. (in press) emphasizes that *M. gemmiparus* is not closely related to any extant *Mimulus* species (P. Beardsley personal communication 2003). *Mimulus gemmiparus* is different from all other *Mimulus* species, and perhaps unique within Holarctic flora, because it produces asexual propagules within petiolar sacs on the leaves (Weber 1972, P. Beardsley personal communication 2003). Moody et al. (1999) analyzed the morphological development of the asexual propagules in *M. gemmiparus* and concluded that this unique reproductive structure could be analogous to the proximal meristem (axillary shoot) of *M. guttatus*, with some novel evolutionary features.

This species assessment treats this species as *Mimulus gemmiparus* W.A. Weber as presented in the PLANTS database (U.S. Department of Agriculture and Natural Resources Conservation Service 2003), Integrated Taxonomic Information System (Integrated Taxonomic Information System 2003), NatureServe database (NatureServe 2003), and Colorado NHP records (Colorado Natural Heritage Program 2003). Common names for *M. gemmiparus* include Rocky Mountain monkeyflower, Weber monkeyflower, and Weber's monkeyflower, and there are no known synonyms (NatureServe 2003, U.S. Department of Agriculture and Natural Resources Conservation Service 2003). *Mimulus gemmiparus* specimens, including the holotype specimen, are housed at the University of Colorado Herbarium, Boulder, CO, and additional specimens are housed at the Kathryn Kalmback Herbarium, Denver, CO.

History of species

Mimulus gemmiparus was discovered by Ruth Ashton Nelson in 1950 and her specimens were housed in the herbarium for over 20 years before William A. Weber officially described it in 1972 (Weber 1972, Colorado Native Plant Society 1989). R.A. Nelson collected the vegetative propagules of this species and experimented with germinating them. M. Douglass also observed this monkeyflower and provided specimens to R.K. Vickery, who performed cytological analyses (Weber 1972). In 1972, this species was only known from three locations in Rocky Mountain National Park. Since 1992, five more occurrences have been located, both inside and outside the park (Colorado Natural Heritage Program 2003). This species was designated as Category 2 by the USFWS in 1980 based on a recommendation from the Smithsonian Institution (Smithsonian Institution 1978). However, this category no longer exists (U.S. Fish and Wildlife Service 1996), and so this species is not currently listed under the ESA.

There are several recent studies on the biology and ecology of *Mimulus gemmiparus*. Some preliminary studies on the biology and habitat characteristics of *M. gemmiparus* were performed by M. Beardsley (1997) in association with D. Steingraeber at Colorado State University. Moody et al. (1999) studied the developmental origin of the vegetative propagules produced by this species. D. Steingraeber is also continuing his work with *M. gemmiparus* through propagation of the species in the greenhouse and studies of genetic variation between and among populations in cooperation with P. Beardsley of Colorado College (D. Steingraeber personal communication 2003).

Morphological characteristics

Many members of the family Scrophulariaceae (or Phrymaceae) are characterized by colorful, zygomorphic flowers that often take the form of a sympetalous tube with petals flaring outward at the end. In *Mimulus* species, the upper petals create a two-lobed "lip" while the lower petals form a three-lobed, down-turned lip sometimes with a colorful, hairy, or ridged palate (Great Plains Flora Association 1986).

Mimulus gemmiparus is a small, annual herb from 1 to 10 centimeters (cm) tall with a glabrous, somewhat succulent, usually unbranched stem (**Figure 2**). The leaves are opposite, entire, ovate, glabrous, and up to 10 millimeters (mm) long and 7 mm wide. The petioles are 2 to 3 mm long and are laterally compressed with a small pouch that contains a lens-shaped propagule functioning in asexual reproduction. Thus, the plant is a series of repeated metamers that are comprised of a length of stem and a pair of opposite leaves with bulbils formed in the petiolar sac. All the leaves produce bulbils except the first (lowermost) pair because these leaves were preformed in the originating bulbil (Weber 1972). The leaves at the top of the plant produce the largest propagules and the most reduced leaves (Weber 1972).

The yellow, solitary, bilabiate flowers are terminal or axillary, 4 to 5 mm long, with spreading lobes and an open throat. Variation in palate spotting is common in the genus *Mimulus* (P. Beardsley personal communication 2003) and observations of *M. gemmiparus* herbarium specimens indicate that the flowers exhibit a range of variations in pubescence, palatal ridges, and red spots. *Mimulus gemmiparus* infrequently flowers in nature (Peterson and Harmon 1983, Spackman et al. 1997, Colorado Natural Heritage Program 2003) but readily flowers in the greenhouse under appropriate conditions (Beardsley 1997).

Mimulus gemmiparus can be easily distinguished in the field from other *Mimulus* species by its unique mode of vegetative reproduction (Spackman et al. 1997). The usual lack of flowers and small stature of this species makes it extremely inconspicuous (Colorado Natural Heritage Program 2003). *Mimulus gemmiparus* shares floral similarities with both *M. guttatus* and *M. glabratus* (Beardsley 1997, Colorado Natural Heritage Program 2003), but is not closely related to either (P. Beardsley personal communication 2003).

A technical description of this species is presented in Weber (1972). Photos and an illustration are available in the *Colorado Rare Plant Field Guide* (Spackman et al. 1997).

Distribution and abundance

Distribution

Mimulus gemmiparus is known only from Colorado (U.S. Department of Agriculture and Natural Resources Conservation Service 2003) (**Figure 1**, **Table 2**). This species has not been identified in Kansas, Nebraska, South Dakota, and Wyoming (Kansas Natural Heritage Inventory 2000, Nebraska Natural Heritage Program 2001, Fertig and Heidel 2002, South Dakota Natural Heritage Program 2002). **Figure 1** illustrates the distribution of *Mimulus gemmiparus* based on eight occurrences reported by the Colorado NHP (2002), and **Table 2** describes the land management and abundance of *M. gemmiparus* at those locations.

Specifically, *Mimulus gemmiparus* has been found within Clear Creek, Grand, Jefferson, Larimer, and Park counties. Of the eight known locations, two populations are in USFS Pike-San Isabel National Forest (Hankins Gulch in Lost Creek Wilderness area; Guanella Pass), one population is in USFS Arapahoe-Roosevelt National Forest (St. Vrain Canyon in Indian Peaks Wilderness area), four populations are located in Rocky Mountain National Park (East Inlet Trail, North Inlet Trail, Old Fall River Road, and Horseshoe Park alluvial fan), and one population is in Staunton State Park (Colorado Natural Heritage Program 2003) (**Table 2**). Thus, three of eight populations are on USFS lands, and two of those are within wilderness areas.

Abundance

The abundance estimates for *Mimulus gemmiparus* vary widely for several reasons. Because this species is an annual species, the abundance varies greatly from year to year depending on annual recruitment. The plants dry up at the end of the season, so abundance is drastically different depending on which month the population was observed. For example, the *M. gemmiparus* individuals at the Guanella Pass population dry up when the seeps dry seasonally or during drought (D. Steingraeber personal communication 2002, Colorado Natural Heritage Program 2003). In addition, the eight *M.*

A.

Photographs by William Jennings. Reprinted with permission from the photographer.

B.

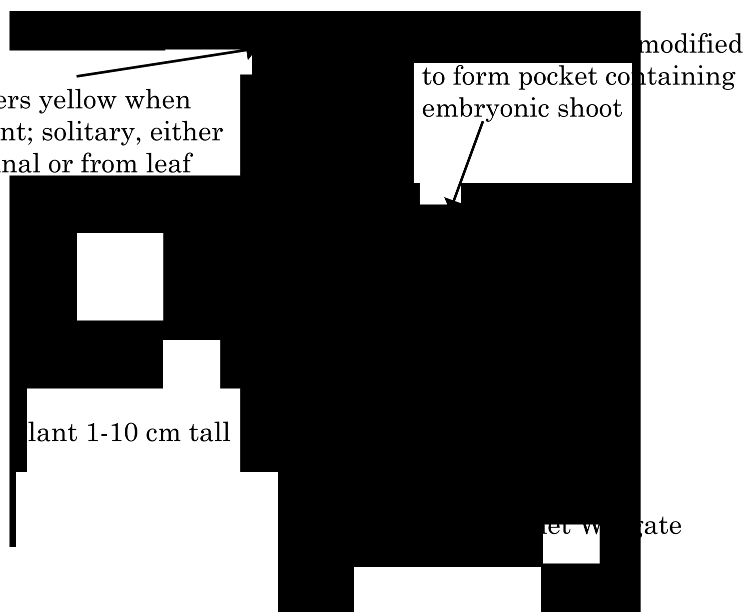

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Figure 2. *Mimulus gemmiparus* (A) photographs in its natural habitat at the Lawn Lake Flood alluvial fan in Horseshoe Park, Colorado, and (B) illustration of the vegetative and reproductive structures. The population of *M. gemmiparus* at Horseshoe Park has not been seen in recent years and it is possible that the habitat conditions at the alluvial fan are no longer suitable for this species (J. Connor pers. comm. 2003).

Table 2. Information on eight *Mimulus gemmiparus* occurrences in Colorado (USFS Region 2). Includes county, site name, date of recorded observations, estimated abundance, and land management context. Information is based on Colorado Natural Heritage Program 2003 element occurrence records, but observations from the 2003 field season are not yet included in the database. Source: Colorado Natural Heritage Program, Fort Collins, CO (2003).

County	Site Name	Date of Recorded Observations	Estimated Abundance	Management Area/Ownership
Boulder	St. Vrain Canyon	1998	several hundred	USFS Arapaho-Roosevelt National Forest (Indian Peaks Wilderness)
Clear Creek	Guanella Pass	1995	400 to 600	USFS Pike-San Isabel National Forest
Grand	North Inlet Trail	1950, 1992	200	Rocky Mountain National Park
	East Inlet Trail	1961, 1982	30	Rocky Mountain National Park
Jefferson	Staunton State Park	1992, 1999	600	Colorado Division of Parks and Recreation
	Hankins Gulch	1979, 1992	1000 to 1500; very small but dense population	USFS Pike-San Isabel National Forest (Lost Creek Wilderness)
Larimer	Horseshoe Park alluvial fan	1987, 1992	1 (1987), 300 (1992)	Rocky Mountain National Park
	Old Fall River Road	1970, 1980	3	Rocky Mountain National Park

gemmiparus populations are geographically isolated, differ in size, and are not consistently monitored. These factors, combined with differing estimate methods used by researchers, leads to varying abundance reports for the species as a whole. We present abundance records as documented in Colorado NHP records (**Table 2**) as well as observations by researchers during recent field visits in August and September 2003 (i.e., S. Olsen personal communication 2003, D. Steingraeber personal communication 2003).

In 1996, the total abundance of *Mimulus gemmiparus* was documented in the Colorado NHP database as 2,850 individuals (Colorado Natural Heritage Program 2003). The abundances of the eight different populations, as recorded in the Colorado NHP database and presented in **Table 2**, are 3, 30, 200, "several hundred", 300, 400 to 600, 600, and 1000 to 1500 (Colorado Natural Heritage Program 2003). Beardsley (1997) estimated the total population size of the Hankins Gulch population, the largest known population, as 114,180 individuals on June 12, 1993. He estimated 37,528 plants in that same population on July 23, 1993. In 2003, the Hankins Gulch population was observed by D. Steingraeber and B. Madsen and the abundance was estimated at several hundred to a few thousand plants (S. Olsen personal communication 2003, D. Steingraeber personal communication 2003). D. Steingraeber and P. Beardsley also visited the Guanella Pass population in August 2003 and observed several hundred plants at that location. P. Beardsley visited the St. Vrain Canyon, North Inlet Trail, and East Inlet Trail populations (D. Steingraeber personal communication 2003), but has not yet submitted abundance information to the Colorado NHP (D. Anderson personal communication 2003). The Staunton State Park and Old Fall River Road locations have not been surveyed in 2003 (D. Steingraeber personal communication 2003). The NPS is currently inventorying the status and abundance of rare species in Rocky Mountain National Park (J. Connor personal communication 2003). The available data for *M. gemmiparus* suggests that the Horseshoe Park alluvial fan population has been extirpated. P. Beardsley also re-visited the alluvial fan population in August 2003 and did not find any individuals (D. Steingraeber personal communication 2003). Similarly, *M. gemmiparus* individuals have not been observed at the Old Fall River Road population since 1980 (J. Connor personal communication 2003, D. Steingraeber personal communication 2003).

Large wildfires burned in the areas near two of the *Mimulus gemmiparus* populations (Hayman Fire in Hankins Gulch, Black Mountain Fire in Staunton State Park) in the summer of 2002 (U.S. Forest Service 2002a, U.S. Forest Service 2002b). As discussed above, D. Steingraeber and B. Madsen visited the Hankins Gulch population in August 2003 and discovered up to several thousand individuals (S. Olsen personal communication 2003, D. Steingraeber personal communication 2003).

The status of the Staunton State Park population is still not known (B. Madsen personal communication 2002, Steingraeber personal communication 2003).

Population trends

As discussed above, the abundance of the different *Mimulus gemmiparus* populations are likely to vary within a single season and between years, so determining population trends is difficult. For example, Beardsley (1997) measured the density and area of the Hankins Gulch population several times throughout one summer to assess fluctuations over one season. He found that significant temporal and spatial fluctuations occurred in the population. There have been not been any long-term studies to consistently document annual population trends for *M. gemmiparus* (Peterson and Harmon 1983, Colorado Natural Heritage Program 2003). *Mimulus gemmiparus* populations have been visited several times by different researchers throughout the years, but it is generally difficult to ascertain if the populations are increasing, decreasing, or constant.

The population of *Mimulus gemmiparus* on Guanella Pass seems to have fluctuated in population number over the past eight years, based on researcher observations. From 1995 to 1998, author William Jennings documented the presence of *M. gemmiparus* on Guanella Pass every year. From 2000 to 2003 (approximately), D. Steingraeber did not see any plants growing at Guanella Pass, perhaps as the result of drought conditions in those years (D. Steingraeber personal communication, 2002). In August 2003, D. Steingraeber and P. Beardsley observed several hundred individuals at that location (D. Steingraeber personal communication 2003).

In contrast, the population of *Mimulus gemmiparus* at the Horseshoe Park alluvial fan in Rocky Mountain National Park may be extirpated, based on observations through the years. The Long Lake flood occurred in 1982 and apparently created suitable conditions for *M. gemmiparus* on the extensive alluvial fan. The population recorded in 1987 consisted of over 300 plants in a 14 meter squared area (Colorado Natural Heritage Program 2003). It is possible that microsite conditions changed from 1982 to 2003 as a result of succession and recovery, and the location is no longer favorable for the growth of *M. gemmiparus* (J. Connor personal communication 2003). Only one plant was found in 1998 (J. Connor personal communication 2003), and no plants have been seen since 2000 (J. Connor personal communication 2003, D. Steingraeber personal communication 2003).

Thus, the current total abundance of *Mimulus gemmiparus* is unknown and environmental conditions (e.g., drought, fire, succession) make it even more difficult to predict if populations are increasing, decreasing, or remaining stable. Although the number of individuals in one *M. gemmiparus* population can be large, the geographic area occupied tends to be very small (M. Beardsley personal communication 2003). This can increase the susceptibility of a population to extirpation.

Habitat characteristics

Mimulus gemmiparus grows in moist, seepy areas, usually on ledges or under overhangs at the base of cliffs. This monkeyflower is a montane to subalpine species, and reported elevations for this species range from 2560 to 3390 m (8,400 to 11,120 ft) (**Table 3**).

Microhabitat descriptions indicate that *Mimulus gemmiparus* forms colonies in the protection of rocky (granite, biotite schist) outcrops, overhanging surfaces of boulders, or on alluvial deposits and amongst roots of dead trees (Colorado Natural Heritage Program 2003) (**Table 3**). *Mimulus gemmiparus* requires very moist conditions and thus grows near seeps, springs, or wet banks, often with visibly dripping water or waterfalls. One occurrence record noted the presence of dried algae on the surface of the soil, indicating that the soils were wet at least part of the year (Colorado Natural Heritage Program 2003). The soils at these locations are generally thin (Colorado Natural Heritage Program 2003). The microhabitat descriptions of seven locations include: crevices and pockets on a granite outcrop (Guanella Pass); under overhang on granite outcrop (Hankins Gulch); under small overhang next to trail (North Inlet Trail); rocky slope (East Inlet Trail); small overhang at base of large cliff (Staunton State Park); cliff ledges and talus on glacially carved rock cliffs (St. Vrain Canyon); and gently sloping granite slopes in the protection of the overhanging rounded surfaces of erratic boulders (Old Fall River Road).

The population of *Mimulus gemmiparus* located on the Lawn Lake Flood alluvial fan in Horseshoe Park of Rocky Mountain National Park seems to occupy different habitat than the other populations. This disturbed open area lacks the presence of a major cliff face or overhang, and the subpopulation clusters are spread out over a greater area (Beardsley 1997). The monkeyflower on the alluvial fan grows in clumps amongst the roots of dead trees (Colorado Natural Heritage Program 2003), and the substrate is deep, unsorted sand and gravel. This alluvial fan site is more

Table 3. Habitat information for eight *Mimulus gemmiparus* occurrences in Colorado. Includes county, site name, elevation range, general habitat description, associated plant species, slope/aspect, substrate, and shading information. Source: Colorado Natural Heritage Program, Fort Collins, CO (2003).

County	Site Name	Elevation Range (m)	General Habitat Description	Associated Plant Species	Slope/Aspect	Substrate	Shading
Boulder	St. Vrain Canyon	3,085 to 3,127	Cliff ledges on glacially carved rock cliffs	*Aquilegia saximontana*	Southwest aspect	Biotile shist	Partial shade from rock overhangs
Clear Creek	Guanella Pass	3,390	At lowerslope of rock outcrop; near seeps with yearround moisture	0 percent cover by trees, shrubs, and graminoids; 1 percent cover by forbs	West aspect 90 percent slope	Granite	Partial shade to shaded
Grand	North Inlet Trail	2,743	Rock outcrop with bare soil next to trail; under a small overhang	Not available (NA)	Not available (NA)	Granite	Not available (NA)
	East Inlet Trail	2,957	Rocky slope	NA	NA	Not available (NA)	NA
Jefferson	Staunton State Park	3,048	Seep and waterfall overhang at base of 200 feet granitic cliff; small overhang with hanging garden at base of large cliff; plants growing alone in pockets of soil on granite adjacent to moss-covered seeps; in and among moss in moist seep; growing in cracks in moss; surrounding hillside is shrub/meadow community (*Jamesia americana*, *Rubus deliciosus*, *Holodiscus* spp., *Ribes* spp.)	Mat-like moss, small liverwort, algae; *Cerastium* spp., *Dodecatheon pulchellum*; *Jamesia americana* at base of cliff; *Mimulus floribundus* in adjacent overhangs	Southwest aspect steep slope, at base of cliff	Granite; dry granite gravel loam which is evidently wet during part of year	Shaded by cliff
	Hankins Gulch	2,560	Under an overhang on granite outcrop; soil mostly bare under rock; directly next to creek and path; moist, thin soil is well shaded beneath *Pseudotsuga* spp. canopy	No other plant species growing within the mat, limited number of plant species growing under overhang; mosses, *Pseudotsuga menziesii*	Southfacing aspect level slope	Beryllium-bearing granite poryphry	Well-shaded beneath tree canopy
Larimer	Horseshoe Park alluvial fan	2,609	Alluvial deposits from a large floodplain as a result of a catastrophic event; wet rocky area with numerous small streamlets meandering through the flood area; atypical habitat that will probably succeed into unsuitable habitat; plants are on bare soil in and among roots bases of dead trees; essentially in a hole between roots with similar conditions to rock overhangs (organic soil accumulation, constantly moist, shaded); on edge of rivulet	Dead *Pinus contorta*, *Mimulus guttatus*, *Epilobium* spp., *Salix* spp., Algae	All aspects level slope	Deep, unsorted, damp coarse sand; sand, gravel, and boulders	Shaded
	Old Fall River Road	2,914 to 3,133	On seeping granite slopes; forming colonies in the protection of the overhanging rounded surfaces of erratic boulders; open sites in *Picea* - *Abies* - *Populus* communities	*Mimulus rubellus*, *Mimulus guttatus*, *Picea* spp., *Abies* spp., *Populus* spp.	Gently sloping	NA	NA

"horizontal" (alluvial deposits on a large floodplain) compared to the other locations with *M. gemmiparus* that tend to have steeper, more "vertical" terrains (cliff faces and outcrops). However, the microhabitats with *M. gemmiparus* individuals at this alluvial site somewhat resemble a cliff habitat (P. Beardsley personal communication 2003). Habitat variation may demonstrate the ability of *M. gemmiparus* to colonize a range of areas and/or reflect our inability to pinpoint the habitat needs of this species.

Mimulus gemmiparus occurs within *Picea* spp.-*Abies* spp.-*Populus* spp. (spruce-fir-aspen) communities often with other *Mimulus* species (e.g., *M. floribundus*, *M. guttatus*, *M. rubellus*) nearby (Weber 1972, Colorado Natural Heritage Program 2003) (**Table 3**). The ground in the vicinity of the *M. gemmiparus* clusters is generally devoid of other vegetation (Beardsley 1997, D. Steingraeber personal communication 2002, Colorado Natural Heritage Program 2003, J. Connor personal communication 2003). Species occurring in the habitat areas may include *Pseudotsuga menziesii* (Douglas-fir), *Cerastium* spp. (chickweed), *Jamesia americana* (fivepetal cliffbush), *Dodecatheon* spp. (shootingstar), *Aquilegia saximontana* (Rocky Mountain blue columbine), *Epilobium* spp. (fireweed), *Salix* spp. (willow), *Campanula rotundifolia* (bluebell bellflower), *Artemisia ludoviciana* (white sagebrush), *Packera plattensis* (prairie groundsel), *Erigeron subtrinervis* (threenerve fleabane), *Rhodiola integrifolia* (ledge stonecrop), *Oreochrysum parryi* (Parry's goldenrod), *Brickellia microphylla* (littleleaf brickellbush), *Amelanchier utahensis* (Utah serviceberry), and *Montia chamissoi* (water minerslettuce). Mosses, liverworts, algae, and ferns can also inhabit these wet areas. The lack of other vegetation around *M. gemmiparus* suggests that this monkeyflower is a poor interspecific competitor (M. Beardsley personal communication 2003, P. Beardsley personal communication 2003).

Reproductive biology and autecology

Mimulus gemmiparus exhibits a unique form of asexual reproduction that largely influences the autecology, life history, and demography of this species. Extensive research and greenhouse experiments were performed with *M. gemmiparus* by Beardsley (1997) to document the extent of asexual and sexual reproduction, create a life history model, study survival and germinability of asexual propagules, and determine the effect of environmental conditions on the growth and reproduction of adult plants. The following sections summarize the overall findings of M. Beardsley's thesis work with regard to reproductive biology and demography without replicating the in-depth analyses and discussions here. Refer directly to Beardsley (1997) for a description of his methodology, numerical results, statistical analyses, and thorough discussions. Detailed descriptions, diagrams, and photographs of the asexual and sexual reproductive structures are available in Weber (1972) and Beardsley (1997). A developmental analysis of the morphological origin of the propagules is presented in Moody et al. (1999).

Reproduction

Mimulus gemmiparus exhibits a highly unique form of asexual reproduction not seen within the *Mimulus* genus or in any other Holarctic species (Weber 1972, Beardsley 1997). *Mimulus gemmiparus* plants produce propagules comprised of "bulbils" (or "gemmae" [Weber 1972]) within deep sacs developed from the petioles of all leaves, except the first pair of preformed leaves. The bulbils have all the components needed to develop into a new individual, including a shoot axis and rudimentary leaves and roots. The bulbil is technically not an embryo, but it is morphologically and functionally analagous to one. When the adult plant senesces in early July to early August, the leaf blades wither and the petiole abscises at the stem to disperse the propagules, which consist of the petiolar sac with bulbil inside. The bulbils, much like sexually produced seeds, overwinter and germinate in the spring to grow into new adult plants (Weber 1972, Beardsley 1997).

In naturally occurring populations, *Mimulus gemmiparus* infrequently flowers (Weber 1972, Colorado Natural Heritage Program 2003). The yellow flowers, if produced, occur in July (Colorado Natural Heritage Program 2003). The presence of flowers has been recorded at the Horseshoe Park alluvial fan, East Inlet Trail, North Inlet Trail, Old Fall River Road, and Guanella Pass populations (Colorado Natural Heritage Program 2003). In most cases, only one flowering individual was reported; the largest number of flowering individuals (29) was recorded at the East Inlet Trail location in 1982. Flowers have not been reported from Hankins Gulch, Staunton State Park, or the St. Vrain Canyon populations (Colorado Natural Heritage Program 2003). Many capsules, or fruits, were observed at East Inlet Trail and Old Fall River Road locations, but there were no seeds (Weber 1972, Colorado Natural Heritage Program 2003).

Several authors (Weber 1972, O'Kane 1988, Colorado Native Plant Society 1989) suggested that *Mimulus gemmiparus* is incapable of reproducing by seeds because the pollen is sterile, thus making this species an obligate asexual annual species. However, P. Beardsley (personal communication 2003) stained pollen from this species and discovered that greater than 95 percent of the pollen grains were viable. In addition, M. Beardsley (1997) grew *M. gemmiparus* in the greenhouse, cross-pollinated flowers, collected seeds, germinated the seeds, and produced a new generation of adult plants, which were capable of producing flowers and seeds. Beardsley (1997) experimented with a variety of conditions in the greenhouse to produce flowers and found that plants in most conditions senesced and died without ever flowering. Flowers were successfully produced on plants growing in partially shaded conditions, during a period with approximately 16 hours light and 8 hours dark, with daytime high temperatures of 27 °C, nighttime low temperatures about 15° to 18 °C, and consistently moist soil conditions. The environmental conditions necessary to induce flowering in natural populations are unknown, but they may be related to moisture conditions (M. Beardsley personal communication 2003).

The dependence of natural *Mimulus gemmiparus* populations on asexual reproduction has important ramifications for the life history and long-term viability of this species. Beardsley (1997, pg. 219) summed up the reproduction of *M. gemmiparus*: "In these populations, it is either vegetative reproduction by bulbils or no reproduction at all!"

Life history and strategy

Mimulus gemmiparus is an annual species, so adult plants germinate, grow, reproduce, and die in one growing season (Beardsley 1997). The life history of *M. gemmiparus*, including both asexual and sexual circuits, is detailed in **Figure 3**. After germination, young plants of this monkeyflower increase their biomass and produce leaves, including bulbils within the petioles. When the leaves die and abscise, the bulbils become separated from the adult plant and disperse (Beardsley 1997). Flowers and seeds are produced only by adults that have reached a later age/stage of development. Based on sexual reproduction alone, the life history of *M. gemmiparus* would be considered a monocarpic (semelparous) annual where producing offspring is a one-time event during the terminal stage of the plant's life. Considering the role of asexual reproduction for this species, though, Beardsley (1997) described the life history of *M. gemmiparus* as an indeterminate (iteroparous) annual where adults have the ability to produce offspring throughout their lifetime. Thus, the production of asexual propagules by *M. gemmiparus* increases its reproductive output and radically influences its life history (Beardsley 1997). An adult plant can produce offspring starting from a young age/stage and continue producing propagules throughout its life.

Based on vegetation strategies described by Grime (1979), *Mimulus gemmiparus* can probably be considered a ruderal, or r-selected, species. Ruderal species can exploit low stress, high disturbance environments by minimizing vegetative growth and maximizing reproductive output (Grime 1979, Barbour et al. 1987). *Mimulus gemmiparus* is a short-lived, small herb with the potential to maximize reproductive output by developing bulbils concurrent with leaf development. Although Grime (1979) referred specifically to flower and seed production for ruderal species, the concepts can be expanded to include the functionally similar bulbils of *M. gemmiparus*. In addition, *M. gemmiparus* exhibited its ability to colonize disturbed habitats by its establishment on the Lawn Lake Flood alluvial fan (Keigley 1993). The frequency or extent of disturbance at other locations is unknown.

Pollinators and pollination ecology

The appearance of flowers in natural populations is so infrequent that pollination biology and specific pollination mechanisms for *Mimulus gemmiparus* have not been studied. Pollination studies of other species within the genus *Mimulus* found that hummingbirds pollinated flowers with the most reflexed, tubular flowers, regardless of color, while bumblebees pollinated the species with pink, lavender, or yellow flowers (Sutherland and Vickery 1993). The flower of *M. gemmiparus* is structurally similar to many yellow, bee-pollinated species in *Mimulus* (P. Beardsley personal communication 2003).

Beardsley (1997) performed artificial pollination in the greenhouse by brushing dehiscent anthers with a cotton swab and inserting the swab into open flowers. This process presumably facilitated both cross-pollination and self-pollination. The stigma of the greenhouse flowers was spatulate in shape and positioned so that it "flapped" in front of the anthers (Beardsley 1997). Pollination is not required for the production of bulbils.

Dispersal mechanisms

The asexually produced propagule of *Mimulus gemmiparus* is a unit comprised of the bulbil encased in the petiolar sac (Weber 1972, Beardsley 1997). Dispersal of the propagules usually occurs during plant senescence. The leaf blades wither, and when the petiole abscises from the drying stem, the entire

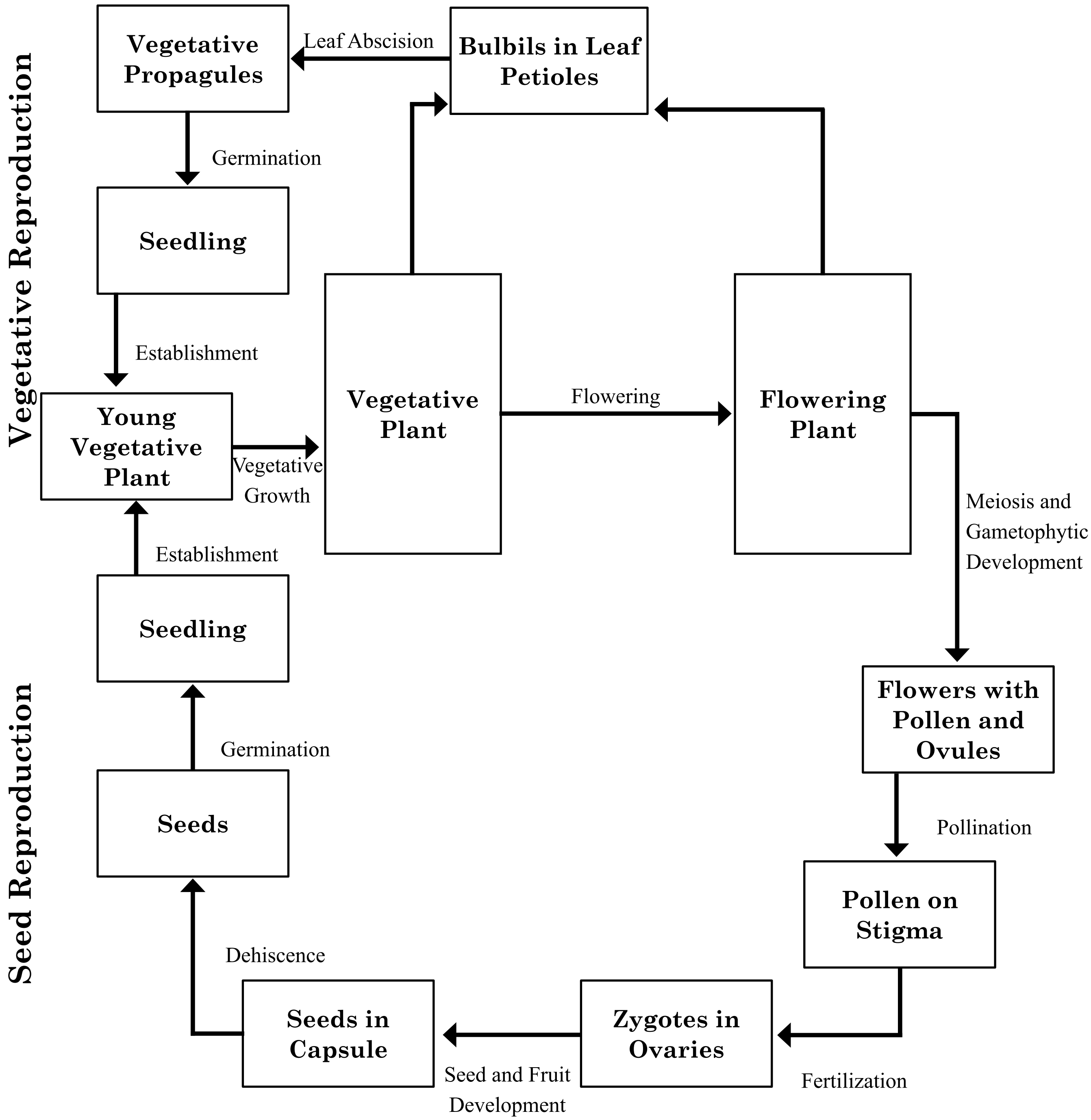

Figure 3. Schematic representation of the hypothesized life history of *Mimulus gemmiparus*, including both asexual and sexual reproductive circuits. Asexual reproduction is the predominant form of reproduction in natural populations. Rates of germination, growth, propagule production, and other demographic parameters are unknown. Figure adapted from Beardsley (1997).

propagule dissociates (Weber 1972). When the adult plant is brushed by a passing object or blown by the wind, propagules are "catapulted" by the dry, springy stem up to 30 cm or more (Beardsley 1997, M. Beardsley personal communication 2003). The petiolar sac probably plays a role in dispersal as well as protecting the bulbil inside (Beardsley 1997). Because there is hollow space around the bulbil within the sac, the propagule is relatively light in density and buoyant. Thus, the propagules could be dispersed by floating downslope in seepage water or being blown by the wind (Weber 1972, Beardsley 1997). Weber (1972) reported that *M. gemmiparus* propagules "float down-slope in seepage water and tend to collect in drifts in sites suitable for germination." Some of the propagules have parts of the leaf blade still attached, which could increase wind resistance and thus promote wind dispersal (Beardsley 1997). When the plant dries out, the stem can break off at the surface and the entire plant is also susceptible to wind dispersal (D. Steingraeber personal communication 2002). Wind and water are the most likely dispersal mechanisms for *M. gemmiparus* (M. Beardsley personal communication 2003).

Beardsley (1997) also hypothesized that animals could function in dispersal because the propagules are small, light, and have a rough surface. Apparently, the propagules stick to clothing with some ease. The population of *Mimulus gemmiparus* found at the Horseshoe Park alluvial fan may have colonized the area after being dispersed by water from an upstream location (Keigley 1993). Theoretically, one propagule could start a population because reproduction occurs through asexual propagation (Beardsley 1997).

When Beardsley (1997) facilitated sexual reproduction in the greenhouse, the plants produced seeds in capsules. The capsules dehisced longitudinally to release seeds. Presumably, dispersal of these small seeds, approximately 0.5 mm in length and 0.3 mm in width, could occur by gravity, wind, or water, as observed for other *Mimulus* species, like *M. guttatus* (P. Beardsley personal communication 2003).

Seed viability and germination requirements

Viability of seeds obtained from greenhouse populations of *Mimulus gemmiparus* was approximately 25 percent germination success on moist potting soil in the greenhouse (Beardsley 1997). The precise germination requirements of seeds are unknown, but may be similar to the requirements of the asexually produced propagules.

Because *Mimulus gemmiparus* populations are dependent on asexual reproduction for replacement of populations every year, the overwintering and germination success of bulbils is critical. Beardsley (1997) performed greenhouse experiments testing the responses of bulbils to desiccation and temperature stress and the germination success of bulbils under different conditions of substrate, temperature, and light. In natural habitats, bulbils are typically exposed to cold temperatures and dry conditions. Air temperatures in the field can be below -30 °C and the microhabitats under cliff and boulder overhangs often lack snow cover and the insulating properties of the snow (Beardsley 1997). The results of Beardsley's experiments indicated that propagules are fairly resistant to desiccation with their protective petiolar coat while exposed bulbils, those that lack a petiolar coat, are more susceptible to drying out. In addition, propagules can tolerate temperatures down to -25 °C although germination occurs only at temperatures above +5 °C. Germination was affected by water availability, temperature, substrate characteristics (e.g., depth, water holding capacity), size of the bulbil, and presence of the petiolar coat (Beardsley 1997).

The longevity of *Mimulus gemmiparus* propagules or extent of a propagule "bank" in the soil are unknown. D. Steingraeber (personal communication 2003) stored propagules on senesced plants at room temperature in the greenhouse and found that fairly modest germination occurred after one to two years of storage and low to no germination occurred after three years of storage. However, the longevity of propagules produced and stored in warm, stable greenhouse conditions provides little insight into the status of a propagule bank in field conditions. Because soils are generally fairly thin in typical *M. gemmiparus* habitat and the propagules need to maintain a high moisture content, it is unlikely that a significant soil bank of propagules exists. The longevity of propagules, the extent of a propagule bank, and the factors affecting germination rates in *M. gemmiparus* under field conditions are important research questions that have not yet been addressed (D. Steingraeber personal communication 2003).

Phenotypic plasticity

Phenotypic plasticity is demonstrated when members of a species vary in morphology, phenology, or other attributes, with change in light intensity, latitude, elevation, or other macrosite or microsite characteristics. Based on experiments of genetically identical adult *Mimulus gemmiparus* plants growing in different environmental conditions (light or nutrient deficient), Beardsley (1997) concluded that phenotypic plasticity is an important component of the *M. gemmiparus* life history. In optimal conditions (adequate water, light, nutrients), the plants grew strong and tall, produced many bulbils, and also reached a flowering phase. The reproductive potential of these plants was very high for both asexual and sexual reproduction. In nutrient deficient conditions, the plants were small and did not reach a flowering phase, but they allocated resources to the early production of bulbils. Plants deprived of light grew tall, thin, and produced no bulbils. Beardsley (1997) hypothesized that these plants were "foraging" for light and could perhaps produce bulbils if they grew into an area with more light. Thus, one genotype was capable of several strategies to cope with different environmental conditions. The phenotypic plasticity of this species to allocate resources to asexually produced propagules despite resource-limited conditions may increase its long-term viability in harsh or variable conditions (Beardsley 1997). This phenotypic plasticity was also observed in the natural population of *M. gemmiparus* at Hankins Gulch (Beardsley 1997). At this location, the phenology and morphology of the plants differed spatially among the clusters of subpopulation groups probably as a result of microsite variation such as light availability and nearness to the water seep.

The production of bulbils with a variety of morphologies by *Mimulus gemmiparus* is also an illustration of phenotypic plasticity. In addition to the "normal" bulbils produced in the petiolar sacs of the leaves, Beardsley (1997) also observed the growth of "free" bulbils in the greenhouse. These naked bulbils grew directly from axillary buds and looked identical to the petiolar bulbils but were not surrounded by any petiolar tissue. Plants produced free bulbils in the greenhouse during periods of dryness, especially when the soil dried rapidly. When the soil was remoistened, those same plants stopped producing free bulbils and instead produced only petiolar bulbils. Both types of bulbils matured, were shed from the parent plant, and germinated successfully in the greenhouse. The free bulbils were never observed in natural populations (Beardsley 1997). Weber (1972) also described another variation in bulbil production at the Old Fall River Road site, where "abortive lateral shoots from the leaf-axils may bear minute leaves and saccate gemmiparous petioles." This form of axillary bulbil was also observed on herbarium specimens from the natural populations of Hankins Gulch and Staunton State Park. These specimens showed multiple bulbils with petiolar sacs arising from short axillary stalks. Thus, it appears that there are at least three variations of bulbils (non-axillary and petiolar; axillary and petiolar; axillary and "free") produced by *M. gemmiparus*. The axillary and non-axillary bulbils seem to be morphologically identical, but the axillary bulbils happen to be located on branch stems (i.e., derived from axillary meristem) (M. Beardsley personal communication 2003). The effects on longevity or germination success as a result of any differences in bulbil morphology have not been quantified.

Another example of phenotypic plasticity may be seen in the different flower phenotypes of *Mimulus gemmiparus*. Herbarium specimens of this species reflect a wide variation in flower markings, palatal folds, and pubescence. For example, the flowers from the North Inlet Trail location were nearly solid yellow with a few red dots in the throat, hairs, and subdued palatal folds. The flowers from the East Inlet Trail location had red spots on the corollas, palatal ridges, and a densely pubescent palate. Flowers described from the holotype population lacked red spots, hairs, or prominent ridges (Weber 1972). In addition, the flowers produced in greenhouse conditions had red-spotted, densely hairy throats with prominent ridges on the palate (Beardsley 1997). D. Steingraeber (personal communication 2002) also observed differences in flower color and morphology between the Hankins Gulch and Guanella Pass populations grown in the greenhouse. Future genetic and taxonomic work to identify differences between populations and closely related species is warranted (Beardsley 1997). D. Steingraeber and P. Beardsley are currently working to test genetic variability within and between different *M. gemmiparus* populations using amplified fragment-length polymorphism protocols (D. Steingraeber personal communication 2003).

Cryptic phases

Because *Mimulus gemmiparus* is an annual species, the only cryptic phases during the life cycle are the dormant propagules and seeds overwintering in or on the soil. The longevity of the propagules or seeds is unknown.

Mycorrhizal relationships

The existence of mycorrhizal relationships with *Mimulus gemmiparus* or other *Mimulus* species was not discussed in the literature.

Hybridization

There were no reported occurrences of hybridization with *Mimulus gemmiparus*, and it is highly unlikely that hybridization played a role in the origin of this particular monkeyflower (M. Beardsley personal communication 2003, P. Beardsley personal communication 2003). The other *Mimulus* species found nearby *M. gemmiparus* populations (i.e., *M. guttatus* and *M. floribundus*) had highly reduced floral displays and putatively reproduce mostly by selfing (P. Beardsley personal communication 2003). Hybridization between common *Mimulus* species is one possible mechanism for the formation of many species within the genus, including *M. glabratus* var. *michiganensis* (U.S. Fish and Wildlife Service 1997). The *M. glabratus* complex also possesses various barriers to crossing and reproductive isolating mechanisms, such as parental incompatibility and hybrid sterility (Vickery 1978).

Demography

Life history characteristics

Beardsley (1997) performed greenhouse experiments and field surveys and created a basic life history model based on his observations. Other population parameters, such as metapopulation dynamics and recruitment and survival rates, have yet to be researched. The features of M. Beardsley's life history model are summarized below; refer directly to Beardsley (1997) for detailed information.

Life cycle diagram and demographic matrix. A life cycle diagram is a series of nodes that represent the different life stages connected by various arrows for vital rates (i.e., survival rate, fecundity). Demographic parameters, such as recruitment and survival rates, are not currently available for *Mimulus gemmiparus*, and so there are no definitive data regarding the vital rates that contribute to species fitness. Although stage-based models based on population matrices and transition probabilities can be used to assess population viability (Caswell 2001), adequate quantitative demographic data are needed for input into the model.

For *Mimulus gemmiparus*, Beardsley (1997) hypothesized the stages that could be incorporated into a demographic matrix, but he did not include any information about vital rates. The main demographic components of *M. gemmiparus* include seed, seedling, young vegetative individuals, mature vegetative adults, and reproductive adults. Presumably, there are seeds or propagules in the soil at existing population locations. The probability of germination and subsequent establishment depends on the longevity of these propagules and whether appropriate environmental conditions exist for germination and growth. Of the seeds or propagules that germinate, grow, and become established plants, the individuals in the population will assimilate and allocate resources. Growth of all *M. gemmiparus* individuals includes the continuous production of repeated units (metamers) consisting of basic body parts (i.e., stem, leaves) and vegetative bulbils. Growth rates and allocation of resources to different organs may be influenced by the availability of resources, such as light, moisture, and nutrients. In addition, if appropriate flowering conditions exist, individuals in the population could produce flowers. Successful seed set would depend on the rate of pollen and ovule formation, pollination, fertilization, and embryo development. If appropriate flowering conditions do not exist, adult plants would continue to produce metamers and bulbils until senescence at the end of the season. Dispersal occurs as leaves senesce and the propagules are released (petiolar sac and bulbils). The fecundity rates depend on the production of bulbils and the percentage of those bulbils that overwinter and survive to the next year.

The life history model created by Beardsley (1997) and presented here provides the first step toward an understanding of the important parameters in the life history of *Mimulus gemmiparus* (**Figure 3**). This model outlines possible environmental controls on *M. gemmiparus* persistence and helps to formulate future demographic study on this monkeyflower.

Population viability analysis. In order to initiate a population viability analysis for *Mimulus gemmiparus*, the rates of germination, fecundity, survival, and other important parameters require additional study.

Ecological influences on survival and reproduction

Little information exists about the ecological factors affecting growth and establishment of *Mimulus gemmiparus* in the field. As previously discussed, Beardsley (1997) performed greenhouse experiments testing the effects of environmental factors, such as temperature, moisture, nutrients, and substrate on the survival of propagules and growth and development of adults. He found that the survival of propagules was strongly affected by moisture, temperature, and substrate type. The growth of adults and allocation of resources to the different reproductive structures was also affected by nutrients and light (Beardsley 1997). In addition, the growth of adults was highly dependent on available moisture; if there was not enough water for two days, *M. gemmiparus* plants in the greenhouse immediately dried up and died (D. Steingraeber personal communication 2002). The absence of plants at several known locations of this species may possibly be a result of the drought conditions present in Colorado (D. Steingraeber personal communication 2002). For example, plants at Guanella Pass dry up and disappear when the seeps dry out (Colorado Natural Heritage Program 2003). The long-term persistence of *M. gemmiparus* at a location most likely depends on a range of ecological influences on reproduction and growth, including climatic fluctuations, microsite conditions, availability of suitable germination sites, and intraspecific competition. The establishment of new populations most likely depends on barriers to dispersal and the availability of suitable germination sites (e.g., bare soils with adequate moisture without competing vegetation).

Spatial characteristics

The distribution of *Mimulus gemmiparus* is highly discontinuous at a regional scale, but extremely clustered and dense at local scales. The eight known locations of *M. gemmiparus* are spread out over five counties, on both sides of the Continental Divide, within different watersheds, and separated by major highway corridors. The explanation(s) for this distribution pattern is unknown but could be the result of highly specialized habitat needs, long-range dispersal ability (possibly wind dispersed), incomplete location of all populations by botanists, historical habitat use or destruction (e.g., use of water sources by humans), and/or long-term environmental fluctuations (leading to historical shrinking or expanding of distribution). It is unknown to what extent *M. gemmiparus* is capable of dispersing, colonizing, and establishing new populations around the landscape. Vickery (1999) found that *M. guttatus* populations in one canyon in Utah increased, decreased, dispersed to new locations, were extirpated, and moved in response to shading and water availability.

In contrast to the regional distribution, the local distribution of *Mimulus gemmiparus* individuals within a population is highly clustered in small, dense, monospecific colonies. The area covered by most populations is very small (e.g., less than a few hundred square meters), which increases the susceptibility of these populations to extirpation from a single disturbance event (M. Beardsley personal communication 2003). Factors that could help explain this distribution include highly specialized habitat needs (e.g., moisture) and dispersal patterns. *Mimulus gemmiparus* needs a consistent source of water for both germination and adult growth (Beardsley 1997, D. Steingraeber personal communication 2002). The plants are clustered around sources of water, such as creeks and seeps, and found under rock overhangs (Colorado Natural Heritage Program 2003). *Mimulus gemmiparus* also grows in locations with minimal competition from other species, although it is unknown if the wet, shady conditions and thin soils prevent other species from existing there or if the density of *M. gemmiparus* precludes colonization from other species. Researchers have observed distinct clusters of *M. gemmiparus* in bare, shady areas and growth of other vegetation in adjacent, sunnier areas (Beardsley 1997, R. Scully personal communication 2002).

Because the habitat requirements for *Mimulus gemmiparus* are not fully known, it is difficult to estimate or quantify how much available habitat exists. The critical features of suitable habitat, such as substrate or water needs, have not been identified for these habitats. Some researchers believe that the habitat is so specialized that very few locations exist where this species could persist (Beardsley 1997, Colorado Natural Heritage Program 2003), while other researchers feel that there is probably suitable habitat and other populations to be discovered (R. Scully personal communication 2002, Colorado Natural Heritage Program 2003). In some cases, researchers have observed adjacent, visibly similar habitat to existing populations by walking along the rock formation, for example, but they have failed to find additional individuals (e.g., Old Fall River Road, Hankins Gulch, Staunton State Park) (D. Steingraeber personal communication 2002, Colorado Natural Heritage Program 2003). These patterns could indicate that there are critical needs met at some locations but not others, or that there are barriers to dispersal to those adjacent locations. In other cases, observers could see that *M. gemmiparus* clusters were present along a geological formation, not just clustered in one overhang only (e.g., St. Vrain Canyon, East Inlet Trail). Richard Scully, volunteer with the Colorado NHP, observed *Mimulus gemmiparus* on a series of horizontal ledges in the St. Vrain Canyon, and he could see that possible habitat could extend the length of the canyon (personal communication, 2002). The terrain was too steep to verify the presence or absence of *M. gemmiparus* there. In addition, the Horseshoe Park alluvial fan is different from the other locations with *M. gemmiparus*, indicating that this species may be capable of inhabiting a variety of habitats. However, this alluvial fan habitat may not be suitable over the long-term due to successional changes, and the long term viability of this population is questionable (J. Connor personal communication 2003).

As discussed, *Mimulus gemmiparus* relies extensively on reproduction by asexual propagules. The dispersal distance capable by these propagules depends on hydrology, wind, and topography. It is possible that propagules could be carried long distance via water or wind (e.g., down Roaring River canyon to alluvial fan during flood), but it is likely that a large percentage of the propagules remain in close proximity to their adult progenitors, resulting in a clustered distribution.

Mimulus gemmiparus is also found near trails or roads in seven out of eight occurrences. Unless the trails have significant effects on water availability or substrate, this is probably a reflection of the fact that botanists are more likely to find populations that are near roads or trails and that trails tend to follow drainages (Beardsley 1997, R. Scully personal communication 2002, M. Beardsley personal communication 2003).

Genetic characteristics and concerns

In general, the genetic status of *Mimulus gemmiparus*, including issues related to variability, hybridization and polyploidy, is largely unknown for this species. *Mimulus gemmiparus* is reported to have n=16 chromosomes, which is the typical chromosome number of species in the large clade that includes *M. gemmiparus* (P. Beardsley personal communication 2003). *Mimulus guttatus* has n=8, 13, 14, 15, 16, 24, or 28 chromosomes and *M. glabratus* has n=14, 15, or 30 chromosomes (Vickery 1970, Cronquist et al. 1984).

D. Steingraeber and P. Beardsley are currently collaborating on a project to study the amount of genetic variability within and among populations of *Mimulus gemmiparus* using amplified fragment-length polymorphism (AFLP) protocols (D. Steingraeber personal communication 2003). As of September 2003, the researchers have collected bulbils from *M. gemmiparus* individuals in five of the eight populations. They plan on growing the individual plants in the greenhouse and performing AFLP analyses in the winter of 2003/2004 (D. Steingraeber personal communication 2003).

Similar to *Mimulus gemmiparus*, *M. glabratus* var. *michiganensis*, a threatened *Mimulus* species found in Michigan, also reproduces primarily by vegetative reproduction with minimal evidence of sexual reproduction (U.S. Fish and Wildlife Service 1990). Researchers are concerned that *M. glabratus* var. *michiganensis* possesses low genetic diversity and a limited number of colonies and individuals, all of which may affect the ability of this species to survive or adapt to environmental change.

Insight into the genetic variability of *Mimulus gemmiparus* would have important implications for our understanding of this species, especially because there is little evidence of sexual reproduction within or between populations. Issues related to gene flow, inbreeding, and genetic isolation could affect the demography, ecology, and management considerations for this species.

Factors limiting population growth

Based on the information presented in the preceding sections, *Mimulus gemmiparus* population establishment or growth could be limited by lack of suitable specialized habitat, inappropriate environmental conditions for germination or growth (i.e., inadequate moisture), or potential competition with other species (e.g., invasive species). Because *Mimulus gemmiparus* reproduces asexually, the successful dispersal of one propagule to a new location could lead to establishment of a new colony or population. However, the rate at which colonization and establishment of new, persistent populations occurs is unknown (Beardsley 1997). The colonization of the Lawn Lake Flood alluvial fan in 1989 is the only observed example of a new colonization event. Beardsley (1997) suggested that the probability of successful dispersal to suitable habitat is unknown but probably very low.

Community ecology

Herbivores and relationship to habitat

The extent or effects of herbivory on *Mimulus gemmiparus* are unknown. There has been no reported evidence of herbivory on *M. gemmiparus* individuals (Peterson and Harmon 1983), nor has author W. Jennings seen evidence of herbivory on individuals in the field. One occurrence record for this species observed that pack rats (*Neotoma floridana*) used the area under an overhang where *M. gemmiparus* was present, but there was no mention of herbivory (Colorado Natural Heritage Program 2003). Author W. Jennings has observed bighorn sheep (*Ovis canadensis*) within several hundred feet of the Guanella Pass population. Elk (*Cervus elaphus*) browse montane vegetation such as aspens found near sites with *M. gemmiparus*, and elk could impact some populations by trampling (Keigley 1993, Colorado Natural Heritage Program 2003). *Mimulus gemmiparus* individuals at the Lawn Lake Flood alluvial fan possibly could be trampled by elk or other browsers that move through the site to the stream. Carr and Eubanks (2002) observed and studied the herbivory by meadow spittlebugs (*Philaenus spumarius*) on *M. guttatus*, but the influence of insect herbivory on *M. gemmiparus* is unknown.

All of the *Mimulus gemmiparus* populations on USFS National Forest land (Hankins Gulch and Guanella Pass in USFS Pike-San Isabel National Forest, and St. Vrain Canyon in USFS Arapahoe-Roosevelt National Forest) occur within active livestock grazing allotments (B. Baker personal communication 2003, S. Olsen personal communication 2003). However, *M. gemmiparus* populations at Guanella Pass and in St. Vrain Canyon occur in cliff areas that are probably too steep and rocky for livestock to access. In addition, S. Olsen (personal communication 2003) reported that livestock numbers have been reduced at Guanella Pass and in Hankins Gulch as a result of unsuitable conditions (e.g., wildfire, poor forage).

Competitors and relationship to habitat

The interactions of *Mimulus gemmiparus* within the plant community are not well known. Interspecific competition seems to be low as the specialized habitat (moist seeps and granite outcrops) may preclude colonization by other species except ferns, mosses, and other species tolerant of wet conditions (Peterson and Harmon 1983, Beardsley 1997, Colorado Natural Heritage Program 2003). The ground where *M. gemmiparus* grows is generally bare and devoid of other vegetation (Beardsley 1997, J. Connor personal communication 2002, R. Scully personal communication 2002, D. Steingraeber personal communication 2002). In sunny areas or outside the boundaries of the population, though, the density of other species (i.e., grasses and forbs) increases. For example, some subpopulation clusters of *M. gemmiparus* at Hankins Gulch occurred on bare patches, with a rock on one side and dense vegetation on the other sides (Beardsley 1997). The lack of other vegetation around *M. gemmiparus* suggests that this monkeyflower is a poor interspecific competitor (M. Beardsley and P. Beardsley personal communication 2003).

Mimulus gemmiparus can live in dense colonies, and the densities of subpopulation clusters can vary widely, ranging from 4 to 280 individuals per square decameter (Beardsley 1997). Peterson and Harmon (1983) suggested that this species can somewhat tolerate high intraspecific competition. In contrast, Beardsley (1997) hypothesized that negative density-dependent factors may have accounted for low young survivorship in some very dense areas.

There are no reports of exotic species negatively affecting *Mimulus gemmiparus*. In some instances, exotic species can outcompete or replace native plants by using space, nutrients, and water. The introduction of exotic species can be a secondary effect of trail and road construction, and *M. gemmiparus* does grow in areas immediately adjacent to trails (Colorado Natural Heritage Program 2003). J. Connor (personal communication 2002) reported that the Horseshoe Park alluvial fan area has invasion by *Cirsium arvense* (Canada thistle), *Carduus nutans* (musk thistle), and *Linaria genistifolia* ssp. *dalmatica* (dalmation toadflax). The thistles do not grow near the *M. gemmiparus* clusters, but toadflax has been invading areas nearer to the monkeyflower. As a result, the NPS has been hand-pulling the toadflax found near the *M. gemmiparus* individuals.

Parasites and disease

There is no evidence of disease or parasites on *Mimulus gemmiparus* (Peterson and Harmon 1983, Colorado Natural Heritage Program 2003).

Symbiotic interactions

Insect pollination of flowering plants is an example of an important symbiotic interaction. Plants lure insects to a pollen or nectar reward and the insects carry pollen to other flowers, thus, helping to cross-fertilize. Specific details concerning pollination ecology of *Mimulus gemmiparus* are largely unknown.

Habitat influences

Mimulus gemmiparus is a habitat specialist because it seems to have strict habitat requirements, such as rocky substrates and mesic conditions (Beardsley 1997). *Mimulus gemmiparus* inhabits moist soils found at forest seeps protected by granitic overhangs or erratic boulders (Colorado Native Plant Society 1989, Colorado Natural Heritage Program 2003). This species also grows at an alluvial fan lacking a cliff or overhang. The availability and quality of suitable habitat most likely ranges from area to area, depending on topography, geology, and hydrology. Overall, though, it is likely that “very few locations would make viable habitat for persistent populations of the species” (Beardsley 1997, pg. 222).

Conservation

Threats

Mimulus gemmiparus populations and habitats throughout its range, including USFS Region 2 lands, could potentially be threatened by human-related actions (e.g., recreation) and ecological fluctuations (e.g., fire). These activities could either affect the existing individuals or reduce reproductive success, available habitat, development of new individuals, establishment of new populations, or other factors important for long-term persistence of the species. In general, disturbances can either create suitable habitat throughout a landscape or directly impact an existing population, depending on frequency, intensity, size, and location. Because *M. gemmiparus* tends to grow in dense colonies within small areas, one small disturbance could extirpate a population (Beardsley 1997). In addition, the small number of populations and individuals and limited sexual reproduction of this species (i.e., possible low genetic variability) may affect the ability of this species to adapt to changing environmental conditions.

Direct or indirect negative impacts to *Mimulus gemmiparus* populations or habitat by human-related activities could occur from motorized and non-motorized recreation, trail or road construction and maintenance, domestic livestock activities, forest clearing or thinning, pollution (e.g., agricultural runoff, herbicide or pesticide use), non-native species invasion, or fragmentation of the surrounding landscape. *Mimulus gemmiparus* is found in popular recreation areas within Rocky Mountain National Park and USFS National Forest lands (e.g., Hankins Gulch). Many of the populations are found near trails or roads and are subject to impact from hikers, horses, dogs, off-road vehicles, or road or trail maintenance activities. Any populations that occur in wilderness areas or NPS lands would be protected from impacts from motorized travel and construction. Although road improvement activities at Guanella Pass may not directly affect the rocky area with *M. gemmiparus*, the activities could possibly affect hydrologic patterns in the area (D. Steingraeber personal communication 2003). One population in Rocky Mountain National Park is bisected by a hiking trail, and the population in Hankins Gulch is located 2 m from the trail. Beardsley (1997) observed entire clusters of *M. gemmiparus* crushed by human, dog, or horse footprints at the Hankins Gulch area. The locations of *M. gemmiparus* in Rocky Mountain National Park are also subject to impact from elk and tourists; one location is used as a latrine and rest stop by hikers, and the beauty of the *M. gemmiparus* hanging gardens may attract attention of tourists (Colorado Natural Heritage Program 2003). In Staunton State Park, *M. gemmiparus* occurs at a waterfall area that will most likely be a popular place for recreationalists to visit (D. Anderson personal communication 2003). Beardsley (1997) surmised that *M. gemmiparus* locations make good camping and shelter areas because they are close to water and trails and have overhangs or caves. "The populations are small enough to be feasibly wiped out by a single unfortunately placed campfire, or possibly by being trampled to death by one group of hikers (perhaps hikers who might choose to seek shelter under the same overhang which houses the rare plant)" (Beardsley 1997, pg. 221). Footprint areas and an old fire ring at Hankins Gulch showed some colonization by *M. gemmiparus* individuals, but a larger disturbed area might not recover as well.

Mimulus gemmiparus populations could also be threatened by any environmental fluctuation or management activity that altered hydrology, topography, soils, or shading. These changes could come about during succession, fire, drought, rockfall, flash flood, global warming, erosion, succession, blowdown, or timber harvest, for example. Several populations were probably affected by wildfires (e.g., Hankins Gulch, Staunton State Park) and drought (e.g., Guanella Pass) in 2002 (B. Madsen personal communication 2002, D. Steingraeber personal communication 2002), and the current status at some locations (e.g., Staunton State Park) needs to be verified. D. Steingraeber (personal communication 2003) observed the Hankins Gulch population in August 2003 and noted up to thousands of individuals at that location. D. Steingraeber also observed intensely burned areas as close as 30 to 40 feet from the *M. gemmiparus* population. It is possible that the location of this population within a riparian area on low flat ground under a rock overhang in wet soil may have prevented more significant, direct fire impacts (M. Beardsley personal communication 2003, P. Beardsley personal communication 2003, D. Steingraeber personal communication 2003). Although the *M. gemmiparus* population at this location was not intensely burned, the entire surrounding watershed was heavily impacted by wildfire. As a result, the environmental setting of this population has been changed and significant changes to hydrologic patterns, vegetation composition, and soil movement may occur. It is possible that increased surface water runoff and increased soil erosion and deposition could negatively impact this population (D. Steingraeber personal communication 2003).

J. Connor (personal communication 2002) noted that there are exotic species in proximity to the *M. gemmiparus* population on the Horseshoe Park alluvial fan. Based on the available data, the population there seems to be extirpated, although the reasons for its extirpation have not been identified. The existence of non-native plant species at other *M. gemmiparus* locations has not been identified. Encroachment of plant invaders could pose a significant threat to *M. gemmiparus*, especially as it seems to be a poor interspecific competitor (M. Beardsley personal communication 2003). In areas affected by wildfire, the establishment of non-native invasive plants during site recovery is also a significant concern.

Livestock grazing does not seem to be a significant threat to *Mimulus gemmiparus*, mainly because this plant species tends to occur in areas that are sparsely vegetated, steep, and rocky. However, it is possible that livestock grazing could threaten the *M. gemmiparus* population at Hankins Gulch if livestock tend to concentrate in the riparian area, which was not as impacted by the wildfire as surrounding slopes (D. Steingraeber personal communication 2003). In addition, livestock activities can be associated with the introduction and spread of non-native invasive plants in some cases.

Other possible environmental and biological threats to individuals and populations of *Mimulus gemmiparus* include environmental fluctuations (e.g., drought), genetic isolation, succession, herbivory, global climate changes, or changes to the natural disturbance regime. The successional stages optimal for *M. gemmiparus* establishment and persistence and the environmental tolerances (e.g., shading) of *M. gemmiparus* are not known. Beardsley (1997) noted that the growth of a single tree could alter shading and possibly create unfavorable conditions for the entire population. The capability of this species to persist despite environmental fluctuations (e.g., drought) is unknown. The Guanella Pass population seems to have persisted despite population decreases in previous years possibly as a result of drought conditions (D. Steingraeber personal communication 2003). Changes to existing climatic and precipitation patterns, perhaps as a result of global climate change, could also impact this species. For example, average temperatures have increased 4.1 ºF, and precipitation has decreased up to 20 percent in some areas of Colorado (U.S. Environmental Protection Agency 1997). Climate changes have the potential to affect plant community composition by altering establishment, growth, reproduction, and death of plants. *Mimulus gemmiparus* is known from eight scattered occurrences within its restricted range; the amount of gene flow, genetic variability, and inbreeding depression is unknown for this species.

Mimulus gemmiparus provides an "opportunity to study the evolution of obligate asexual reproduction in an otherwise sexually reproducing genus" (O'Kane 1988). Despite its uniqueness, this species does not seem to be overutilized for commercial, sporting, scientific, or educational use (Peterson and Harmon 1983). All of the greenhouse experiments performed by Beardsley (1997) used plant material obtained from *ex situ* material propagated from original stock to minimize exploitation of the existing natural populations.

Threats to *Mimulus gemmiparus* populations or habitats likely differ for each of the eight locations. The most significant threats to the three populations on USFS Region 2 lands (e.g., Hankins Gulch, St. Vrain Canyon, Guanella Pass) probably include direct impacts to existing individuals and habitat changes (e.g., hydrology) from intense wildfires in 2002, recreation associated with adjacent trails, roadwork activities, non-native plant invasion, and environmental fluctuations (e.g., precipitation fluctuations). The most significant threats to the five populations outside USFS lands (e.g., East Inlet Trail, North Inlet Trail, Old Fall River Road, Horseshoe Park alluvial fan, and Staunton State Park) include those threats as well as successional processes and park development leading to increased recreational land use.

Conservation Status of the Species in USFS Region 2

Mimulus gemmiparus is a rare plant found in unique habitats with individuals clustered in a few, dense populations, putting it at risk for local extirpations. The current status of several populations is unknown as a result of wildfires and successional processes. Three of the five populations of *M. gemmiparus* occurring outside USFS lands have unknown status or are possibly extirpated. As a result, the conservation of the three populations on USFS lands seems to be especially important to the global conservation status of this species. As of September 2003, recent observations suggest that these three populations are robust. However, these observations do not provide information on the integrity of the surrounding environment or reproductive success of the population. The vulnerability of this species on USFS National Forest lands is extremely high, and the long-term viability of this species is unknown.

Population declines

Based on data collected, it would be difficult for one to conclude that the abundance of *Mimulus gemmiparus* is declining or expanding throughout its range. Although a few populations have been re-observed several times since their initial identification, the reports do not always include detailed abundance or demographic information. Because this species has an annual life cycle, the population size is directly related to the germination of propagules and seeds each season. The current status of several populations is unknown, as a result of wildfire, drought, and successional conditions. The rate at which this species disperses and colonizes new locations is unknown because we know little of the ability for long-distance dispersal or availability of suitable habitat. This species is thought to be a habitat specialist strictly confined by habitat conditions (Beardsley 1997). In contrast, new locations of this species have been discovered in recent years, and some researchers feel that there are probably more occurrences yet to be found (R. Scully personal communication 2002, Colorado Natural Heritage Program 2003).

Habitat variation and risk

As previously discussed, *Mimulus gemmiparus* is a habitat specialist existing in small, geographically isolated populations. It is not known how much suitable habitat is available for future colonization or how many undiscovered populations there are. Existing populations occur as dense colonies within small areas, and drastic changes to environmental factors could potentially cause local extirpations. In contrast, disturbed areas may provide suitable habitat for *new* populations of *M. gemmiparus* to establish. Extreme changes in soil structure, geology, and hydrology created new habitat for *M. gemmiparus* population establishment at the Horseshoe Park alluvial fan. Limiting factors or risks within the habitat that could negatively impact existing populations could include potential competition from surrounding vegetation (e.g., succession, non-native plant invasion), changes to hydrology or topography (e.g., reduced water availability, erosion and deposition), lack of suitable germination sites, conditions too harsh for adequate growth and development (e.g., shading, cold temperatures), or other fluctuations in natural disturbance processes (e.g., precipitation, fire). For example, Vickery (1999) found that changes to water availability, possibly linked to local effects from global warming, affected the population persistence of *M. guttatus*. Soil moisture, water availability, and other hydrologic factors have been implicated as possibly the most important environmental factors to the persistence and reproduction of *M. gemmiparus* (Beardsley 1997, D. Anderson personal communication 2003, M. Beardsley personal communication 2003). There is a large potential for ecological fluctuations (e.g., drought, fire, succession) to drastically reduce the already small abundance of this species.

Mimulus gemmiparus does not seem to be at immediate risk or severely threatened by consequences of current land management. However, changes to management activities in the future, such as severe surface-disturbing activities (e.g., trail maintenance activities) could endanger specific populations.

Potential Management of the Species in USFS Region 2

Because there have been no long-term studies of this species in its natural setting, we can only hypothesize how changes in the environment due to ecological fluctuations or management practices may affect the abundance, distribution, and long-term persistence of this species.

Management implications

To date, studies evaluating the threats impacting *Mimulus gemmiparus* viability across its current range have not been performed. It is the professional opinion of the authors that *M. gemmiparus* does not seem to be at immediate, direct risk as a result of current management activities within its range. However, any future changes to management activities in the locations with *M. gemmiparus* could possibly affect the viability of this species. The primary human-related threat to this species is disturbance from activities related to nearby trails. Trail maintenance activities or off-trail hiking and camping cause direct harm through trampling, and indirect harm by altering soil and water conditions or introducing non-native invasive plants. Other management activities that could negatively affect *M. gemmiparus* include any direct trampling impacts from wildfire-related activities or exotic plant species control activities. Because of the characteristics of *M. gemmiparus* habitat (rocky, bare, steep), management activities such as grazing and timber removal are unlikely to occur near most populations of this monkeyflower. However, any increases to livestock grazing in riparian areas with *M. gemmiparus* (e.g., Hankins Gulch) could possibly cause trampling impacts.

As a result of few populations, limited sexual reproduction, and unknown ability to colonize and establish new populations, the loss of any populations or individuals could be detrimental to the survival of *Mimulus gemmiparus*. Thus, the long-term persistence of this species may rely on adequate management intervention to reduce any human-related threats to existing populations. Currently, there are no management actions specifically protecting populations of this species. Some examples of management practices that would protect *M. gemmiparus* habitat and minimize possible plant destruction include re-routing trails away from existing populations, encouraging hikers to stay on trails, preventing the spread and establishment of non-native invasive species, monitoring post-fire erosion, and regulating livestock activities to avoid sensitive riparian areas. Habitat management could also consider issues related to the surrounding landscape, such as hydrologic changes upstream from existing populations, barriers to dispersal, and landscape fragmentation.

Potential conservation elements

Mimulus gemmiparus is vulnerable to population declines because of its small number of occurrences, low abundance, small geographic area, and limited sexual reproduction. This species is extremely susceptible to population extirpation through stochastic environmental factors or human-related disturbance. Protecting existing populations of this species from damage is a key conservation tool (Beardsley 1997).

Features of *Mimulus gemmiparus* biology that would affect conservation of this species (i.e., key conservation elements) include its small size, specialized habitat needs, reliance on an adequate water supply, discontinuous distribution, annual life history, unique asexual reproduction, and lack of interspecific competitive ability. *Mimulus gemmiparus* occurs in rocky habitats with adequate moisture and minimal competition from other species. It is unknown how much suitable habitat for this species exists, so preventing damage to soil structure, geology, or hydrology at *existing* locations is critical for conservation efforts. This monkeyflower grows in geographically isolated locations, and it is unlikely that there is any exchange of propagules or other genetic material from one population to another. If a population is extirpated, there is low probability that the location would be colonized again through dispersal. The limited sexual reproduction and probably limited genetic variability of this species also raises questions about its ability to adapt to different environmental conditions.

Because *Mimulus gemmiparus* is an annual species, the population size relies on the production and survival of propagules, or seeds, from year to year. The ability of this species to produce asexual propagules, even under low nutrient and low-light conditions, helps increase the chances of proliferation of this species (Beardsley 1997). However, the longevity of propagules (bulbils or seeds) in the soil is unknown. Therefore, maintaining at least a few productive individuals at each location every year is important for population persistence. In addition, adequate moisture is necessary for *M. gemmiparus* to establish, grow, and develop propagules. Water is also necessary for the dispersal and germination of propagules. Thus, preventing changes to the hydrologic patterns and soil conditions of existing population sites will increase the chances of persistence. The successful production and germination of propagules in greenhouse environments introduces the possibility of restoration efforts (Beardsley and Olmstead 2002).

Tools and practices

In addition to field observations and habitat surveys by several botanists, the bulk of research on *Mimulus gemmiparus* has occurred in conjunction with D. Steingraeber's laboratory at Colorado State University, including the thesis work by M. Beardsley in 1997. Beardsley (1997) used both field and greenhouse methods to elucidate the basic biology of *M. gemmiparus*. D. Steingraeber is currently cooperating with P. Beardsley to analyze genetic variability between and within several *M. gemmiparus* populations (D. Steingraeber personal communication 2003). Future conservation work should consult these resources for information on studying and propagating this species.

Based on the current understanding of this species and the needs for further information, we can outline areas where more information will help inform a conservation plan. Habitat surveys, quantitative species monitoring, and biological and ecological studies are priorities for constructing a conservation plan and developing management objectives.

Species inventory and habitat surveys

The distribution and total abundance of *Mimulus gemmiparus* is not sufficiently known to formulate conservation strategies on USFS Region 2 lands. Understanding the distribution of *M. gemmiparus* through inventories and status assessment is important for developing a conservation plan for this species. If additional populations exist, then the actual distribution and abundance of *M. gemmiparus* may be underestimated. Researchers could visit all documented sites to ascertain both current distribution and population status. The data collected could be compared to existing records (e.g., Beardsley 1997, Colorado Natural Heritage Program 2003), and the sites could be regularly re-visited to ascertain long-term population trends. Ascertaining the current abundance of this species would help to estimate the vulnerability of this species to environmental fluctuations and to monitor the effects of human activities.

Additional surveys of potential habitat are needed to document the full spatial extent of *Mimulus gemmiparus*. Current reports of existing populations will provide a useful base of information to develop a survey protocol for new populations of *M. gemmiparus* within Region 2. Currently, *M. gemmiparus* is known to occur in eight geographically isolated locations along both sides of the Front Range. The distribution map for *M. gemmiparus* in Region 2 (**Figure 1**) indicates that the locations of this species are scattered and that other montane canyons could have undocumented populations. For example, *M. gemmiparus* is known from the St. Vrain Canyon and additional occurrences may exist in adjacent drainages of the Indian Peaks Wilderness. Also, there are only two populations of *M. gemmiparus* west of the Continental Divide, and it is possible that additional occurrences exist in montane areas there.

Once survey areas have been identified, researchers could further identify areas of potential habitat using topographic maps, geologic maps, land status maps, and aerial or satellite images. For example, it may be possible to identify areas where granite schist substrates occur near seeps and streams (D. Anderson personal communication 2003). Surveys could use existing populations as a starting point because habitat zones may extend along the length of a cliff or slope. Because *M. gemmiparus* propagules could be dispersed by water, gravity or wind, researchers could survey habitat upstream, upslope, or upwind from existing populations as well as habitat located downstream, downslope, or downwind. The population of *M. gemmiparus* found at the Horseshoe Park alluvial fan may have colonized the area after being dispersed by water from an upstream location (Keigley 1993). Observed vegetation, topography, and geology associations at existing locations can also be a useful starting point for identifying new survey areas within Region 2 and help understand the habitat requirements of *M. gemmiparus*.

The size and extent of existing or new populations could be mapped and recorded using global positioning system and geographic information system (GIS) technology. Mapping each known population of *Mimulus gemmiparus* will maintain consistency for future observations and help in making estimates of density and abundance over time. Populations in areas slated for various management, maintenance, or disturbance activities could be readily identified.

Population monitoring and demographic studies

Additional information is needed to gain an understanding of the life cycle, reproductive biology, demography, and population trends of *Mimulus gemmiparus*. The life cycle of *M. gemmiparus* is understood as an annual forb species with the ability to produce asexual propagules. However, information is lacking on germination requirements, propagule survival and longevity, fecundity, factors affecting flower development, and gene flow between populations. This type of species-specific information would be useful in assessing threats to this species, estimating species viability, and developing mitigation and restoration strategies. For example, researchers could observe the abundance and spatial distribution of propagules to assess dispersal, survival, and germination needs for this species. It may be possible to create non-destructive seed "traps", such as trays or stream sieves, to estimate propagule production and dispersal (D. Anderson personal communication 2003). Studies of this type would elucidate potential limiting factors for the establishment of new individuals and populations. Existing research on this species (e.g., Beardsley 1997) and studies on the reproductive biology of other *Mimulus* species could provide useful information and tools for designing future studies of *M. gemmiparus*. For example, Beardsley (1997) suggested that his studies of population density could be enhanced by following the survivorship of individuals through individual tracking techniques.

Minimal data are available on population trends for *Mimulus gemmiparus*. The abundance of several populations has been noted over time, but no long-term demographic monitoring has been initiated. Long-term monitoring studies could yield helpful information, such as temporal patterns of abundance and dormancy, environmental factors that influence abundance (e.g., hydrologic fluctuations), whether populations are increasing, decreasing, or remaining stable, and the minimum number of plants necessary to perpetuate the species. In addition, further studies on the morphological and genetic differences between different populations will clarify metapopulation dynamics and ecological needs of this species. Understanding certain aspects of demography, as indicated by the following questions, is a priority in order to provide basic population information.

- ❖ What are the rates of propagule production, survival, and recruitment?
- ❖ What is the current abundance of each population?
- ❖ What is the extent of the "propagule" bank in the soil?
- ❖ What is the role of phenotypic plasticity or genetic variability in the ability of this species to adapt to changing environmental conditions?
- ❖ What are the possible dispersal distances and potential of this species to colonize new areas?
- ❖ What are the population fluctuations from year to year?
- ❖ What is the gene flow, if any, between populations?
- ❖ What are the effects of disturbances and environmental fluctuations on demographics?
- ❖ What is the extent of sexual and asexual reproduction?

Long-term monitoring programs are required to answer these kinds of questions, but it may take decades for a clear pattern to emerge. Several groups have developed protocols for monitoring population and demographic trends of rare plant species. These protocols can be easily accessed and used to develop specific monitoring plans for use in Region 2. For example, Hutchings (1994) and Elzinga et al. (1998) are general references that provide concrete guidance on designing and implementing quantitative monitoring plans for rare plant species. Austin et al. (1999) and Bonham et al. (2001) provide helpful protocols specifically designed for federal agencies monitoring plants on public lands. In addition, population matrix models that measure individual fitness and population growth provide flexible and powerful metrics for evaluating habitat quality and identifying the most critical feature of the species' life history (Hayward and McDonald 1997). Deterministic demographic models of single populations are the simplest analyses and are used as powerful tools in making decisions for managing threatened and endangered species (Beissinger and Westphal 1998).

Habitat monitoring and management

The habitat characteristics of *Mimulus gemmiparus* have not been adequately described to understand what factors are critical in maintaining or restoring habitat for this species. For example, it is currently not known what types, intensities, or frequencies of disturbance create and maintain habitat and are tolerated by existing populations of this species. The extent of land management activities and cumulative beneficial or detrimental effects of these management activities on *M. gemmiparus* and its habitats have not been studied or monitored. Documenting land management and monitoring habitat could occur in conjunction with population monitoring efforts in order to associate population trends with environmental conditions.

The response of *Mimulus gemmiparus* to habitat changes is not known in sufficient detail to evaluate the effects of management or environmental fluctuations. As discussed above, there is still much to learn regarding germination, colonization, dispersal, and overall persistence of *M. gemmiparus*. Research studies to evaluate the effects of wildfire, drought, floods, and succession on *M. gemmiparus* survival at various scales (population and regional) would provide valuable input to the development of conservation strategies and management programs. In specific, changes to hydrologic conditions (e.g., drought) could profoundly affect *M. gemmiparus* populations by affecting growth and reproductive success, and this could potentially be studied in the greenhouse (P. Beardsley personal communication 2003). Mark Beardsley (1997, pg. 226) stated that, "Of even more importance could be the study of the role of water (e.g. soil moisture, etc.) on populations of *M. gemmiparus*. My observations of populations in the field lead me to believe that this one habitat requirement is extremely important to the timing of germination and determination of lifespan of individuals." The types of monitoring studies required to understand how this species responds to environmental fluctuations, changes in the disturbance regime, or natural succession would be complex and could take decades. Beardsley (1997) provided maps of the spatial distribution of the Hankins Gulch population, and new maps could be created to assess changes in spatial distribution over time. It will be difficult to determine to what extent disturbances are necessary to create suitable habitat, what disturbance intensity and frequency may be most appropriate, and whether encroaching vegetation would result in local extirpation of a population.

Biological and ecological studies

Much of the information regarding habitat requirements, establishment, reproduction, dispersal, relationship with herbivores, competition with other species, and overall persistence has not been studied for *Mimulus gemmiparus*. The ecological needs of *M. gemmiparus* are not known in sufficient detail to evaluate the response of this species to habitat changes such as environmental fluctuations, changes in the natural hydrologic regime, or natural succession. The extent of seed reproduction in natural populations is not known and has possible ramifications for population persistence and genetic variability. Research studies to evaluate the effects of hydrologic fluctuations, recreation, livestock activities, landscape fragmentation, drought, succession, and fire at local and regional scales would provide valuable input to the development of conservation strategies and management programs. It will be difficult to determine the characteristics of the optimal natural hydrologic regime to maintain populations of this species and appropriate habitat.

Research on the biology of other *Mimulus* species, such as *M. guttatus*, will provide useful information and tools for designing future studies of *M. gemmiparus* (e.g., Grant 1924, Vickery 1978, Sutherland and Vickery 1988, Sutherland and Vickery 1993, Willis 1993, Karron et al. 1995, Vickery 1999, Carr and Eubanks 2002). The recovery plan for the conservation of *M. glabratus* var. *michiganensis* produced by the USFWS (1997) also discusses important issues to consider in the conservation of a threatened *Mimulus* species. For example, the recovery of *M. glabratus* var. *michiganensis* depends on the protection of relatively few known occurrences of the species, field surveys to better determine the status of the species, and biosystematic research and long-term monitoring to understand its basic natural history.

Availability of reliable restoration methods

The unique asexual form of reproduction exhibited by *Mimulus gemmiparus* provides an opportunity for *ex situ* propagation of plant materials. Beardsley (1997) believed that the biology of this species made it a good candidate for reintroduction efforts. *Mimulus gemmiparus* produces propagules that can be grown with minimal expense, effort, and time in the greenhouse; reintroduced individuals would probably adapt well to local conditions because it is a phenotypically plastic plant; and putatively very little genetic variation does not seem to be a problem for this species (Beardsley 1997). Germination and transplantation studies of *M. gemmiparus* in natural environments as well as possible habitat restoration may be helpful for populations that are at risk of extirpation.

Although R.K. Vickery (1970) seemed to have problems sustaining live plants and germinating propagules, D. Steingraeber collected a small number of source propagules from two populations (Hankins Gulch and Guanella Pass) in 1992 and has maintained those individuals through propagation in the greenhouse. Because the plants are small, up to 50 plants can be grown in small 8 by 8 inch flats. D. Steingraeber maintains *ex situ* populations of *Mimulus gemmiparus* by harvesting and germinating the propagules of greenhouse populations and will continue to do so (D. Steingraeber personal communication 2002). Material could be collected from each population and propagated separately to ensure adequate representation of genetic variability (M. Beardsley personal communication 2003, D. Steingraeber personal communication 2003).

The possibilities for long-term storage of the propagules seem to be minimal, because the propagules need to maintain a high water content (Beardsley 1997). D. Steingraeber reported that germination is moderately high for propagules stored for one to two years at room temperature in the greenhouse, but that germination success is very low for propagules stored for three years (D. Steingraeber personal communication 2003).

Information Needs and Research Priorities

Based on our current understanding of *Mimulus gemmiparus*, we can identify research priorities where additional information will help to develop management objectives, initiate monitoring and research programs, and inform a conservation plan. To address these data gaps, information can be obtained through surveys, long-term monitoring plans, and extended research programs. Surveys and inventories are useful in the short term to locate populations and to determine population sizes and distributions of populations within the region. Populations that are located by surveys or inventories can be immediately protected if threats to the population are imminent. Long-term monitoring programs are useful components of conservation planning; the resulting information can be used to direct management actions and to initiate adaptive management practices as the project proceeds over time. Long-term research studies, such as genetic analyses and germination studies, can supplement the current biological knowledge of this species and may be useful in providing feedback for use in long-term monitoring programs.

There is so little known about the long-term viability of *Mimulus gemmiparus* that there are a large number of research projects that could be implemented. Re-visiting all populations, estimating current abundance, assessing imminent threats, understanding the ability of this species to persist despite environmental fluctuations, studying genetic variability, and determining ecological needs and limitations are of primary importance to further the understanding of this species in Region 2. The following types of studies would supplement basic knowledge regarding this species:

- ❖ Re-visitation and detailed mapping of existing populations
- ❖ Surveys for new populations within Region 2
- ❖ Multi-year measurements of population area, size, and density
- ❖ Studying demographic parameters (e.g., fecundity, propagule longevity, survival)
- ❖ Addressing imminent threats to known populations (e.g., non-native plant invasions, trail activity, hydrologic changes)
- ❖ Habitat characterizations and measurements; habitat modeling
- ❖ Documenting and monitoring current land and water management practices
- ❖ Studies on biological and ecological limitations (e.g., moisture requirements, propagule longevity, germination requirements, dispersal capabilities, mycorrhizal associations)
- ❖ Genetic analyses to assess gene flow and variability throughout range (e.g., metapopulation dynamics, inbreeding depression)
- ❖ Restoration techniques (e.g., storage of propagules and reintroduction of plants)

Additional research and data that may be useful but are not incorporated into this assessment include aspects related to managing data for efficient use. Data acquired during surveys, inventories, monitoring programs, and research projects are most easily accessible if they are entered into an automated relational database. The Colorado NHP and NatureServe have developed databases and GIS components to assist in information storage and habitat modeling (D. Anderson personal communication 2003). Such a database should be integrated with GIS and allow queries and activities such as the following:

- ❖ Efficient incorporation of data in the field
- ❖ Generation of location and habitat maps
- ❖ Identification of population locations
- ❖ Characterization of associated habitat types
- ❖ Identification of population trends over time
- ❖ Identification of data gaps that require further information gathering
- ❖ Easy modification of the database as additional information becomes available.

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DEFINITIONS

Abscission – The process by which plant parts are shed.

Annual – A plant that completes its entire life cycle (germinates, flowers, and sets seed) in a single growing season.

Asexual reproduction – Any form of reproduction not involving the union of gametes.

Axillary – Located in the angle between the stem and branch (or leaf) of a plant.

Bilabiate – Two-lipped; usually referring to a flower corolla

Bulbil – An asexually produced propagule, consisting of a shoot axis, rudimentary leaves, and roots, which detaches from the mother plant and starts a new one.

Category 1 ranking (C1) – Taxa for which substantial biological information exists to support proposing to list as threatened or endangered (USFWS).

Category 2 ranking (C2) – Taxa for which current information indicates that proposing to list as endangered or threatened is possible but there is insufficient information to support immediate rulemaking (USFWS).

Category 3C ranking (3C) – Taxa that have proven to be more abundant or widespread than was previously believed, and/or those that are not subject to any identifiable threat (USFWS).

Corolla – Portion of flower comprised of petals.

Dehisce – To split or open, discharging seeds, pollen, or other contents, as the ripe capsules or pods of some plants.

Demographics – The study of fecundity and mortality parameters that are used to predict population changes.

Disjunct – Characterized by separation (e.g., one population outside the range of other populations).

Dormancy – A period of growth inactivity in seeds, buds, bulbs, and other plant organs even when environmental conditions normally required for growth are met.

Endangered – Defined in the Endangered Species Act as any species which is in danger of extinction throughout all or a significant portion of its range.

Endemic – A population or species with narrow physiological constraints or other restrictions, which limit it to a special habitat or a very restricted geographic range, or both.

Entire – Having a margin that lacks any toothing or division, as the leaves of some plants.

Fertility – Reproductive capacity of an organism.

Fitness – Success in producing viable and fertile offspring.

Forb – An herbaceous plant, other than grass.

Fruit – A mature ovary; contains seeds.

Gemma (pl. gemmae) – An asexually-produced propagule that detaches from the mother plant and starts a new one.

Genotype – Genetic constitution of an organism.

Glabrous – Smooth, without hairs or glands.

Habitat fragmentation – The breakup of a continuous landscape containing large patches into smaller, usually more numerous, and less connected patches. Can result in genetic isolation.

Habitat isolation – When two or more habitats are separated (i.e., geographically) to an extent to prevent cross breeding, thereby genetically isolating two parts of a once continuous population.

Herbaceous – Adjectival form of herb (an annual or perennial plant that dies back to the ground at the end of the growing season because it lacks the firmness resulting from secondary, woody growth).

Holarctic – Geographic region encompassing northern areas of the earth.

Hybridization – The result of a cross between two interspecific taxa.

Indeterminate – Not terminating growth with flowering; continuing to grow at apex.

Inflorescence – A group of flowers attached to a common axis in a specific arrangement.

Interspecific competition – Competition for resources between individuals of different species.

Intraspecific competition – Competition for resources among individuals of one species.

Iteroparous – Capable of reproducing several or many times over a lifetime (e.g., perennial plants.

Metamer – Each of several, similar body segments, consisting of the same internal structure.

Monocarpic – Flowering and bearing fruit only once.

Mycorrhiza – Symbiotic association between a fungus and the root of a higher plant.

Ovary – The enlarged portion of the female reproductive structure (pistil) that contains the ovules and develops into the fruit.

Ovate – Egg-shaped, with the larger end toward the base (i.e. ovate leaves).

Ovule – Part of "female" plant reproductive system that becomes a seed after fertilization.

Palate – The raised part of the lower lip of a corolla, constricting or closing the throat.

Perfect flower – Flower with both "male" (stamens) and "female" (pistils) reproductive organs.

Perennial – A plant that lives for 3 or more years and can grow, flower, and set seed for many years; underground parts may regrow new stems in the case of herbaceous plants.

Petiole – Leaf stalk.

Phenotype – The external visible appearance of an organism.

Phenotypic plasticity – When members of a species vary in height, leaf size or shape, flowering (or spore-producing time), or other attributes, with changes in light intensity, latitude, elevation, or other site characteristics.

Polycarpic – Flowering and bearing fruit multiple times.

Polyploidy – Having more than two complete sets of chromosomes per cell.

Population Viability Analysis – An evaluation to determine the minimum number of plants needed to perpetuate a species into the future, the factors that affect that number, and current population trends for the species being evaluated.

Propagule – A reproductive body.

Recruitment – The addition of new individuals to a population by reproduction.

Reflexed – Bent backward.

Ruderal habitat – Temporary or frequently disturbed habitats.

Ruderal species – Species that can exploit low stress, high disturbance environments.

Saccate – In the shape of a sac or pouch.

Semelparous – Reproducing only once throughout a lifetime, usually followed by death (e.g., annual plants)

Senescence – Changes that occur in an organism (or part of an organism) between maturity and death (i.e., ageing).

Sexual reproduction – Reproduction involving the union of gametes.

Solitary – Single, sole.

Symbiosis – An intimate association between two dissimilar organisms that benefits both of them.

Sympatric – Occupying the same geographic region.

Sympetalous – Having united petals, at least at the base.

Terminal – Occurring at the tip or end.

Threatened – Defined in the Endangered Species Act as any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Throat – The opening of a sympetalous corolla.

Vegetative reproduction – A form of asexual propagation whereby new individuals develop from specialized multicellular structures that often detach from the mother plant.

Viability – The capability of a species to persist over time. A viable species consists of self-sustaining and interacting populations that have sufficient abundance and diversity to persist and adapt over time.

Zygomorphic – Bilaterally symmetrical; displaying symmetry along one plane only.

Zygote – Cell formed from the union of two gametes.

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