Mimulus gemmiparus Populations: Current Status and Extended Search

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Summary

To more accurately assess the current conservation status of the rare plant *Mimulus gemmiparus* (Phrymaceae), we visited all previously known sites of occurrence and documented the location, size, and condition of populations, and we searched for additional populations in nearby areas. In 84 searcher-hours of intensive search, we found at least 15 new populations/sites of occurrence (separated from other populations by at least 30 m), 13 in Middle Saint Vrain Canyon (Roosevelt National Forest), and 2 in Horseshoe Park (Rocky Mountain National Park (RMNP)). Some additional populations or patches at other locations in RMNP are likely new, as well. Two previously known populations in RMNP (the type locality near Fall River Road, and the Alluvial Fan population) were not found, and may not persist. The newly discovered populations and patches increase the estimated total abundance of *M. gemmiparus* by approximately 21,000 plants (to a total of ~126,000 plants), with the majority of these newly found plants (~14,000) in Middle Saint Vrain Canyon. Our search results indicate that more occurrences of *M. gemmiparus* are likely, and we recommend the following actions:
1) The search for additional populations of *M. gemmiparus* in areas with suitable habitat should be continued and expanded.
2) Efforts to minimize adverse human impacts on existing populations should be expanded. For instance, the Hankins Gulch Trail in the Pike National Forest should be rerouted to eliminate trampling of plants.
3) Fine-scale demographic and genetic analyses of populations and patches should be undertaken to provide information on population dynamics and genetic structure.
4) A reintroduction program (with *ex situ* propagation) to establish new experimental populations seems feasible, and should be undertaken.

Introduction

Mimulus gemmiparus W.A. Weber (budding monkeyflower), first described by Weber (1972), is one of Colorado's rarest plants. The species is endemic to Colorado, and only 8 small populations have been known to exist. However, researchers have been unable to locate plants in recent years at two of the four known population sites (including the type locality) in Rocky Mountain National Park. Due to the seemingly tenuous existence of some populations, the Colorado Natural Heritage Program in 2003 upgraded its ranking of *M. gemmiparus* to the highest possible rank, G1 (i.e., the species is critically imperiled globally because of extreme rarity).

An additional consideration affecting population viability in *M. gemmiparus* is its unique mode of reproduction: successful sexual reproduction (seed set) has never been observed in natural populations (Beardsley, 1997). Instead, the plants reproduce asexually (clonally) by forming a bulbil (a tiny, embryo-like propagule that develops from an "extra" axillary bud) inside the petiole (stalk) of each leaf (Moody *et al*., 1999). When plants die in late summer or autumn, the leaves abscise with bulbils inside, and the dry, seemingly dead leaves lying on the surface of the soil become the critical overwintering stage for the population. The following summer, new plants germinate and grow from the bulbils inside these seemingly dead leaves to renew the population. The species thus behaves like an annual, but with asexually produced bulbils carrying out the function of seeds.

Since *M. gemmiparus* plants are small and inconspicuous, and its habitat occurs in remote and inaccessible areas, it is possible that more populations of this rare plant exist, but have remained undiscovered. This project was undertaken to provide a more accurate assessment of the current population status of *M. gemmiparus* by censusing the known sites of occurrence, and by carrying out a systematic search for new, as yet undiscovered populations in likely areas of occurrence. More specifically, the goals of this project were the following: 1) to visit each location where *M. gemmiparus* has been found in the past and document the current status of the population at each site; 2) to systematically search nearby locations with suitable habitat in an attempt to determine whether there are additional, as yet undocumented populations of *M. gemmiparus*; and 3) to use this information to provide an updated estimate of the conservation status of *M. gemmiparus*, including an assessment of likely threats to the persistence of known populations, and the likelihood of occurrence of additional populations.

Methods

A list of all 8 previously known sites of occurrence of *M. gemmiparus* was compiled from a variety of sources, including 1) the Element Occurrence Database of the Colorado Natural Heritage Program (CNHP); 2) locality information from herbarium specimens in the collections of the Colorado State University Herbarium (CS) and the University of Colorado – Boulder Herbarium (COLO); and 3) unpublished notes and records from our previous field work. All sites had been visited by us or colleagues at some time in the past (1992-2004), but specific location/distribution information for some sites remained vague. For instance, the location information on some herbarium

specimens is rather vague (e.g., "Rocky Mountain National Park, North Inlet Trail"), so it was unclear whether such sites represented single or multiple occurrences/populations. It was also unclear whether populations last seen and documented several years ago, such as the type locality along Trail Ridge Road (last documented in 1980, and which we have been unable to locate in the past) and the Alluvial Fan population (last documented in the 1990s), have persisted. Furthermore, although the CNHP database contains latitude/longitude coordinates for the 8 presumed sites of occurrence, our previous field experience had indicated that some of these coordinates were in error.

In the summer of 2005, we visited each of the known sites of occurrence to collect more specific location information and to document the current status of each population, and we intensively searched likely potential habitat in the general vicinity of all but one of the known populations, focusing on areas up- or down-drainage from each site. (In Staunton State Park (SSP), we searched for plants at the known population site but did not expand the search; the area was searched extensively by the CNHP in their Biological Inventory of SSP; see Spackman, *et al*., 1999.) We also spent some time searching locations which seemed to be appropriate *M. gemmiparus* habitat, but which were not adjacent to the known populations. These additional non-adjacent searches were performed opportunistically, when we happened to be in a likely area.

At locations where we found *M. gemmiparus*, we intensively searched in the vicinity of the occurrence to determine the spatial extent and distribution of plants nearby. We generally searched outward in all directions from the initial observation site, and marked the locations or boundaries of patches with surveying flags so that the locations and extent of patches would be more obvious at longer range and in photographs. We measured or estimated the size of individual patches of occurrence, and estimated the number of plants per patch by counting the number of plants in a small area and extrapolating over the entire patch or the portion of the patch with a seemingly similar density. We recorded observations regarding the size, developmental stage, and condition of plants and surrounding vegetation and habitat conditions. Latitude/longitude (GPS) coordinates were obtained as close as possible to individual patches or sites of occurrence; in some sites, cliff faces or other obstacles forced us to take readings in spots adjacent to (but within a few meters) of the actual sites of occurrence. Initially, we attempted to use a Leica GS20 GPS receiver, but at all sites where we attempted to use it, satellite coverage was insufficient to provide a fix. We therefore obtained our GPS readings using either a Garmin eTrex Vista or a Garmin eTrex Summit GPS receiver (both WAAS-enabled), with the Map Datum set to WGS84 and the position format in degrees and decimal minutes. We also obtained altimeter (elevation) readings from the GPS units, which contained barometric altimeters. We recorded the amount of time at each site spent in "intensive search" mode, as well as the number of searchers, to provide an index of "searcher-hour" effort expended at each site. In one visit each to two of the sites, we were accompanied and assisted in our search by colleagues familiar with *M. gemmiparus*: Chris Way (NI site), and Dr. Tracy Halward and Bill Baker (EI site).

At all sites, patches of plants that occurred in fairly close proximity to one another (not separated by a distance of approximately 30 m) were considered to belong to the same population. Thus, we defined populations as collections of patches that are separated from one another by distances greater than 30 m. Though this is a somewhat arbitrary definition, it is based upon our assumption that such a distance likely constitutes

a pronounced barrier to gene flow between patches, given the small stature and likely limited dispersal capabilities of *M. gemmiparus* plants.

Results

Details regarding the populations and our searches are presented below, organized by major areas/sites. Population description/location data are contained in Tables 1-7, which are referred to in individual sections below; Table 8 contains summary information on estimated population sizes and total area occupied at each major site. Similarly, Figures 1-124 (attached in electronic form as .jpg files) are presented in individual sections below. A key to the Figures is also attached, and the file names for individual figures contain explanatory captions.

Note regarding tables and figures: In Tables 1-7 (and relevant figures), "Patch ID" numbers correspond to identifying numbers assigned to patches in the field and are unique within each site. We decided to retain these patch numbers in tables and figures so that they would continue to be consistent with the patch numbers contained in our field notes.)

Middle Saint Vrain Canyon Populations (SV) – Roosevelt National Forest

The Middle Saint Vrain area was visited and searched on July 28 & 29, 2005. The one previously known population in this area was identified using a photo provided by Paul Beardsley, who had visited the population in 2003 (Steingraeber & Beardsley, 2003). At this location, we found four individual patches of *M. gemmiparus*, and designated this population "SV-1". This location is near the lower end of an enormous south-facing mountainside consisting of slabs and cliff bands interspersed with forested benches and several gulleys. During a preliminary reconnaissance of this broad face, we found several more patches of *M. gemmiparus*, and so broadened our search outward from the original site.

Our intensive search covered an area approximately 800 m in length by 150 m in elevation, and our search time in the area totaled 18.0 searcher-hours. Thirty-nine discrete patches of *M. gemmiparus* were found, distributed in 14 separate populations (Table 1). Figures 2 & 3 present an overview of the distribution of the populations at the site; Figure 1 shows where these photos were taken from. Figures 4-44 depict patches and plants constituting the 14 populations, and are presented sequentially (see Key to Figures). The patches varied in area from less than 0.1 m^2 to about 15 m^2; number of plants per patch ranged from 10 to 4000. The total number of plants estimated in these populations is 14,660, occupying approximately 68 m^2. Previous population estimates for this location were "several hundred" plants (in CNHP database: see Beatty, *et al.*, 2003; Steingraeber & Beardsley, 2003), and the previously known occurrence was limited to the population we have designated SV-1. Thus, our intensive search of a relatively small area revealed 13 additional populations and several thousand additional plants.

Hankins Gulch Population (HG) – Pike National Forest

The Hankins Gulch area was visited on Aug. 11, 2005, with search effort totaling 5.0 searcher-hours. In addition, nearby areas in the Lost Creek Wilderness were searched for 4.0 searcher-hours on August 18. (Areas searched are shown in Fig. 45.) No new populations were found in these searches. The Hankins Gulch population (characterized in detail in Beardsley, 1997) consists of 3 patches (Table 2; Fig. 46-52), but one of the patches in which we had previously found plants (in 1993) was unoccupied this year. Overall population size and condition, however, were similar to what we have observed here from 1992 to present, with an estimated total of approximately 102,000 plants. The Hankins Gulch population is (by far) the largest known population in terms of number of plants (see Table 8), but the plants are densely clustered in a relatively small area (13 m^2).

Guanella Pass Population (GP) – Pike National Forest

The Guanella Pass population was visited on three separate occasions in 2005, with intensive searching for 3.5 searcher-hours on August 11. The original population was located and characterized (Table 3; Fig. 53-56), and no new patches or populations were found. Two small patches occupied by ~ 100 plants each in 2004 were unoccupied this year. Our estimate of 600 plants here is similar to what has been observed previously (Beatty, *et al*., 2003; Steingraeber & Beardsley, 2003).

Fall River Road Population (FRR) – Rocky Mountain National Park

The Fall River Road area is noteworthy because it is the type locality for *M. gemmiparus*: the type specimen was collected here on July 8, 1970. However, the CNHP database lists the last recorded observation in this area as in 1980, with the number of plants listed as 3. Despite repeated attempts, we have been unable in past years to locate this site. We therefore searched the area intensively on July 20 & 21, 2005, expending a total of 14.0 searcher-hours. Areas searched are shown in Fig. 57. Despite extensive efforts, no plants were found, and the current existence of the type locality/population remains in doubt.

Horseshoe Park Populations (HP) - Rocky Mountain National Park

Historically, the Horseshoe Park region of RMNP is noteworthy for the occurrence of an unusual population of *M. gemmiparus*: following the Lawn Lake flood of 1982, plants were found growing on the alluvial fan at the junction of Roaring Creek and Fall River, presumably washed down in the flood and becoming established (along with other high-elevation plants) on the outwash fan (Keigley, 1993). However, plants were last observed here in the 1990s, and it was unclear whether this population remained. We therefore searched the alluvial fan proper, as well as areas downstream from the fan along Fall River, on July 13, 2005 (expending 5.5 searcher-hours). Additionally, on July 28, 2005, 4.0 searcher-hours were expended searching in the Lawn Lake-Roaring Creek area (shown in Fig. 58), the presumed source area for the Alluvial Fan population. No plants were found along Roaring Creek, or on the alluvial fan proper.

However, 2 new populations (designated HP-1 and HP-2; see Table 4) were found downstream along Fall River, above the Highway 34 bridge. Population HP-1 (shown in Fig. 59-68) is a few hundred meters upstream of the bridge, on the south side of Fall River, and contains an estimated 3000 plants. Population HP-2 (shown in Fig. 69-72) is a few hundred meters upstream of HP-1, and contains ~ 200 plants.

Both HP-1 and HP-2 occur on similar substrate, a sand/pebble bar surface immediately adjacent to Fall River. It is highly likely that these populations are inundated during periods of high stream flow, such that *M. gemmiparus* may be dispersing downstream from its earlier site of occurrence on the alluvial fan proper. However, our search was limited to the area upstream of the Highway 34 bridge; the region downstream is closed to off-trail travel. Nonetheless, our limited Horseshoe Park search resulted in the discovery of 2 new populations containing approximately 3200 plants. The alluvial fan population (HP-3), however, may no longer persist.

North Inlet Trail Populations (NI) - Rocky Mountain National Park

The North Inlet Trail area was visited on August 8, 2005, with 3 searchers participating. We searched likely areas in the vicinity of the trail between the trailhead and Cascade Falls, expending a total of 13.5 searcher-hours. Three widely separated populations were found (Table 5). NI-1 (shown in Fig. 73-81) occurs on and around a cliff face 30-50 meters north of the trail, and contains ~2200 plants in 2 patches. NI-2 (shown in Fig. 82-85) is directly adjacent to the trail, and consists of a single patch containing ~ 1000 plants. Further uptrail, NI-3 consists of 2 distinct patches: patch 4 (shown in Fig. 86-90) is directly adjacent to the trail and contains ~1000 plants. Patch 5 (shown in Fig. 91-92), perched on a ledge approximately 25 m uptrail from patch 4 and 7 m above the trail, contains ~1200 plants.

Due to the sketchy information regarding previous observation/collection sites along the North Inlet Trail, it is uncertain which, if any, of the populations we found represent new finds. It is likely that the patches directly adjacent to the trail (NI-2 and NI-3 patch 4) represent the sites previously known. Additionally, Paul Beardsley found plants in the vicinity of NI-1 in 2003 (Steingraeber & Beardsley, 2003), but was uncertain at that time whether that constituted a new location. It seems likely, therefore, that NI-1 and NI-3 patch 5 represent occurrences that have not been known or described in detail previously, and our estimate of a collective total of ~ 4400 plants in the North Inlet populations is a marked increase over previous estimates of 200 (Beatty, *et al.*, 2003; Steingraeber & Beardsley, 2003).

East Inlet Populations (EI) - Rocky Mountain National Park

The East Inlet Trail area was visited on August 25, 2005, with 3 searchers participating. We searched areas adjacent to the trail from the trailhead to the Cat's Lair Campground, expending a total of 15.5 searcher-hours. Two distinct populations were found (Table 6). EI-1 (shown in Fig. 93-99) consist of a single patch and is located at the base of a rock face ~ 3 m from the trail; it contained ~ 200 plants. Further uptrail, EI-2 (Fig.100-111) consists of 3 separate patches of approximately 200 plants each. Patch 2 is at the base of a rock face 2-3 m north of the trail. Patch 3 is immediately adjacent to

the rock steps of the trail. Patch 4 is ~ 15 m uptrail from patch 3, at the base of a rock ~ 5 meters off the trail.

As with the North Inlet Populations, it remains unclear whether any of the populations/patches we have described on the East Inlet Trail are new sites of known occurrence. We previously have found plants sparsely distributed in the general vicinity of both EI-1 and EI-2, but our population estimates for the EI populations (~800 plants total) greatly exceed previous estimates of ~30 plants (Beatty, *et al*., 2003; Steingraeber & Beardsley, 2003).

Staunton State Park Population (SSP)

The Staunton State Park population was visited on Sept. 13, 2005, with 1.0 searcher-hour expended. The population (Table 7; Fig. 112-124) was similar in size and condition to what we observed here in September, 2003 (Steingraeber & Beardsley, 2003). Fewer than 100 plants were distributed among 3 distinct, very small patches (totaling 1.0 m^2), making this population the smallest we encountered both in area and in number of plants.

Discussion

Number and Sizes of Populations

In 84.0 searcher-hours of intensive search, we found at least 15 previously unknown populations (13 at Saint Vrain, 2 at Horseshoe Park); some populations or patches at North Inlet and East Inlet are likely new, as well. However, despite intensive searching, we were unable to locate the Fall River Road population or the Alluvial Fan population. This suggests that although there are likely additional populations that have escaped detection previously, other, previously known populations may not persist.

Whether the newly discovered patches of plants represent new populations, or extensions of the previously known populations, is open to interpretation. Definitive resolution of what constitutes a population in a diminutive, asexually reproducing species like *M. gemmiparus* is problematic, and would require more detailed demographic and genetic data. Given the small size and extremely patchy distribution of plants, we believe our definition of "population", based on spatial separation of at least 30 meters, may be accurate. Regardless of how one defines a population in *M. gemmiparus*, however, our work indicates that there are many more patches of occurrence than previously known.

Our estimates of population sizes (summarized in Table 8) represent a significant increase in the estimated cumulative total abundance of *M. gemmiparus* by approximately 21,000+ plants. The bulk of this increased abundance (+ ~14,000) is contributed by the newly discovered SV populations in the Roosevelt National Forest, the newly discovered HP populations in RMNP (+ ~3,200), and possibly newly discovered populations or patches at NI (+ ~4200) and EI (+ ~ 770) in RMNP. These population gains are offset by the apparent extinction of populations at HP-3 (the alluvial fan) and FRR in RMNP. Populations at GP and HG in the Pike National Forest appear not to have changed markedly in size.

As noted above in the "Methods" section, we estimated population sizes by counting plants in a small area and extrapolating densities over areas exhibiting visually similar distributions. We suspect that this method may have underestimated the actual number of plants present, especially in patches that contain many plants. Our previous demographic work on *M. gemmiparus* suggests that without systematic and extremely fine-scaled demographic sampling, there is a natural tendency to underestimate numbers of extremely small plants. For instance, although the Hankins Gulch population has been casually estimated by others as containing a few thousand individuals, a systematic inventory in 1993 estimated that the population contained over 100,000 plants in mid-June; by late July, "thinning" of many very small plants had diminished the population to approximately 37,000 (Beardsley, 1997). It is not uncommon for *M. gemmiparus* plants to rapidly senesce and "shatter" within a few weeks, especially if soil moisture diminishes. Thus, the "apparent" population size in *M. gemmiparus* can vary extremely widely in a very brief period of time, which adds a large "range of error" to population estimates made from short-term observations. More accurate population estimates would require intensive, repeated censusing of individual populations over the entire growing season.

At some localities (SV, NI, EI), newly found locations were located off-trail in areas not easily accessed, suggesting that a more thorough search of suitable habitat in areas that are less accessible to humans might be fruitful. However, such searches of suitable habitat along Fall River Road and in the Lost Creek Wilderness were unsuccessful. Nonetheless, since *M. gemmiparus* is so small and can easily escape detection, and it grows in remote and sometimes precarious locations (for searchers!), there may well be additional populations that have not yet been found. Suggested areas for further search efforts in the Roosevelt National Forest include: 1) a more extensive search in the Middle Saint Vrain Canyon, where much suitable habitat appears to exist; and 2) nearby, adjacent drainages in the Indian Peaks Wilderness, which also seem to contain likely habitat. In Rocky Mountain National Park, suggested search areas include: 1) Fall River, downstream from the Highway 34 bridge (additional populations, similar to HP-1 and HP-2, may have become established by dispersal downstream from the alluvial fan area); and 2) additional off-trail areas in the North Inlet and East Inlet drainages, which contain abundant suitable habitat (as do many other areas in RMNP.)

Threats to the Persistence of Populations

Although we have documented that there are more populations and more plants of *M. gemmiparus* than previously known, plants nonetheless are restricted in their distribution to a relatively few extremely small areas, which increases the likelihood of disturbance or negative impact from seemingly stochastic events. Small disturbances, human-caused or otherwise (e.g., trampling, fire, drought), could easily remove individual patches of plants in most locations. The extremely patchy distribution of plants, coupled with our observations that individual patches in some populations appear not to persist from year to year, suggests that patch and population dynamics in *M. gemmiparus* may be highly dynamic, and that individual small patches may be transient and may not persist for long periods of time. It is quite possible that *M. gemmiparus* exhibits metapopulation dynamics (Frankel, *et al*., 1995), such that individual patches of

plants "come and go", and regional persistence is maintained by effective establishment of new patches to replace those that do not persist.

Nonetheless, some of the populations seem especially vulnerable to specific threats. The following is our assessment of the principal threat(s) to the persistence of populations at individual sites.

SV - The most likely threats at this site are fire and drought. Many patches here occur on very shallow soil and likely rely on surface flow of water from rain or snowmelt, making this population susceptible (as are all) to drought.

HG – This population occurs within the Hayman Fire area, in close proximity to severely burned slopes and right next to Hankins Gulch Creek. Thus, the area seems potentially susceptible to flash flood events and drought. Additionally, the Hankins Gulch Trail actually crosses the population (see Fig. 46-47). (The majority of the population occurs on one side of the trail, but plants occur on both sides, and plants routinely are trampled by hikers.) We strongly recommend that the trail be rerouted to the other side of the creek in the vicinity of the population. The trail crosses the creek repeatedly nearby, and it would not seem particularly difficult to reroute the trail to minimize damage to the population. (The terrain on the other side of the creek seems suitable for the trail.) Additionally, we feel it is important to note that the Hankins Gulch population is especially noteworthy and deserving of conservation efforts for the following reasons: 1) it is (by far) the largest known population, containing approximately 80% of all known *M. gemmiparus* plants; 2) these plants occupy a relatively small total area (13 m^2); and 3) this extremely high density, coupled with the close proximity of plants to the trail and the stream, would seem to make the population extremely vulnerable to disturbances.

GP – The most likely threat here is probably drought. Some of the ledges on which plants occur are sun-exposed, and in recent drought years, some of these ledges appeared to have dried up and lacked plants. Although the population here is in close proximity to the road (5-30 meters from the road), it is sufficiently upslope that it appears not to be threatened by human activity.

HP – Given that the habitat occupied by *M. gemmiparus* here is atypical when compared with all other sites, we would not be surprised if these populations are less persistent than others. Nonetheless, the most likely current threats here are 1) high stream flow events (flood and scour), and 2) trampling by animals or humans. These populations are right along Fall River, which receives high use by fishermen. In all our visits to the sites, fishermen were observed wading and walking along the stream bank nearby, and such traffic could easily trample plants in these populations.

NI & EI – These populations are quite similar, and share the likely threat of trampling by hikers on the adjacent trails. While some patches on these trails are tucked into the cliff base and somewhat protected, others (e.g., at NI-2, NI-3, EI-2) are under "inviting" overhangs that might attract hikers off-trail (e.g., to get out of the rain; see Fig. 82, 83, & 87), or are directly adjacent to the trail and in danger of being trampled (e.g., see Fig. 103-105).

SSP - The extremely small size and area of this population make it especially vulnerable to seemingly random disturbances. Since the Park is not yet open to visitation, human-caused threats are not evident at present.

Recommendations

Based upon our analysis, we recommend the following actions to enhance the likelihood of persistence of *M. gemmiparus* populations, and to increase our base of relevant scientific information that could inform management and conservation efforts:

1) The search for additional populations should continue, especially in areas such the Middle Saint Vrain Canyon, Horseshoe Park, and the North Inlet and East Inlet drainages, where additional populations seem likely.
2) Efforts to minimize adverse human impacts on populations should be enhanced. For instance, we strongly recommend that the Hankins Gulch Trail, which crosses the Hankins Gulch Population in the Pike National Forest, be rerouted to the opposite side of Hankins Gulch Creek in the vicinity of the population to eliminate trampling of plants by hikers. Trails adjacent to populations in RMNP are probably less easily moved, given the more severe aspect at the sites, but such populations should be regularly monitored for signs of human disturbance.
3) In order to determine more definitively the sizes of populations (and whether they are highly dynamic over short time periods, as our observations suggest), fine-scale demographic sampling of populations should be undertaken, with sampling repeated several times within a growing season. Similarly, fine-scale genetic analysis of populations and patches should be performed to provide more definitive information on population structure and gene flow.
4) Given that much suitable, but currently unoccupied habitat for *M. gemmiparus* appears to exist, and that plants are easily propagated in the lab or greenhouse, *ex situ* propagation of bulbils followed by experimental planting would appear to be feasible. Such a "captive breeding"/reintroduction program could well result in the establishment of additional experimental populations at modest cost or effort.

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Key to Figures

Note: File names contain abbreviated explanations/captions for individual figures.

Fig. 1-44: Saint Vrain Populations
Fig. 1. View (from Population 1) of meadow below, showing location from which Fig. 2 & 3 were taken.
Fig. 2-3. Overviews of SV populations from meadow below.
Fig. 4-5. SV Population 1.
Fig. 6-8. SV Population 2.
Fig. 9-10. SV Population 3.
Fig. 11-14. SV Population 4.
Fig. 15-17. SV Population 5.
Fig. 18-20. SV Population 6.
Fig. 21. SV Population 7.
Fig. 22-25. SV Population 8.
Fig. 26-32. SV Population 9.
Fig. 33. SV Population 10.
Fig 34. Overview showing SV Populations 11-13.
Fig. 35-39. SV Population 11.
Fig. 40. SV Population 12.
Fig. 41. SV Population 13.
Fig. 42-44. SV Population 14.

Fig. 45-52: Hankins Gulch Population
Fig. 45. Map showing areas searched near Hankins Gulch Population.
Fig. 46-52. HG Population.

Fig. 53-56: Guanella Pass Population
Fig. 53. Overview of GP population showing 3 patches.
Fig. 54-56. Different views of GP-1, patch 1.

Fig. 57-111: Rocky Mountain National Park Populations
Fig. 57. Map showing areas searched along Fall River Road.
Fig. 58. Aerial photo showing areas searched around Lawn Lake and Roaring Creek.

Fig. 59-72: Horseshoe Park Populations
Fig. 59-68. HP Population 1.
Fig. 69-72. HP Population 2.

Fig. 73-92: North Inlet Populations
Fig. 73-81. NI Population 1.
Fig. 82-85. NI Population 2.
Fig. 86-90. NI Population 3, patch 4.
Fig. 91-92. NI Population 3, patch 5.

Fig. 93-111: East Inlet Populations
Fig. 93-99. EI Population 1.
Fig. 100-111. EI Population 2.

Fig. 112-124: Staunton State Park Population
Fig. 112-113. SSP Population, patch 1.
Fig. 114-119. SSP Population, patch 2.
Fig. 120-124. SSP Population, patch 3.

Table 1. Population Descriptions and Locations - Middle Saint Vrain Canyon Populations							
Popl. ID	Patch ID	Description	area (m^2)	est.# plants	Plant condition and size	GPS*	Elevation (ft)
SV-1	22a	Rock shelf on small cliff, shallow soil.	1.0	200	1-6 cm, 2-5 nodes, all dry, no flowers		10230
	22b	Small overhang at base of small cliff, "ground level". Few meters belw #22a.	2.0	300	1-6 cm, 2-5 nodes, all dry, no flowers		10223
	22c	Talus below cliff immediately east of #22a. Interspersed with forbs and shrubs.	4.0	300	2-12 cm, 3-12 nodes, all dry, some dried flowers		10223
	22d	Talus below east of #22. Interspersed with forbs and shrubs.	8.0	2000	2-12 cm, 3-12 nodes, all dry, some dried flowers		10223
SV-2	28a	Top of another gulley 40 m west of #27 and 25 m lower.	0.5	100	1-2 cm, 2-3 nodes, mostly green, no flowers, very tiny		10407
SV-3	27a	Small shelf on side of gulley about 50 m west of the large arch roof of #26b.	0.2	30	1-2 cm, 2-3 nodes, mostly green, no flowers, very tiny		10483
	27b	Inside gulley about 50 m west of the large arch roof of #26b.	1.0	150	1-2 cm, 2-3 nodes, mostly green, no flowers, very tiny		10483
SV-4	26a	Under a large overhang behind trees. 20 m west of a deep, wet gulley. 60-70 m above population 9.	1.0	200	1-2 cm, 2-3 nodes, mostly green, no flowers, very tiny		10497
	26b	20 m west of #26a on a tiny, ground level, rock ledge below a huge 3-m arch-shaped overhang.	2.0	200	1-6 cm, 2-5 nodes, all dry, no flowers		10497
SV-5	38a	West end of a huge roof.	0.1	30	1-3 cm, 2-3 nodes, mostly green, no flowers		10486
	38b	West end of a huge roof.	0.2	150	1-3 cm, 2-3 nodes, mostly green, no flowers		10486
	38c	West end of a huge roof.	0.1	30	1-3 cm, 2-3 nodes, mostly green, no flowers		10476
	39a	On terrace under small overhang at base of cliff band. Several meters west of the huge roof at #38.	8.0	2500	1-6 cm, 2-8 nodes, mostly green, no flowers		10476
	39b	A small patch between #38 and #39a.	0.5	100	1-6 cm, 2-8 nodes, mostly green, no flowers		10476
	40	On tier directly below #38. Plants under deep overhang at base of 20-m cliff	1.0	200	1-6 cm, 2-6 nodes, mostly green, no flowers		10454
SV-6	36	Under an overhang at base of cliff band about 75 m higher than popl. 10, 11, 12 band and slightly east. Near a large roof.	0.5	100	1-2 cm, 2 nodes, green, no flowers, very tiny		10450
	37	On same tier as popl. 5. East of the huge roof with seep at popl 5. West of #36.	2.0	600	1-6 cm, 2-6 nodes, most smaller, mostly green, no flowers		10467
SV-7	42	Sporadic plants under overhang split by 2-3" crack. Far east end of cliff band above talus.	1.0	200	1-4 cm, 2-5 nodes, dry, no flowers		10435
	41	At overhanging east edge of slab where it meets talus slope. Adjacent to huge log on talus edge.	1.0	200	1-4 cm, 2-7 nodes, dry, no flowers		10399

SV-8	23	Under overhang. 30 m higher and 75 m east of #22. 8m above "ground." Near 15' dead tree stump.	5.0	200	1-7 cm, 2-8 nodes, mostly dry, no flowers		10320
SV-9	24	On small rock shelf in dihedral at base of cliff. 25 m west of dripping "waterfall."	0.2	100	2-5 cm, 2-4 nodes, mostly dry, no flowers		10221
	25	On terrace at base of cliff. 10 m west of dripping "waterfall." Most plants in 3 tiny dense patches.	1.0	100	2-5 cm, 2-4 nodes, mostly dry, no flowers, very tiny		10230
	31a	50 m west of dripping "waterfall." High in a 5-m gulley that splits the cliff band on a shelf.	0.6	100	1-7 cm, 2-10 nodes, green, no flowers		10292
	31b	On same terrace as #24, 25. 50 m west of dripping "waterfall." Dispersed in gulley.	0.5	100	2-5 cm, 2-6 nodes, mostly green, no flowers		10292
	32a	10 m high on cliff face just right of dripping "waterfall." In a small "hanging garden."	0.2	10	Plants ~ 5-8 cm, 4-6 nodes, green, no flowers		10280
	32b	On a 2-m-wide ledge 10 m up on cliff 6 m left of dripping "waterfall."	1.0	100	2-6 cm, 2-6 nodes, mostly green, no flowers		10280
SV-10	33	On 1 m terrace in 20 m cliff band below a black overhang with shrubs. E of dripping "waterfall."	1.0	300	2-6 cm, 2-6 nodes, mostly green, no flowers		10274
SV-11	34a	Under overhang at base of 20-m cliff. Same cliff band as #33, 50 m east of #33.	1.0	100	1-4 cm, 2-4 nodes, dry, no flowers		10261
	34b	Second patch 5 m east of #34a.	1.0	100	1-4 cm, 2-4 nodes, dry, no flowers		10261
	34c	On a ledge 6 m above #34a. Below another (upper) overhang.	0.1	100	1-4 cm, 2-7 nodes, dry, no flowers		10261
	34d	5 m east of #34b on same terrace next to the top of a vertical, leaning dead log.	1.0	200	1-5 cm, 2-8 nodes, dry, no flowers		10261
	35a	Sloping terrace immediately east of #34.Below black/white-streaked cliff that overhangs at bottom.	15.0	4000	2-6 cm, 2-10 nodes, 80% dry, ~ 100 plants w/flowers		10233
	35b	In alcove 3 m above #35a. Plants scatterred in patches.	2.0	300	Most 1cm, 2 nodes, green. One patch 3-6 cm, 5-10 nodes, green, some flowering		10233
	35c	25 m east of #35a on same trerrace.	0.3	50	2-6 cm, 2-6 nodes, all green, no flowers		10233
SV-12	35d	Base of chimney near small waterfall. Same level as #35a but 60 m east. On small shelf.	0.1	10	1-4 cm, 2-7 nodes, dry, no flowers		10277
SV-13	43	At bottom of cliff band 20 m directly below #34c.	1.0	200	1-4 cm, 2-7 nodes, dry, no flowers		10230
	44a	At base of same cliff and just west of #43.	1.0	500	1-4 cm, 2-7 nodes, most dry but ~ 100 green, no flowers		10213
	44b	10 m west of #44a.	1.0	300	1-4 cm, 2-7 nodes, dry, no flowers		10213
SV-14	29	Terrace above a 35-m tall cliff. 100 m east of the prominent low rock slab. At the base of a dihedral.	1.0	200	2-6 cm, 2-6 nodes, mostly green, no flowers		10407
			68.1	14660			

*WGS84 Datum, field-collected with Garmin eTrex Summit, +/- 1-5 m.

Table 2. Population Descriptions and Locations - Hankins Gulch Population							
Popl. ID	Patch ID	Description	area (m^2)	est.# plants	Plant condition and size	GPS*	Elevation (ft)
HG-1	1	On Hankins Gulch trail, mostly on north side. Under overhang with water seep at back. < 2 m from creek.	10.0	100,000	2-20 cm, 3-120+ nodes, most green, but dry plants at margins, no flowers yet		8520
	2	Previously described patch on cliff base several m east of main patch. In 1993 there were 1000+ plants here.	1.0	0	no plants		8520
	3	Slab to northeast of main patch. Rock slab with duff and shrubs. Several patches of plants on small ledges.	2.0	2,000	2-6 cm, 3-8 nodes, all dry, no flowers		8520
			13.0	102,000		*WGS84 Datum, field-collected with Garmin eTrex Summit, +/- 1-5 m.	

Table 3. Population Descriptions and Locations - Guanella Pass Population							
Popl. ID	Patch ID	Description	area (m^2)	est.# plants	Plant condition and size	GPS*	Elevation (ft)
GP-1	1	Main patch on cliff face of rock outcrop. Several pockets holding plants.	8.0	600	2-10 cm, 3-16 nodes, most green, but some pockets of dry plants, no flowers		11120
	2	Base of cliff on ground below cliff-face patch. In 2004 there were approx. 100 plants here.	1.0	0	no plants		11120
	3	Previously described patch under boulder 20 m NW of main patch. In 2004 there were approx. 100 plants here.	1.0	0	no plants		11112
			10.0	600		*WGS84 Datum, field-collected with Garmin eTrex Summit, +/- 1-5 m.	

Table 4. Population Descriptions and Locations - Horseshoe Park Populations							
Popl. ID	Patch ID	Description	area (m^2)	est.# plants	Plant condition and size	GPS*	Elevation (ft)
HP-1		Lower Fall River gravel bar. South bank of river. Approximately 300 m downstream of #2, and 200 m upstream Hwy 34 bridge	30.0	3,000	1 - 6 cm, 1 - 5 nodes, many flowering.		8550
HP-2		Lower Fall River gravel bar. South bank of river.	8.0	200	0.5 - 3 cm, 1 - 3 nodes, no flowering.		8570
HP-3		Alluvial fan		0	no plants observed in recent years		
			38.0	3,200		*WGS84 Datum, field-collected with Garmin eTrex Vista, +/- 1-5 m.	

Table 5. Population Descriptions and Locations - North Inlet Populations							
Popl. ID	Patch ID	Description	area (m^2)	est.# plants	Plant condition and size	GPS*	Elevation (ft)
NI-1	1	At base of dihedral/chimney on SE-facing, 20-m cliff. In small side-drainage, 50 m N of trail	4.0	200	small, none in flower		8700
	2	Small patch near #1	10.0	2,000	small, none in flower		8690
NI-2	3	Adjacent to trail on north side. Ground level under overhanging boulder face.	6.0	1,000	small, none in flower		8681
NI-3	4	Adjacent to trail on north side. In alcove with overhang and very shallow soil. Just below where trail meets falls area.	3.0	1,000	small, none in flower		8817
	5	2 small patches on ledge 25 meters west of and 7 meters above patch #4.	2.0	200	small, none in flower		8831
			25.0	4,400		*WGS84 Datum, field-collected with Garmin eTrex Vista, +/- 1-5 m.	

Table 6. Population Descriptions and Locations - East Inlet Populations							
Popl. ID	Patch ID	Description	area (m^2)	est.# plants	Plant condition and size	GPS*	Elevation (ft)
EI-1	1	in crevice at rock base 3 m north of trail	5.0	200	plants dried up		8440
EI-2	2	at base of rock face 2-3 m north of trail	3.0	200	small, some green		9200
	3	directly adjacent to rock steps 5 m up trail from patch 2	3.0	200	small, some green		9202
	4	above rock steps, ~ 15 m up trail from patch 3	2.0	200	small, some green		9215
			13.0	800		*WGS84 Datum, field-collected with Garmin eTrex Vista, +/- 1-5 m.	

Table 7. Population Descriptions and Locations - Staunton State Park Population							
Popl. ID	Patch ID	Description	area (m^2)	est.# plants	Plant condition and size	GPS*	Elevation (ft)
SSP-1	1	4 m to left of base of waterfall	0.2	3	green but small, 3-5 nodes		9577
	2	4 m to right of falls	0.5	50	up to 10 nodes; drying		9585
	3	30 m to right of falls	0.3	20	plants dry and shattering		9585
			1.0	73		*WGS84 Datum, field-collected with Garmin eTrex Vista, +/- 1-5 m.	

Table 8. Summary of estimated number of plants and area occupied at each major site		
Site	est.# plants	area (m^2)
St. Vrain (SV)	14,660	68
Hankins Gulch (HG)	102,000	13
Guanella Pass (GP)	600	10
Horseshoe Park (HP)	3,200	38
North Inlet (NI)	4,400	25
East Inlet (EI)	800	13
Staunton State Park (SSP)	73	1
TOTAL	125,733	168

2006 Addendum and Update by David A. Steingraeber – September 5, 2006

In 2006, I visited populations at Horseshoe Park (in Rocky Mountain National Park) and at Staunton State Park to monitor populations and to show the populations to relevant agency personnel. On July 5, 2006, I visited the Horseshoe Park populations with Jeff Connor from RMNP. Plants had recently germinated and were just beginning to grow at both HP-1 and HP-2. Since plants were tiny and not fully apparent, population sizes were not formally estimated. However, it appeared that the populations were probably quite similar in size and condition to what we had observed in 2005.

On August 29, 2006, I visited the Staunton State Park population, accompanied by Rob Billerbeck from Colorado State Parks. We found plants present in all three patches described in 2005. In contrast to previous visits in 2003 and 2005 (in mid-September both years), we did not find evidence that some plants had already dried up and shattered. All plants observed were alive, and estimated total abundance was slightly higher than what we had observed in previous years (perhaps due to some plants already having died and escaped detection when observations were made in 2003 and 2005). Patch 1 contained a single plant (in contrast to 3 plants in 2005). Patch 2 contained 16 small plants, fewer than the 50 plants that were observed here in 2005. Patch 3, however, contained significantly more plants (~150-200) than were observed in 2005 (20). Thus, the estimated total population size in 2006 is roughly double what has been observed/estimated in previous years, but the population remains the smallest of all known populations.

During 2006, I germinated bulbils from field collections made in 2005, and Paul Beardsley and I will be carrying out AFLP analyses of these plants in the next few months. Our preliminary analyses (carried out in 2003 & 2004) indicated a surprisingly large amount of genetic variation, with ~2/3 of the variation occurring within populations. Furthermore, cluster analysis indicated that populations in close proximity to one another clustered together. Our ongoing work will replicate the preliminary analyses and will include additional populations. Additionally, we will use AFLP analysis to test whether the multiple "offspring" (bulbils) produced by one plant are truly genetically identical to the parent plant, or whether somatic mutations might be serving as a source of within-population (and within-plant!) genetic variation.

I am continuing to grow plants from several populations in the lab and plan to maintain such "lines" for further work, including possible reintroduction efforts. Interestingly, plants from different populations grown under identical conditions in the lab exhibit pronounced morphological differences. For instance, Guanella Pass plants are the only ones flowering under lab conditions, and the plants from GP are smaller-statured than those from Saint Vrain and Hankins Gulch. Thus, it appears likely that at least some of the genetic variation among populations is manifested in observable morphological and phenological variation, as well.