Population dynamics, rarity, and risk of extinction for populations of *Mimulus gemmiparus* (budding monkeyflower) on National Forests of Colorado

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Summary

We surveyed the three known populations of the rare endemic plant, *Mimulus gemmiparus* (budding monkeyflower), on National Forest System (NFS) lands to document demographic conditions and population dynamics parameters. The numbers of adult plants found at each of these three sites in 2013 were generally similar to observations made in past years, but the condition of individual patches of plants varied. Our results further support the idea that populations are best understood as groups of individual patches of plants that may be somewhat ephemeral. The persistence of populations is therefore dependent both on the risk that any given patch will become extinct in the face of disturbance and on the number and distribution of patches.

The Middle Fork of the Saint Vrain holds the only extant population of *M. gemmiparus* where stable metapopulation dynamics may occur. That is, colonization and establishment of new patches in this population may be sufficient to counteract the long term likelihood that existing patches will go extinct. At all of the other locations, populations appear to behave more like "remnants" with limited potential for colonization and new patch establishment. Persistence of these populations is much more tenuous.

A management strategy for protection of the species should focus on passive management to protect the most viable population at Saint Vrain, which the U.S. Forest Service (USFS) is already doing, along with considering active management at Hankins Gulch and Guanella Pass to encourage the establishment of more numerous and widely dispersed patches within these populations. Future research should focus on better understanding the population dynamics of this species in the wild and specifically tracking the fate of individual patches of plants. The question of rarity is best addressed by systematically surveying potential habitat that has yet to be explored.

Introduction

Mimulus gemmiparus (budding monkeyflower) is one of Colorado's rarest plants. The species has very strict habitat requirements (Beardsley 1997). It is endemic to the state, and its range is limited to just a few very small locations in the mountains along Colorado's Front Range. At the time of our last species status update to the USFS in 2005, eight locations were known range-wide (Steingraeber and Beardsley 2005). One of these original populations (the type location near Fall River Road in Rocky Mountain National Park) is now presumed to be extinct, but one other new population was discovered at Staunton State Park in 2007 by Paul Beardsley (Beardsley and Beardsley 2007), so the present count of extant localities remains at eight.

Three of the eight known locations are on National Forest System (NFS) lands. The Saint Vrain (SV) location is on the Roosevelt NF, and the Guanella Pass (GP) and Hankins Gulch (HG) locations are on Pike NF. According to 2005 estimates, these three locations accounted for about 93% of the total population of *M. gemmiparus* in terms of the number of individual plants, and about 54% of the estimated geographical extent of the species (Steingraeber and Beardsley 2005). We visited each of these three populations in August, 2013, to provide an update on the status of the species on lands managed by the US Forest Service. This work is a continuation of our ongoing efforts to monitor the status and conservation of the species, which dates back to the early 1990's.

Methods

Each of the three populations on NFS lands were visited according to the schedule in Table 1. At each location, we visited all of the patch locations where the plant has been documented in the past. These locations are described in Steingraeber and Beardsley (2005)[1]. In that report, there was confusion over some of the site locations at Guanella Pass, so we corrected the list of patch locations at that site for this inventory. All known locations of *M. gemmiparus* on NFS land were surveyed in this study, and the timing of these visits was selected to target the season when the species is most robust in the growth stage and most visible.

Table 1. Schedule of 2013 site visits to *M. gemmiparus* populations on National Forest System lands in Colorado.

2013 Schedule of site visits (*M. gemmiparus* locations on USFS)		
Location	Dates	Observers
Saint Vrain (SV)	8/10 and 8/11	Mark Beardsley
Guanella Pass (GP)	8/4	Mark Beardsley
	8/17	Mark Beardsley, David Steingaeber, Seema Sheth
Hankins Gulch (HG)	8/5	Mark Beardsley, Dustin Gannon

[1] In our 2005 report, each known patch of plants was assigned an identification number. "Patch ID" numbers were assigned to patches in the field and are unique within each site. We decided to retain these patch numbers in these reports so that they would continue to be consistent with the patch numbers contained in our field notes. These numbers have no relevance except as unique identifiers for each known patch to simplify data recording and for ease in re-locating these specific locations in future surveys.

As in past years, we estimated the number of individual plants present at each identified patch location 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 by visual estimation. Concerns about the accuracy of estimating population numbers this way are described in our 2005 report.

For each patch, we recorded observations regarding the size, developmental stage, and condition of plants. These data were especially useful for estimating the number of potential propagules (bulbils) present at each patch. We calculated this parameter by combining data for the number of plants and a description of the developmental stage of the plants (estimated mean number of nodes per plant) at each patch according to the method outlined in Beardsley (2012). Because the species is a "vegetative annual," the number of bulbils is a good representation of population size because it represents the number of individuals that exist during critical periods of the plant's life history.

As in past seasons, we also intensively searched likely potential habitat in the vicinity (approx. 100 meters) of the known populations, focusing on areas up- or down-drainage from each site, to look for additional patches that had not been previously documented. When new patches were found, we described the locations and named each patch with a unique identification number.

In our 2005 report, we used terminology that considered a population to be any group of plants that is separated from other groups of plants by a distance of approximately 30 meters (m). By this convention, there were multiple populations of the species present at some of the locations (*e.g.*, by this definition, there were 14 reported "populations" at the SV site). While this characterization does have some biological relevance (Steingraeber and Beardsley 2005), we found that it tends to imply an exaggerated sense of the plant's distribution in common vernacular, and there are equally valid biological reasons for not considering these groups to be separate populations. For this report, each major location, by drainage, is considered one population, and the individual groups separated by 30 m or more are termed "subpopulations."

Results

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

The Middle Saint Vrain area was visited and searched on August 10-11, 2013, by Mark Beardsley. We were able to find the locations of each of the patches identified in the 2005 report and update the condition of the patches with observations from this site visit. Numerical population data are summarized in Table 2, which also provides a comparison of 2005 and 2013 observations. Overall, the condition of the population in 2013 was similar to what we described in 2005. The estimated number of individual plants was similar (17,165 in 2013 compared to 14,660 in 2005), but the number of bulbils in 2013 was estimated at about double the figure for 2005 (236,790 and 137,140, respectively), which is a result of the fact that the plants seen in 2013 had developed more nodes.

In a few cases, we found that groups of plants that had been previously described as separate patches would actually be better described as a single, broader patch, since the boundary between them was not distinct. Specifically, patches #22c and #22d from the 2005 report were grouped into one patch (#22c). Similarly, patches #31a and #31b were grouped together as #31a, and #44a and #44b were grouped together as #44a.

Our search for "new" patches (*i.e.*, plant occurrences that have not yet been described) was limited to the main cliff face upon which all the existing patches are located. Basically, the searcher checked likely habitat locations while travelling between the known locations. This search resulted in the discovery of several new patches within subpopulation 8 near patch #23. These patches were called #23b, #23c, #23d, and #23e, and the patch that had been identified as #23 is now called #23a.

We found plants at most of the patches that were occupied in 2005, but there were exceptions. No plants were found on any of the patches in subpopulation 2, 3, or 14. These subpopulations each held very few plants in 2005, with just 100, 180, and 200 plants in subpopulations 2, 3, and 14, respectively. The locations of these patches were described in detail in our field notes, but it is possible that we did not find the correct sites in 2013 for these instances. This is not likely, however, because the searched locations matched both GPS readings and photographs taken in 2005. This means that these patches probably did not have live plants at the time of our survey. In addition, no evidence was found of dried stems at these sites. Therefore, the results suggest that no adult plants were present at these locations in 2013, despite documented presence in 2005.

Similarly, we have confidence in the observation that four specific patches within subpopulations 5, 9, and 11 that had plants in 2005 were without plants in 2013. These were all very small patches that had 100-200 individuals in 2005. The data for subpopulation 8, on the other hand, are difficult to interpret. We found plants in four separate patches near the described location for that subpopulation, but none at the exact location that was described for the sole patch identified in 2005. Clearly, there is a healthy number of plants in subpopulation 8, with 750 individuals estimated in 2013 compared to just 200 in 2005, but the distribution among patches has changed. It seems possible that plants on patches #23b-23e may have been present in 2005 but were undetected.

Table 2. Population estimate data for the Saint Vrain population of *M. gemmiparus*, 2005 and 2013. Highlighted cells indicate patches in which no plants were found in an observation year.

Sub-Popl. ID	Patch ID	2005		2013	
		est.# plants	est. # bulbils	est.# plants	est. # bulbils
1	22a	200	1,000	60	700
	22b	300	1,500	1,100	33,000
	22c	2,300	34,000	1,000	16,000
2	28a	100	200	0	0
3	27a	30	60	0	0
	27b	150	300	0	0
4	26a	200	400	100	400
	26b	200	600	200	1,000
5	38a	30	60	20	80
	38b	180	360	200	1,800
	39a	2,500	22,000	2,500	30,000
	39b	100	1,000	0	0
	40	200	2,000	0	0
6	36	100	150	100	400
	37	600	3,600	3,000	30,000
7	42	200	1,000	100	600
	41	200	1,500	200	1,000
8	23a	200	1,600	0	0
	23b	0	0	200	4,000
	23c	0	0	150	1,800
	23d	0	0	200	2,500
	23e	0	0	200	3,000
9	24	100	250	30	480
	25	100	250	0	0
	31a	200	1,200	600	9,600
	32a	10	80	5	50
	32b	100	600	200	2,000
10	33	300	1,800	200	2,000
11	34a	100	400	20	120
	34b	100	400	20	160
	34c	100	800	80	500
	34d	200	2,000	0	0
	35a	4,000	48,000	4,500	80,000
	35b	300	450	300	1,000
	35c	50	300	800	4,000
12	35d	10	80	100	1,000
13	43a	200	1,600	400	5,000
	43b	0	0	80	600
	44a	800	6,400	500	4,000
14	29	200	1,200	0	0
TOTAL		**14,660**	**137,140**	**17,165**	**236,790**

<u>Hankins Gulch Population (HG) – Pike National Forest</u>

The Hankins Gulch area was visited on Aug. 5, 2013, by Mark Beardsley and Dustin Gannon (student). This population (characterized in detail in Beardsley, 1997) has been described as a singular subpopulation with one main patch and two much smaller "satellite" patches. The main patch historically holds more plants than any other complete population of *M. gemmiparus*, with seasonal counts often peaking at more than 100,000 individuals. Our estimate of 102,000 plants here in 2005 accounted for about 80% of the total plant number for the species at the time. We estimated there to be about 42,000 plants present during our visit in 2013 with 756,000 bulbils (see Table 3), which is about half the estimate made in 2005.

The two "satellite patches" were originally described in the late 1990's, and have only occasionally been seen to have plants (unpublished data). Numerous intensive searches for more *M. gemmiparus* in the vicinity of the Hankins Gulch population have never revealed any additional locations, and likewise no new patches were discovered during extended searches in 2013.

Table 3. Population estimate data for the Hankins Gulch population of *M. gemmiparus*, 2005 and 2013. Highlighted cells indicate patches in which no plants were found in an observation year.

Sub-Popl. ID	Patch ID	2005		2013	
		est.# plants	est. # bulbils	est.# plants	est. # bulbils
1	1	100,000	1,400,000	42,000	756,000
	2	0	0	0	0
	3	2,000	18,000	0	0
TOTAL		**102,000**	**1,418,000**	**42,000**	**756,000**

Guanella Pass Population (GP) – Pike National Forest

The Guanella Pass population was visited on August 4, 2013, by Mark Beardsley. The population was surveyed again on August 17 by Mr. Beardsley with David Steingraeber and Seema Sheth to sort out contradictions about the location of patches from past reports and field notes. It is now clear that plants had been identified in seven different patches as of 2005, in two subpopulations (see Figure 1).

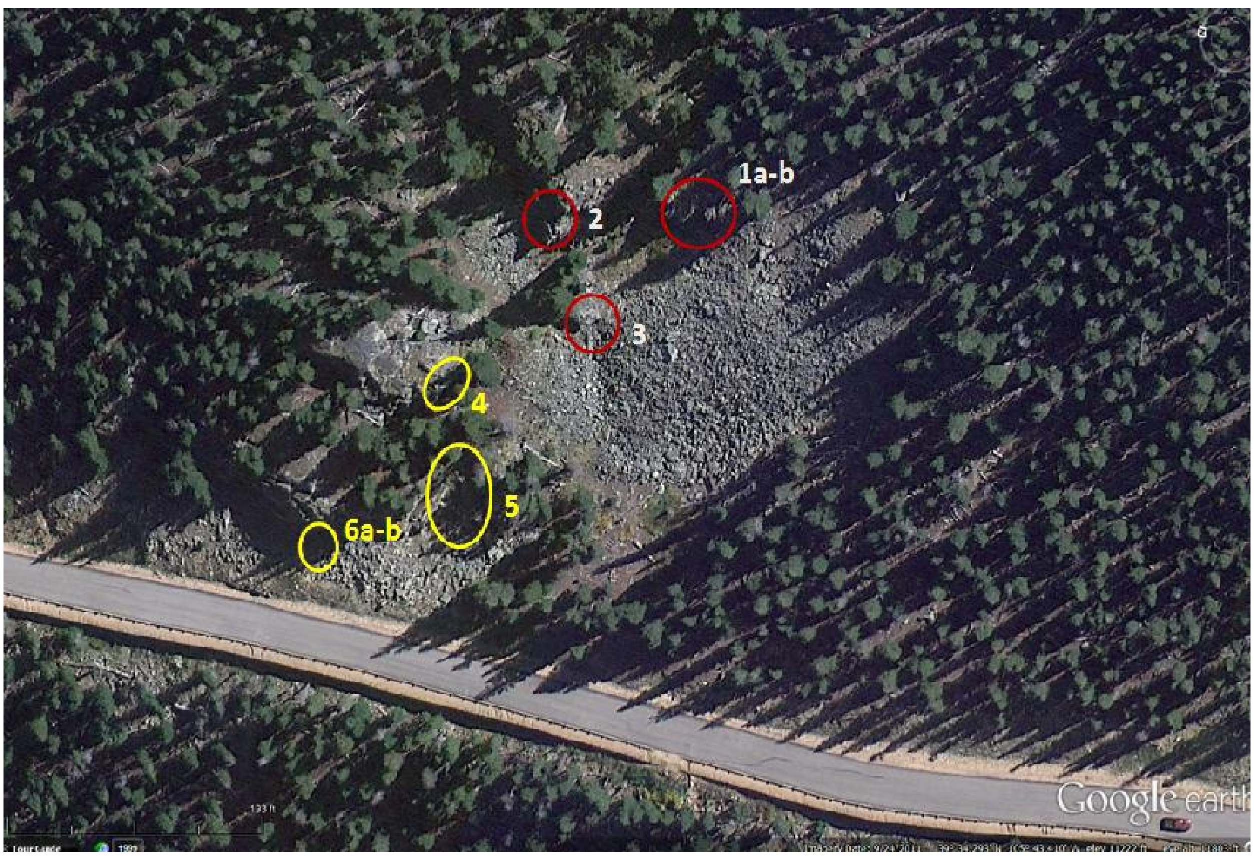

Figure 1. Location of patches at the Guanella Pass population. Patches circled in red (uppermost three circles farthest from road) are in subpopulation 1, and those in yellow (lowermost three circles) are in subpopulation 2.

Each of these patches was surveyed on August 17, and the demographic results are summarized in Table 4. We found plants at each of the previously described patches in 2013 except for patch 3 in subpopulation 1, which was also devoid of plants in 2005 but had about 100 individuals in 2004. In addition to the seven originally described patches, we also identified one new patch (#2) in 2013, which held a singular *M. gemmiparus* plant. It is also interesting that we found about 200 plants growing on patch 1b, which did not have adult plants in 2005. Our estimate of 900 plants and about 15,000 bulbils in subpopulation 1 is not much different from estimates made in past seasons.

Subpopulation 2 is the location that was originally described when *M. gemmiparus* was first discovered at Guanella Pass. We found plants on all of the described patches of this subpopulation on our August 17 visit, and also identified a "new" patch on a rock tier above these sites that had not yet been identified. This patch (#4) is significant, with an estimated 500 adult plants and about 4,200 bulbils. The total number of plants in subpopulation 2 was estimated at around 1,280; bulbil production was estimated at about 15,300 bulbils. Unfortunately, we do not have data from 2005 with which to compare these values. Due to the confusion in patch location descriptions, subpopulation 2 may not have been thoroughly searched in 2005, so the fact that no plants were described for these locations in 2005 is not a good indicator that plants were not actually present during that growing season. On the other hand, if plants had been present in these densities in 2005, it would have been unlikely that we would have missed them.

Table 4. Population estimate data for the Guanella Pass population of *M. gemmiparus*, 2005 and 2013. Highlighted cells indicate patches in which no plants were found in an observation year.

Sub-Popl. ID	Patch ID	2005		2013	
		est.# plants	est. # bulbils	est.# plants	est. # bulbils
1	1a	600	12,000	700	15,000
	1b	0	0	200	800
	2	n/a	n/a	1	14
	3	0	0	0	0
2	4	n/a	n/a	500	4,200
	5	n/a	n/a	600	10,000
	6a	n/a	n/a	150	800
	6b	n/a	n/a	30	300
TOTAL		**600**	**12,000**	**2,181**	**31,114**

Discussion

Population dynamics

Overall, the estimated number of plants on NFS lands is 52% less in 2013 compared to estimates made in 2005 (Table 5). The estimated number of bulbils is 64% less. Looking at these simple numerical data alone, one may conclude that species numbers are declining. It is interesting that the decreased number of plants is totally due to changes observed at the Hankins Gulch population. The other two populations actually showed increased numbers in 2013 compared to 2005. At Hankins Gulch, the population has shown significant variation in the number of individuals in the past, with August observations ranging from 114,000 in 1993, 102,000 in 2005, only 20,000 in 2010 (Beardsley 2010), and 42,000 in 2013. This pattern suggests that a disturbance occurred between 2005 and 2010 which decreased the number of plants present at the site, and that perhaps the population is now recovering with increased numbers. In other words, one explanation for the apparent decline could be could be that is the result of a single acute disturbance at the Hankins Gulch site, from which the population is not yet fully recovered.

Table 5. Total plants numbers estimated for the three known populations occurring on NFS lands.

Popl. ID	2005		2013	
	est.# plants	est. # bulbils	est.# plants	est. # bulbils
SV	14,660	137,140	17,165	236,790
HG	102,000	1,418,000	42,000	756,000
GP	600	12,000	2,181	31,114
TOTAL	**117,260**	**1,567,140**	**61,346**	**1,023,904**

We also need to point out that these population number estimates are quite rudimentary. Not only might there be a large amount of error in estimating plant numbers using the methods we employed, the estimates are also based on just one or two observations of each population per season, which may or may not have been made at the exact time that the populations were at peak numbers. In this study, we also have limited data points over a relatively short time frame (8 years). While the data illustrate that there are fewer individual plants in 2013 than 2005, establishing a trend from these data is really not statistically possible. That is, the differences in estimates for the number of plants or bulbils at any of these populations from year to year (or, more specifically from 2005 to 2013) is not greater than what may be expected from the error inherent with sampling or by natural annual variation.

Patterns of plant distribution, or, more precisely, in the expression of various patches of plants from year to year, presents a more useful analysis. While monitoring population dynamics of *M. gemmiparus* the past 20 years across its range, we have seen more than a few instances where patches of plants have apparently gone extinct. In some of these cases, plants reappeared after one or more years (suggesting that bulbils can survive multiple years in dormancy), but in other cases apparently extinct patches have so far remained extinct. Likewise, there have been several instances where we suddenly found plants at locations that we are quite sure did not have plants before. In this study alone, we found at least 3 new patches in areas that had been searched in previous years. It is rather easy to dismiss the sudden appearance of a new patch with the rationalization that "we probably simply never noticed it before..." Because budding monkeyflower is an extremely small and inconspicuous plant that is only visible for 1-2 months of the year, this rationalization is probably valid in most instances.

Instances in which we are unable to find plants at locations where they had previously been observed, or "apparent patch extinction" events, are more difficult to dismiss. This phenomenon is documented 12 times in this study. Out of 51 previously occupied patch locations surveyed, 12 (24%) did not have identifiable plants during our 2013 site visits. The rationale for dismissing apparent patch extinctions is based in the argument that observers may commonly fail to notice plants that are really there. That is, "maybe they were there but we simply didn't see them this year..." or more likely "maybe we were looking in the wrong spot." Missing the location for described patches was actually a very reasonable rationale in the early years of our monitoring because site locations were typically simple narrative descriptions. But now, with the advent of GPS and digital photography, combined with the convenience of having such technology packaged in a “smart phone,” it seems less and less likely that these apparently disappearing patches are all cases of missed location or failed observation. Rather, it is highly probable that some of these patches were truly not present at the time of our survey. That is, the patches either went extinct or for some reason did not germinate in that season adequately enough to form adult plants.

The point of this explanation is that there is mounting evidence to support the observation of real population dynamics at the level of the patch within native *M. gemmiparus* populations. It is becoming clear that individual patches of plants within greater populations may come and go relatively frequently, and the evidence that they frequently "go" is stronger than the evidence that they frequently "come." That is, patches appear to be somewhat ephemeral, and at least in this study we see more cases of patches apparently disappearing (12) than of patches appearing (6). Furthermore, due to the issues of observer error/reliability described above, the cases of apparent patch extinction are probably more likely real than the cases of apparent patch establishment. The main point is that understanding the ecology and demographics of the species at this level may be far more important for establishing its level of “endangeredness” or susceptibility to extinction than simply monitoring the number of individuals within populations. Further efforts to better understand susceptibility of the species will benefit from studying population dynamics at the level of patches of plants.

The demographics of *Mimulus gemmiparus* are interesting. Counting individuals for demographic analysis the way we have done in this study leads to very high numerical estimates that are far greater than numbers commonly seen for "rare" plants. As a determination of rarity, though, these numbers are misleading. This plant grows in extremely small, dense patches that rarely exceed 1 m^2 in size, and patches are typically smaller than 1 dm^2 (Figure 2). Moreover, individuals of this species are, by all accounts, completely or nearly completely vegetative, with little or no sexual reproduction at play within populations. In all of these ways, patches, rather than singular plants, are more appropriate units for demographic analysis. The group of adult plants that make up a patch are obviously spatially and physiologically separate from one another, but the group functions together as an individual in the sense that it represents a discrete vegetative unit with its own particular genotype[2]. That is to say, a patch of *M. gemmiparus* behaves in all demographically important ways like an individual plant.

Figure 2. Typical patch size for *M. gemmiparus* is on the order of 1 dm^2 and rarely exceeds 1 m^2. The patches in these photos are part of the Saint Vrain population.

When viewed in this more appropriate perspective, the question about rarity of the species and susceptibility to disturbance becomes obvious. Most populations consist of a small number of patches (*i.e.*, individuals), with the Saint Vrain population having the largest number at 40, most of which occupy an area much smaller than a typical individual shrub or bushy forb. With eight identified patches, the Guanella Pass population is second among native *M. gemmiparus* populations in terms of demographic size[3]. Interestingly, the population with the greatest number of plants, Hankins Gulch, is presently represented by the fewest number of

[2] This is not to say that there is no genetic diversity within patches of plants (Beardsley, Steingraeber and Suni, 2004), but the mechanism for altering genotype within *M.gemmiparus* patches is likely the same as the mechanism by which genotypes change within individual plants, namely somatic mutation.

[3] According to our 2005 report, no other population had more than 6 identified patches. The two populations at Staunton State Park have recently been bolstered by the establishment of new patches via active planting, *i.e.*, re-introduction (Beardsley 2012) and if these efforts continue to be successful, these two populations will then contain more extant patches than Guanella Pass.

patches (one), which is basically the equivalent of one rather robust demographic individual at that site.

Another way of understanding the population dynamics of this species and its unusual life history is to employ the concept of metapopulation dynamics, as we suggested in 2005. Metapopulation theory is applied in conditions where a number of discrete populations exist within a matrix of unoccupied and available habitat. According to the theory, individual populations subject to demographic stochasticity have relatively short finite life spans, and they go extinct regularly and quite frequently. But if the rate of extinction of populations is balanced by the rate at which new populations become established, then the metapopulation (a sum of all the populations) will be stable (Frankel *et. al.* 1995).

It is tempting to think of *M. gemmiparus* in this way. Individual patches would be considered "populations" in this view, and the metapopulation would be the population of these populations (*e.g.*, Saint Vrain, Hankins Gulch, and Guanella Pass would each be a separate metapopulation). There also does seem to be a large amount of suitable, unoccupied habitat near where the plant is found, which meets another important condition for metapopulation dynamics to operate. Tempting as this theory may be, its applicability to *Mimulus gemmiparus* is probably unrealistic at most sites for a few basic biological reasons. Stable metapopulation dynamics occur in species that are capable of relatively rapid and frequent dispersal. This is because stability of the metapopulation is inherently dependent on the ability of individuals to routinely colonize new habitat space and to establish new populations at a rate that is equal to or greater than the rate of population extinction.

Not to say that dispersal is unheard of in *M. gemmiparus*, or that some mechanism of frequent dispersal might not be discovered for the species in the future, but at this time the best evidence is that propagule dispersal is generally limited to a few centimeters by the normal method where bulbils simply fall to the ground or spring from dried plant stems. Given the biology of the plant and the terrain in which it is found, longer dispersal distances would seem to be uncommon occurrences that are limited to rare instances where animal vectors such as pack rats or birds may transport bulbils longer distances. Another possible vector of long-range (>1 m) dispersal is water. There may be a general flow of bulbils in the downward direction on steep terrain from high patches to lower ones following intense rain storms or snowmelt runoff. But again, these events are seemingly rare and, in the case of the water vector, limited in location and direction.

If the plant does frequently disperse and regularly colonize new habitat patches, then we should expect to see common "satellite" patches in the vicinity of more established ones. Indeed, the Saint Vrain population, and to a lesser extent the Guanella Pass population, do appear to be exhibiting active colonization. For instance, we did find a new patch at Guanella Pass that contained a solitary plant. Could this be the result of a lone bulbil that happened to land in a promising spot? If this patch persists, then it appears we will have just witnessed the colonization of a new population. However, why are there no other patches of *M. gemmiparus* present in the apparently abundant potential habitat that surrounds the Hankins Gulch population? The two satellite patches that have been documented at Hankins Gulch in the past were both directly adjacent to, and perhaps even part of, the main patch.

The Saint Vrain population consists of many small patches dispersed about a large tiered rock face, and this pattern supports metapopulation dynamics that are probably absent in other *M. gemmiparus* populations. We suspect that flowing water is an active dispersal agent at this site, which can spread bulbils down the steep rocky terrain where new unoccupied patches of habitat may be found. Because of this mechanism, the rate of dispersal and colonization of new patches may be sufficiently high in this population to support stable metapopulation dynamics - so long as the patches near the top of the cliff persist to keep supplying bulbils for dispersal downhill. At all of the other populations this mechanism, and the notion of stable metapopulation dynamics, seems far-fetched. There simply isn't a mechanism for establishing new patches.

Most of the other populations of *M. gemmiparus* are best understood as "remnants," or populations without a working mechanism of metapopulation dynamics. Hankins Gulch is the extreme, with the population consisting of a solitary patch that sits alone on the floor of the valley (Figure 3). With no apparent means for dispersal (the water mechanism could not work here since it can't move bulbils uphill) and no new habitat to colonize downhill of the site (since that would place the plants within in an active creek channel), the persistence of this population depends upon survival of the one main patch. For the past 20 years, this patch has survived even in the face of what would seem to be great risk, including human use and trampling.

Figure 3. The Hankins Gulch population consists of this singular patch, located at the valley floor.

Apparently by luck, the patch was spared being burned in the Hayman fire of 2002 and was never seriously impacted by flash flooding following the fire, even though this threat seemed imminent. It survived decades of trampling in its location on a popular hiking trail (which has since been relocated away from the plants), persisted through years of drought, and maintained its numbers alongside encroaching vegetation. That said, we did document a significant decline in the number of plants in this patch from over 100,000 in 2005 to about 20,000 in 2010. According to Steve Olson (pers. comm.), Forest Botanist for the Pike NF, the population suffered an acute disturbance in 2010 when a group of hikers took refuge from a storm under the overhang, which would place them squarely in the center of the population. It is easy to imagine a large portion of the plants in the population being trampled to death by a few people standing around in the area for just a few minutes. I made similar observations of trampled plants and even a fire ring within the population in the 1990's and early 2000's. The USFS relocated the trail to the other side of the creek in 2011, which greatly reduces the risk that people (and wildlife) will inadvertently trample the plant, but the risk is not altogether eliminated. In any event, despite its success in surviving the past 20 years, we must recognize that two decades is a very short time frame from the point of view of the persistence of a population. The important observations are that threats are common and unpredictable in this environment, and that a population consisting of one very small patch is vulnerable and very much at risk. Any one of the disturbances described above (fire, flooding, drought, trampling, encroachment) or perhaps some yet unknown disturbance could easily kill all the plants in the population or make the site uninhabitable.

"...the 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, such that individual small patches may be transient and may not persist for long periods of time."

Steingraeber and Beardsley (2005)

In our 2005 report, we made a list of the most likely threats to persistence of *Mimulus gemmiparus* populations, which generally consisted of disturbance-related factors such as fire, drought, trampling, encroachment, etc. These are not deterministic factors that affect populations in a regular and predictable way. Rather, they are stochastic and generally unpredictable events that could rapidly wipe out individual patches. The number of plants making up a patch is just one factor among many that determine its likelihood of surviving each growing season. The best way of understanding threats to the persistence of populations is to realize that for each individual patch, there is some small but significant probability each year that it will be extirpated by one of these disturbance factors. The risk of extinction of a population is therefore, in the simplest terms, a function of the probability of individual patch extinction divided by the number of individual patches.

From a management perspective, the latter of these two factors is far easier to manage than the former. That is, it is difficult to decrease the probability of extinction or risk for any one patch beyond simply protecting it from obvious threats, such as trampling by people. Moving the trail away from the plants at Hankins Gulch by the USFS is an excellent example of reducing the risk of a particular patch extinction via protection against a specific obvious threat. However, most threats are not obvious and not predictable, and therefore the annual probability of patch extinction can never be driven to zero. That is, one can never protect natural patches of plants from all the random adverse things that could happen to it, especially since we can't predict what those things will be or when they will happen. That is simply the nature of stochasticity in small populations.

The number and distribution of individual patches is far easier to manage. Saint Vrain is the one population of *M. gemmiparus* that does have numerous patches and potentially stable metapopulation dynamics, so protection of this keystone population is critical. Passive protection of the greater Saint Vrain Canyon area via its occurrence in a Wilderness Area is already probably the best thing that can be done at this location, along with an awareness for where this population is located when planning land management activities. The critical thing is to not focus protection on just the individual plants and patches of this population, but to protect the broad matrix of available and suitable habitat in this area to also promote successful future colonization since this is a key factor to maintain stable metapopulation dynamics.

For the other populations (Hankins Gulch and Guanella Pass), a more active approach may be required to make a difference in reducing the risk of extinction. The Hankins Gulch site is protected in a designated Wilderness Area. A recent road improvement project on Guanella Pass was designed to avoid direct and indirect impacts to the Guanella Pass site (S. Popovich, pers. comm. August 2013). Protecting extant sites from adverse management actions in this way is the first step towards managing for conservation of the species. Beyond this, if the USFS (or anyone else) wishes to take action to protect these populations from extinction, the best approach would be to actively encourage the establishment of new patches. This conservation approach is currently being tested and applied by the Colorado Natural Areas Program and Colorado Parks and Wildlife who have teamed up on a study to establish new experimental populations of *M. gemmiparus* in Staunton State Park.

The natural populations of the plant in Staunton State Park are similar to Hankins Gulch in that they consist of one or two individual patches, but unlike Hankins Gulch the patches making up Staunton populations are very small, and their plant numbers are an order of magnitude less than at Hankins. In 2012, we began an experiment at Staunton to assess the feasibility of increasing the number and distribution of patches by establishing new patches using introduced plants that were propagated in a greenhouse. The approach can be described as "assisted migration" or "artificial establishment," and initial results are promising (Beardsley 2012). A similar approach could be taken at Guanella Pass and possibly at Hankins Gulch.

If successful, the approach of establishing new patches could even be extended to the creation of new populations where promising habitat exists in unoccupied drainages. This level of action may be a bit extreme as a prophylactic conservation measure, but it could be an important reactive measure to protect the species from extinction should we document the loss of multiple populations. The key to maintaining this treatment as a viable emergency management strategy is keeping a store of viable plant material with significant genetic diversity protected both in the wild and *ex situ*.

In addition to the previously discussed conservation measures, a prudent management strategy for the species should also include further study to better understand the population dynamics of *M. gemmiparus* populations by testing the ideas and assumptions that have been laid forth in this report. A start towards this end would be to support long-term monitoring aimed at specifically tracking the fate of individual patches of plants.

Ongoing efforts to search for additional extant populations may also be an important management objective. Though previous attempts at finding undiscovered populations have been generally unsuccessful (Steingraeber and Beardsley 2005, Beardsley and Beardsley 2007), there are many drainages on National Forests within Colorado with much apparent suitable *M. gemmiparus* habitat that have probably never been even cursorily surveyed. Because of the abundance of unexplored habitat, we may be tempted to speculate that the plant is less rare than it appears. But based on what is actually known about the species, that it consists of just eight populations of which seven are tenuous due to small patch numbers and vulnerability to disturbance, our present assessment is that *M. gemmiparus* is not only very rare but also at risk of extinction.

To date, efforts towards further exploration have mostly validated the appraisal of rarity and vulnerability. However, when it comes to surveying the potential range of the species to determine its actual physical extent, we may have only just scratched the surface. Only a small fraction of potential *Mimulus gemmiparus* habitat has been effectively explored. It is quite possible that further exploration may reveal that the plant is less rare and vulnerable than we suspect, but this is pure speculation until more such studies are undertaken.

It is easy to say, as we have, that the species is at risk of extinction, but quantifying the level of risk is something that will require a great deal more effort than and data than this study provides. Compiling all known observations and occurrence records for the plant would be one good way to gain more insight into the key parameters such as rates of patch extinction and establishment, as would a more rigorous survey of all known patches of the plant. Ideally, all of the patches in each of the known populations should be more clearly identified, located, and tracked through multiple seasons. Characterization of environmental conditions at each site using protocols similar to those we developed for the Staunton study (Beardsley 2012) and documentation of disturbance at these sites might also be an important component to future studies to relate these factors to the probability of patch extinction and to better define the range of potential habitat for the species.

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