

*Erigeron mancus* elevational density gradient as a baseline to  
detect future climate change in LaSal Mountain habitats

USFS  
Rocky Mountain Research Station, Flagstaff, AZ  
Manti-LaSal National Forest, Moab, UT

James F. Fowler, RMRS  
Barb Smith, Manti-LaSal NF

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## RESEARCH NEED AND QUESTIONS ADDRESSED

The LaSal daisy, *Erigeron mancus*, is endemic to timberline and alpine habitats of the LaSal Mountains in Utah (Nesom 2006)(Fig. 1), an insular, laccolithic mountain range on the Colorado Plateau in southeastern Utah (Blakey and Ranney 2008). *Erigeron mancus* occurs in alpine herbaceous communities from timberline to the crestline of the Middle Group of the LaSals (Smith 2008) and is on the Forest Service Sensitive Plant Species List (USFS 2003). Prior to the current study little was known about the population biology of this species.

Our study was conducted in and near the Mt. Peale Research Natural Area (RNA) which was established specifically to protect ecosystem structure and function in representative alpine and subalpine habitats. Research natural areas are part of a national network of ecological areas designated in perpetuity for research and education and/or to maintain biological diversity on National Forest System lands. Research natural areas are for nonmanipulative research, observation, and study. Forest Service objectives for these areas include protection against serious environmental disruptions and serve as baseline areas for measuring long-term ecological changes. The Manti-La Sal National Forest Land and Resource Management Plan (USFS 1986) requires management of the designated area with an emphasis on research, interpretation and protection against use that could jeopardize the diversity and pristine condition that led to original establishment of the RNA. It is important to maintain pristine conditions so that long-term changes can be monitored. Yet due to a lack of funding, no permanent study plots were established in the Mt. Peale RNA prior to our work.

Our primary goal in this study was to measure basic population biology parameters for the *E. mancus* population on the ridge from Mt. Laurel west to treeline. We estimated plant density and patch size in order to estimate the total number of *E. mancus* plants on this ridge. A Secondary goal was to describe vascular plant species composition within the area populated by *E. mancus*. For both of these goals, we were also interested in the influence of elevation within alpine habitats.

We also incorporated two more speculative goals to our work. The black rosy finch (*Leucosticte atrata*) is a summer resident of alpine and snow bed habitats in the Rocky Mountains. The LaSals are at the southern end of its known summer breeding range, yet summer sightings in southeastern Utah are rare. The species has not been documented in the LaSals since 1961 (Behle et al. 1963). There are anecdotal observations of a black rosy-finch from the northern portion of the La Sal range in 2008 and it has commonly been sighted at winter feeding stations at the western base of the LaSal Mountains. So the research question was: is the black rosy finch a summer resident of the alpine area in the Middle Group of the LaSals? The second more speculative goal focused on a snow glade plant community in the spruce-fir forest at the north base of Mt. Mellenthin. Snow glades are well known in the Rocky Mountains but may not have been recognized before in the LaSals. They form within conifer forests downwind from

large open areas where wind deposited snow persists well into the summer and prevents conifer establishment (Arno and Hammerly 1984). We conducted a floristic survey of the snow glade to see if it contained rare plant species.

We addressed these research goals and questions in the context of current and predicted global warming and the need to establish baseline ecological information in order to understand future climate change effects.

## METHODS

The study area was in the central high peaks of the La Sal Mountains in Grand and San Juan Counties in southeastern Utah (Fig. 1) and is managed by the USDA Forest Service, Manti-La Sal National Forest, Moab Ranger District. The study area was defined as the Mt. Peale Research Natural Area (RNA), the ridge just west of Mt. Laurel, and the snowglade at the north base of Mt. Mellenthin.

The week of June 22, 2009 we established a 1-km elevational ridgeline transect from timberline to the large talus field at the west base of Mt. Laurel. This included three vegetation patches with gaps for the large talus patches near the USFS pre-Laurel weather station. It covers an elevational range from 3430 m to 3629 m through patches of alpine herbaceous vegetation. We measured both *Erigeron mancus* density (Fig. 2) and vascular plant species composition (Fig. 3) within 1-m x 1-m square frames along this transect in mid-July (12-20) near peak flowering time. Vascular plant species composition was measured at 20-m intervals along the above transect with a random start sampling location within first 20 m and systematic 20-m intervals thereafter. *Erigeron mancus* density was measured at randomly chosen points along *E. mancus* patch widths at the same 20-m intervals along this transect. On August 5, 2009, we established a 100-m long *E. mancus* density transect along the Middle Group of the LaSals crest line in the saddle just south of Mt. Laurel. Density measurements were taken as above using this transect as a baseline to measure patch widths. Elevational range of this transect was 3632-3642 m. We recorded latitude, longitude, and elevation at each sampling frame with Trimble® Geo XT 2005 Series GPS at sub-meter accuracy. All plant field work was conducted by Jim Fowler, Brian Casavant, and Addie Hite from RMRS in Flagstaff, AZ.

Voucher specimens of vascular plant species were collected at each of the June, July, and August trips. We collected 52 voucher plant specimens for the floristic survey of the snowglade community at the north base of Mt. Mellenthin the first week of August after snow melt. Plants were identified by Fowler using descriptions and keys published in FNA (1993+) and comparisons with known specimens in the Rocky Mountain Herbarium in Laramie, WY and the USFS Herbarium at RMRS in Flagstaff, AZ.

Field surveys for black rosy-finch were conducted in the project area in late June by Laura Doll (RMRS, Flagstaff) and Barb Smith (Manti-LaSal NF, Moab). Digital recording devices were deployed in late August to mid-September in upper Dark Canyon and at a saddle along the

Mt. Laurel ridge/crestline on the eastern slope of the range. The acoustic data were analyzed using Song Scope (Wildlife Acoustics, Concord, MA), which was programmed to recognize black rosy-finch calls.

Descriptive statistics for plant densities and species centroid elevations were calculated with SAS/STAT 9.2 (SAS 2008). Jaccard similarity indices (Krebs 1989) for species composition comparisons along the elevational transect were calculated with Excel 2007. A cluster analysis of these indices was performed with SAS/STAT (2008) to examine patterns of species composition change by elevation.

## RESULTS

### Projected

1. *Erigeron mancus* density, patch size, and population size estimates along the ridge running west from Mt. Laurel down to treeline.
2. Vascular plant species richness and compositional change along the same transect.
3. Floristic survey of a snow glade within the spruce-fir forest at the north base of Mt.

### Mellenthin

4. Evaluate whether the black rosy finch is a summer resident on the above ridge.

### Actual

*Erigeron mancus* was confined to dry ridgelines along the elevational transect (Fig. 4). It was not found in large, loose talus areas and tended to sharply decrease in abundance near more mesic areas, especially where snow appeared to persist later into the growing season. Plant counts per sampling frame ranged from 0 to 35, reflecting the species' visual patchiness. A range of plant sizes was observed with the smaller ones having a single unbranched caudex and the larger ones having multiple caudex branches. We did not measure plant size or age but some appeared to be relatively young with a small diameter at the top of the caudex while others appeared to be much older with a relatively large diameter caudex and/or a pedicellate caudex due to soil erosion. Mean density was 7.09 plants/m<sup>2</sup> (Table 1) which yielded a population estimate of over 200,000 plants along Mt. Laurel ridge and its nearby southern crestline. Density does not appear to change significantly with elevation since the standard errors of the density estimates of the three main patches overlap (Table 1). The largest *E. mancus* patch size with the largest number of plants is located above and just east of the USFS pre-Laurel weather station (Table 1, Fig. 4).

The elevation of the sampled *E. mancus* population centroid weighted by *E. mancus* density was 3537 m (12,330 ft) which is within the largest patch near a shallow windswept saddle east of the weather station (Figure 2). We also found a small outlier patch in an open area well within the spruce-fir forest at 3356 m (11,010 ft) and 74 m below the next patch at the timberline start of our sampling transect at 3430 m (11,247 ft). There are additional, unsampled patches of *E. mancus* along the crestline of the Middle Group of the LaSals and at the north base of Mt. Mellenthin.

Vascular plant diversity along the Mt. Laurel ridge transects averaged  $17 \pm 0.58$  SE species per square meter with a richness range of 10-26 species per square meter. A total of 70 species were encountered along this transect. A checklist of all 147 vascular plant species collected in the alpine and nearby spruce-fir habitats during 2008-2009 is shown in Appendix I. We collected one new Utah state record, *Artemisia pattersonii*, and one new LaSal record, *Aquilegia scopulorum*.

For most of the many of the 70 species encountered along the elevation transect, the elevation of population centroids were calculated based on occurrence with individual sampling frames then placed in ascending elevation order (Table 2). Most species in the middle part of Table 2 occurred fairly often and ranged over most of the transect's elevation range, 3430-3629 m. *Gentiana parryi*, *Draba abajoensis*, *Erigeron grandiflorus*, *Carex rossii*, and *Calamagrostis purpurea* were restricted to the lower part of the elevation range, <3550 m. *Silene acaulis*, *Trifolium nanum*, *Androsace chamaejasme*, *Minuartia obtusiloba*, and *Poa glauca* subsp. *glauca* were restricted to the upper part of the elevation range, >3481 m. Two species, *Draba aurea* and *Elymus scribneri*, had a relatively narrow elevation ranges, well within the transect elevation range, and centroids with relatively narrow standard errors. The two varieties of *Potentilla ovina* had well separated centroid elevations with non-overlapping standard errors indicating that those centroid elevations are significantly different. However, that is not the case between *Poa glauca* subsp. *glauca* and *Poa glauca* subsp. *rupicola* where the centroid standard errors overlap, thus indicating no significant difference.

The average number of species gained and lost moving from one sampling point to the next (turnover) along the elevational gradient transect was  $13.59 \pm 0.77$  SE species per sampling point. The turnover rate, calculated as turnover divided by the total species richness of two adjacent frames at 20 m intervals, averaged 56 % for this transect. Adjacent sampling frames averaged  $10.33 \pm 0.44$  SE species in common. Jaccard's similarity index (Krebs 1989) is based on the number of common species and unique species between samples and is essentially one minus the turnover rate. A cluster analysis of the Jaccard similarity index matrix with all pairwise sample comparisons showed that the sequentially numbered sampling frames along the transect tend to cluster together (Fig. 5). For example, sampling frame #1 clustered with sampling frame #2 due since those two are more similar in species composition to each other than either is to any other sampling frame. Thus species composition of one frame was most similar to its adjacent sampling frames 20 m away.

The snow glade at the north base of Mt. Mellenthin was 0.6 ha in size and had a total of 36 vascular plant species representing 13 families (Table 3). Using Thorne (1993) as a guide, these species are found in four floristic regions: Rocky Mountain, Madrean, Circumboreal, and North American Atlantic in decreasing order of frequency of occurrence. Only four species are restricted to the Rocky Mountain floristic region: *Artemisia pattersonii* A. Gray, *Erigeron melanocephalus* (A. Nelson) A. Nelson, *Carex haydeniana* Olney, *Polemonium pulcherrimum* Hook. subsp. *delicatum* (Rydb.) Brand. The two former species are found only in the Southern

Rocky Mountains whereas the latter two are more widespread in the Rocky Mountain cordillera. *Artemisia pattersonii* is also new collection record for Utah and the LaSals, but it is not restricted to the snowglade since we also found it along the elevational transect on the ridge west of Mt. Laurel (Table 2).

Twenty two bird species were noted along our transects on the Mt. Laurel ridge (Appendix II), however the black rosy finch was not encountered. Neither were the digital acoustic recordings along the crest line near Mt. Laurel successful in detecting rosy-finch calls in 40 days of recording (Hetzler 2010).

## CONCLUSIONS

The *E. mancus* population along the ridge west of Mt. Laurel appears to be stable. There were dry, windswept areas where *E. mancus* was the dominant plant species as well as other meadow areas with dense forb/graminoid cover in which *E. mancus* was one of many species growing very close together. The similar density estimates for *E. mancus* between the major patches we measured (Table 1) and the observed range of plant sizes and presumable ages would support the hypothesis of a stable population. Similarly, its range from timberline to crest line, including the additional population patches we documented last year (Smith 2008), indicate that it may be quite widespread within the Middle Group of the LaSals. Thus *E. mancus* seems to be persisting under current levels of anthropogenic activity and the current climate patterns. Whether this will remain so under a warming climate is a much more open question. The plant densities, population size, and elevation centroids we measured should make possible future population changes detectable.

Our results from cluster analysis of a Jaccard similarity index matrix for samples along the Mt. Laurel elevational gradient transect are similar to what we found at Mt. Goliath RNA in Colorado (unpublished data). We also have similar alpine data from Hoosier Ridge RNA that is awaiting analysis. We plan to use these three data sets to further investigate the possibility of using binary similarity indices like Jaccard's as a measure of spatial autocorrelation. Baseline data we collected from the Mt. Laurel transect on species richness, species composition, and turnover rates will also provide a basis for comparisons with the above RNAs.

The population centroid elevation, frequency of occurrence, and elevation range data for the species shown in Table 2 provide the baseline data for future comparisons. Significant changes in these measures may represent ecological change due to climatic or anthropogenic influences. The elevational data for each species along this transect represent their ecological amplitude along this elevational gradient using raw elevation as a surrogate for temperature, wind, precipitation, and other variables that describe the ecological niche of each species. We recommend re-measurement of this transect at five year intervals beginning in 2014 in order to detect possible changes in occurrence, range, and centroid elevations. Particular species to watch are *Draba aurea* and *Elymus scribneri*, since the standard errors of the centroid elevation estimate and their elevational range within the transect are narrow. These species would be the

easiest on which to detect statistical change. There are ten other species noted in the results section which tend to be found at the lower or upper ends of the transect and for which elevational shifts over time could be detected along the transect. Lastly, we now have precise spatial coordinates for multiple occurrences of 70 vascular plant species along the elevational transect which should make detection of impending local extinction possible.

The snowglade flora is closely affiliated with the Rocky Mountain flora and supports Cronquist et al.'s (1972) statement that the LaSal Mountains are a floristic outlier of the Southern Rocky Mountains. The LaSals are on the border between the Rocky Mountain and Madrean floristic regions (Thorne 1993) and not surprisingly the snow glade is mostly composed of species from these two floristic regions (Table 2). The two species found only in the Southern Rockies, *Artemisia pattersonii* A. Gray and *Erigeron melanocephalus* (A. Nelson) A. Nelson, may warrant further monitoring in the snow glade.

We found one more possible snow glade in the North Group of the LaSal Mountains by examining one meter resolution satellite photos. No other possible snow glades were found in the LaSals. A second snowglade adds credibility to any research/monitoring plan for snow glade persistence with possible changes in snow amounts and wind deposition patterns due to global warming. This research / monitoring could focus on possible loss of snowglade habitat but we found no plant species restricted to that habitat.

The 2009 research effort did not document the black rosy finch as an alpine summer resident on the central group of the LaSal range. This species was not found during field surveys nor was its song detected in a late season attempt to determine its presence. Failure to detect the species during this one year does not preclude their use of the area during other years. The species is known to nest in high elevation cliffs, and it has proven to be difficult to document nesting even where the species is more common. If the La Sal Mountains still support a low density breeding population as found in 1961 (Behle et al. 1963), then a more intensive effort involving the northern portion of the range and conducted over multiple years may be required to find them.

For *E. manicus*, interpretive emphasis should be placed on its endemic status, its estimated density and population size, and the elevation of its population centroid along the ridge west of Mt. Laurel. Equal emphasis should be placed on the idea that this study produced baseline data that may allow detection of changes in *E. manicus* population parameters due to global warming or other anthropogenic influences. Similarly, educators and interpreters could emphasize the utility of baseline data shown in Table 2 for 38 additional plant species on the same ridge to detect future elevational shifts due to ecological change from global warming.

## FUTURE RESEARCH NEEDS

We recommend re-measurement of the *E. mancus* population parameters and the species composition along the ridge west of Mt. Laurel at five-year intervals in order to detect impending change in species distribution and abundance. A slight increase in sampling intensity for *E. mancus* patch widths >20 m is also recommended in order to narrow the density standard errors. There is also a need to understand the reproductive biology in *E. mancus*, so seed viability, seed production, seed dispersal, and vegetative reproduction should be investigated. This could be followed by studies to determine whether the *E. mancus* population in the Middle Group of the LaSals is a single interbreeding population or whether they are a group of metapopulations (Levins 1969) in which each patch behaves as a local population with occasional gene flow between populations. There is also a need to understand the relationship between snow deposition and timberline location with the viability of *E. mancus* populations since changes in either of these may have strong influences on *E. mancus* persistence at a particular site.

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Table 1. *Erigeron mancus* population parameters for Mt. Laurel ridge and saddle, Middle Group of the LaSal Mts. Mean  $\pm$  SE is shown for density and patch width along with number of frames sampled. Elevation of the population/patch centroid is the mean elevation of sampled points, weighted by number of *E. mancus* plants at that point.

Population parameter	Ridge below weather station	Ridge above weather station	Crestline	Total*
Density, # /m <sup>2</sup>	6.46 $\pm$ 1.73	5.29 $\pm$ 1.37	8.90 $\pm$ 6.64	7.09 $\pm$ 1.30
Patch width, m	12.75 $\pm$ 2.09	49.48 $\pm$ 8.74	12.55 $\pm$ 4.95	27.99 $\pm$ 4.42
Transect length, m	467	420	100	1020
Number of frames	24	21	5	52
Elevation of population centroid, m	3491.36 $\pm$ 6.94	3552.45 $\pm$ 6.34	3638.42 $\pm$ 0.71	3537.80 $\pm$ 7.62
Estimated Population Size	38,464	109,935	11,170	202,418

\* includes small patch within the scree near the weather station

Table 2. Population centroid elevation (m) for selected vascular plant species based on frequency of occurrence (not density) within sampling frames along an elevational transect from treeline, 3430 m, to the talus field, 3630 m, at the west base of Mt. Laurel, Middle Group of the LaSal Mountains, Utah. Species are in ascending order of centroid elevation. Selected species had  $\geq 5$  occurrences and were not bimodally distributed along the transect. Mean elevation of all sampling frames,  $3525.52 \pm 8.04$  SE m ( $n = 47$ ), is indicated by the dashed line below *Carex elynoides*. Frequency of occurrence is based on a total sample size of 47.

Species	Centroid elevation	frequency of occurrence	Standard error	Minimum	Maximum
Below transect mean					
<i>Gentiana parryi</i>	3452.15	6	5.46	3439	3470
<i>Draba abajoensis</i>	3455.36	6	6.23	3440	3483
<i>Erigeron grandiflorus</i>	3457.42	5	8.14	3440	3483
<i>Elymus trachycaulis</i>	3479.29	15	13.15	3430	3622
<i>Carex rossii</i>	3483.36	7	19.37	3430	3545
<i>Calamagrostis purpurea</i>	3491.61	8	16.41	3445	3550
<i>Cymopterus lemmonii</i>	3502.24	15	16.77	3438	3629
<i>Achillea millefolium</i>	3505.28	25	11.88	3434	3629
<i>Potentilla ovina</i> var. <i>decurrens</i>	3513.32	12	20.01	3430	3608
<i>Solidago multiradiata</i>	3517.02	28	11.43	3430	3622
<i>Noccaea fendleri</i>	3518.61	20	11.71	3440	3615
<i>Trifolium dasyphyllum</i>	3520.38	34	10.14	3430	3629

<i>Polemonium viscosum</i>	3521.49	21	13.09	3434	3629
<i>Poa abbreviata</i>	3522.01	25	10.08	3434	3615
<i>Cerastium arvense</i>	3522.45	30	11.12	3434	3629
<i>Carex scirpoidea</i>	3522.88	18	12.28	3430	3603
<i>Carex elynoides</i>	3525.00	32	10.92	3430	3629
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Above transect mean					
<i>Eremagone fendleri</i>	3525.94	40	8.24	3430	3615
<i>Festuca brachyphylla</i>	3527.24	34	8.83	3430	3622
<i>Geum rossii</i>	3527.59	40	8.41	3438	3629
<i>Draba aurea</i>	3527.89	20	8.01	3470	3584
<i>Hymenoxys grandiflorus</i>	3531.68	16	10.71	3466	3596
<i>Erigeron mancus</i>	3531.71	30	8.89	3430	3622
<i>Elymus scribneri</i>	3534.59	12	6.42	3494	3567
<i>Castilleja sulfurea</i>	3539.76	26	10.94	3430	3622
<i>Sedum lanceolatum</i>	3540.32	11	19.30	3440	3622
<i>Mertensia viridis</i>	3545.53	12	19.34	3440	3629
<i>Artemisia pattersonii</i>	3546.69	17	12.84	3455	3622
<i>Potentilla ovina</i> <i>var. ovina</i>	3548.58	25	8.75	3450	3622

<i>Selaginella densa</i>	3549.48	27	9.00	3434	3622
<i>Poa glauca subsp. glauca</i>	3553.62	5	23.67	3481	3622
<i>Minuartia obtusiloba</i>	3554.91	21	6.16	3494	3622
<i>Cymopterus bakeri</i>	3556.91	23	9.93	3438	3629
<i>Carex albonigra</i>	3556.95	9	22.51	3455	3622
<i>Androsace chamaejasme</i>	3558.34	18	8.24	3494	3622
<i>Poa glauca subsp. rupicola</i>	3558.37	8	19.36	3434	3615
<i>Trifolium nanum</i>	3563.56	6	10.10	3530	3591
<i>Silene acaulis</i>	3572.05	8	7.38	3544	3603

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Table 3. Vascular plant species collected in the snow glade within a spruce-fir stand at the north base of Mt. Mellenthin, Middle Group of the LaSal Mountains, Utah. Floristic region classification is based on Thorne (1993).

Family	Species	Floristic Region
Apiaceae	<i>Cymopterus lemmonii</i>	Rocky Mountain, Madrean
Asteraceae	<i>Achillea millefolium</i>	Rocky Mountain, Madrean, Circumboreal, North American Atlantic
Asteraceae	<i>Agoseris aurantiaca var. purpurea</i>	Rocky Mountain, Madrean
Asteraceae	<i>Artemisia pattersonii</i>	Rocky Mountain
Asteraceae	<i>Erigeron grandiflorus</i>	Rocky Mountain, Madrean
Asteraceae	<i>Erigeron melanocephalus</i>	Rocky Mountain
Asteraceae	<i>Hymenoxys hoopesii</i>	Rocky Mountain, Madrean
Asteraceae	<i>Sececio triangularis</i>	Rocky Mountain, Madrean, Circumboreal
Asteraceae	<i>Senecio crassulus</i>	Rocky Mountain, Madrean, North American Atlantic
Asteraceae	<i>Solidago multiradiata</i>	Rocky Mountain, Madrean, Circumboreal
Boraginaceae	<i>Mertensia ciliata</i>	Rocky Mountain, Madrean
Brassicaceae	<i>Draba crassifolia</i>	Rocky Mountain, Madrean, Circumboreal
Brassicaceae	<i>Draba abajoensis</i>	Rocky Mountain, Madrean
Brassicaceae	<i>Noccaea fendleri</i>	Rocky Mountain, Madrean
Caryophyllaceae	<i>Eremagone fendleri</i>	Rocky Mountain, Madrean
Caryophyllaceae	<i>Stellaria umbellata</i>	Rocky Mountain, Madrean, Circumboreal
Cyperaceae	<i>Carex albonigra</i>	Rocky Mountain, Madrean, Circumboreal
Cyperaceae	<i>Carex haydeniana</i>	Rocky Mountain
Cyperaceae	<i>Carex rossii</i>	Rocky Mountain, Madrean, Circumboreal, North American Atlantic
Fabaceae	<i>Trifolium parryi var. parryi</i>	Rocky Mountain, Madrean
Juncaceae	<i>Juncus drummondii</i>	Rocky Mountain, Madrean, Circumboreal
Juncaceae	<i>Luzula spicata</i>	Rocky Mountain, Madrean, Circumboreal

Liliaceae	<i>Zigadenus elegans</i>	Rocky Mountain, Madrean, Circumboreal, North American Atlantic
Poaceae	<i>Agrostis variabilis</i>	Rocky Mountain, Madrean
Poaceae	<i>Danthonia intermedia</i>	Rocky Mountain, Madrean, Circumboreal, North American Atlantic
Poaceae	<i>Phleum alpinum</i>	Rocky Mountain, Madrean, Circumboreal, North American Atlantic
Poaceae	<i>Poa cusickii subsp. epilis</i>	Rocky Mountain, Madrean, North American Atlantic
Poaceae	<i>Poa reflexa</i>	Rocky Mountain, Madrean
Poaceae	<i>Trisetum spicatum</i>	Rocky Mountain, Madrean, Circumboreal
Polemoniaceae	<i>Polemonium pulcherrimum subsp. delicatum</i>	Rocky Mountain
Rosaceae	<i>Geum rossii var. turbinatum</i>	Rocky Mountain, Madrean, Circumboreal
Rosaceae	<i>Potentilla nivea</i>	Rocky Mountain, Madrean, Circumboreal
Rosaceae	<i>Sibbaldia procumbens</i>	Rocky Mountain, Madrean, Circumboreal
Scrophulariaceae	<i>Castilleja sulfurea</i>	Rocky Mountain, North American Atlantic
Scrophulariaceae	<i>Pedicularis racemosa var. alba</i>	Rocky Mountain, Madrean
Scrophulariaceae	<i>Veronica wormskjoldii</i>	Rocky Mountain, Circumboreal, North American Atlantic

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### Figure captions

Fig. 1 Location of LaSal Mountain study area showing the insular nature of the laccolithic uplift.

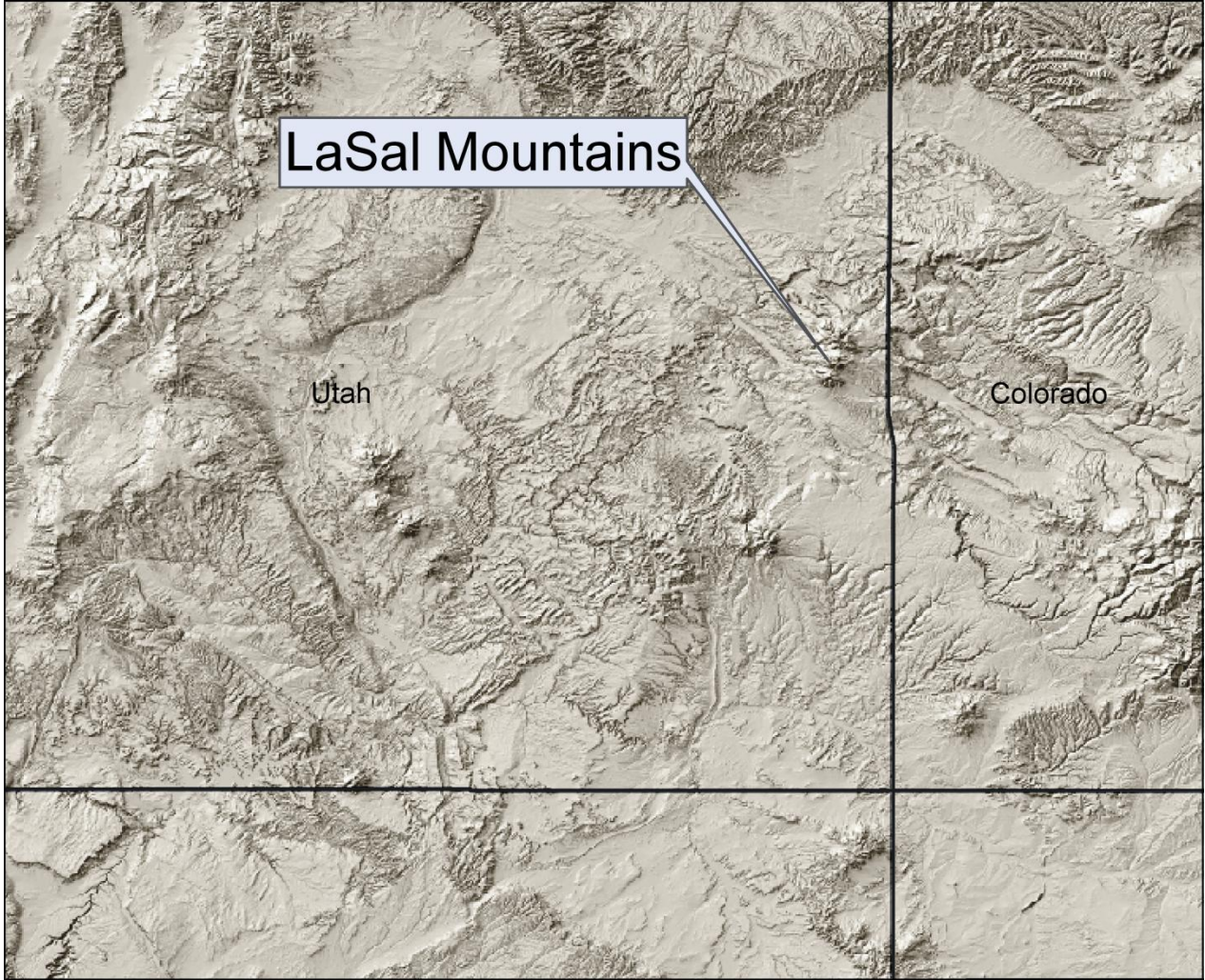
Fig. 2 Photo of *Erigeron mancus* density plot with flags showing plant locations.

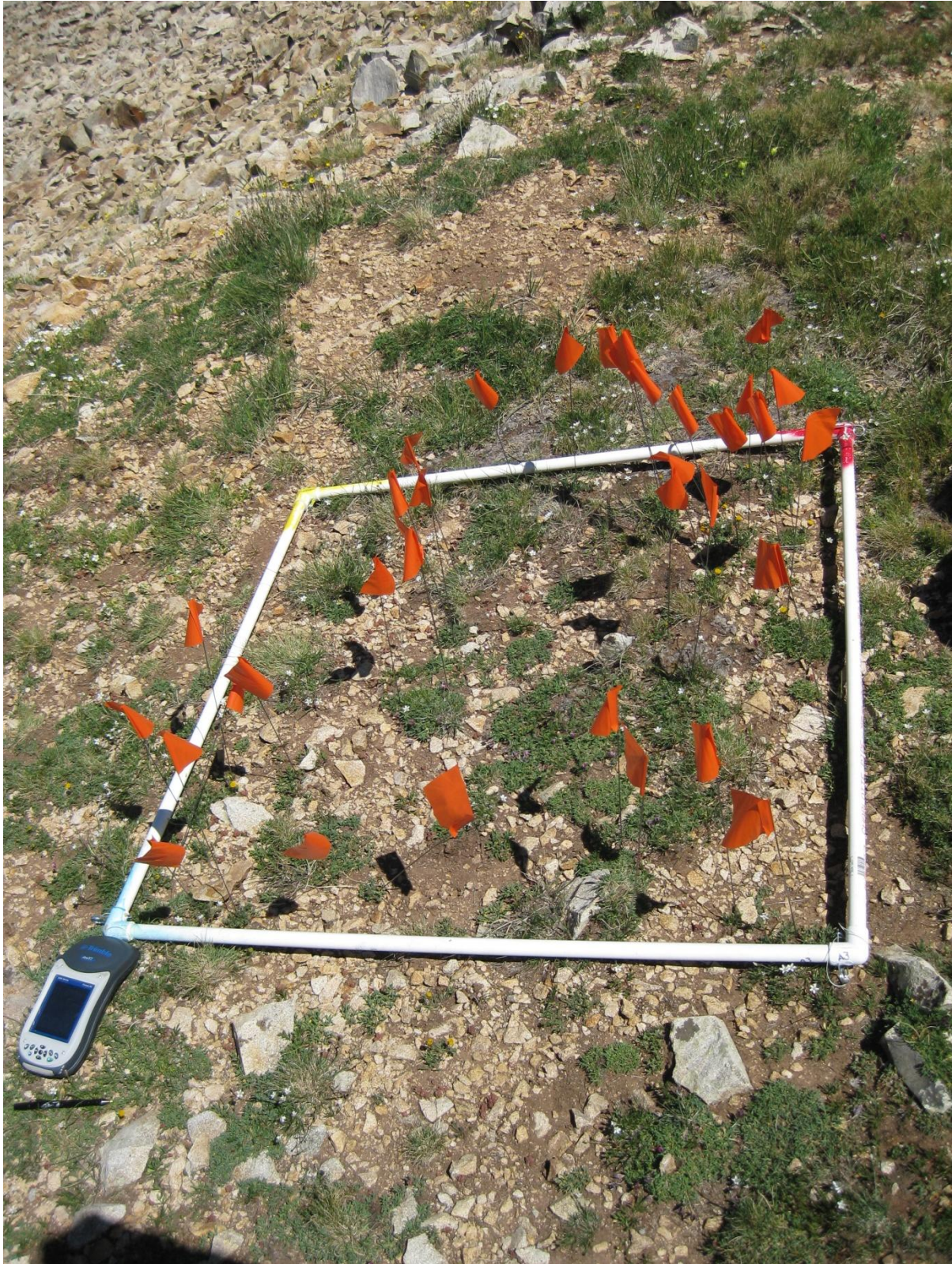
Fig. 3 Photo of plant species composition plot centered on ridgeline transect with GPS point on lower edge.

Fig. 4 *Erigeron mancus* sampling points along the west ridge and southern crest line from Mt. Laurel. These points were random locations on patch widths measured from the sampling baseline placed along the ridge top. Plant diversity sampling was along this base ridgeline transect.

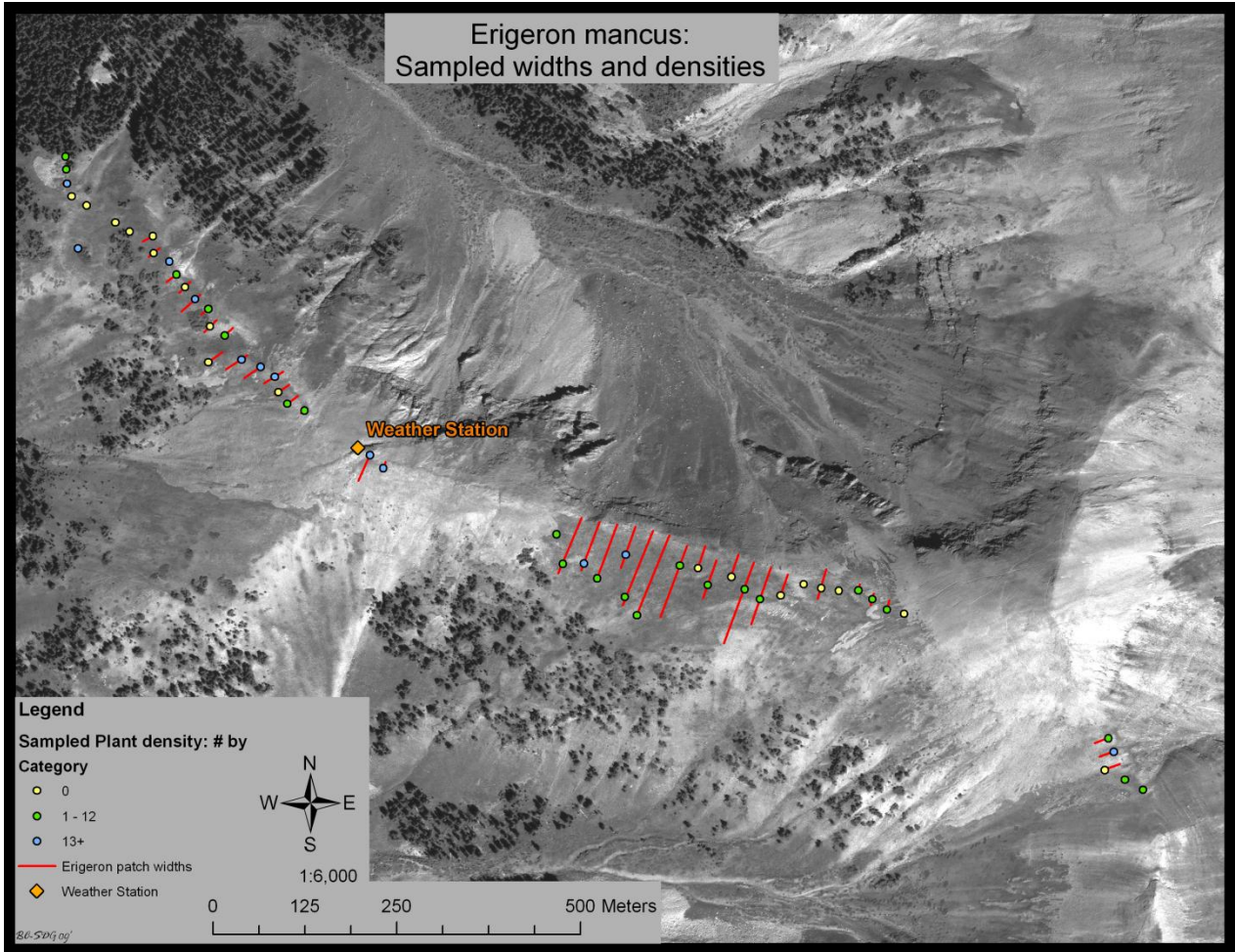
Fig. 5 Cluster analysis results using a matrix of the Jaccard similarity indices of plant species composition. Sampling points were labeled as sequential observations from timberline to the base of the talus slope west of Mt. Laurel prior to analysis. Each sampling point tends to be most similar to its nearest neighbors.

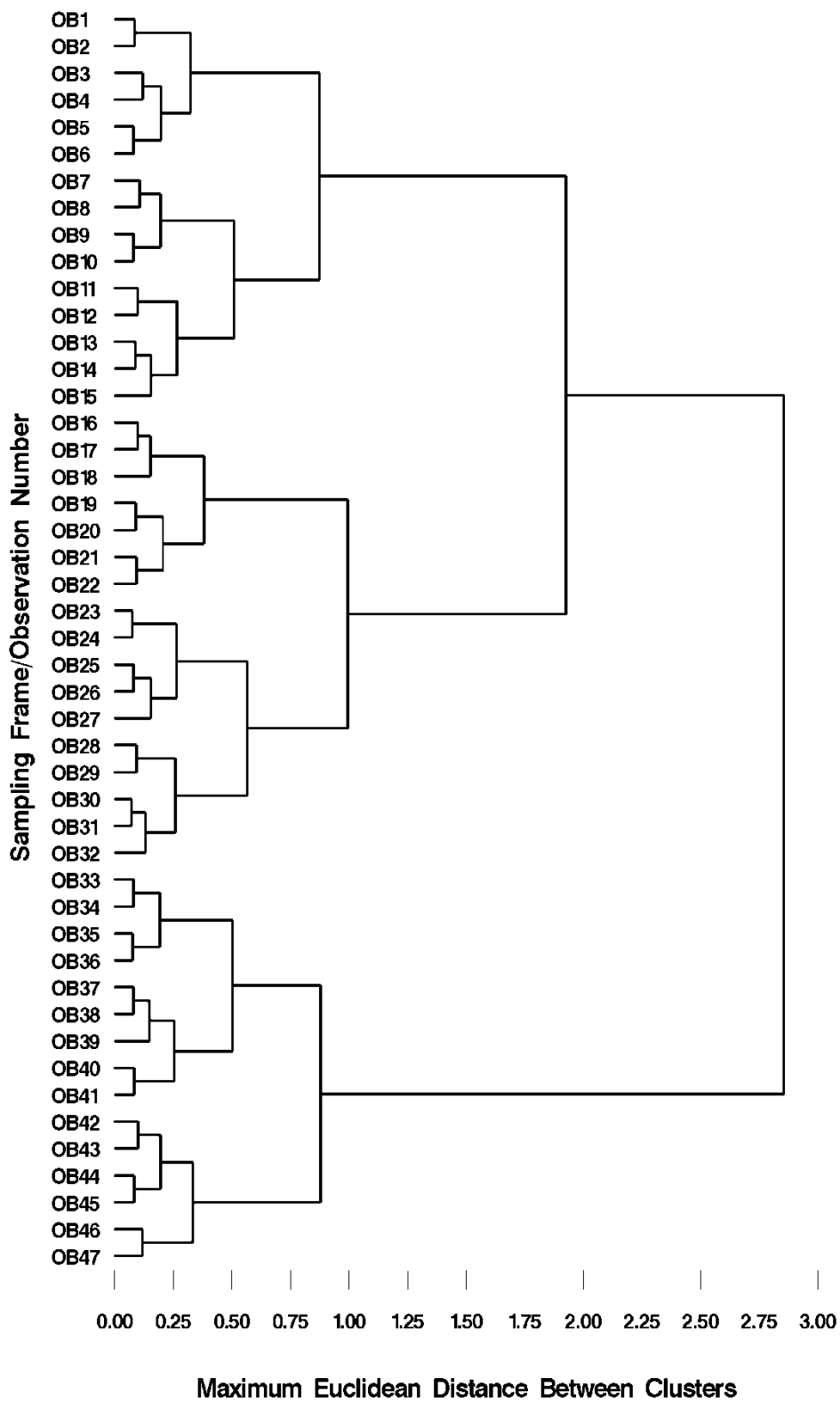












Appendix II. Species seen and/or heard in alpine and timberline habitats on Mt Laurel ridge, Middle Group of the La Sal Mountains, Utah in June 2009.

- Bald Eagle
- Hairy Woodpecker
- Northern Flicker
- Western Wood-pewee
- Common Raven
- Steller's Jay
- Clark's Nutcracker
- Mountain Chickadee
- White-breasted Nuthatch
- Red-breasted Nuthatch
- Pygmy Nuthatch
- Brown Creeper
- Ruby-crowned Kinglet
- American Robin
- Hermit Thrush
- Western Bluebird
- Plumbeous Vireo
- Warbling Vireo
- Brown-headed Cowbird
- Dark-eyed Junco
- Pine Siskin
- Red Crossbill

## Appendix I

Checklist of vascular plant specimens collected in summer 2008 & 2009 during *Erigeron manicus* studies near Mt. Peale RNA. Specimens were collected and identified by Jim Fowler with most species verified by staff at the Rocky Mountain Herbarium, University of Wyoming, Laramie. Collection numbers shown in parentheses belong to Fowler. An \* indicates specimens in need of independent verification at the Rocky Mountain Herbarium.

### Apiaceae

*Cymopterus bakeri* (J.M. Coulter & Rose) M.E. Jones (5934, 6221, 6434a)

Baker's alpine parsley  
Alpine meadow, crest line  
Manti-LaSal NF species of concern

*Cymopterus lemmonii* (J.M. Coulter & Rose) Dorn (5888, 5901, 5939, 5962, 6373, 6334b)

Lemmon's mountain parsley  
Spruce-fir, alpine meadow, snow glade, crest line

*Cymopterus longilobus* (Rydberg) W.A. Weber (5854, 5863, 5877, 6000, 6222, 6433)

Mountain spring parsley  
Spruce-fir, crest line

### Asteraceae

*Achillea millefolium* Linnaeus (6194, 6362, 6423)

Common yarrow  
Alpine meadow, snow glade, crest line

*Agoseris aurantiaca* (Hooker) Greene var. *purpurea* (A. Gray) Cronquist (6359, 6360, 6361)

Mountain agoseris  
Snow glade

*Agoseris glauca* (Pursh) Rafinesque var. *dasycephylla* (Torrey & A. Gray) Jepson (6241)

Prairie agoseris  
Alpine meadow

*Antennaria media* Greene (6193)

Rocky Mountain pussytoes  
Alpine meadow

*Antennaria rosea* Greene subsp. *rosea* (5966, 5986, 5987, 6245)

Rosy pussytoes  
Snow glade, alpine meadow

*Arnica cordifolia* Hooker (5861, 5883, 6191, 6349)

Heart leaf arnica  
Spruce-fir, alpine meadow

*Artemisia michauxiana* Besser (6418)

Lemon sagewort

Crest line

*Artemisia pattersonii* A. Gray (5938, 5967, 5988, 6220, 6354)

Patterson sagewort

Alpine meadow, snow glade

LaSal and UT State Records

*Cirsium eatonii* (A. Gray) B. L. Robinson var. *eriocephalum* (A. Gray) D. J. Keil (6425)

Mountaintop thistle

Crest line

\**Crepis nana* Richardson (6431)

Crest line

*Erigeron compositus* Pursh (5985)

Cut leaf daisy

Alpine meadow

*Erigeron formosissimus* Greene var. *viscidus* (Rydberg) Cronquist (6192)

Beautiful fleabane

Alpine meadow

*Erigeron glacialis* (Nuttall) A. Nelson var. *glacialis* (6365)

Subalpine fleabane

Snow glade

*Erigeron grandiflorus* Hooker (5936, 5984, 6180, 6235, 6358, 6428, 6429)

Rocky Mt. alpine fleabane

Alpine meadow, snow glade, crest line

*Erigeron mancus* Rydberg (5923, 6426)

LaSal Daisy

Alpine meadow, crest line

Endemic to the LaSals

USFS Region 4 sensitive species

*Erigeron melanocephalus* (A. Nelson) A. Nelson (5968, 6363)

Blackhead fleabane

Snow glade

Manti-LaSal NF species of interest



\**Erigeron vagus* Payson (6430)  
Rambling fleabane  
Crest line

*Heterotheca villosa* (Pursh) Shinnars var. *pedunculata* (Greene) V. L. Harms ex Semple (6419)  
Crestline

*Hymenoxys grandiflora* (Torrey & A. Gray) K.F. Parker (5937, 5998, 6421)  
Old-man-of-the-mountain  
Alpine meadow, crest line

*Hymenoxys hoopesii* (A. Gray) Bierner (5884, 6190, 6227, 6355)  
Orange sneezeweed  
Spruce-fir, alpine meadow, snow glade

*Packera streptanthifolia* (Greene) W.A. Weber & A. Love (5862, 5891)  
Rocky Mountain groundsel  
Spruce-fir

\**Senecio atratus* Greene (6422)  
Crest line

*Senecio crassulus* A. Gray (6183, 6356)  
Alpine meadow, snow glade

*Senecio fremontii* Torrey & A. Gray var. *inexpectatus* Cronquist (6427)  
Crest line  
Endemic to the LaSals  
Manti-LaSal NF species of concern

*Senecio triangularis* Hooker (6357)  
Snow glade

*Solidago multiradiata* Aiton (5989, 6242, 6364, 6424)  
Rocky Mt. goldenrod  
Alpine meadow, snow glade, crest line

*Taraxacum ceratophorum* (Ledebour) de Candolle (6164, 6420)  
Alpine dandelion  
Alpine meadow, crest line

*Taraxacum officinale* Weber ex F.H. Wiggers (5898)  
Common dandelion  
Spruce-fir

## **Boraginaceae**

*Mertensia ciliata* (James ex Torrey) G. Don (5885, 6176, 6377)

Mountain bluebells  
Spruce-fir, alpine meadow, snow glade

*Mertensia viridis* (A. Nelson) A. Nelson (5918, 5991)

Mountain bluebells  
Alpine meadow

## **Brassicaceae**

*Boechnera stricta* (Graham) Al-Shehbaz (5905, 5996)

Drummond rock cress  
Spruce-fir, alpine meadow

*Cardamine cordifolia* A. Gray var. *cordifolia* (5973)

Heartleaf bitter cress  
Snow glade

*Draba abajoensis* Windham & Al-Shehbaz (5867, 5868, 5904, 5910, 5911, 5971, 6161, 6162, 6163, 6187, 6340, 6374)

Showy draba  
Spruce-fir, snow glade, alpine meadow

*Draba aurea* Vahl ex Hornemann (5997, 6213, 6214, 6411)

Golden whitlow-wort  
Alpine meadow, crest line

*Draba crassifolia* Graham (6376)

Golden draba  
Snow glade

*Draba fladnizensis* Wulfen (6160)

Patterson's draba  
Alpine meadow  
Manti-LaSal NF species of interest

*Noccaea fendleri* (A. Gray) Holub (5907, 5919, 5972, 6167, 6375)

Wild candytuft  
Spruce-fir, alpine meadow, snow glade

*Smelowskia calycina* (Stephani Ex Willdenow) C. A. Mey. var. *americana* (Regel & Herder) Drury & Rollins (5999)

Alpine smelowskia  
Alpine meadow

## **Caprifoliaceae**

*Lonicera involucrata* (Richard) Banks ex Sprengel (5853, 5882)

Twinberry honeysuckle

Spruce-fir

*Lonicera utahensis* S. Watson (5852)

Utah honeysuckle

Spruce-fir

*Sambucus racemosa* Li (6234)

Elderberry

Alpine meadow

## **Caryophyllaceae**

*Cerastium arvense* Linnaeus subsp. *strictum* Gaudin (5909, 6207)

Mouse-ear chickweed

Spruce-fir, alpine meadow

*Cerastium beeringianum* Chamisso & Schlechtendal (5859, 5915)

Bering chickweed

Spruce-fir, alpine meadow

*Eremogone fendleri* (A. Gray) Ikonnikov (5876, 5914, 5969, 5981, 6382)

Cowboy grass

Spruce-fir, alpine meadow, snow glade

*Eremogone kingii* (S. Watson) Ikonnikov var. *glabrescens* (S. Watson) Dorn (6247, 6407, 6410)

King's sandwort

Alpine meadow, crest line

*Minuartia obtusiloba* (Rydberg) House (5913, 5941, 5970, 5979, 5980, 6208, 6405)

Alpine sandwort

Alpine meadow, snow glade, crest line

*Minuartia rubella* (Wahlenberg) Hiern (6224)

Beautiful sandwort

Alpine meadow

*Silene acaulis* (Linnaeus) Jacquin (5916, 5982, 6406)

Moss champion

Alpine meadow, crest line

*Stellaria longipes* Goldie subsp. *longipes* (5978, 6339)

Long-stalked starwort

Spruce-fir, alpine meadow

\**Stellaria umbellata* Turczaninow (6338, 6353)  
Umbellate starwort  
Spruce-fir, snow glade

### **Crassulaceae**

*Sedum lanceolatum* Torrey (6179)  
Alpine meadow

### **Cupressaceae**

*Juniperus communis* Linnaeus (6409)  
Common juniper  
Crest line

### **Cyperaceae**

*Carex albonigra* Mackenzie (5949, 6009, 6150, 6151, 6154, 6366, 6393b)  
Blackhead sedge  
Alpine meadow, snow glade

*Carex arapahoensis* Clokey (5948, 5953, 6203, 6206, 6216, 6218, 6229, 6436)  
Arapaho sedge  
Alpine meadow, snow glade, crest line

*Carex bella* L. H. Bailey (6347)  
Spruce-fir

*Carex elynoides* T. Holm (5955, 6156, 6157, 6158, 6238)  
Kobresia sedge  
Alpine meadow, snow glade

*Carex geyeri* Boott (5875)  
Elk sedge  
Spruce-fir

*Carex haydeniana* Olney (6367, 6008)  
Cloud sedge  
Snow glade

*Carex nova* L. H. Bailey (6402)  
Black sedge  
Alpine meadow

*Carex phaeocephala* Piper (5881, 6188, 6202)  
Spruce-fir, alpine meadow

*Carex rossii* Boott (6184)  
Alpine meadow

*Carex scirpoidea* Michaux var. *pseudoscirpoidea* (Rydberg) Cronquist (5946, 5947, 5951, 5952, 6155, 6204, 6205, 6368, 6369, 6370, 6435)

Western single spike sedge  
Alpine meadow, snow glade, crest line

\**Carex siccata* Dewey (6217)

Dry spike sedge  
Alpine meadow

*Carex chalciolepis* T. Holm (6437)

Crest line

### **Dryopteridaceae**

*Cystopteris fragilis* (Linnaeus) Bernhardt (6233)

Fragile fern  
Alpine meadow

### **Ericaceae**

*Orthilia secunda* (Linnaeus) House (5869, 6337)

Side bells wintergreen  
Spruce-fir

*Vaccinium myrtillus* Linnaeus (5864)

Whortleberry  
Spruce-fir

### **Fabaceae**

*Trifolium dasyphyllum* Torrey & A. Gray (5893, 5944, 5945, 5992, 6415, 6416)

Whip root clover  
Spruce-fir, alpine meadow, crest line

*Trifolium nanum* Torrey (5943, 5995, 6165, 6417)

Dwarf clover  
Spruce-fir, alpine meadow, crest line

*Trifolium parryi* A. Gray var. *parryi* (5960, 5961, 6195, 6196, 6215, 6371, 6372)

Parry clover  
Snow glade, alpine meadow

### **Gentianaceae**

*Gentiana parryi* Engelmann (6174, 6240, 6408)

Alpine meadow, crest line

*Gentianella amarella* (Linnaeus) Boerner ssp. *heterosepala* (Engelmann) J. M. Gillett (6397)

Alpine meadow

### **Geraniaceae**

*Geranium caespitosum* E. James var. *caespitosum* (5897)

Small leaf geranium  
Spruce-fir

### **Grossulariaceae**

*Ribes montigenum* McClatchie (5855, 5993, 6175)

Mountain gooseberry  
Spruce-fir, alpine meadow

*Ribes wolfii* Rothrock (5860)

Wolf's currant  
Spruce-fir

### **Hydrophyllaceae**

*Phacelia sericea* (Graham ex Hook.) A. Gray var. *sericea* (6236)

Alpine meadow

### **Juncaceae**

*Juncus drummondii* E. Meyer (5954, 6396)

Drummond rush  
Snow glade

*Juncus mertensianus* Bongard (6403)

Alpine meadow

*Luzula parviflora* (Ehrhart) Desvaux (6348)

Small flowered wood rush  
Spruce-fir

*Luzula spicata* (Linnaeus) de Candolle (6201, 6395)

Spiked wood rush  
Alpine meadow, snow glade

### **Liliaceae**

*Allium geyeri* S. Watson var. *geyeri* (5957)

Geyer's onion  
Snow glade

*Maianthemum racemosum* (Linnaeus) Link subsp. *amplexicaule* (Nuttall) LaFrankie (5889)

Large false Solomon's seal  
Spruce-fir

*Zigadenus elegans* Pursh (5917, 6378, 6399)

Mountain deathcamas

Alpine meadow

**Pinaceae**

*Abies bifolia* A. Murray (5976, 6223)

Rocky Mountain alpine fir

Alpine meadow

*Picea engelmannii* Parry ex Engelmann (6210)

Spruce

Alpine meadow

**Plantaginaceae**

\**Plantago tweedyi* A. Gray (6198)

Tweedy's plantain

Alpine meadow

**Poaceae**

*Agrostis variabilis* Rydberg (6387)

Mountain bentgrass

Snow glade

*Calamagrostis purpurascens* R. Brown (6182, 6231)

Purple reed grass

Alpine meadow

*Calamagrostis stricta* (Timm) Koeler subsp. *stricta* (6401)

Alpine meadow

*Danthonia intermedia* Vasey (6393a)

Timber oat grass

Snow glade

*Elymus scribneri* (Vasey) M.E. Jones (6211, 6212, 6239a, 6441)

Baker's wheatgrass

Alpine meadow, crest line

State record

*Elymus trachycaulus* (Link) Gould ssp. *trachycaulus* (6005, 6186, 6239b, 6442)

Slender wheatgrass

Alpine meadow, crest line

*Festuca brachyphylla* Schultes & Schultes subsp. *coloradensis* Frederiksen (5906, 6007)

Alpine fescue

Spruce-fir, alpine meadow

*Festuca minutiflora* Rydberg (6345)

Little fescue  
Spruce-fir

*Phleum alpinum* Linnaeus (6181, 6394, 6440)  
Alpine timothy  
Alpine meadow, snow glade, crest line

*Poa abbreviata* subsp. *pattersonii* (Vasey) A. Love (6189)  
Patterson's bluegrass  
Alpine meadow

*Poa cusickii* subsp. *epilis* (Scribner) W. A. Weber (5958, 6388, 6389, 6391)  
Skyline bluegrass  
Snow glade

*Poa fendleriana* (Steudel) Vasey subsp. *fendleriana* (5887, 5950)  
Mutton grass  
Spruce-fir, alpine meadow

*Poa fendleriana* (Steudel) Vasey subsp. *longiligula* (Scribner & T. A. Williams) Soreng (6438)  
Muttongrass  
Crest line

*Poa glauca* Vahl subsp. *glauca* (6439, 6443, 6444)  
Glaucous bluegrass  
Crest line

*Poa glauca* Vahl subsp. *rupicola* (Nash) W.A. Weber (6159, 6237, 6445)  
Timberline bluegrass  
Alpine meadow, crest line

*Poa interior* Rydberg (6006)  
Interior bluegrass  
Alpine meadow

*Poa reflexa* Vasey & Scribner (5908, 6244, 6392)  
Nodding bluegrass  
Spruce-fir, alpine meadow, snow glade

*Poa wheeleri* Vasey (6200)  
Wheeler's bluegrass  
Alpine meadow

*Trisetum spicatum* (Linnaeus) K. Richt. (6346, 6390, 6400)  
Spike Trisetum



Spruce-fir, snow glade, alpine meadow

### **Polemoniaceae**

*Polemonium pulcherrimum* Hook subsp. *delicatum* (Rydberg) Brand (5857, 5879, 6177, 6343, 6381)

Jacob's ladder

Spruce-fir, alpine meadow, snow glade

*Polemonium viscosum* Nuttall (5932, 5990)

Sky pilot

Alpine meadow

### **Polygonaceae**

*Bistorta vivipara* (Linnaeus) Delarbre (5977, 6342)

Alpine bistort

Spruce-fir, alpine meadow

*Oxyria digyna* (Linnaeus) Hill (5873, 6232)

Alpine sorrel

Spruce-fir, alpine meadow

### **Portulacaceae**

*Claytonia megarhiza* (A. Gray) Parry ex S. Watson (6225, 6230)

Fell-fields claytonia

Alpine meadow

*Lewisia pygmaea* (A. Gray) B.L. Robinson (5956)

Dwarf lewisia

Snow glade

### **Primulaceae**

*Androsace chamaejasme* Host. var. *carinata* R. Knuth (5920, 6404)

Boreal rock-jasmine

Alpine meadow, crest line

USFS Region 4 sensitive species

*Androsace septentrionalis* Linnaeus (5900, 5921, 6341)

Northern rock-jasmine

Spruce-fir, alpine meadow

### **Ranunculaceae**

*Anemone multifida* var. *stylosa* (A. Nelson) B. E. Dutton & Keener (6185)

Alpine meadow

*Aquilegia coerulea* E. Jones var. *coerulea* (5886, 6336)

Colorado blue columbine

Spruce-fir

*Aquilegia elegantula* Greene (5856)

Western red columbine

Spruce-fir

*Aquilegia scopulorum* Tidestrom (5975)

Rock columbine

Snow glade

LaSal Record

*Delphinium barbeyi* (Huth) Huth (6398)

Alpine meadow

State record

*Ranunculus alismifolius* Geyer ex Bentham var. *montanus* S. Watson (5963)

Water plantain buttercup

Snow glade

*Ranunculus inamoenus* Greene var. *inamoenus* (5866, 5912)

Drab buttercup

Spruce-fir

*Thalictrum fendleri* Engelmann ex A. Gray (5858, 5871, 5872)

Fendler's meadowrue

Spruce-fir

## **Rosaceae**

*Amelanchier alnifolia* (Nuttall) Nuttall ex Roemer var. *alnifolia* (5890)

Serviceberry

Spruce-fir

*Fragaria virginiana* Mill (5896, 6199)

Virginia strawberry

Spruce-fir, alpine meadow

*Geum rossii* (R. Brown) Seringe var. *turbinatum* (Rydberg) C.L. Hitchcock (5870, 5935, 5959, 6379, 6412)

Alpine avens

Spruce-fir, alpine meadow, snow glade, crest line

*Potentilla diversifolia* Lehmann var. *diversifolia* (5924b, 6003, 6172)

Varileaf cinquefoil

Alpine meadow

*Potentilla gracilis* Douglas ex Hook var. *pulcherrima* (Lehmann) Fernald (6173)

Slender cinquefoil  
Alpine meadow

*Potentilla hookeriana* Lehmann (6001)  
Hooker's cinquefoil  
Alpine meadow

*Potentilla nivea* Linnaeus (6246, 6414)  
Snow cinquefoil  
Alpine meadow, crest line

*Potentilla ovina* Macoun var. *decurrens* (S. Watson) S.L. Welsh & B.C. Johnst. (5924a, 5925, 5927, 5928, 5930, 6169, 6170, 6171, 6380)  
Sheep cinquefoil  
Alpine meadow, snow glade

*Potentilla ovina* Macoun var. *ovina* (5926, 5940, 6002)  
Sheep cinquefoil  
Alpine meadow

*Potentilla pensylvanica* Linnaeus var. *pensylvanica* (5929, 6004, 6178)  
Pennsylvania cinquefoil  
Alpine meadow

*Potentilla rubicaulis* Lehmann (6219)  
Rocky Mountain cinquefoil  
Alpine meadow

*Sibbaldia procumbens* Linnaeus (5874, 5922, 5974, 6386, 6413)  
Creeping sibbaldia  
Spruce-fir, alpine meadow, snow glade, crest line

### **Salicaceae**

*Salix reticulata* Linnaeus var. *nana* Andersonn (5994)  
Snow willow  
Alpine meadow

### **Saxifragaceae**

*Saxifraga bronchialis* Linnaeus var. *austromontana* (Wiegand) Piper ex. G.N. Jones (5851, 5878, 5983)  
Spotted saxifrage  
Spruce-fir, alpine meadow

*Saxifraga caespitosa* Linnaeus (5942, 6226)  
Tufted alpine saxifrage  
Alpine meadow

*Saxifraga rhomboidea* Greene (5931, 6166)  
Diamond-leaf saxifrage  
Alpine meadow

*Saxifraga rivularis* Linnaeus (5865)  
Weak saxifrage  
Spruce-fir

### **Scrophulariaceae**

*Besseya alpina* (A. Gray) Rydberg (6168)  
Alpine kitten tails  
Alpine meadow

*Castilleja occidentalis* Torrey (6432)  
Western paintbrush  
Crest line

*Castilleja rhexifolia* Rydberg (5895)  
Split leaf paintbrush  
Spruce-fir

*Castilleja sulfurea* Rydberg (5902, 5933, 6245, 6385)  
Sulfur paintbrush  
Spruce-fir, alpine meadow

*Pedicularis bracteosa* Bentham var. *paysoniana* (Pennell) Cronquist (5880, 6350)  
Bracted lousewort  
Spruce-fir

*Pedicularis racemosa* Douglas ex Bentham subsp. *alba* (Pennell) Cronquist (6351, 6352)  
Sickle top lousewort  
Spruce-fir, snow glade

*Penstemon whippleanus* A. Gray (5850, 5892, 6228)  
Whipple penstemon  
Spruce-fir

*Veronica wormskjoldii* Roemer & Schultes (6197, 6383, 6384)  
American alpine speedwell  
Alpine meadow, snow glade

### **Selaginaceae**

*Selaginella densa* Rydberg (6209)

Prairie club-moss

Alpine meadow

**Valerianaceae**

*Valeriana occidentalis* A. Heller (5894)

Western valerian

Spruce-fir

**Violaceae**

*Viola canadensis* Linnaeus (5899)

Canadian white violet

Spruce-fir

Total - 10/25/2010 147