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^2 (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 ± 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 ± 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 ± 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. mancus,* 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. mancus* 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.

REFERENCES

Arno, S.F., and R.P. Hammerly. 1984. Timberline, mountain and arctic forest frontiers. The Mountaineers, Seattle, WA.

Behle, W.H., J.H. Bushman and C.M. White. 1963. Distributional data on uncommon birds in Utah and adjacent states. The Wilson Bulletin 75(4): 450-456.

Blakey, R., and W. Ranney. 2008. Ancient Landscapes of the Colorado Plateau. Grand Canyon Association, Grand Canyon, AZ.

Cronquist, A., A.H. Holmgren, N.H. Holmgren, and J.L. Reveal. 1972. Intermountain flora, vascular plants of the intermountain west, USA, vol. 1. New York Botanical Garden, NY.

Flora North America Editorial Committee, eds. 1993+. Flora on North America north of Mexico 13+ vols. Oxford University Press, New York and Oxford.

Hetzler, B. 2010. Analysis of digital recordings collected in the La Sal Mountains, Utah, to assess the presence of black rosy-finches (*Leucosticte atrata*). Final report to USDA Forest Service, Manti-La Sal National Forest.

Krebs, C. J. 1989. Ecological Methodology. Harper & Row, Publishers, New York.

Levins, R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. Bulletin of the Entomological Society of America 18:237-240.

Nesom, G. L. 2006. *Erigeron*. In: Flora of North America north of Mexico, Volume 20, Magnoliophyta: Asteridae, part 7: Asteraceae, part 2. Oxford University Press: 570-602.

SAS/STAT. 2008. SAS/STAT® software, version 9.2 of the SAS System for Windows XP. SAS Institute Inc., Cary, NC.

Smith, B. 2008. Mt. Peale Research Natural Area Alpine Vegetation Impact Assessment, final report to Canyonlands Natural History Association.

Thorne, R. F. 1993. Phytogeography. Pp. 132-153 *in* Flora of North America North of Mexico, Vol. 1, Flora of North America Editorial Committee, Oxford University Press, New York.

USFS. 2003. Intermountain Region proposed, endangered, threatened, and sensitive species list, R4. http://www.fs.fed.us/r4/resources/tes/r4_tes_lst_0408.pdf accessed 2-23-2010

USFS. 1986. Manti-La Sal National Forest Land and Resource Management Plan. http://www.fs.fed.us/r4/mantilasal/projects/forest_plan_1986/planindex.shtml accessed 2-23-2010

Table 1. *Erigeron mancus* population parameters for Mt. Laurel ridge and saddle, Middle Group of the LaSal Mts. Mean ± 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^2	6.46 ± 1.73	5.29 ± 1.37	8.90 ± 6.64	7.09 ± 1.30
Patch width, m	12.75 ± 2.09	49.48 ± 8.74	12.55 ± 4.95	27.99 ± 4.42
Transect length, m	467	420	100	1020
Number of frames	24	21	5	52
Elevation of population centroid, m	3491.36 ± 6.94	3552.45 ± 6.34	3638.42 ± 0.71	3537.80 ± 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 ≥5 occurrences and were not bimodally distributed along the transect. Mean elevation of all sampling frames, 3525.52 ± 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					
Gentiana parryi	3452.15	6	5.46	3439	3470
Draba abajoensis	3455.36	6	6.23	3440	3483
Erigeron grandiflorus	3457.42	5	8.14	3440	3483
Elymus trachycaulis	3479.29	15	13.15	3430	3622
Carex rossii	3483.36	7	19.37	3430	3545
Calamagrostis purpurea	3491.61	8	16.41	3445	3550
Cymopterus lemmonii	3502.24	15	16.77	3438	3629
Achillea millefolium	3505.28	25	11.88	3434	3629
Potentilla ovina var. decurrens	3513.32	12	20.01	3430	3608
Solidago multiradiata	3517.02	28	11.43	3430	3622
Noccaea fendleri	3518.61	20	11.71	3440	3615
Trifolium dasyphyllum	3520.38	34	10.14	3430	3629

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

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

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

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

Figure captions

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

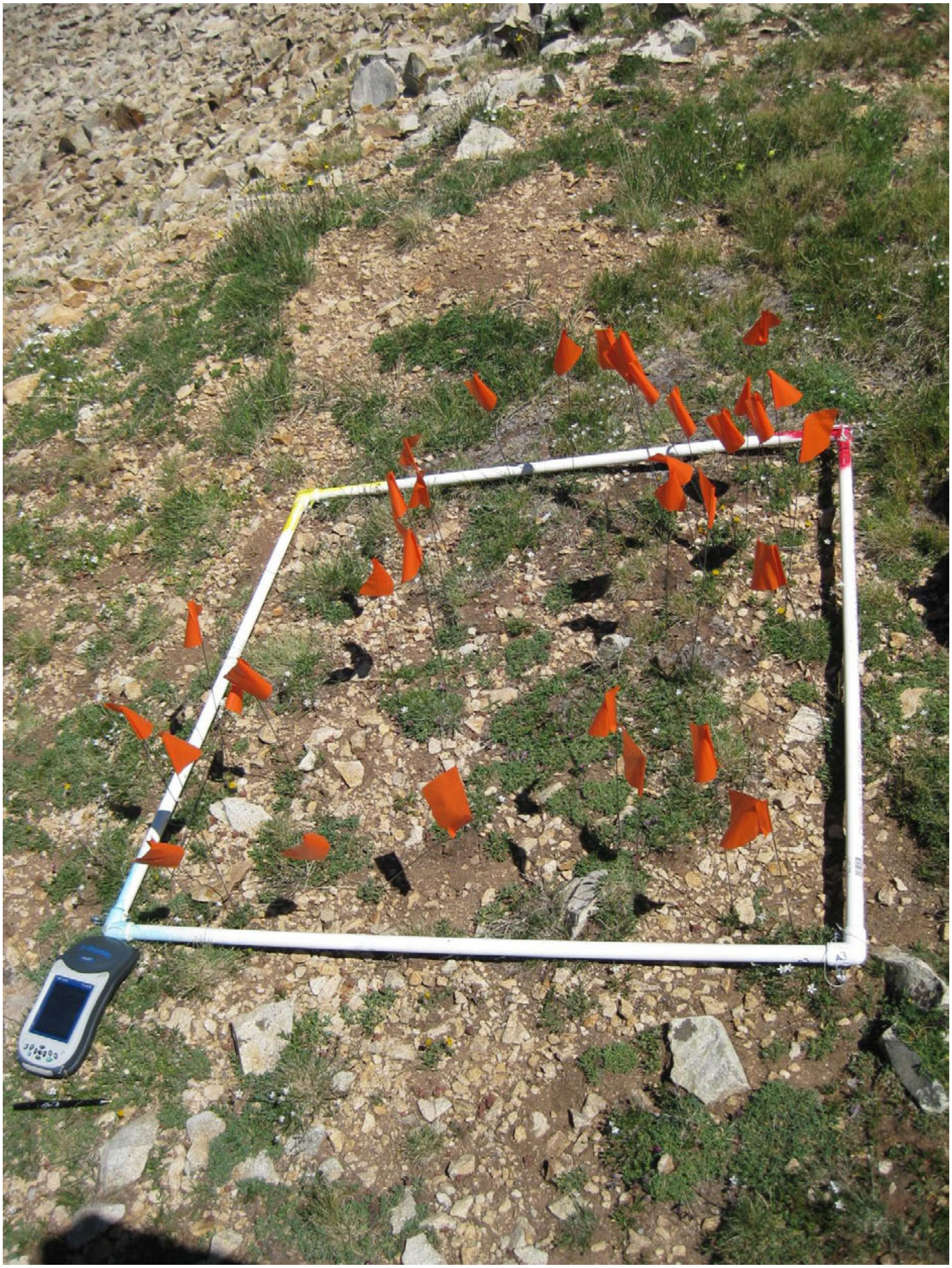
Fig. 2 Photo of *Erigeron mancus* density plot with flags showing plant locations.

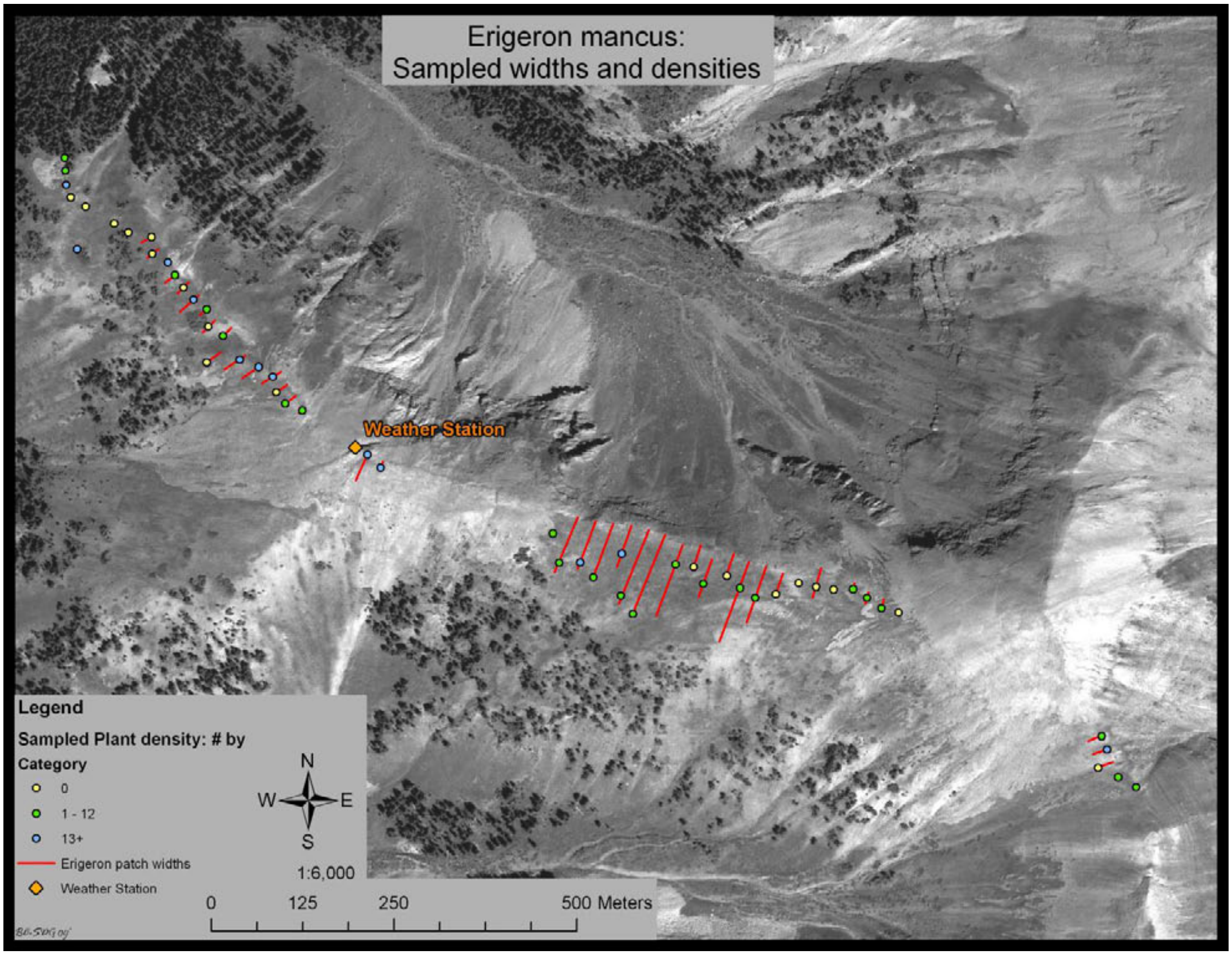
Fig. 3 Photo of plant species composition plot centered on ridgeline transect with GPS point on lower edge.

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.

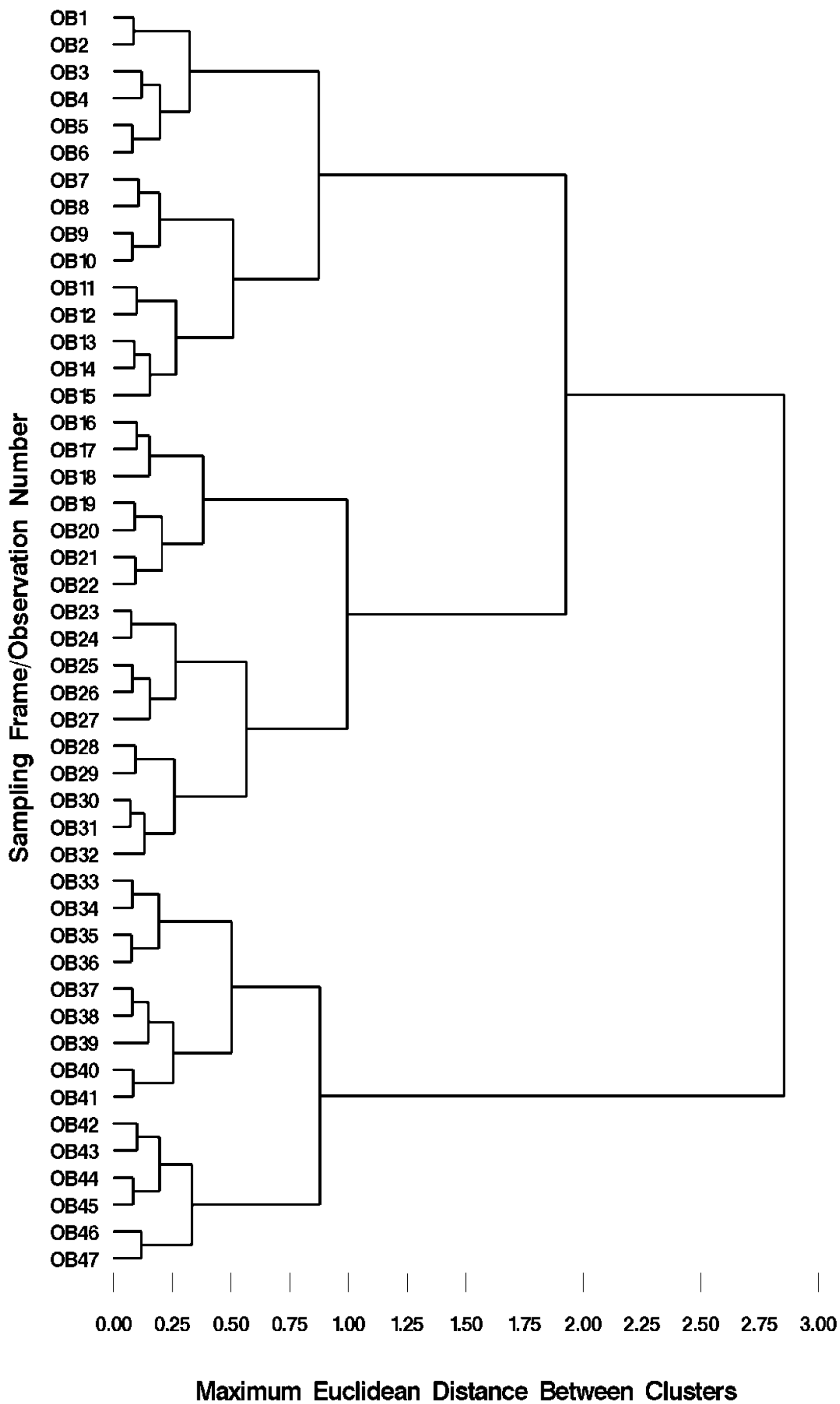
Fig. 5 Cluster analysis results using a matrix of the Jaccard similarity indices of plant species composition. Sampling points were labeled as sequential observations from timberline to the base of the talus slope west of Mt. Laurel prior to analysis. Each sampling point tends to be most similar to its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


LaSal Mountains
Utah
Colorado





Erigeron mancus:
Sampled widths and densities
Weather Station
Legend
Sampled Plant density: # by
Category
0
1 - 12
13+
Erigeron patch widths
Weather Station
N
W
E
S
1:6,000
0
125
250
500 Meters


Sampling Frame/Observation Number
OB1
OB2
OB3
OB4
OB5
OB6
OB7
OB8
OB9
OB10
OB11
OB12
OB13
OB14
OB15
OB16
OB17
OB18
OB19
OB20
OB21
OB22
OB23
OB24
OB25
OB26
OB27
OB28
OB29
OB30
OB31
OB32
OB33
OB34
OB35
OB36
OB37
OB38
OB39
OB40
OB41
OB42
OB43
OB44
OB45
OB46
OB47
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
Maximum Euclidean Distance Between Clusters