

ERIGERON MANCUS (ASTERACEAE) DENSITY AS A BASELINE TO DETECT FUTURE CLIMATE CHANGE IN LA SAL MOUNTAIN HABITATS

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ABSTRACT

The La Sal Daisy, *Erigeron mancus* Rydb., is endemic to timberline and alpine habitats of the La Sal Mountains in Utah, an insular, laccolithic mountain range on the Colorado Plateau in southeastern Utah. It occurs in alpine herbaceous communities from timberline to the crestline of the La Sals. Our primary goal in this study was to measure basic population biology parameters for the *E. mancus* population on the ridge from Mt. Laurel in the Middle Group of the La Sals west to treeline. We measured both *E. mancus* density and vascular plant species composition within 1-m × 1-m square frames along a ridgeline transect in mid-July near peak flowering time. Mean density was 7.09 plants/m² 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. 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. 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. This study provides baseline data on the population biology of *E. mancus* which will then allow future re-measurements of density, population size, and elevational centroid to indicate population trends in response to climate change and anthropogenic stressors.

RESUMEN

La margarita de La Sal, *Erigeron mancus* Rydb., es endémica del límite altitudinal del bosque y hábitats alpinos de las montañas de La Sal en Utah, una cadena de montañas insulares, lacolíticas en la meseta del Colorado en el sureste de Utah. Aparece en comunidades alpinas herbáceas desde el límite altitudinal del bosque hasta las crestas de La Sal. Nuestro objetivo primario en este estudio fue medir los parámetros básicos en biología de poblaciones de la población de *E. mancus* en la cadena del Mt. Laurel en el grupo central del oeste de La Sal hasta el límite del arbolado. Medimos la densidad de *E. mancus* y la composición de especies de plantas vasculares en cuadrados 1-m × 1-m a lo largo de un transecto a mediados de julio cerca del pico de floración. La densidad media fue 7.09 plantas/m² que dio una población estimada de más de 200,000 plantas a lo largo de la cadena del Mt. Laurel y su crestería por el sur. La densidad no parece cambiar significativamente con la elevación ya que el error estándar de la densidad estimada en las tres manchas se solapa. La elevación del centroide de la población muestreada de *E. mancus* ponderado con la densidad de *E. mancus* fue 3537 m (12,330 ft) que cae dentro de la mancha mayor cerca de un collado plano barrido por el viento. La diversidad de plantas vasculares en los transectos a lo largo de la cadena del Mt. Laurel dio una media de 17 ± 0.58 SE especies por metro cuadrado con un rango de riqueza de 10–26 especies por metro cuadrado. Este estudio aporta los datos básicos de la biología de la población de *E. mancus* que permitirá en el futuro otras medidas de densidad, tamaño poblacional, y altitud del centroide para indicar las tendencias de la población en respuesta al cambio climático y estrés antropogénico.

INTRODUCTION

The La Sal Daisy, *Erigeron mancus* Rydb., is endemic to timberline and alpine habitats of the La Sal Mountains in Utah, an insular, laccolithic mountain range on the Colorado Plateau in southeastern Utah (Blakey & Ranney 2008). It was listed as a Candidate 2 species under the 1973 Endangered Species Act by the U.S. Fish and Wildlife Service (1993) since sufficient biological data were lacking to determine if Threatened or Endangered status was justified. It is also listed as a G2 species (globally imperiled) under the NatureServe Conservation Status guidelines due to its very restricted range (Utah Native Plant Society 2010). *Erigeron mancus* occurs in alpine herbaceous communities from timberline to the crestline of the La Sal Mountains (Smith 2008) including Mt. Peale Research Natural Area (RNA) which was established specifically to protect ecosystem structure and function in representative alpine and subalpine habitats in the La Sals.

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 (U. S. Forest

Service 1994). Forest Service objectives for these areas include protection against serious environmental disruptions and serve as baseline areas for measuring long-term ecological changes. No permanent study plots were established in the Mt. Peale RNA prior to our climate change work on *E. mancus*.

Global mean temperature is predicted to rise 1–6° C in the next century due to increased concentration of greenhouse gases (Solomon et al. 2007) and has increased 0.4° C over the previous 150 years (Trenberth et al. 2007). The predicted general response of species to this increased warmth is to migrate north in latitude or up in altitude (Grabherr et al 1994; Theurillat & Guisan 2001; Walther 2002; Root et al. 2003; Kullman 2008; Lenoir et al. 2008) although most ecologists expect species to respond individually and not as intact communities (Franklin et al. 1991; Theurillat & Guisan 2001). Alpine species population decline and extinction are also possible since there may be little available habitat for species' upward migration (Chapin & Körner 1994; Grabherr et al 1994; Theurillat & Guisan 2001). These potential ecological changes indicate the need to establish baseline plant species' distributions and abundances at local scales to definitively detect changes (Post et al. 2009). Locally abundant, single mountain endemic species like *E. mancus* offer good opportunities to establish baseline studies for this purpose.

Our primary goal in this study was to measure basic population biology parameters for the *E. mancus* population on the ridge from Mt. Laurel in the Middle Group of the La Sals 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 addressed these research 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 Middle Group of the La Sal Mountains in San Juan County in southeastern Utah (Fig. 1) on the Manti-La Sal National Forest. The study area was defined as the Mt. Peale Research Natural Area (RNA) and the ridge just west of Mt. Laurel. In June, 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 *E. mancus* density and vascular plant species composition within 1-m × 1-m square frames along this transect in mid-July 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 at 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. In August 2009, we established a 100-m long *E. mancus* density transect along the Middle Group of the La Sals 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 using the North American Datum 1983.

Voucher specimens of vascular plant species were collected in June, July, and August. Plants were identified using descriptions and keys published in FNA (1993+) and by comparison with known specimens in the Rocky Mountain Herbarium in Laramie, WY and the USFS Herbarium at RMRS in Flagstaff, AZ. Specimens are deposited at the latter herbarium. Plant nomenclature follows FNA (1993+) and the Intermountain Flora (Cronquist 1972+) in that order of priority. Descriptive statistics for plant densities and species centroid elevations were calculated with SAS/STAT 9.2 (SAS 2008).

RESULTS

Erigeron mancus was confined to dry ridgelines along the elevational transect (Fig. 2). It was not found in large, loose talus areas and tended to sharply decrease in abundance near more mesic areas, especially where

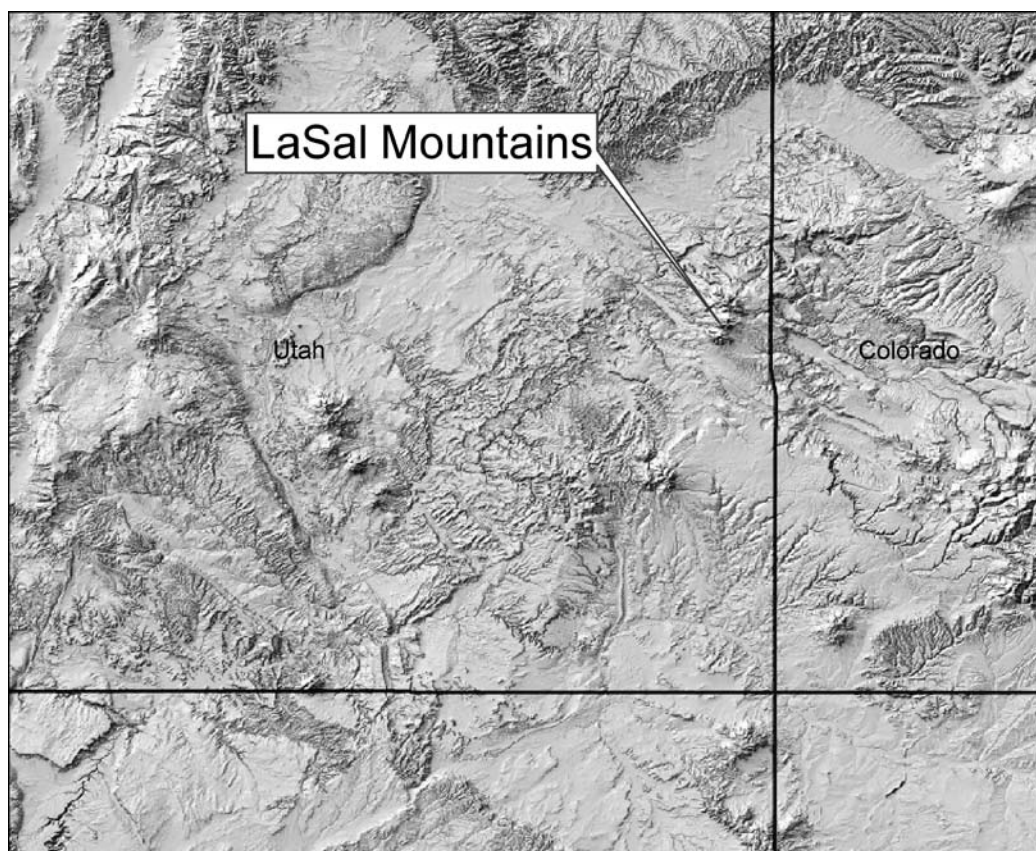


FIG. 1. Location of La Sal Mountains study area in southeast Utah showing the insular nature of the laccolithic uplift.

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/m² (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. 2).

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 (Fig. 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 La Sals 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. We collected one new Utah state record, *Artemisia*



FIG. 2. *Erigeron mancus* sampling points along the west ridge and southern crest line from Mt. Laurel. Mt. Laurel is at 38.455017 N latitude, 109.238257 W longitude. 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.

TABLE 1. *Erigeron mancus* population parameters for Mt. Laurel ridge and saddle, Middle Group of the La Sal 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 ²	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
Patch size, ha	0.60	2.08	1.26	2.86
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

pattersonii A. Gray. 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.

TABLE 2. Population centroid elevation (m) for 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 La Sal Mountains, Utah. Species are in ascending order of centroid elevation. Species listed 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
<i>Gentiana parryi</i> Engelm.	3452.15	6	5.46	3439	3470
<i>Draba abajensis</i> Windham & Al-Shehbaz	3455.36	6	6.23	3440	3483
<i>Erigeron grandiflorus</i> Hook.	3457.42	5	8.14	3440	3483
<i>Elymus trachycaulis</i> (Link) Gould	3479.29	15	13.15	3430	3622
<i>Carex rossii</i> Boott	3483.36	7	19.37	3430	3545
<i>Calamagrostis purpurea</i> (Trin.) Trin.	3491.61	8	16.41	3445	3550
<i>Cymopterus lemmonii</i> (J.M. Coult. & Rose) Dorn	3502.24	15	16.77	3438	3629
<i>Achillea millefolium</i> L.	3505.28	25	11.88	3434	3629
<i>Potentilla ovina</i> Macoun ex J.M. Macoun var. <i>decurrens</i> (S. Watson) S.L. Welsh & B.C. Johnst.	3513.32	12	20.01	3430	3608
<i>Solidago multiradiata</i> Aiton	3517.02	28	11.43	3430	3622
<i>Nocca fendleri</i> (A. Gray) Holub	3518.61	20	11.71	3440	3615
<i>Trifolium dasyphyllum</i> Torr. & A. Gray	3520.38	34	10.14	3430	3629
<i>Polemonium viscosum</i> Nutt.	3521.49	21	13.09	3434	3629
<i>Poa abbreviata</i> R. Br.	3522.01	25	10.08	3434	3615
<i>Cerastium arvense</i> L.	3522.45	30	11.12	3434	3629
<i>Carex scirpoidea</i> Michx.	3522.88	18	12.28	3430	3603
<i>Carex elynoides</i> T. Holm	3525.00	32	10.92	3430	3629
Transect mean elevation					
<i>Eremagone fendleri</i> (A. Gray) Ikonnikov	3525.94	40	8.24	3430	3615
<i>Festuca brachyphylla</i> Schult. & Schult.	3527.24	34	8.83	3430	3622
<i>Geum rossii</i> (R. Br.) Ser.	3527.59	40	8.41	3438	3629
<i>Draba aurea</i> Vahl ex Hormem.	3527.89	20	8.01	3470	3584
<i>Hymenoxys grandiflora</i> (Torr. & A. Gray) K.F. Parker	3531.68	16	10.71	3466	3596
<i>Erigeron mancus</i> Rydb.	3531.71	30	8.89	3430	3622
<i>Elymus scribneri</i> (Vasey) M.E. Jones	3534.59	12	6.42	3494	3567
<i>Castilleja sulfurea</i> Rydb.	3539.76	26	10.94	3430	3622
<i>Sedum lanceolatum</i> Torr.	3540.32	11	19.30	3440	3622
<i>Mertensia viridis</i> A. Nels.	3545.53	12	19.34	3440	3629
<i>Artemisia pattersonii</i> A. Gray	3546.69	17	12.84	3455	3622
<i>Potentilla ovina</i> Macoun ex J.M. Macoun var. <i>ovina</i>	3548.58	25	8.75	3450	3622
<i>Selaginella densa</i> Rydb.	3549.48	27	9.00	3434	3622
<i>Poa glauca</i> Vahl subsp. <i>glauca</i>	3553.62	5	23.67	3481	3622
<i>Minuartia obtusiloba</i> (Rydb.) House	3554.91	21	6.16	3494	3622
<i>Cymopterus bakeri</i> (J.M. Coult. & Rose) M.E. Jones	3556.91	23	9.93	3438	3629
<i>Carex albonigra</i> Mackenzie	3556.95	9	22.51	3455	3622
<i>Androsace chamaejasme</i> Wulfen ex Host	3558.34	18	8.24	3494	3622
<i>Poa glauca</i> Vahl subsp. <i>rupicola</i> (Nash) W.A. Weber	3558.37	8	19.36	3434	3615
<i>Trifolium nanum</i> Torr.	3563.56	6	10.10	3530	3591
<i>Silene acaulis</i> (L.) Jacq.	3572.05	8	7.38	3544	3603

For the 38 species encountered along the elevation transect five or more times, the elevation of population centroids were calculated based on occurrence within 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 grandiflora*, *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.

DISCUSSION

Prior to this study little was known about the species density of *E. mancus*, however the 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 La Sals. Thus *E. mancus* seems to be persisting under current levels of anthropogenic activity and the current climate pattern. Whether this will remain so under a warming climate is a much more open question.

The population centroid elevation, frequency of occurrence, and elevation range data for the species associated with *E. mancus* 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 now have precise spatial coordinates for multiple occurrences of 38 vascular plant species along this elevational transect which should make detection of impending local extinction possible.

The main rationale for Candidate 2 status species is that sufficient data on biological vulnerability and threat are not currently available to propose listing a species as Threatened or Endangered and that Candidate 2 listing will encourage the necessary research (U.S. Fish and Wildlife Service 1993). They also listed status trend as Unknown for *E. mancus* to indicate that additional survey work is required to determine current trends. This study provides current baseline data on a few aspects of the population biology of *E. mancus* which will then allow future re-measurements of density, population size, and elevational centroids to indicate population trends in response to climate change and anthropogenic stressors.

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REFERENCES

- BLAKEY, R. AND W. RANNEY. 2008. Ancient landscapes of the Colorado Plateau. Grand Canyon Association, Grand Canyon, AZ.
- CHAPIN, S.F. III AND C. KÖRNER. 1994. Arctic and alpine biodiversity: patterns, causes and ecosystem consequences. *Trends Ecol. Evol.* 9:45–47.
- CRONQUIST, A., A.H. HOLMGREN, N.H. HOLMGREN, AND J.L. REVEAL. 1972+. Intermountain flora, vascular plants of the intermountain west, U. S. A., 6 volumes. The New York Botanical Garden, Bronx.
- FLORA NORTH AMERICA EDITORIAL COMMITTEE, EDS. 1993+. Flora on North America north of Mexico 16+ vols. Oxford University Press, New York and Oxford.
- FRANKLIN, J.F., F.J. SWANSON, M.E. HAMON, D.A. PERRY, T.A. SPIES, V.H. DALE, A. MCKEE, W.K. FERRELL, J.E. MEANS, S.V. GREGORY, J.D. LATTIN, T.D. SCHOWALTER, AND D. LARSEN. 1991. Effects of global climate change on forests in northwestern North America. *Northw. Environm. J.* 7:233–254.
- GRABHERR, G., M. GOTTFRIED, AND H. PAULI. 1994. Climate effects on mountain plants. *Nature* 369:448.
- KULLMAN, L. 2008. Thermophilic tree species reinvade subalpine Sweden - early responses to anomalous late Holocene climate warming. *Arctic Antarc. Alpine Res.* 40:104–110.
- LENIOR, J., J.C. GÉGOUT, P.A. MARQUET, P. DE RUFFRAY, AND H. BRISSE. 2008. A significant upward shift in plant species optimum elevation during the 20th century. *Science* 320:1768–1770.
- NESOM, G.L. 2006. *Erigeron*. In: Flora of North America Editorial Committee, eds. Flora of North America north of Mexico. Oxford University Press, New York and Oxford. 20:570–602.
- POST, E., M.C. FORCHHAMER, M.S. BRET-HARTE, T.V. CALLAGHAN, T.R. CHRISTENSEN, B. ELBERLING, A.D. FOX, O. GILG, D.S. HIK, T.T. HØYE, R.A. IMS, E. JEPPESEN, D.R. KLEIN, J. MADSEN, A.D. MCGUIRE, S. RYSGAARD, D.E. SCHINDLER, I. STIRLING, M.P. TAMSTORF, N.J.C. TYLER, R. VAN DER WAL, J. WELKER, P.A. WOOLEY, N.M. SCHMIDT, AND P. AASTRUP. 2009. Ecological dynamics across the Arctic associated with recent climate change. *Science* 325:1355–1358.
- ROOT, T.L., J.T. PRICE, K.R. HALL, S.H. SCHNIEDER, C. ROSENZWEIG, AND J.A. POUNDS. 2003. Fingerprints of global warming on wild animals and plants. *Nature* 42:57–60.
- 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. Report to Canyonlands Natural History Association. URL: <http://www.cnha.org/discoverypool.cfm?mode=detail&id=12194255728> 26. Accessed 9 Sep 2010.
- SOLOMON, S. (AND 29 OTHERS). 2007. Technical summary. In: Climate change 2007: the physical science basis. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor, and H.L. Miller, eds.]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, U.S.A. Pp. 20–91.
- THEURILLAT, J.-P. AND A. GUISAN. 2001. Potential impact of climate change on vegetation in the European Alps: a review. *Climatic Change* 50:77–109.
- TRENBERTH, K.E. (AND 11 OTHERS). 2007. Observations: surface and atmospheric climate change. In: Climate Change 2007: The physical science basis. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor, and H.L. Miller, eds.]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Pp. 235–336.
- UNITED STATES FISH AND WILDLIFE SERVICE. 1993. Endangered and threatened wildlife and plants: a review of plant taxa for listing as endangered or threatened species. *Fed. Reg.* 58: 51144–51190.
- UNITED STATES FOREST SERVICE. 1994. Forest service manual 4063 research natural areas. U.S. Department of Agriculture, Forest Service Research, Washington, DC.
- UTAH NATIVE PLANT SOCIETY. 2010. Utah rare plants guide. URL: <http://www.utahrareplants.org>. Accessed 24 May 2010.
- WALTHER, G.-R., E. POST, P. CONVEY, A. MANZEI, C. PARMESAN, T.J.C. BEEBEE, J.-M. FROMENTIN, O. HOEGH-GULDBERG, AND F. BAIRLEIN. 2002. Ecological responses to recent climate change. *Nature* 416:389–395.