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ANALYSIS OF TEMPORAL CHANGE IN HIGH-ELEVATION PLANT  
COMMUNITY COMPOSITION, EAST RIVER BASIN, COLORADO, USA

by

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Thesis

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To the Graduate Faculty:

The members of the committee appointed to examine the thesis of STEPHANIE D. ZORIO find it satisfactory and recommend that it be accepted.

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## Dedication

To CDZ— father and former complex organism.

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CHAPTER 1  
MODERN REANALYSIS OF AN IMPORTANT HISTORIC MONTANE PLANT  
COMMUNITY DATASET

**ABSTRACT**

Well-defined and ecotonal plant communities can be substantially affected by disturbances, including those from anthropogenic sources. Historical datasets are invaluable baseline tools for measuring these effects that may include changes to both biodiversity and species composition. A seminal study by Langenheim conducted from 1948-1951 in the Gunnison Basin near Crested Butte, Colorado, USA, characterized plant communities of the Rocky Mountains in >200 sites from 2,590 to 4,100 m in elevation. Unpublished transect data from this original thesis were reanalyzed with contemporary methodologies. GIS was used to locate sites and derive environmental data: e.g., substrate; slope; aspect; and elevation. The compositional distinctiveness of four community types (sagebrush, spruce-fir, upland-herbaceous, and alpine) identified in the original study was evaluated. Non-metric multidimensional scaling (NMDS) ordination, flexible- $\beta$  linkage and partitioning around medoids (PAM) clustering analyses, and permutational multivariate analysis of variance (PERMANOVA) revealed that two of the four types identified by Langenheim were compositionally distinct, but the spruce-fir and upland-herb communities were not clearly defined. Community sub-types exist within these latter types that are consistent with current Forest Service and other classifications for the region.

## Introduction

Documenting patterns of vegetation change over time can be difficult due to the general lack of baseline historical data of sufficient accuracy and resolution, especially for herbaceous montane plant communities (Korner, 2003). Further, change detection may be hampered because historical vegetation datasets have often been analyzed using relatively primitive methods that have inadequately described the diversity of species within a habitat ( $\alpha$ -diversity), the degree of change in species composition from one habitat to another ( $\beta$ -diversity), or the overall multivariate structure of plant communities (Aho et al., 2008; Tingley & Beissinger, 2009). Thus, revisiting historical data with contemporary methodologies forms not only an informative starting-point, but a potential source for new discoveries (Swetnam et al., 1999).

Scientists have frequently gained new insight from historical datasets by reexamining them in novel ways (Waser et al., 1996). For example, Wipf et al. (2013) resurveyed the summit flora of the Piz Linard, an area intermittently sampled since 1835, and related species abundance and richness to temperature trends. Because of this reanalysis and combination of long-term data, the investigators were able to determine that species richness and abundance had increased during the 20<sup>th</sup> century at an accelerating rate, contradicting the theory that a warming climate will cause extirpation of species at the highest altitudes (Gottfried et al., 2012; Wipf et al., 2013). Revisiting historical datasets with updated methodology can also be used to verify or refute past results. For instance, previous analyses of historic and contemporary data from the Des Moines River showed little change in nitrate concentrations over time. A recent reanalysis of these data, however, using updated statistical approaches, revealed

important trends and identified issues for management consideration (McIsaac & Libra, 2003).

In our work, we reconsider a seminal 65-year-old dataset describing plant species composition in relation to environmental conditions in the upper East River drainage of the Gunnison National Forest near Crested Butte, Colorado, USA (Langenheim, 1962, Figure 1). The approximately 0.51°C difference in average global temperature from the 1940s to 2010 (14 - 14.51°C; Goddard Institute for Space Studies, 2010) make this dataset a useful baseline for considering the effects of climate change (Pauli et al., 1996; Rowlands & Brian, 2001). We note that while many studies have addressed plant responses to climate change (Price & Waser, 1998; Nemani et al., 2003; Von Holle & Delcourt, 2003; Halloy & Mark, 2007; Doxford & Freckleton, 2012; Reyer et al., 2013), few of these have had access to detailed historical data for particular sites, especially at high elevation regions in North America.

Langenheim (1962) comprehensively studied characteristics of high-elevation plant communities in the upper East River Basin (termed the Upper Gunnison Basin in the original study). Over 200 transects were sampled in a variety of plant communities defined *a priori*, including ecotonal zones and seral stages. Her study was one of the first to relate the unique geologic substrate of the area to similarly distinctive vegetative communities and environmental factors. Langenheim (1962) used these data to measure effects of abiotic factors, such as slope and aspect, geologic substrate, precipitation, and human-driven factors, such as incidence of fire, and grazing on patterns for plant-community composition. She reported that the vegetation in the Crested Butte area was

more similar to southwestern Colorado, and markedly different than the typical patterns observed on the eastern slope of the Rocky Mountains in Colorado.

The objectives of this study were to: 1) reconsider Langenheim's data collected in four high-elevation plant communities using modern analytical methods and indices, and 2) compare classifications of vegetation explicitly designated by Langenheim in her papers or implicit from our data analysis to current surveys of vegetative communities, including those within the study area (e.g., Johnston et al., 2001). Of particular interest was the identification of sub-types within highly heterogeneous communities.

## **Methods**

### *Area of Study*

The East River Basin is located in Gunnison County near the town of Crested Butte, Colorado, USA (38.8697° N, 106.9878° W). The East River is a headwater stream that drains into the Gunnison River. The area has been part of the Gunnison National Forest since its establishment by Theodore Roosevelt in 1905, and contains the Maroon Bells-Snowmass Wilderness Area. The East River Basin encompasses approximately 780 km<sup>2</sup> on the western slope of the Colorado Rockies (Figure 1). This area is characterized by long, very cold winters, and short and mild summers. The region is snow-covered for most of the year, and snow persists year round at the highest elevations. The average maximum temperature in July is 10.8 °C and average minimum temperature in January is -7.8 °C. Average total precipitation is 59.9 cm, and average snowfall is 502.7 cm, with an average snow event depth of 25.4 cm (10 in.; Western Regional Climate Center, 2013). The original study by Langenheim (1962) was conducted over an area approximately 249 km<sup>2</sup> on the east side of the upper East River drainage (Figure 1).

Langenheim (1962) identified five distinct plant communities in this region that form zones along altitudinal gradients, with ecotonal regions along zonal borders. *Artemisia tridentata* Nutt. communities are prevalent from 2,600 to 2,900 m. Stands of *Populus tremuloides* Michx. range from 2,600 to 3,400 m in elevation with a distinct belt occurring from 2,900 to 3,200 m. Third, mixed-conifer forests are present between 2,900 to 3,500 m. *Pinus contorta* Douglas ex Loudon stands occur in the northern reaches of the basin. *Abies lasiocarpa* (Hook.) Nutt. and *Picea engelmannii* Parry ex Engelm. forests comprise the bulk of the forested areas within the subalpine zone, whereas *Pseudotsuga menziesii* (Mirb.) Franco dominates the lower elevation conifer stands. *Juniperus scopulorum* Sarg. also is common on rocky outcroppings in montane areas. Fourth, subalpine meadows, termed the “upland herbaceous” zone (Langenheim, 1962; Komárková, 1986; Komárková et al., 1988; Johnson, 2001) are present between 3,200 to 3,800 m with a distinct belt occurring from 3,500 to 3,800 m. Alpine-tundra communities range from 3,800 to 4,100 m in elevation.

The Gunnison Basin contains a diverse variety of parent rock substrates, of which approximately 90% are sedimentary and 10% are of igneous origin. Sandstone and conglomerates compose 60% of the rock types in the Gunnison Basin. Other widespread sedimentary substrates include shale, siltstone, mudstone, and limestone (Langenheim, 1952; Hunter et al., 1975; Johnston, 2001).

The topography in the area is rugged with steep, jagged peaks that contrast with the rolling summits of the eastern slope of the Colorado Rocky Mountains. The most prominent mountains are composed of the strikingly red-colored sandstone of the Maroon Formation. Steep-sided ridges and buttes are formed by sandstone, and open drainages

and gulches often are comprised of shale types (Hunter et al., 1975; Johnston et al., 2001).

### *Original Field methods*

All analyses for this study are based on line-transect and quadrat (in forested zones) data from field work performed from 1948 to 1952. These data were included in Langenheim's Ph.D. thesis (1953) but only summarized in her later publication (Langenheim, 1962). In the current study, we reanalyze data describing four of the five community types defined by Langenheim (1953): *Artemisia* (sagebrush), *Picea-Abies* (spruce-fir), upland-herbaceous, and alpine. The aspen community was excluded from analyses because field notes from Langenheim (1953) were insufficient to relocate Langenheim's aspen sampling sites. Langenheim employed the "step-point method" to collect data (Levy & Madden, 1933) wherein approximately 100 m were "paced" or walked in a straight line. At every paced ~1-meter increment, all plants touching a mark on the front of her boot were recorded. Most plants were identified to species, but with a high degree of uncertainty in species designations for grasses, sedges, and the genus *Vaccinium* (Langenheim, 1953). The original plant count data was reported as relative abundance of species in a community type and was calculated as the total number of individuals of a species across all sites divided by the total number of sites within a community. This equals the average abundance for each species over all sites in a community, and was used to rank species by relative frequency (Langenheim, 1953, 1962). It was determined empirically from the lowest constancy (the proportion of sites within a community in which a species is found) reported in the original study data

(Langenheim, 1953) that species were only included in the original study that occurred above ~14% constancy.

### *GIS*

Exact coordinates for the 125 resampled sites in this study were not specified in the original manuscript (Langenheim, 1953). Approximate locations were determined through Langenheim's notes in the draft thesis, personal correspondence with the author, and from voucher specimens (Langenheim, 1953). The doctoral thesis contained geographic names and photos with some location information describing the general region of each site within the East River Basin. Voucher specimens collected by Langenheim during the survey were primarily accessed from the CU-Boulder Herbarium ([cumuseum.colorado.edu/research/botany/databases](http://cumuseum.colorado.edu/research/botany/databases)) and the Southwest Environmental Information Network (SEINet, [swbiodiversity.org/portal/index.php](http://swbiodiversity.org/portal/index.php)). The label information on those voucher specimens often contained more specific habitat location and some geographic coordinates. These coordinates were no doubt assigned *post-hoc* with large error radii around the coordinate point. All sites were mapped and analyzed in ArcGIS 10.2 (ESRI, 2013). Orthoimagery from Bing© provided a 10-30m resolution basemap for the study sites. Fifty meter buffers were drawn around each likely sampling point and a random point was generated within each buffer zone. The buffer size was chosen because it was the largest buffer size that would ensure that the random points would still be generated within an area assigned to a particular community type instead of being placed in another community type or in an unlikely location, such as a sheer cliff. One hundred twenty-five total sampling sites in four plant communities (sagebrush: 27; spruce-fir: 32; upland-herbaceous: 31; alpine: 35) were relocated and mapped. A 1/3<sup>rd</sup> arc second (10m resolution) National Elevation Dataset (NED) from the USGS

([earthexplorer.usgs.gov/](http://earthexplorer.usgs.gov/)) provided the basis for calculating elevation, slope, and aspect for each site. Another feature class layer from the USGS site contained general geologic substrate data, and was used to further classify sites

### *Statistics*

The original manuscript denoted species present but occurring at low frequency (<1%) within a site as “x” (Langenheim, 1953). To make the data suitable for analyses we replaced these values with frequencies of 0.5%. This lowered the re-estimation of average relative abundance a negligible amount (~ 0.02% per community). Species name changes and other synonymy issues were addressed using Weber and Wittmann (2012) and the USDA PLANTS Database ([plants.usda.gov](http://plants.usda.gov)).

Species accumulation curves were generated for each community using the “exact” method of Ugland et al. (2003). Bray-Curtis dissimilarity (Bray & Curtis, 1957) was used as the underlying resemblance metric for sites in this analysis due to its propensity to effectively represent dissimilarity structures in zero-inflated **datasets (Aho et al., 2008)**. Average Bray Curtis dissimilarity was used as a measure of beta diversity (Aho et al., 2008). The Shannon-Weiner index (Shannon & Weaver, 1948) was used to measure alpha diversity. As an information statistic index, the Shannon-Weiner index assumes all species are represented, and is relatively sensitive to the occurrence of rare species (Magurran, 2004).

### *Cluster Analyses*

Two distinct types of classification analyses were performed to obtain a consensus “objective” classification of vegetation, for comparison with Langenheim’s “subjective” classes. These were the non-hierarchical clustering method, partitioning around medoids (PAM; Kaufman & Rousseeuw, 1990), and flexible- $\beta = -0.25$  hierarchical

agglomerative clustering (Lance and Williams, 1967). PAM and flexible- $\beta$  clusters were both calculated from the Bray-Curtis dissimilarity matrix.

The optimal number of clusters in the flexible- $\beta$  and PAM analyses was determined using three different classification efficacy indices: average silhouette width (Kaufman & Rousseeuw, 1990), 1-average indicator species analysis (ISA)  $P$ -value (Dufrière & Legendre, 1997), and the number of statistically significant ( $\alpha = 0.05$ ) ISA species.

### *Ordination*

Metric Multidimensional Scaling (i.e., Principal Coordinates Analysis; PCoA) and Non-Metric Multidimensional Scaling (NMDS) ordination were used for indirect gradient analysis (Jongman et al., 1995; Legendre & Legendre, 1998). Environmental variables (elevation; slope; aspect; and geologic substrate) were overlaid on the species space of the ordination, and tested for significance using vector fitting (Oksanen et al., 2013). Bray-Curtis dissimilarity was again used as the underlying resemblance metric in both PCoA and NMDS. Resulting configurations from PCoA and NMDS were compared using Procrustes analysis (Legendre & Legendre, 1998) to verify that similar multivariate interpretations could be generated from distinct methods (Aho et al, 2014).

### *Multivariate Hypothesis Testing*

PERMANOVA (a permutational analogue of MANOVA; Anderson, 2001) was used to determine whether the communities outlined by Langenheim, were distinct in multivariate species space. The Bray-Curtis index was used as the underlying dissimilarity matrix. The value  $\alpha = 0.05$  was used as the significance level after 100 permutations.

## *Software*

The statistical software package R was used for all analyses (R core team, 2014). In particular, we relied heavily on the package *vegan* (Oksanen et al., 2013) for ordination, PERMANOVA, and other community level analyses, and the package *cluster* (Maechler et al., 2014) for cluster analyses.

## **Results**

### *Community Composition*

Sites within the four community types contained 157 species from 27 families. The four species with the highest relative abundance in Langenheim's alpine community were *Oxytropis deflexa* (Pall.) DC., *Dryas octopetala* L., *Artemisia scopulorum* A. Gray, and *Tetraneuris grandifolia* (syn. *Hymenoxys grandiflora* (Torr and A. Gray) K.F. Parker) (Table 1). In the upland-herbaceous community, *Ligusticum porteri* J.M. Coult. & Rose occurred with the highest relative abundance, followed by *Lupinus parviflorus* Nutt. ex Hook., *Senecio crassulus* A. Gray, and *Carex ebenea* Rydb. *Vaccinium* spp. was the dominant genus in the spruce-fir community in frequency and abundance, and was followed in dominance by the species *Pedicularis racemosa* Douglas ex Benth., *Arnica cordifolia* Hook., and *Lupinus parviflorus*. The most frequently occurring and most abundant species in the sagebrush community was *Artemisia tridentata*, followed by *Festuca thurberi* Vasey, *Chrysothamnus* spp., and *Arenaria congesta* Nutt. (Table 1). Species richness was similar for sagebrush and spruce-fir communities; however, the upland-herb type had the highest Shannon-Weiner diversity index (Table 2).

The distribution of site aspects revealed a sampling bias against north-facing slopes, with east-facing slopes being the most well-represented, followed by west-facing and south-facing slopes. Sampled sites tended to be located at higher elevations (the distribution of sampled elevations was positively skewed) with a distinct clustering of sites at relatively flat areas, and on steeper slopes from 20-30° (Table 2, Figure 2).

The asymptotic character of species accumulation curves indicated that sample sizes were adequate for making inferences concerning true species richness and community composition (Appendix B, Figure 1). PERMANOVA analyses indicated that the communities identified by Langenheim were distinct from each other ( $F_{(3,116)} = 40.93$ ,  $P < 0.001$ ) (Table 3).

#### *Cluster Analyses*

Classification evaluators indicated that the four cluster PAM and flexible- $\beta$  solutions were optimal (Figure 3; Table 2). In both PAM and flexible- $\beta$  analyses, the optimal four cluster solution was essentially identical to the *a-priori* community classification of Langenheim (1962). The one exception, in both analyses, was an upland-herbaceous site 25 (U25) that was clustered with the sagebrush community. This site contained a low abundance of typical dominant meadow species, but had a high abundance of *Festuca thurberi* Vasey—the second most abundant species in the sagebrush community.

Classification evaluation of the PAM solution and depiction of the flexible- $\beta$  dendrogram indicated that the sagebrush type was the most distinct community, whereas the alpine and upland-herb types were the most similar communities (Figure 3 and 4). From a hierarchical perspective, in the three cluster flexible- $\beta$  solution combined the

upland-herb community and alpine community. The spruce-fir community type was split in the 5 cluster solution with 14 sites in one cluster and 18 in a second (Figure 4). Spruce-fir was the most heterogeneous (high beta diversity) community after upland-herbaceous, with the potential for several meaningful subtypes, as demonstrated by the eight cluster dendrogram (Figure 4).

### *Ordination*

The results of both NMDS and PCoA ordinations were checked for concordance with Procrustes analysis (Williams & Langron, 1984). The analysis revealed that the NMDS and PCoA solutions were highly similar ( $r = 0.89$ ,  $p = < 0.001$ ), indicating that the spread of sites within the ordinations was not an artifact of methodology. Given the similarity of the projections, we only present NMDS results here.

After 100 iterations, a three dimensional NMDS projection was obtained with a stress low enough (0.079) to allow for confident inferences concerning the true community relationships among sites (Kruskal, 1964). The entire three dimensional projection is shown in Figure 2a. A flattened (from the top) projection of just dimensions 1 and 2 is presented in Figure 2b. Ninety-five percent confidence ellipses for the true multivariate centroids of the Langenheim *a priori* types are overlaid on Fig. 2b, along with results from vector and factor fitting analyses (Oksanen et al. 2013).

Sites in the relatively homogenous sagebrush type were tightly clustered, resulting in a small confidence ellipse in dimensions 1 and 2, whereas sites in the more heterogeneous spruce-fir type were broadly scattered with a large confidence ellipse (Fig. 2b). Note that within dimensions 1 and 2, the sagebrush and alpine communities were

distinct, whereas overlap occurs between the upland-herb and Spruce-Fir communities. These latter types, however, were distinct along the third NMDS dimension (Fig. 2a).

The lengths of the vector fitting arrows in the two dimensional NMDS scatterplot correspond to the  $R^2$  values from a multiple regression model with the environmental variable as the response and the ordination scores as predictors (Table 3, Figure 2b). All environmental variables under consideration were significantly associated with NMDS scores ( $p$ -value = 0.001), although aspect was not as strongly associated ( $R^2 = 0.053$ ,  $p$ -value = 0.024) as other variables (Table 3). The community type assignments had a high correlation ( $R^2 = 0.86$ ,  $p$ -value = 0.001) with the ordination projection, reflecting the distinctiveness of types in Langenheim's original classification. Elevation was also strongly correlated with ordination scores ( $R^2 = 0.52$ ,  $p$ -value = 0.001), illustrated by the spread and clustering of sites in regards to the elevation vector in the first and second dimensions (Table 3, Figure 2b). The similar directions of arrows for slope and elevation in these dimensions indicate that those variables have a large and parallel influence on the orientation of sites in community space.

The sagebrush community occurs more frequently on south-eastern aspects below 3,000 m in elevation (Table 2, Fig. 2b). The upland-herb community was more widely distributed across aspects than sagebrush, and was more affected by slope and elevation. Sites within the alpine community were relatively closely clustered, with most sites on east-facing aspects, and varied little with respect to slope and elevation.

## **Discussion**

In her original analysis of these data Langenheim (1953, 1962) described five community types (sagebrush, aspen, spruce-fir, upland-herbaceous, alpine) and successional stages, and three interzonal types (Fescue grassland, Douglas Fir-Limber Pine, and hydric communities). Data from her thesis (Langenheim, 1953), stored in the Rocky Mountain Biological Laboratory archives, provided enough information to relocate sites and subsequently generate subsets of environmental data to objectively analyze the four communities discussed here.

The distribution of plant communities in the upper East River drainage is strongly associated with topography (slope and aspect), elevation, and geologic substrate (Figure 3). These factors have been shown to be important predictors of vegetation composition in other mountainous areas at high-altitude (Curtis & Macintosh, 1951; Theurillat & Guisan, 2001; Zu et al., 2009; Wipf et al., 2013). Ecotonal areas are points of transition and mixing between more distinct groupings. Several ecotonal sites are evident in the ordinations (Figure 2). In particular, some sites in the alpine, upland-herbaceous, and spruce-fir communities appeared to represent ecotonal transitions between these types based on shared species and habitat. We note that the number of sites sampled within each community was subequal; however, the geographic distribution of sites across the East River drainage was not evenly or randomly distributed. Much of the field work of original study was performed in tandem with a geologic study (Langenheim, 1952). Consequently, survey areas were often located near Maroon Formation and associated substrates (Figure 1). Nevertheless, we believe that the high number of sites and length of

transect (100m) provided a thorough representation of vegetation within the East River drainage (Figure 1).

The first objective of this study was to reconsider Langenheim's data collected in four high-elevation plant communities using modern analytical methods and indices. Of interest was whether or not updated statistical techniques could independently arrive at the number of community types defined by Langenheim (1962). Not surprisingly, cluster analyses and PERMANOVA results indicated that the four communities were distinct, and classification evaluators indicated that species space was best subdivided into four clusters, essentially identical to Langenheim's types. Consideration of finer scale classifications, however, revealed the potential for sub-types within the dominant community type described by Langenheim (1962), and insights into possible shifts in vegetation over the last sixty years. The optimal number of clusters from PAM and flexible- $\beta$  classifications was four; however, varying the number of clusters in these analyses yielded instructive results (Figure 3 and 4; Appendix B, Table 2). Ecotonal sites in the four type classification, evident as cluster outliers in the NMDS ordination, were grouped into new subtypes as the number of clusters in the analyses was increased.

Our second objective was to compare classifications of vegetation explicitly designated by Langenheim, and implicit from our data analysis, to current surveys of plant communities within the study area (e.g., Johnston et al., 2001). Analogs for subtypes identified in our reanalysis in the current literature were found for most of these subtypes (e.g. Komárková, 1986; Hartman and Rottman, 1987; Johnston et al., 2001). Some of these communities, however, appear to be poorly described in regional phytosociological survey.

We rely largely on Johnston et al. (2001) for community comparison as their study is the most recent for the East River Basin region. This analysis allows comparative studies by not only providing a baseline for comparison, but by highlighting particular areas of interest in the East River drainage that may undergo shifts in community composition sooner, or to a greater degree than others in response to environmental changes over time.

### Alpine Community

The alpine community was a well-defined (Average Bray-Curtis dissimilarity = 0.413) type characterized by *Oxytropis deflexa*, *Dryas octopetala*, *Artemisia scopulorum*, and *Tetranneuris grandifolia* (Table 1). This community, as described by Langenheim, had the second highest Shannon-Weiner diversity ( $H' = 2.51$ ) and species richness (51 species) of the four community types (Table 2). *Dryas octopetala* is a well-documented species in alpine areas throughout the central and southern Rocky Mountains (Komárková, 1979; Willard, 1979). Interestingly, *Oxytropis deflexa*, the most abundant species in Langenheim's alpine community, is not cited as an important species by other studies in the Elk Mountains (Hartman & Rottman, 1987), or in neighboring states like Wyoming or Utah. However, *O. deflexa* has a wide geographic range that spans Europe, parts of Asia, and the central-southern Rocky Mountains (Høiland & Laane, 1989). A sub-cluster of five sites occurring  $\geq 3,700$  m in elevation, with a plutonic substrate and steep slopes were compositionally distinct from the main alpine cluster in the NMDS ordination. These sites also comprise an alpine sub-cluster within the eight cluster flexible- $\beta$  solution. Notably, the associated sites were not adjacent geographically, but shared a species assemblage that resembles an alpine type (AL02), *Kobresia*/curly sedge-

club-moss, regionally described by Johnston et al. (2001), with dominant species: *Kobresia bellardii* var. *macrocarpa* (Clokey ex Mack.) H.D. Harr., *Polemonium viscosum* Nutt., and *Carex drummondiana* Dewey.

### Upland-Herbaceous Community

The upland-herbaceous community was the most heterogeneous (Average Bray-Curtis dissimilarity = 0.495) and most diverse type (species richness = 59,  $H' = 2.70$ ). The most abundant species in the community were *Ligusticum porteri*, *Lupinus parviflorus*, *Senecio crassulus*, and *Carex ebenea* (Table 1). As the number of flexible- $\beta$  clusters increased from the optimal number of four, sites with low relative abundance of characteristic species were segregated into sub-types (Figure 3 and 4). The species composition of most of these sites resembles sub-alpine and alpine types regionally identified by Johnston et al. (2001) and Hartman and Rottman (1987). Specifically, a sub-cluster of sites strongly correlated with West-facing aspect in the ordination fall more closely within the *Ligusticum porteri* series of Johnson et al. (2001) than the majority of those within the upland-herbaceous 95% confidence ellipse (Figure 2). The most common species in the sub-cluster are *Ligusticum porteri*, *Lupinus* spp., *Helianthella quinquenervis* (Hook.) A. Gray, *Festuca thurberi*, and *Delphinium barbeyi* (Huth) Huth. The sub-cluster of Johnson et al. also correspond to the subalpine meadow of Baker (1983), that is distinguished by *Ligusticum porteri* and *Lupinus parviflorus* Nutt. ex Hook. & Arn. A comparison of information from Langenheim (1962) and the local report of Johnston et al. (2001) suggest a possible elevational shift for this sub-type over time. Local average temperatures have increased 0.51° over the last 70 years (Goddard Institute for Space Studies, 2010). Further, west-facing slopes, characteristic of this type,

experience greater heat storage and increased evapotranspiration compared to East-facing slopes (Geiger et al., 2009). We hypothesize that this combination may have resulted in shift of past ambient conditions at these locations to higher elevations, resulting in a shift upward in the associated plant community.

Langenheim (1962) readily distinguished the upland-herbaceous community (sub-alpine meadow) from the spruce-fir community; however, the NMDS ordination and the results of cluster analyses revealed shared species and environmental characteristics (Figure 2). The majority of the convergent sites in the two communities had similar elevations and aspect, shared many of the same dominant species, and occurred relatively close geographically (Figure 2; Appendix B, Table 1). Important shared species (those occurring with at least 20% frequency in each type) include *Vaccinium* sp., *Lupinus parviflorus*, *Achillea millefolium*, *Pseudocymopterus montanus* (A. Gray) J.M. Coult. & Rose, and *Geranium richardsonii* Fisch. & Trautv.

One upland-herbaceous site (U 25) was clustered, in both the PAM and flexible- $\beta$  classifications, within the sagebrush type due to low species richness and overall plant abundance, and the prevalence of the sagebrush community dominant, *Festuca thurberi*. At 3,000 m, U 25 also had the lowest elevation of any upland-herbaceous site (Appendix B, Table 1). Sites that are dominated by *Festuca thurberi* are similar to the *Festuca thurberi* Herbaceous Alliance described by the Western Ecology Working Group (2015), and share common forb species, such as *Lathyrus lanszwertii* Kellogg var. *leucanthus* (Rydb.) Dorn, *Vicia americana*, and *Achillea millefolium*.

As with the alpine community type, outlying sites in the upland-herbaceous community seemed to be those low in species richness. We note that ecotonal sites in the

lower portion of the 2<sup>nd</sup> NMDS axis are found on steeper slopes whereas those in the upper portion of the 2<sup>nd</sup> axis are found on more gentle slopes (Figure 2b). Continued survey of these areas could further sub-divide and enhance the current classifications.

### Spruce-Fir Community

This community commonly occurs at the study area at between 3,000 – 3,500 m of altitude, and corresponds to a community regionally described by Johnston et al. (2001) with 8 sub-types. Only understory species (forbs, shrubs, and graminoids) were included in the original survey (Langenheim, 1962). The spruce-fir community spanned a wide swath paralleling the first NMDS axis. Dominants included *Vaccinium* spp., *Pedicularis racemosa*, *Arnica cordifolia*, and *Lupinus parviflorus* (Table 1, Figure 3). Sites in this type had relatively low species richness (43), and the third highest level of  $\beta$ -diversity (Average Bray-Curtis dissimilarity = 0.408). Sites were primarily spread along the first dimension suggesting the influence of elevation on species composition in this community (Figure 2b). For instance, most of the wettest sites occur at lower elevations, located on the left side of the first dimension (Figure 2), and contain species such as *Trollius laxus* Salisb. and *Equisetum palustre* L. that are not found at higher, drier, and more exposed sites, located on the right side of the first dimension (Figure 2). Heterogeneity is also introduced through successional processes and other environmental factors, such as forest stand ages, elevation range, avalanche zones, and marshy areas and streams that are contained within the borders of the conifer forest.

Langenheim (1962) and later studies of the region have reported that coniferous forest, particularly of *Abies lasiocarpa* and *Picea engelmannii*, have the largest extent

and range in elevation of any community in the upper East River Basin (Langenheim, 1962; Komárková et al., 1988; Johnson et al., 2001). The vegetation of the study area is similar to the *Abies lasiocarpa/Vaccinium scoparium* association described by Weaver (1990), although *Pinus albicaulis*, common at higher elevation in Weaver (1990), are absent in Langenheim's study (1962). As in the previous example, Komarkova et al. (1988), included *Picea engelmannii* as a commonly occurring co-dominant, or possibly dominant species. *A. lasiocarpa* was more abundant at smaller diameter classes, seedlings, and sapling in Langenheim's survey. Langenheim did not identify species of *Vaccinium*; however, most of the spruce-fir sites of Langenheim would be categorized under the *Abies lasiocarpa/Vaccinium scoparium*, or *Abies lasiocarpa/Vaccinium myrtillus* habitat types of (Komarkova et al., 1988).

Although soil water content was not taken into consideration in the original study, some of the spread in the ordination can be related to riparian and marshy areas within the spruce-fir community maintained by snowmelt run-off. These sites have a higher abundance of species, such as *Senecio triangularis* Hook., *Mertensia ciliata* (James ex Torr.) G. Don, *Caltha leptosepala* (DC.) W.A.Weber, and *Poa leptocoma* Trin. The Colorado Natural Heritage Program (CNHP) includes the *Senecio triangularis* Temporarily Flooded Herbaceous Alliance within the Alpine-Montane Wet Meadow group that also contains these species (CNHP, 2005). These areas are often next to stands of *Abies lasiocarpa* and *Picea engelmannii* and mixing probably occurs over the forest edge.

An overlap between the spruce-fir and upland-herbaceous communities occurs in the spruce-fir sites at the highest sampled elevations (Figure 2). This ecotone is

transitional between sub-alpine and alpine zones. The Engelmann spruce-mountain gooseberry (FL 8) sub-type regionally described by Johnston et al. (2001) closely resembles five of Langenheim's spruce-fir sites that lay within the upland-herbaceous 95% confidence ellipse, and are first grouped together within the five cluster flexible- $\beta$  result (Figure 4). These sites were characterized by a low abundance of *Vaccinium* and high abundance of *Lupinus parviflorus*, *Ribes montigenum* McClatchie, and *Polemonium delicatum* Rydb. on East-facing slopes (Figure 2).

Spruce-fir sites outside the upland-herb 95% confidence ellipse were generally found on gentler slopes (Figure 2b). Sites closer to the center of the ordination were located in the Copper Creek area north-east of the RMBL and had a greater abundance of *Pachystima myrsinites* (Pursh) Raf. and *Lathyrus lanszwertii* Kellogg var. *leucanthus* (Rydb.) Dorn, than average. These sites are consistent with the description for the Fir-Spruce/*Pachistima* (FL 3) subtype in the current literature (Johnston et al., 2001). Outlier Spruce-Fir sites 1, 2, 3, and 32 that resemble the alpine community type were located in the Copper Creek area on West-facing steep slopes often interspersed with talus areas and are also differentiated by high amounts of bare area. Those sites also comprised all of the members within a small Spruce-Fir group beginning at the eight cluster flexible- $\beta$  solution (Figure 4). While the four most dominant species generally remain constant throughout all Spruce-Fir sites, differences in the abundance of other species occur in sub-types that may be influenced by environmental variables unmeasured by Langenheim (1962), for instance, average soil water availability, or fine scale substrate differences.

## Sagebrush Community

The sagebrush community was the most compositionally homogenous (Average Bray-Curtis dissimilarity = 0.358), and had the lowest species richness (43) and Shannon-Weiner diversity (2.37) of the four major types (Table 2, Figure 2). The sagebrush community also contained the highest number of substrate types. Thus, we conclude that substrate types –as obtained from a GIS shapefile with a resolution of 100m did not strongly affect species composition at the study site. Langenheim’s (1953, 1962) classification describes the sagebrush sub-type found in the upper Gunnison Basin above 2,500m, and corresponds to the Mountain sagebrush/Thurber-Arizona fescues (SU 1) type under the most current classification of the region by Johnston et al. (2001). This sub-type is defined by species that are also the most abundant in the original study, such as *Artemisia tridentata*, *Festuca thurberi*, *Chrysothamnus* spp., and *Arenaria congesta*. (Table 1). The CNHP’s Inter-mountain Basins Montane Sagebrush Steppe describes the *A. tridentata*-dominated community that Langenheim observed. This plant association is found on cooler and wetter regions at higher elevation than other sagebrush communities (CNHP, 2005) Other sites within the sagebrush community are more aligned with the lowland Great Basin-Colorado Plateau Sagebrush classification of West (1979) due to a much higher abundance of shrub species, such as *A. tridentata* and *Chrysothamnus viscidiflorus*, and lower abundances of forbs, like *Astragalus* spp.

One reason for the lack of apparent sub-types may be due to uncertainty, demonstrated by Langenheim (1962), in identifying several important sagebrush associated genera to species, including *Chrysothamnus* spp., *Symphoricarpos* spp.,

*Geranium* spp., *Rosa* spp., and *Antennaria* spp. (Hess and Wasser, 1982; Weber and Wittmann, 2001).

#### *Community-Environment Interactions*

Environmental variables appear to have a significant effect on the spatial structuring of plant communities within the East River drainage, although their inferred impacts may be inexact because data were acquired long after the original sampling period. Inherent uncertainty occurred in environmental variables obtained from shapefiles, and quantified from relocated sites via GIS. Nonetheless, significant associations were revealed between the ordination projection and this environmental data. The position of the East River drainage on the west side of the continental divide undoubtedly also strongly dictates species composition, and distinguishes it from other regional floras (Weber & Wittmann, 2012). The composition of the four community types described by Langenheim (1962) suggest that topography, specifically microclimatic effects of slope and aspect, may strongly influence community composition (Figure 2). For example, *Artemisia tridentata* dominates the sagebrush community at lower elevations, but *Lupinus* spp. and *Rosa woodsii* were found in abundance on steeper, south-facing slopes and were within sites that fell out of the community 95% confidence ellipse (Figure 2b). In another instance, *Lupinus parviflorus*, the second most abundant species in the upland-herbaceous community and fourth most abundant in the spruce-fir community, was more commonly found in south-facing spruce-fir sites at higher elevations that receive a greater amount of solar radiation and contain less well-developed soils (Table 1). Other unconsidered factors include water

availability soil depth and texture, soil nutrient levels and land-use history; for instance, mining activities during the late 1800s-early 1900s.

### *Conclusions and Future Directions*

Langenheim's classifications made 65 years ago are statistically valid. With relatively modern techniques like cluster analyses and ordination we were able to further explore these data and identify sub-types described in more detail since the time of Langenheim's original work (Komárková, 1986; Komárková et al., 1988; Johnston et. al, 2001; Damm, 2001; CNHP, 2005; Coop et al., 2013). Langenheim (1962) did not have the benefit of multivariate analytical techniques like ordination; however, despite the challenges of analyzing a large dataset with additional environmental data she was able to describe, albeit coarsely, plant communities still recognized today (Komárková, 1986; Komárková et al., 1988; Johnson, 2001; Coop et al., 2014). Although general trends in the distribution of vegetation in the upper East River drainage can be explained, and are reflected in current descriptions of that area (Komárková, 1986; Komárková et al., 1988; Johnston et al., 2001), subtypes indicated by the NMDS and clustering methods may have further differentiated over time.

Our work here highlights the need for studies investigating environmental patterns and associated vegetation of the region in greater detail. The Langenheim (1962) dataset, presented here with updated synonymy and environmental data, is likely to be extremely useful in establishing biodiversity conservation benchmarks, and as a baseline for identifying temporal shifts in response to climate change in central Colorado. We plan to pursue this by comparing historic and contemporary data collected from Langenheim's relocated sites.

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## Tables and Figures

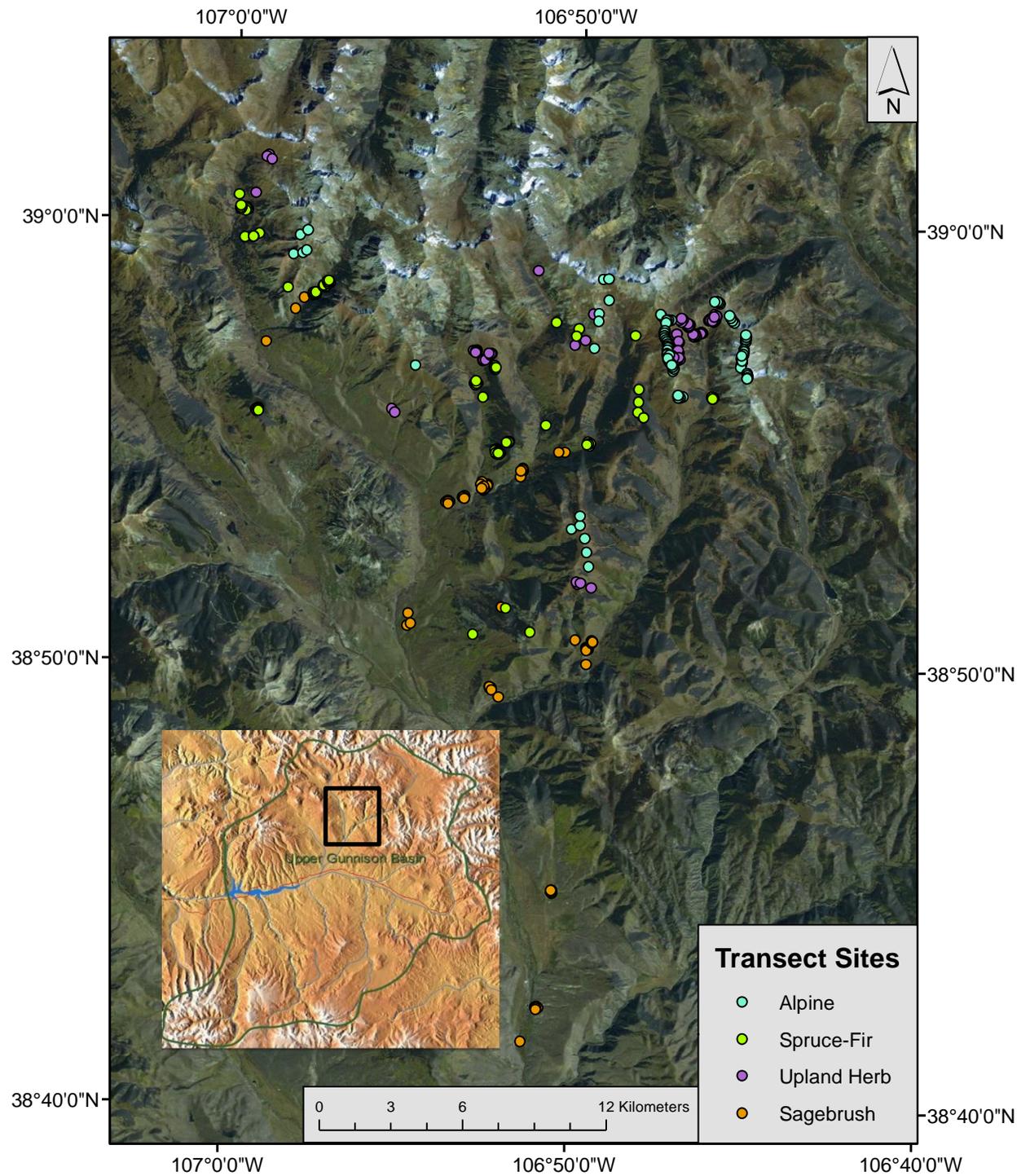


Table 1. The four most abundant species for each community described by Langenheim (1962). Relative abundance is noted in parentheses.

<b>Sagebrush</b>	<b>Spruce-Fir</b>	<b>Upland-Herb</b>	<b>Alpine</b>
<i>Artemisia tridentata</i> (32.52)	<i>Vaccinium spp.</i> (27.28)	<i>Ligusticum porteri</i> (10.15)	<i>Oxytropis deflexa</i> (3.99)
<i>Festuca thurberi</i> (6.09)	<i>Pedicularis racemosa</i> (10.13)	<i>Lupinus parviflorus</i> (9.18)	<i>Dryas octopetala</i> (3.86)
<i>Chrysothamnus spp.</i> (4.19)	<i>Arnica cordifolia</i> (9.04)	<i>Senecio crassulus</i> (6.32)	<i>Artemisia scopulorum</i> (3.79)
<i>Arenaria congesta</i> (3.89)	<i>Lupinus parviflorus</i> (7.15)	<i>Carex ebenea</i> (3.63)	<i>Tetranneuris grandifolia</i> (3.71)

Table 2. Comparison of environments of four community types described by Langenheim (1962) in the upper East River drainage. Standard errors are included with sample means.

<b>Variable</b>	<b>Sagebrush</b>	<b>Spruce-Fir</b>	<b>Upland-herb</b>	<b>Alpine</b>
Number of plots	27	32	31	35
Total richness	43	43	59	51
Shannon-Weiner div.	2.37 ± 0.06	2.38 ± 0.09	2.7 ± 0.07	2.51 ± 0.05
β-diversity	0.358 ± 0.005	0.408 ± 0.006	0.495 ± 0.007	0.413 ± 0.005
Elevation (m)	2783 ± 42.1	3235 ± 55.5	3460 ± 34.4	3772 ± 18.7
Slope (degrees)	11.45 ± 1.5	13.1 ± 1.4	19.39 ± 1.6	25.25 ± 1.6
Aspect (deg. from N)	125.3 ± 0.5	208.7 ± 5.4	166.6 ± 15.6	83.3 ± 28.3

Table 3. Association of the NMDS ordination, vector fitting analysis of environmental variables, and PERMANOVA (Maechler et al., 2014) of Langenheim's (1962) *a-priori* community classifications.

<b>Vectors</b>	<b>Partial <math>R^2</math></b>	<b><math>p</math>-value</b>
Slope (degree)	0.19	0.001
Elevation	0.52	0.001
Aspect (degrees from N)	0.053	0.024
<b>Factors</b>		
Substrate	0.22	0.001
Community	0.86	0.001
PERMANOVA	0.51	0.001

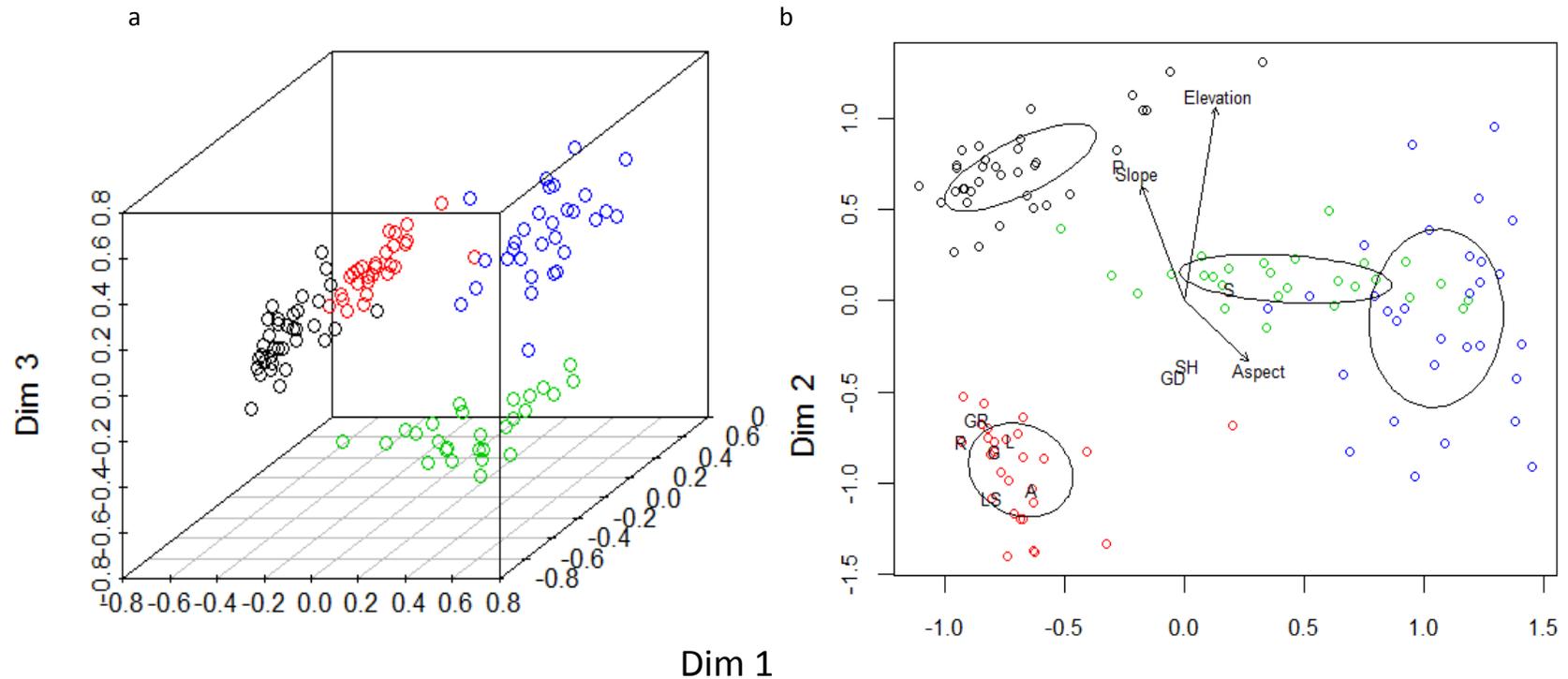


Figure 2. Sites within species space of four community types described by Langenheim (1953) in the upper East River basin, Colorado, USA. Arrows indicate increasing slope and elevation, and western-facing aspects. Red, black, blue, and green represent sagebrush, alpine, Spruce-Fir, and upland-herbaceous, respectively. Letters stand for substrate types and are as follows: S-sandstone; P-plutonic; L-limestone; R-rhyolite; G-granitoid; GD-glacial drift; GR-gravel; LS-landslide; SH-shale; A-alluvium. a) 3D scatterplot of sites within communities with dimension 1 and 3 facing forward. b) NMDS ordination of dimension 1 and 2 and regression results for environmental variables. Final stress for 4D NMDS solution = 0.079.

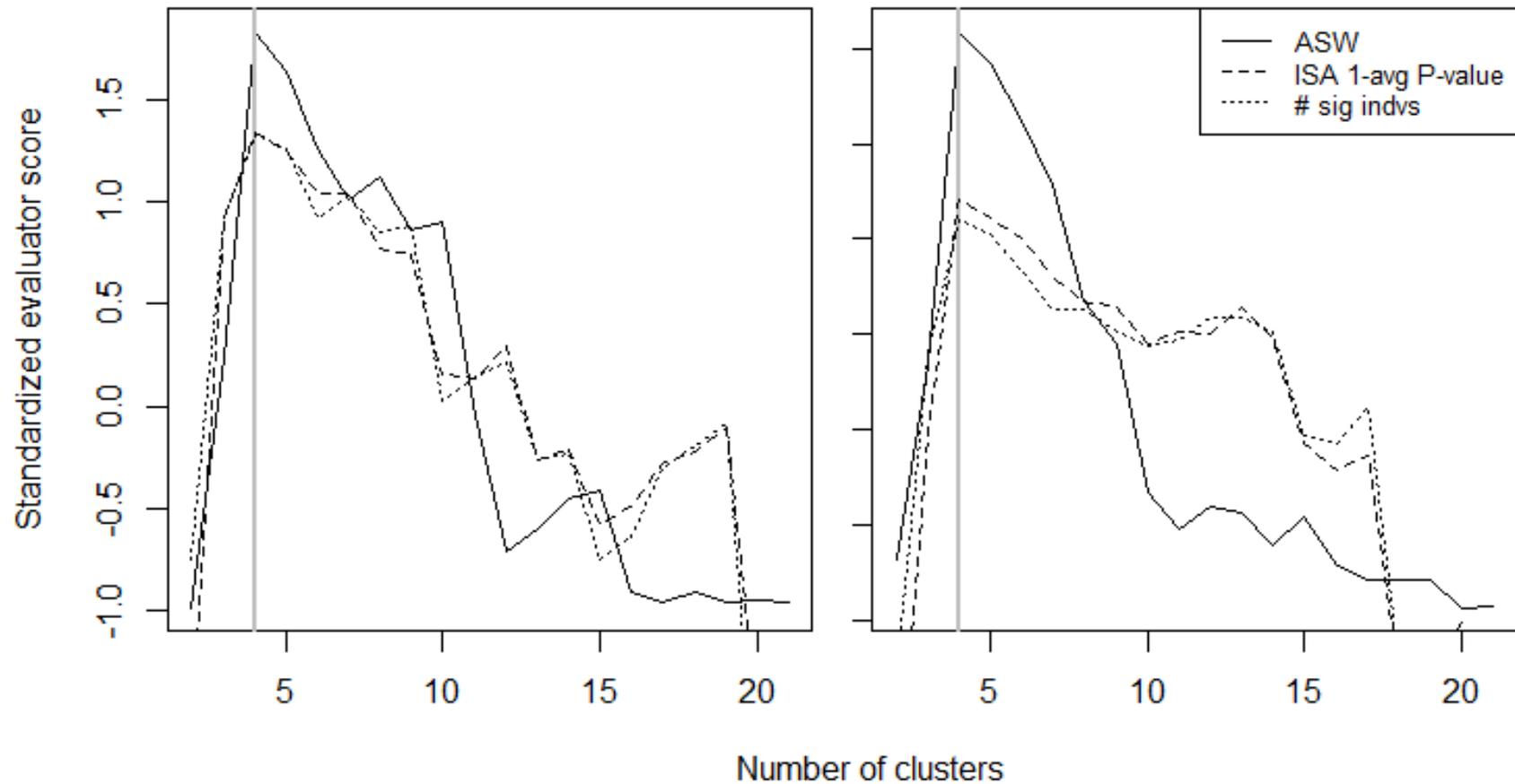


Figure 3. Standardized evaluator indices for flexible- $\beta$  (A) and PAM clustering (B). Three evaluator indices (average silhouette width, 1-[average p-value of cluster #], # indicator species) were used to determine the optimum number of clusters (i.e. communities) based on a Bray-Curtis dissimilarity matrix of plant community data from Langenheim (1953). The gray lines in (A) and (B) indicate the optimal cluster solution of 4.

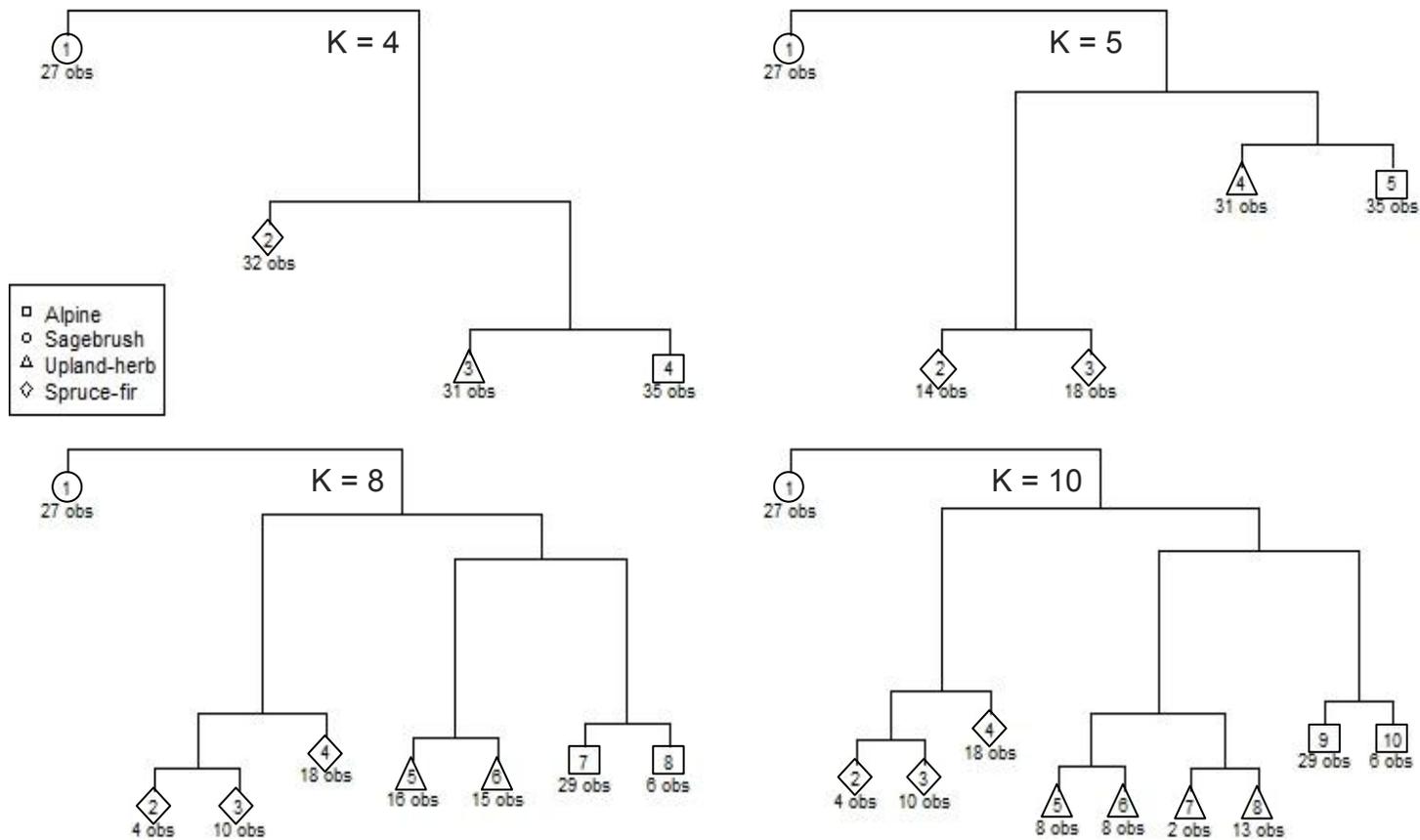


Figure 4. Flexible- $\beta$  clusters for four community types, including Langenheim's original cluster number ( $K=4$ ) and other selected cluster numbers.

## Appendix A. Supplementary Data

Table 1A. Cluster scores for 3 indices (average silhouette width, 1-[average p-value of cluster #], # indicator species) used to evaluate flexible- $\beta$  and PAM methods. Optimal cluster solution appears in bold type.

Cluster No.	ASW		1-ISA P-value		No. Sig. Individ.	
	Flexible- $\beta$	PAM	Flexible- $\beta$	PAM	Flexible- $\beta$	PAM
2	0.196	0.196	0.909	0.910	96	94
3	0.259	0.250	0.985	0.965	146	136
<b>4</b>	<b>0.341</b>	<b>0.340</b>	<b>0.997</b>	<b>0.998</b>	<b>156</b>	<b>154</b>
5	0.331	0.332	0.995	0.995	153	152
6	0.312	0.316	0.989	0.992	146	147
7	0.299	0.298	0.989	0.987	147	142
8	0.305	0.267	0.981	0.984	143	142
9	0.291	0.255	0.979	0.983	141	139
10	0.293	0.215	0.962	0.978	120	137

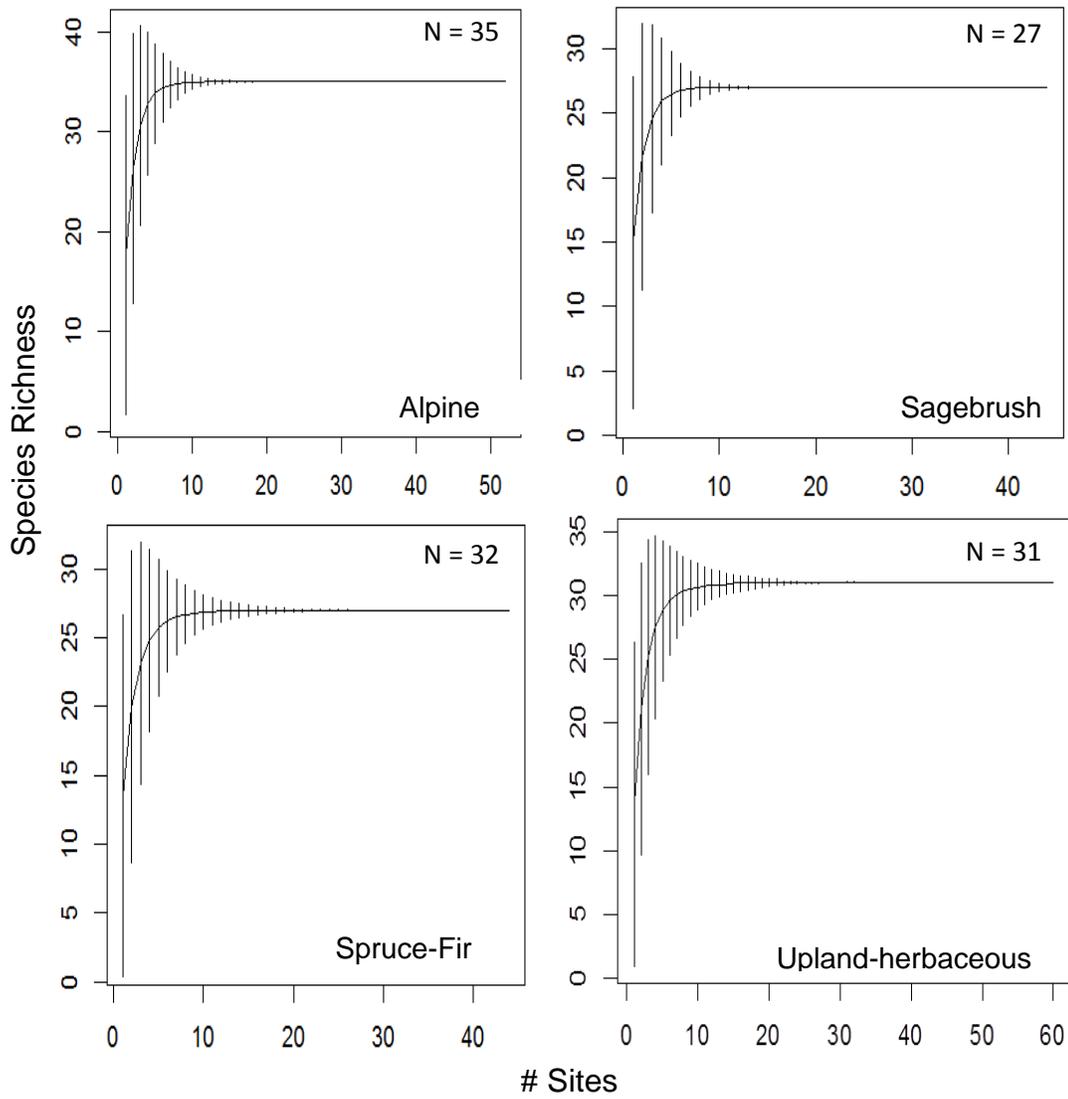


Figure A1. Species accumulation curves produced for four community types surveyed by Langenheim (1953,1962) in the upper East River drainage.

## CHAPTER 2

### ANALYSIS OF TEMPORAL CHANGE IN HIGH-ELEVATION PLANT COMMUNITY COMPOSITION, EAST RIVER BASIN, COLORADO, USA

#### **ABSTRACT**

The sensitivity of species in mountain systems to disturbance from anthropogenic sources like climate change is well-documented. However, less research has been focused on the effect of these forces on change in plant community composition in high-elevation landscapes. As a baseline for detection we obtained unpublished transect data acquired from 1948-1951 in the East River Basin near Crested Butte, Colorado, USA. We revisited 122 of those sites within four community types (sagebrush, spruce-fir, upland-herbaceous, and alpine), ranging from 2,600 to 4,100 m in elevation. Satellite imagery, original notes, historical maps, and data from voucher specimens from the original survey were used to relocate sites and derive environmental data: e.g., substrate; slope; aspect; and elevation. Changes in plant communities were quantified using univariate abundance and diversity indices and multivariate analyses. Non-metric multidimensional scaling (NMDS) ordination and permutational multivariate analysis of variance (PERMANOVA) indicated that the four communities were more compositionally distinct within the original survey than at present. All communities have experienced increased heterogeneity over time, as well as increased species richness. Significantly increased proportions of graminoids, shrubs, and bare area occurred in most communities along with decreased proportions of forbs in all communities. The alpine community was the only type to demonstrate near complete species turnover of its 15 most abundant species.

The dominant species in this community are now composed of grasses instead of herbaceous forbs.

## **Introduction**

Global climate change is projected to have pronounced effects on plant communities through alterations of habitat stability (Germino et al., 2014), biodiversity (Thomas et al., 2004; Stöckli et al., 2012), and the genetic structure of populations (Chen et al., 2011). The unique nature of high-elevation plant communities makes them natural litmus tests for these impacts (Grabherr et al., 2000; Pauli et al., 2003; Walther et al., 2005). This is largely because the insular limits of their distributions are likely to be dramatically altered by climate change (Doxford and Freckleton, 2012).

Climate induced effects, particularly important to alpine ecosystems, include increased length and advanced start of the growing season (Inouye and Mcguire, 1991; Anderson et al., 2012), higher soil temperatures (Harte et al., 1995), species range shifts (Pauli et al., 1996; Schob and Choler, 2007), decreased resistance of native flora to invasive species (Hellmann et al., 2008), and loss of phenological synchrony with pollinators (Theurillat and Guisan, 2001; Harris, 2008; McKinney et al., 2012). The U.S. Global Change Research Program (USGCRP) predicts an average increase of annual temperature within the USA of 6°C by 2100 (USGCRP, 2009). In concert, the National Research Council (NRC) reports that snowpack is expected to decrease by 15% by 2100 in the northern hemisphere (NRC, 2011). More detailed research is needed, as the effects of climate change may vary dramatically across plant communities and individual species (Inouye and Mcguire, 1991; Anderson et al., 2012; Stöckli et al., 2012; Wipf et al., 2013).

Our understanding of the complex patterns of change in plant communities across spatial and temporal scales is hampered by the paucity of baseline historical data of sufficient accuracy and resolution (Korner, 2003). Data is even scarcer for herbaceous montane plant communities in the USA, as most long-term research has been conducted in Europe (Pauli et al., 1996; Grabherr et al., 2001; Dirnbock et al., 2003; Pauli et al., 2003; Gottfried et al., 2012). Recent studies, however, demonstrate the ability of contemporary scientists to revisit and expand on historical ecological data (Bahre & Shelton, 1993; Grabherr et al., 2001; Rooney et al., 2004; Wipf et al., 2013; Sproull et al., 2015).

One of the best documented plant community datasets in the USA was started by Curtis (1959) and spans several regional plant communities in Wisconsin. The archival data of Curtis (1959) provided the basis for studies such as Rooney et al. (2004) that described the increase in non-native and fast-growing species within upland-forests as a possible consequence of climate change. Another study originating from Curtis, suggested that floodplain forests near the upland forests described in Rooney et al. (2004) are also increasing in species richness, but conversely to the aforementioned study, are increasing in homogeneity (Johnson et al., 2013). Thus, reliable historical data is essential for accurately depicting and measuring variation across multiple scales over time (Tingley & Beissinger, 2009; Stöckli et al., 2012).

An example of the use of historical data in montane research is a recent study by Sproull et al. (2015), in Boulder Co., CO, USA. These researchers revisited sites, permanently marked since the 1960s, in four plant communities that ranged from lower montane to alpine in order to measure changes in community composition and diversity.

With their long-term monitoring, Sproull et al. (2015) were able to compare changes in plant community structure over a span of 17 and 32 years. Their analysis shows the upward expansion of eight plant species, as well as an increase of species richness throughout all communities along an elevation gradient. The results of Sproull et al. (2015) are similar to the results of Wipf et al. (2013) in the European Alps that correlate temperature increase to increasing and accelerating rate of species richness on the summit flora of the Piz Linard over an area sampled since the mid-1800s. Similarly, Grabherr et al. (2001) have detected the upward movement of plant species from data compiled from flora studies spanning approximately 200 years in the Alps.

The high-elevation herbaceous plant communities in our study area, the upper East River drainage of the Gunnison National Forest near Crested Butte, Colorado, USA (Langenheim, 1962, Figure 1), may likewise be sensitive to an increasingly warmer and unstable climate (Aldridge, 2011; Anderson et al., 2012; Rudgers et al., 2014; Sproull et al., 2015). Despite growing research focused on plant responses to climate change (Harte et al., 1995; Price and Waser, 1998; Nenami et al., 2003; Von Holle and Delcourt, 2003; Doxford and Freckleton, 2012; Reyer et al., 2013), site specific data for high-elevation regions in North America is relatively rare (Tingley & Beissinger, 2009; Stöckli et al., 2012). In this study, a detailed 65-year-old dataset was used as a baseline for consideration of changes in plant community composition and diversity in relation to environmental conditions over time. A more detailed description of the work of Langenheim (1962) can be found in Ch. 1. For simplification, the survey performed by Langenheim (1962) is referred to as the original survey, and this survey is referred to as the new survey.

We hypothesized that characteristics of the *a priori* community types of Langenheim (1962), including plant species diversity, community composition, and abundance will be altered since the original study. Further, we predict the greatest change will be measured within community types at the highest elevations surveyed where sensitivity to disturbance is greatest (Price & Waser, 1998; Harris, 2008; Chen et al., 2011). We expect that heterogeneity will increase throughout all communities, but will be most pronounced in the sagebrush and alpine communities where there are more plants adapted to specific environments. Conversely, the spruce-fir habitat should have the least significant change over time as the forest overstory provides a climate-mediating effect across elevations.

## **Methods**

### *Area of Study*

The East River Basin is located in Gunnison County near the town of Crested Butte, Colorado, USA (38.8697° N, 106.9878° W; elevation 2400 m). The original study by Langenheim (1962) was performed over an area approximately 249 km<sup>2</sup> on the east side of the upper East River drainage (Figure 1). Refer to Chapter 1 for detailed information about the study area and the plant communities identified by Langenheim (1962).

### *Field Methods*

The plant community survey methods in this study were designed to be comparable to field methods performed from 1948 to 1952 by Langenheim (1962). Detailed transect data for four community type were available from Langenheim's Ph.D. thesis (1953) that were not included in Langenheim's published work (1962). These four community types are: *Artemisia* (sagebrush), *Picea-Abies* (spruce-fir), upland-herbaceous (often termed sub-alpine meadow), and alpine. The aspen community also described in Langenheim (1962) was excluded from our field survey due to a lack of sufficient data for relocating Langenheim's original sites.

Some of the original sampling methods were updated in the recent survey to reflect current practices. In the original survey, Langenheim collected data with the "step-point method" (Levy and Madden, 1933) where approximately 300 feet were "paced" or walked in a straight line. All plants touching a mark at the toe of her boot were recorded at every paced approximately 1-meter increment. In our study a 100 m fiberglass tape was used. Four transects of 75 m were laid from a site center point identified from ArcGIS because this increased the likelihood of resampling the same areas of Langenheim (1962). Two transects were laid along the contour, and two transects were laid uphill and downhill. Locations for quadrats within the spruce-fir community of original study were also unspecified, although it was noted in the manuscript and personal correspondence that at every site a 10x10 m quadrat was placed alongside the transect (Langenheim, 1962). We also surveyed quadrats at each spruce-fir site with the modification of randomly generating a point to begin the quadrat along one transect in a site. All trees (>3 m, >4cm diameter), saplings (>1m, <4cm diameter), and seedlings (<1 m) within each

quadrat were recorded. The distribution of site aspects revealed a sampling bias against north-facing slopes, with east-facing slopes being the most well-represented, followed by west-facing and south-facing slopes. Most sites were above 9,500 ft., positively skewing the distribution of sampled elevations, and located primarily on either steeper slopes from 20-30° or relatively flat areas.

### *Site Relocation*

No explicit coordinates were included in the draft or published manuscript of the original study (Langenheim, 1953, 1962). The approximate location for sites were largely determined from additional information included in the archived draft, personal correspondence with Dr. Jean Langenheim and Dr. Ralph Langenheim, and from plant voucher specimens. The CU-Boulder Herbarium ([cumuseum.colorado.edu/research/botany/databases](http://cumuseum.colorado.edu/research/botany/databases)) and the Southwest Environmental Information Network (SEINet, [swbiodiversity.org/portal/index.php](http://swbiodiversity.org/portal/index.php)) were the herbarium databases used to access Langenheim's digitized voucher specimen information. The voucher specimen information often contained more detailed locality data, including more detailed descriptions of habitat.

### *GIS*

ArcGIS 10.2 (ESRI, 2015) was used to map and analyze sites in the four communities. Orthoimagery from Bing© provided a 10-30m resolution basemap for the study sites. Several steps were employed to further increase the likelihood of resampling Langenheim's original sites and remove bias from choosing site centerpoints. Sites in the original study were determined to often appear in clusters. Clusters frequently contained sites within one type of community. Using the general locations of sites as a guide,

polygons were digitized that contained the general habitat of each community. A number of random points equal to the number of sites that would have likely appeared within the polygon were generated in each polygon. Fifty meter buffers were also included for each of the randomly generated points because this was a sufficient size to ensure that the random points would not overlap. All of the sites (125 total) in four plant communities from the original survey (sagebrush: 27; Spruce-Fir: 32; upland-herbaceous: 31; alpine: 35) were relocated and mapped (Figure 1). A 1/3<sup>rd</sup> arc second (10m resolution) National Elevation Dataset (NED) from the USGS ([earthexplorer.usgs.gov/](http://earthexplorer.usgs.gov/)) provided the basis for calculating elevation, slope, and aspect for each site. Another feature class layer from the USGS site containing general geologic substrate data was used to further classify sites.

#### *Data Preparation*

The original manuscript denoted species present but occurring at low frequency (<1%) within a site as “x” (Langenheim, 1953). To make the data suitable for analyses we replaced these values with frequencies of 0.5%. This lowered the re-estimation of relative abundance a negligible amount (~ 0.02% per community). Species names from the original survey were updated using Weber and Wittmann (2012) and the USDA PLANTS Database ([plants.usda.gov](http://plants.usda.gov)). The original plant count data (100 points per site) was summed for each species in each site. The relative abundance of each species in a community was calculated as the total number of individuals of a species divided by the total number of sampled points within a community (Langenheim, 1953, 1962).

For comparison, and to retain consistent sample size, a matrix containing the original data was updated to include columns for species not detected at that time. Similarly, a site by species matrix was compiled for the new data that included columns for species detected

in the original study, but not in the resurvey. From the original study data, it was empirically deduced that counts of each species in each community were reported as the number of individuals divided by the transect length multiplied by 100 (300 ft; Langenheim, 1953). The species counts in the new survey data (300 points/site) were divided by 3 to make them directly comparable in the matrix to the original data. To reduce artificial inflation of species richness in the new survey data, species mainly grouped by genera in the original study were also consolidated in the resurvey matrix. The original study also focused analysis on species occurring above approximately ~14% constancy (the percentage of sites within a community in which a species occurred). Constancy was determined empirically from the lowest constancy reported in the original study data (Langenheim, 1953). For comparability, data from the new survey was updated to also reflect the same constancy limit, but the full dataset will be made available for future comparative studies. Most plants in the original study were identified to species, but only to genus for species with a high degree of uncertainty including some grasses, sedges, and the genus *Vaccinium* (Langenheim, 1953). Plants detected in the new study were largely identified to the species level, but the frequency of non-flowering individuals at times confounded precise identification.

#### *Diversity and Distribution Statistics*

Beta diversity between paired sites of the two survey periods was measured using average Bray-Curtis dissimilarity (Bray and Curtis, 1957). The Shannon-Weiner index was used to measure  $\alpha$ -diversity within habitats (cf. Aho et al., 2008). As an information statistic index, the Shannon-Weiner assumes all species are represented, and is relatively

sensitive to the occurrence of rare species (Magurran, 2004). Paired *t*-tests (paired sites in the original and new surveys) were used to test for differences in richness,  $\beta$ -diversity,  $\alpha$ -diversity, and abundance of average proportion of predominant growth forms (forb, shrub, graminoid) and bare area between study periods. Growth form data were generated by first assigning a growth form class (forb, graminoid, shrub, or bare) to each species. The summed abundance of all of one type of growth form was divided by the total abundance in each site as the response variable. We tested the null hypothesis that the true mean relative abundance was identical for the two surveys for each functional group. *P*-values were adjusted via the Holm's procedure to adjust for family-wise (community in this case) Type I error (Holm, 1979). Size classes, and the number of seedling and saplings for *Picea engelmannii*, *Abies lasiocarpa*, and *Pinus contorta* within forest quadrats were compiled for comparison with a summary table provided in Langenheim (1962).

### *Ordination*

Metric Multidimensional Scaling (i.e., Principal Coordinates Analysis; PCoA) and Non-Metric Multidimensional Scaling (NMDS) ordination were used for indirect gradient analysis (Jongman et al., 1995; Legendre and Legendre, 1998). Configuration results from PCoA and NMDS were compared using Procrustes analysis (Legendre and Legendre, 2012) to verify that similar multivariate interpretations could be generated from distinct methods (Aho et al, 2008). Environmental variables (elevation; slope; aspect; and geologic substrate) were overlaid on the species space of each ordination, and tested for significance using vector fitting (Oksanen et al., 2013). Ordination

configurations from both the original survey and new survey were computationally rotated to the environmental data to facilitate visual comparisons.

Bray-Curtis dissimilarity (Bray and Curtis, 1957) was used as the underlying resemblance metric in both PCoA and NMDS due to its propensity to effectively represent dissimilarity structures in zero-inflated datasets (Aho et al., 2008). Ordinations of the entire original Langenheim and resurvey dataset were performed separately, followed by community-specific comparisons over time.

#### *Multivariate Hypothesis Testing*

Repeated measures PERMANOVA (a permutational analogue of MANOVA; Anderson, 2005) was used to determine whether the communities outlined by Langenheim in the original and new survey were distinct in multivariate species space, and to test for effects of time. The value  $\alpha = 0.05$  was used as the significance level for all significance tests.

#### *Software*

The statistical software package R was used for all analyses (R Core Team, 2015). In particular, we relied heavily on the package *vegan* (Oksanen et al., 2013) for ordination, PERMANOVA, and other community level analyses.

## **Results**

### *Changes in Community Composition*

A total of 295 species from 45 families were documented from the 122 sites within the four community types surveyed. A reduced dataset of 121 species from 35 families was used for comparative statistical analyses. This group was comprised of species satisfying the 14% constancy cut-off used in the original survey. The most

dominant families include Asteraceae and Poaceae (Appendix A). Representative species increased in number over time for most families, notably within Brassicaceae, Liliaceae, and Polygonaceae. Species were found within a number of families that were not represented in the original study, including Juncaceae, Portulacaceae, and Violaceae (Appendix A).

Changes in richness, diversity, and dominant species assemblages occurred in all community types between the original survey and the new survey (Table 1, Table 2, Table 3a,b). Two sites (spruce-fir site 24, alpine site 1) were not successfully resampled due to snow cover and dangerous weather. One other site (alpine site 35) was not included in the final comparative analysis because it did not contain any species occurring at or greater than the 14% constancy cut-off (Table 1).

Compared to the much higher species richness in the new survey, Shannon-Weiner values of  $\alpha$ -diversity changed only marginally and increases were not consistent across community types (Table 1, Table 2). Shannon-Weiner values increased in the sagebrush and upland-herbaceous communities (sagebrush: 2.30 to 2.42, upland-herbaceous: 2.68 to 3.07) but decreased in the spruce-fir and alpine communities (spruce-fir: 2.21 to 2.17, alpine: 2.62 to 2.04; Table 1). Increases in total richness were significant in all four community types (Table 1, Table 2), although the spruce-fir community was only marginally significant ( $t_{(30)} = -1.769, p = 0.0435$ ). There was an overall increase in total species richness of 42, 22, 32, and 8 species in the sagebrush, spruce-fir, upland-herbaceous, and alpine communities between the original and new survey, respectively (Table 1). The communities at the highest elevations, upland-herbaceous and alpine, demonstrated the greatest differences in diversity across survey periods (Table 2).

Shannon-Weiner diversity ( $t_{(30)} = 5.519$ ,  $p = 3.01 \times 10^{-6}$ ) and richness ( $t_{(30)} = -9.482$ ,  $p = 1.09 \times 10^{-10}$ ) significantly increased the upland-herbaceous community (Table 1, Table 2). The alpine community also increased in species richness from 51 to 65 ( $t_{(32)} = 4.106$ ,  $p = 1.30 \times 10^{-4}$ ), but significantly decreased in Shannon-Weiner diversity ( $t_{(30)} = -7.346$ ,  $p = 4.18 \times 10^{-6}$ ; Table 2).

Bray-Curtis values increased markedly between survey periods, indicating that increased community heterogeneity has occurred (Table 1). In the sagebrush community, formerly the most compositionally homogenous of the four communities, beta-diversity increased from 0.358 to 0.708. In the spruce-fir community, beta increased from 0.408 in the original survey to 0.562 in the new survey. The upland-herbaceous community had the highest Bray-Curtis value in the original (0.495) and new survey (0.716).

Heterogeneity among sites in the alpine community increased from the original (0.413) to the new survey (0.514; Table 1).

Table 3a and 3b show the 15 most abundant species in the original and new survey for each of the four community types. All of the most abundant species in the four communities have decreased in relative abundance and constancy over time, but varied in species turnover of the most dominant species. The sagebrush community retained nine of the most abundant species found in the original survey. New species include *Artemisia frigida* Willd., *Artemisia dracuncululus* L., *Elymus scribneri* (Vasey) M.E. Jones, *Koeleria macrantha* (Ledeb.) Schult., *Castilleja linariaefolia* Benth., and *Festuca idahoensis* Elmer (Table 3a.) The spruce-fir community retained the highest number of the historically most abundant species (10) and now additionally includes the unidentified *Carex* spp., *Geranium richardsonii* Fisch. & Trautv., *Ligusticum porteri* J.M. Coult. &

Rose, *Epilobium angustifolium* L., and *Lathyrus lanszwertii* var. *leucanthus* (Rydb.) Dorn among the most abundant species (Table 3a). The upland-herbaceous community retained only eight dominant species between survey periods. New abundant species are *Bromelica spectabilis* (Scribn.) W.A. Weber, *Fragaria virginiana* Duchesne, *Salix drummondiana* Barratt ex Hook, *Bromopsis ciliata* (L.) Holub, *Potentilla quinquefolia* (Rydb.) Rydb., *Mertensia ciliata* (James ex Torr.) G. Don, and *Bromus inermis* Leyss. (Table 3b). The alpine community retained only five dominant species, the least among survey periods of the four community types. Species that remain are *Geum rossii* (R. Br.) Ser. var. *turbinatum* (Rydb.) C.L. Hitchc., *Silene acaulis* (L.) Jacq., *Potentilla* spp., *Oxytropis deflexa* (Pall.) DC. var. *sericea* Torr. & A. Gray, *Dryas octopetala* L., and *Oxytropis podocarpa* A. Gray (Table 3b).

The communities identified by Langenheim in the original survey were compositionally distinct from each other as indicated by PERMANOVA; both in the original and new survey (original study:  $F_{(3,120)} = 49.30$ ,  $R^2 = 0.558$ ,  $p = 0.001$ ; new study:  $F_{(3,120)} = 20.50$ ,  $R^2 = 0.346$ ,  $p = 0.001$ ). Community composition also differed significantly between sampling periods for the sagebrush ( $F_{(1,53)} = 10.74$ ,  $R^2 = 0.168$ ,  $p = 0.001$ ), spruce-fir ( $F_{(1,61)} = 11.13$ ,  $R^2 = 0.154$ ,  $p = 0.001$ ), upland-herbaceous ( $F_{(1,59)} = 21.76$ ,  $R^2 = 0.268$ ,  $p = 0.001$ ), and alpine ( $F_{(1,65)} = 33.53$ ,  $R^2 = 0.333$ ,  $p = 0.001$ ) communities.

### *Growth Forms*

There were significant changes between sampling periods in the proportional abundance of the most common growth forms in most communities (Figure 5). In the sagebrush community, forbs ( $t_{(26)} = -0.17$ ,  $p = 0.864$ ) and bare area ( $t_{(26)} = -1.99$ ,  $p = 0.055$ )

were not significantly different, shrubs decreased ( $t_{(26)} = 6.56, p = 5.97 \times 10^{-7}$ ), and graminoids increased ( $t_{(26)} = -4.78, p = 6.01 \times 10^{-5}$ ; Figure 5). Forbs significantly decreased in the spruce-fir community ( $t_{(30)} = 3.32, p = 2.40 \times 10^{-3}$ ), shrubs ( $t_{(30)} = -6.23, p = 7.44 \times 10^{-7}$ ) and bare area ( $t_{(30)} = -5.99, p = 1.42 \times 10^{-6}$ ) increased, but graminoids were not significantly different ( $t_{(30)} = 3.19, p = .639$ ). In the upland-herbaceous community, shrubs ( $t_{(29)} = -5.04, p = 2.25 \times 10^{-5}$ ), graminoids ( $t_{(29)} = -3.51, p = 1.50 \times 10^{-3}$ ) and bare area ( $t_{(29)} = -4.64, p = 6.88 \times 10^{-5}$ ), increased, while forbs decreased ( $t_{(29)} = 8.72, p = 1.34 \times 10^{-9}$ ). In the alpine community, shrubs ( $t_{(32)} = -4.45, p = 9.77 \times 10^{-5}$ ) and bare area ( $t_{(32)} = -9.78, p = 3.91 \times 10^{-11}$ ) increased, but graminoids did not change significantly ( $t_{(32)} = 1.65, p = 0.291$ ). Forbs in the alpine community have decreased ( $t_{(32)} = 12.05, p = 1.95 \times 10^{-13}$ ; Figure 5).

### *Species Shifts*

A table was created that shows the presence or absence of the 121 species in each of the four communities of the original and new survey (Appendix A). A total of 82 species from 27 families are found in new communities. Forty of these species (47%) were found at higher elevation communities than in the original study. The next largest proportion (37%) was comprised of 32 species that moved to a community at lower elevation. Eight species (9%) expanded upward and downward. Only six species (7%), all within the Scrophulariaceae family, that were present in the original study contracted their ranges from multiple communities to single communities (Appendix A).

### *Tree Species Comparison*

The distribution of tree size classes and species have remained similar across survey periods (Table 4), although comparison is difficult with the summarized data from

the original survey (Langenheim, 1962). Trees in the largest size classes are *Picea engelmannii* Parry ex Engelm. in both surveys, while *Abies lasiocarpa* (Hook.) Nutt. continues to have the highest average density of seedlings. *Pinus contorta*, occurred sporadically in the study area, and appeared at low average density. *P. contorta* within both the original study and the new study did not appear in the largest size classes, and no seedlings or saplings were detected; however the data cannot be reliably compared beyond that (Table 4). *P. contorta* values could be inflated because Langenheim may have only used stands containing *P. contorta* to calculate average density.

### *Ordination*

The results of NMDS and PCoA ordinations, for the original and new study, were checked for concordance with Procrustes analysis (Williams & Langron, 1984). The analysis revealed that the NMDS and PCoA solutions were highly similar (original study:  $r = 0.89$ ,  $p = < 0.001$ ; new survey:  $r = 0.69$ ,  $p = < 0.001$ , based upon 1000 permutations), indicating that the spread of sites within the ordinations was not an artifact of methodology. Given the similarity of the projections, we only present NMDS results here.

Three dimensional NMDS projections were obtained from 100 random starting configurations with a stress value under 0.14, allowing confident inferences concerning the true community relationships among sites and across survey efforts (Cox & Cox, 2001). A projection of dimensions 1 and 2 for the original and new survey is presented in Figure 2 and a projection of dimensions 1 and 3 is shown in in Figure 3. Ninety-five percent confidence ellipses for the true multivariate centroids of the four *a priori* community types of Langenheim are overlaid on Figure 2, along with results from vector

and factor fitting analyses (Oksanen et al., 2013). Vector fitting results are also included in Figure 3 with confidence ellipses. Time series ordinations for each of the four community types were projected onto two dimensional NMDS solutions, and overlaid with directional arrows connecting sites of the original study to the same sites in the resurvey (Figure 4). Proportions of the three growth forms (forb, graminoid, and shrub) and bare area were overlaid on Figure 4 based on vector fitting analyses (Oksanen et al., 2013).

The ordination of the original survey revealed communities well-separated in species space. It is probable that this result is largely due to the sampling technique of Langenheim (1962), as she may have chosen sites to sample to be representative of an *a priori* community type. Sites in the relatively homogenous (in species composition) sagebrush and alpine community types were tightly clustered, resulting in a small confidence ellipse in dimensions 1 and 2. Sites in the spruce-fir and upland-herbaceous communities were relatively dispersed in loose clouds along the first dimension corresponding to change in community composition over an elevation gradient as ordinations were rotated so that the first dimension paralleled elevation (Figure 2 and 3). In the new survey, all communities are more heterogeneous, with a wider dispersion in species space than in the original survey. There is also more overlap among community types, with sites from different *a priori* community types interspersed in species space. Communities from the resurvey are not as well-defined in the ordination diagram (Figure 2 and 3). The spruce-fir community is relatively heterogeneous and, like the alpine community, is also largely spread along the first (elevation-correlated) dimension. The sagebrush community in the new survey ordination is relatively heterogeneous, with

some sites resembling spruce-fir, upland-herbaceous, and even alpine sites. The upland-herbaceous community contained more sites within its 95% confidence ellipse than sagebrush. This community also had sites that overlapped with all other communities. Many sites appeared similar to the spruce-fir and alpine communities in particular (Figure 2).

Sites within communities of the original survey displayed in dimensions 1 and 3 are somewhat less distinct, although communities remain distinguishable (Figure 3). The original survey, however, is more distinct than the new survey (Figure 3). In the new survey, the centroids of the upland-herbaceous and spruce-fir communities overlap, but the alpine community is more distinct than in dimension 1 and 2 (Figure 2 and 3). Some sagebrush community sites comingle with sites in the spruce-fir community in dimensions 1 and 3 (Figure 3).

The correlation of each environmental variable to the spread of communities within the ordinations was analyzed through multiple regression (Table 7, Figure 2). For the elevation, slope, and aspect factors, the strength of the correlation is represented by the length of the arrows in the ordination diagrams (Figure 2). Arrowheads indicate the direction of the most rapid change for a given environmental variable (Figure 2). In the ordination diagram the alpine community at the highest elevations appears near the elevation arrowhead, while the sagebrush, the lowest elevation community corresponds to the tail of the elevation vector (Figure 2). Increasing slope is generally found with increasing elevation. The sagebrush and spruce-fir community sites were often found on west-facing aspects (Figure 2). Not surprisingly, the community types of Langenheim, when used as factors in the multiple regression analysis, had the highest correlation to the

ordination configuration for the original dataset, as these types drove Langenheim's sampling efforts ( $R^2 = 0.883$ ,  $p$ -value = 0.001). The USGS GIS substrate feature data was weakly correlated to the ordinations of both the original data ( $R^2 = 0.207$ ,  $p$ -value = 0.001) and the new survey ( $R^2 = 0.171$ ,  $p$ -value = 0.001). Conversely, elevation was relatively strongly correlated with ordination scores in both the original ( $R^2 = 0.721$ ,  $p$ -value = 0.001) and new survey ( $R^2 = 0.545$ ,  $p$ -value = 0.001). Slope and aspect had the poorest correlations to ordination configurations among the quantitative environmental factors under consideration. Slope and aspect had higher correlations to the original survey ( $R^2 = 0.339$ ,  $p$ -value = 0.001;  $R^2 = 0.261$ ,  $p$ -value = 0.001, respectively), than to the new survey ( $R^2 = 0.207$ ,  $p$ -value = 0.002;  $R^2 = 0.197$ ,  $p$ -value = 0.001). While the lengths of the vector arrows are similar for the original and new survey, communities in the new survey are not as distinct along environmental variables (Figure 2).

The 2-D NMDS community-level ordinations comparing the two surveys revealed movement of sites along both dimensions (Figure 4). The distribution (similarity) of sites in species space became more divergent diagonally along both dimensions in the sagebrush community with points moving from a tight cluster to a dispersed pattern. The spruce-fir community was highly variable in the trajectory of sites. Some sites within the spruce-fir community moved parallel to the first dimension, while most primarily shifted along the second dimension. The upland-herbaceous community became more dispersed over time along the first and second dimensions. Sites in the alpine community became more dispersed along the second dimension, but more clustered along the first dimension (Figure 4).

Proportions of the three growth forms (forb, graminoid, and shrub) and bare area were overlaid on intra-community ordinations from vector fitting analyses (Figure 4 and 5). These correlations often correspond to the direction in which the sites moved in species space in the intra-community ordinations over time (Figure 4). The direction of site shifts is the same as the growth form vector (positive association) or opposite direction (negative association). The configuration of the sagebrush community was highly associated with graminoids ( $R^2 = 0.727$ ,  $p$ -value= 0.001), bare area ( $R^2 = .658$ ,  $p$ -value= 0.001), and forbs ( $R^2 = 0.246$ ,  $p$ -value= 0.002), but was poorly associated with shrubs ( $R^2 = 0.370$ ,  $p$ -value= 0.109). Forbs ( $R^2 = 0.643$ ,  $p$ -value= 0.001), bare area ( $R^2 = 0.631$ ,  $p$ -value= 0.001), shrubs ( $R^2 = 0.268$ ,  $p$ -value= 0.001), and graminoids ( $R^2 = 0.179$ ,  $p$ -value= 0.002) were significantly correlated with the spread of points in the spruce-fir community (Figure 4). The upland-herbaceous community was most highly associated with forbs ( $R^2 = 0.645$ ,  $p$ -value= 0.001; Figure 4), followed by bare area ( $R^2 = 0.484$ ,  $p$ -value= 0.001), shrubs ( $R^2 = 0.355$ ,  $p$ -value= 0.001), and graminoids ( $R^2 = 0.288$ ,  $p$ -value= 0.003; Figure 4). The configuration of alpine sites in the ordination was most associated with bare area ( $R^2 = 0.798$ ,  $p$ -value= 0.001) and forbs ( $R^2 = 0.728$ ,  $p$ -value= 0.001), and to a lesser extent, shrubs ( $R^2 = 0.378$ ,  $p$ -value= 0.001), and graminoids ( $R^2 = 0.360$ ,  $p$ -value= 0.001; Figure 4).

## **Discussion**

In this comparative study, we investigated change in patterns of species richness, diversity, and relative abundances in four high-elevation plant communities defined by Langenheim (1962) between 1950 and the present. Significant alterations in species composition have occurred in all four community types defined by Langenheim over 70

years (Table 1 and 2), although only two communities had significant changes in  $\alpha$ -diversity. The Shannon-Weiner value in the upland-herbaceous community increased, whereas the alpine community's decreased (Table 1). Beta-diversity has increased significantly within all four communities, particularly within the historically homogenous sagebrush community (Table 1). Increasing community heterogeneity is largely driving the spread in of sites within the ordinations and is indicative of the fluctuation of the composition and abundance of dominant species and proportions of major growth forms (Table 2, Figures 2, 3, and 5). Dropping many infrequently observed species from the new survey data to match the original study for comparability may have had the effect of artificially deflating species richness as up to 50% of species were culled from the analysis due to low constancy.

Patterns of change identified here, e.g. increased species richness, shifts of dominant species within communities, range expansion of species, and increase of grasses and shrubs may be indicative of the effects of climate change along an elevation gradient (Peter et al., 2007; Van de Ven et al., 2007; Rudger et al., 2014; Sproull et al., 2015). While not as significant, changes in lower elevation sites, namely within the sagebrush community, share the same patterns of increases in abundance and diversity (Table 1; Marvier et al., 2004; Kelly & Goulden, 2008; Stohlgren et al., 2013). Although we did not directly consider environmental variables related to climate, alterations within the four high-elevation communities are generally consistent with a large number of other studies that have found warmer temperatures and less precipitation are strong drivers of change within plant communities (Harper et al., 1981; Price and Waser, 1998; Theurillat & Guisan, 2001; Grabherr et al., 2012). That the four communities were not equally

affected suggests that other factors affecting species diversity and abundance, such as microclimatic conditions, elevation, the effect of the forest overstory (on the spruce-fir community), and conditions particular to the sagebrush and alpine communities (cf. Price & Waser, 2000; Coop et al., 2014; Sproull et al., 2015).

### *Alterations in richness, relative abundance, and constancy*

Although  $\alpha$ -diversity has changed relatively little,  $\beta$ -diversity among sites increased markedly between survey periods (Table 1 and 2). Changes in diversity and abundance over time appear to correspond with both the addition of new species and changes in the most abundant and frequently occurring species within each community. Most of the abundant species that remain in all of the communities from the original study have become less constant and have lower relative abundances (Table 3a,b). Sites have become more heterogeneous in regard to species composition, and this is reflected in the greater spread of sites in the ordinations (Figure 2 and 4). There are less clear delineations of communities based on species composition of current sites (Table 2a,b, Figure 2 and 4). These changes suggest that these plant communities are generally experiencing range expansion of species, leading to increased species richness in high-elevation montane ecosystems (Keller et al., 2001; Pauli et al., 2003; Wipf et al., 2013; Sproull et al., 2015). Also evident is the competitive advantage of some plant growth forms, such as grasses, under climate change scenarios (Bahre & Shelton, 1993; Harte & Shaw, 1995; Bai et al., 2011; Rudgers et al., 2014). Considerable variation exists within and among (e.g. the sagebrush and spruce-fir) communities that do not correspond to the predicted trends of increasing change along an elevation gradient (Powell et al., 2000;

Price & Waser, 2000; Walther et al., 2005). Trends occurring within each of the four community types are addressed in the following community-specific summaries.

### *Sagebrush Community*

The  $\alpha$ -diversity of the sagebrush community has not changed significantly since the original study perhaps because the two most abundant species, *Artemisia tridentata* and *Festuca thurberi*, remained strongly dominant (Table 3a). However,  $\beta$ -diversity has greatly increased and permutational MANOVA indicated that the current community composition was significantly different from the original survey (Table 1). The species with the highest relative abundances were found at or near 100% constancy in the original survey (Table 3a). Heterogeneity among sites increased as both relative abundance and constancy for the most abundant species declined (Table 1, Table 3a). The rank order of the most abundant species also changed substantially between sampling periods, and is reflected in the significant PERMANOVA result (Table 3a). For instance, *Achillea millefolium* is now the third most abundant species, compared to fourteenth in the original study, and has the highest constancy at 59%. The most abundant species in both survey periods, *A. tridentata*, has decreased in relative abundance (32.52 to 16.48) and in constancy (100% to 53%; Table 3a). Similarly, the confidence centroid around the sagebrush community has widened considerably as sites are more widely dispersed in species space (Figure 2b). In the intra-community ordination, the growth form vectors reflect the effect of the increasing abundance of grasses like *Festuca thurberi*, *Elymus scribneri*, and *Koeleria macrantha* and decreasing abundance and constancy of dominant shrubs, such as *A. tridentata* and *Ericameria* spp. (Figure 4 and 5, Table 3a).

Along with being exposed to the effects of increased temperature and decreased precipitation, most of the sites within the sagebrush community experience at least some amount of grazing from livestock. Out of the 27 surveyed sites, four appear on intensely grazed private land and 23 occur on Forest Service or BLM land. Movement of livestock and anthropogenic land development within the lower elevations of the study area could have created disturbances that resulted in decreased abundance and frequency of the dominant *Artemisia tridentata*, and increased species richness as disturbed areas are colonized by increasing numbers of forbs such as *Achillea millefolium*, and relative abundance of grasses like *Festuca thurberi* and *Koeleria macrantha*. We note that sagebrush ecosystems are among the most heavily impacted by livestock and development in North America (Lambrecht et al., 2007; Davies et al., 2011; Rivera et al., 2011; Germino et al., 2014).

Some studies have predicted an increase in seedling germination and expansion of *A. tridentata* (Harte et al., 1995; Germino et al., 2014), but this expansion may be hampered by increased mortality of seedlings when exposed to freezing temperatures and decreased spring snowpack (Lambrecht et al., 2007; NRC, 2011; Germino et al., 2014). While the most abundant species are unlikely to be replaced, sagebrush at the upper limits of their elevation range, as found within our study area, may be more sensitive to extreme weather and susceptible to invasion from species not formerly present, such as *Artemisia dracunculus*, or species present in the original survey that have increased in abundance, like *Eriogonum umbellatum* (Table 3a).

### *Spruce-fir Community*

While a permutational MANOVA indicated that the spruce-fir community was significantly different between survey periods, the community remained relatively stable over time with respect to species composition (Figure 2). Note that in Table 3a the species with the highest relative abundance from the original study remain the dominant species at present. The intra-community time series ordination (Figure 4) and growth form analyses (Figure 5) indicate that bare ground and shrubs have increased, and forb cover has decreased. A driver of shrub increase is the appearance of new shrub species occurring at low relative abundance, such as *Rosa woodsii* Lindl., and *Arctostaphylos uva-ursi* L. (Appendix A). Concurrently, there has been a slight increase in total relative abundance of shrubs, like *Vaccinium* spp., *Paxistima myrsinites*, and *Ribes montigenum*, among the most common species that were abundant in the original study. The proportion of shrubs, typically shade-tolerant, in the spruce-fir community in our survey significantly increased (Figure 5). This could be another factor influencing the retention of common species between surveys, as well as contributing to the comparatively smaller  $\beta$ -diversity than the other three communities (Table 1 and 3a). A recent study by Sproull et al. (2015) included forest understory sites that are similar to the spruce-fir community in our survey. Increased canopy coverage was correlated with a larger proportion of shade-tolerant species and decelerated increase of heterogeneity in the future (Sproull et al., 2015).

*Arnica cordifolia*, a common species limited to the spruce-fir community in the original survey, was the only one to increase in relative abundance (Table 3a). *Lupinus* spp., more common in open areas, was still common, but dramatically less abundant

(Table 3a). We note that the uniformity and size of the spruce-fir stands in the East River Basin may provide a buffer against rapid change in that community in the future.

No significant logging has occurred since before the time of Langenheim's study (1953). Thus, spruce-fir stands have continued to mature with understory vegetation largely following in suit. Langenheim reported that the spruce-fir community was the largest continuous habitat in the Upper Gunnison Basin (Langenheim, 1962). The spruce-fir community shares much of its elevation range with the upland-herbaceous community. In this study we made no distinction for ecotonal areas near forest edges. This could be one reason why this community has retained the highest number of dominant species (10) of all communities, but changed in the rank abundances of the most common species, and increased in total richness along with the other three communities (Table 3a.). No detailed data were available for forest quadrats from Langenheim (1953) but a size class comparison of tree species indicated that forest structure appears to be stable (Table 4). The increased abundance of species commonly found in subalpine meadows (the upland-herbaceous community), such as *Epilobium angustifolium*, and aspen understory, such as *Geranium richardsonii* and *Osmorhiza depauperata* appeared in sites near forest fringes and upper and lower elevation boundaries. This is illustrated in the amount of spruce-fir sites appearing within the upland-herbaceous community confidence ellipse in the community ordination (Figure 2b).

#### *Upland-herbaceous Community*

Only eight of 15 of the most abundant species from the original survey remained dominant in the new survey of the upland herb community (Table 3a,b). This result is in contrast to the sagebrush and spruce-fir communities that retained somewhat more of the

most abundant species between surveys (Table 3a,b). New dominants included *Salix drummondiana* and *Mertensia ciliata*. As with other communities, the most abundant species have generally decreased in relative abundance and community evenness has increased over time (Table 1, Table 3b). Lateral movement along the first dimension of the intra-community time series ordination parallels pairwise differences among sites, indicating that similar changes have occurred to sites collectively over time (Figure 4). These changes include decreased cover of forbs and increased cover of bare ground, shrubs and graminoid growth forms (Figure 5). For example, the species with the highest relative abundance in the new survey include five graminoids and one shrub species, compared to three graminoids and no shrubs in the original survey (Table 3b).

#### *Alpine Community*

The alpine community nearly underwent complete species turnover of its most abundant species (Table 3b). It was the only community to significantly decrease in Shannon-Weiner diversity (Table 1). *Oxytropis deflexa* var. *sericea* remains the species with the highest constancy in alpine sites but is half as abundant in the new survey (2.31% relative abundance) as the original (4.01% relative abundance; Table 3b). Because even frequently occurring species appear in relatively low abundance in comparison to other communities, this community may be more sensitive to environmental change, resulting in a loss of species diversity (Table 1 and 3b; Grabherr et al., 2001; Pauli et al., 2003; Wipf et al., 2013; Sproull et al., 2015). Increasing temperature and decreased precipitation have been shown to cause habitat fragmentation in high-elevation plant communities that could be driving changes in species composition and abundance of dominant species (Dirnbock et al., 2003; Van de Ven et al, 2007). The

intra-community time series ordination (Figure 4) and growth form analyses (Figure 5) demonstrate increases in bare ground and shrub cover, and decreases in forb cover. Despite these changes, the alpine community maintained relatively low  $\beta$ -diversity between surveys, showing that the highly specific environmental constraints in these areas drives consistency in community in species composition (Appendix A).

### ***Abundance of growth forms***

A consideration of changes in major growth forms (forbs, shrubs, and graminoids) is useful for characterizing the different communities because the likelihood of consistent identifications over time is much higher (Swetnam et al., 1999). The relative abundance of forbs decreased significantly over time in all but the upland-herbaceous community (Figure 5). Shrubs decreased substantially within the lowest elevation community (sagebrush) due to the lower relative abundance and constancy of the dominant shrub species, *Artemisia tridentata*, from the original survey (rel. abund.: 32.52%, const.: 100%) to the new survey (rel. abund.: 16.48%, const.: 53%; Table 3a, Figure 4 & 5). The significant increase of shrubs in the spruce-fir community and the movement of sites associated with increasing shrub abundance in the intra-community ordinations may indicate that this community is moving toward a more typical conifer understory assemblage dominated by shrubs and shade-tolerant vegetation, such as *Paxistima myrsinites* and *Arnica cordifolia* (Table 3a, Figure 4; Coop et al., 2014). In contrast to some studies (Powell, 2000; Dirnbock et al., 2003), willow species like *Salix drummondiana* in the upland-herbaceous community and *Salix arctica* in the alpine community have increased despite an increase in average annual temperature. This could in part be caused by natural patterns of succession or increased available habitat

(Kueppers & Harte, 2005; Bai et al., 2011) as forb species decrease in proportion within the spruce-fir, upland-herbaceous, and alpine communities (Figure 4 and 5). We note that Langenheim may not have included areas with large amounts of *Salix* as representative of the *a priori* upland-herbaceous community type. *Salix* may also have been present, but occurred below the assumed 14% constancy limit and this was not included in the dataset used in Langenheim (1953).

A potential driver of alterations in richness, diversity, and elevation range is the increased presence and abundance of graminoid species (Table 1, Figure 4 and 5). Increases in graminoid abundance could be caused by a wide range of anthropogenic activities in the sagebrush type (Davies et al., 2011; Rivera et al., 2011; Germino et al., 2014). Increases in graminoid abundance, however, are more apparent in upland-herbaceous community at higher elevations (Table 3b). Interestingly, the current two most abundant species, *Elymus trachycaulus* and *Elymus scribneri*, in the alpine community are grasses, but graminoid abundance did not significantly change and was not highly correlated with the alpine projection of sites within the intra-community ordination (Table 3b, Figure 4). This is likely due to the replacement of dominant graminoids that were present in similar abundance in the original survey, such as *Kobresia sibirica* (Turcz. ex Ledeb.) Boeck., *Trisetum spicatum* (L.) K. Richt, and *Festuca ovina* L. (Table 3b). Stress from climate change can cause the loss of typical slow-growing high altitude species and the colonization of fast-growing species in areas of newly available bare area (Hellmann. 2008; Venn et al., 2014). For instance, Paschke et al. (2000) demonstrated that *Elymus trachycaulus* was a superior native species for restoring disturbed habitats on shale type similar to those occurring in the study area. The

increase in bare area (11% to 28%) may also be an indication that this trend is occurring within our study area (Figure 4). Long-term studies within the study area predict increased graminoid dominance with annual temperature increase (Price & Waser, 1998; Rudgers et al., 2014). Other studies support the observation that C4 plants, like many graminoids, and shrubby species that have morphologies conducive to prevent water loss, such as secondary growth, will continue to increase in abundance as average annual temperatures increase (Van de Ven et al., 2007; Venn et al., 2014).

### ***Trends of change at high elevation***

Higher elevation sites (i.e. upland-herbaceous and alpine) within the study area showed the greatest compositional changes (Table 1 and 3b), but this may not necessarily indicate that these communities are changing faster than the lower spruce-fir and sagebrush communities. In mountain systems globally, distinct topographic, climatic, and other environmental factors such as precipitation and incident radiation, not directly addressed in this study, largely form the boundaries of plant communities (Figure 2; Peet, 1978; Pauli et al., 1996; Walther et al., 2005). Changes to regional temperatures will result in unavoidable changes in species composition with a high degree of variation in magnitude that may or may not be more pronounced at higher altitudes (Van de Ven, 2007; Trivedi et al., 2008; Doxford & Freckleton, 2012).

In our study, Langenheim's plant communities are still best distinguished by elevation among the measured environmental variables (Figure 2). The delineations, however, are less distinct in the new survey (Table 7, Figure 2). For example, in the new survey all communities are becoming more heterogeneous. This is evident in the ordinations as an increase in the spread of points and a widening of the confidence

ellipses for the true community centroids (Figure 2). Notably, communities at the extreme low and high elevation range of the study area, sagebrush and alpine, have moved closer together in species space (Figure 2). The highest elevation community types, particularly in the alpine, experienced the highest rate of species-turnover, suggesting that these sites are the most sensitive to environmental changes that have occurred over the last 65 years (Table 1, 3a,b; Grabherr et al. 1994; Pauli et al., 1996; Schob and Choler, 2007; Wipf et al., 2013).

### ***Range shifts of species***

Range shifts of certain species may explain alterations in species abundance and composition across communities. Many studies such as Wipf et al. (2013) and Walther et al. (2005) indicate that some species will undergo range expansion due in part to climate change, causing a net increase in species at the highest elevations, as was also observed in this study (Table 1). Among the 86 species that experienced range shifts, the largest proportion (47%, 40 spp.) were found in higher elevation community types than in the original study (Appendix A). In our study, the greatest increases in total species richness did not occur in the alpine community, but rather in the sagebrush community, the lowest elevation type within the study (Table 1). In comparison, 32 species (37%) which underwent range shift were found in lower elevation community types (Appendix A). However, the alpine community was the only type that experienced near complete replacement of the most abundant species (Table 3b). *Elymus trachycaulus*, for instance, originally occurred in several community types, but was not found at all within the alpine community in the original survey (Table 3a,b). In the new survey *E. trachycaulus* has decreased abundance in the sagebrush community, and was not redetected in the spruce-

fir community, suggesting that this species is now less abundant at lower elevations (Appendix A). *Agrostis scabra* occurred at low abundance in the upland-herbaceous community in the original survey. In the new survey, this species occurs in the alpine community as the 12<sup>th</sup> most abundant species, but was not redetected in the upland-herbaceous community (Table 3b; Appendix A).

Grasses were not the only growth form to undergo range shifts. For example, *Ligusticum porteri*, is an abundant forb species now frequently found in spruce-fir and the upland-herbaceous community (Table 3a,b). *L. porteri*'s upward expansion is reflected by its increased abundance in the upland-herbaceous community and new detection as the eleventh most abundant species in the new survey of the spruce-fir community (Appendix A). Further, *L. porteri* was also found in the sagebrush community (Appendix A). We speculate that if aspen stands are expanding within the study area then common understory species like *L. porteri* may be increasing in tandem (Powell, 2000; Landhäusser, 2010; Coop et al., 2014). *Fragaria virginiana* is another example of range expansion of dominant species across elevation. In the original study *F. virginiana* in the spruce-fir and upland-herbaceous, but was not a dominant species in either. Now *F. virginiana* is the third most abundant species in the upland-herbaceous communities and also occurs in the sagebrush and alpine communities (Appendix A).

Shrub species in general did not experience range shifts to the same degree as forbs or graminoids, and were often found in lower elevation communities than previously. *Symphoricarpos* spp., was previously found in the sagebrush and spruce-fir community, but was only redetected in the spruce-fir community (Appendix A). *Ribes montigenum* was a new appearance in the sagebrush community and maintained

membership in the spruce-fir community (Appendix A). The partial exception to this trend appears within the alpine community where the increase in the proportion of shrubs is largely caused by the greater relative abundance of *Salix arctica*, a species also occurring in the original survey (Table 3b). The movement of species like these confounds identification of trends described by Van de Ven et al. (2007) and Trivedi et al. (2008) that predict the expansion of shrub species via wind-dispersal of seeds to higher elevation.

### ***Challenges***

Adapting historical data for use in comparative studies presents several challenges. Along with sampling methodology, we also focused on proper interpretation of the original data and plant identification. The considerable variation that occurs within each community typical of high mountain systems further complicates the detection of change over time.

Transects have long been considered to be an effective way to make inference to vegetation within a large area, but caution must be used when determining definite presence or absence of species. For example, *Tetaneuris grandiflora* is a common species visually observed in the alpine community and was frequently observed during the new survey, but was detected in low abundance within transects of both the original and new study. The strong effects of aspect on plant communities are not apparent, as have been reported, and may have affected the detection of species because of sampling bias (Langenheim, 1962; Zorio et al., Ch. 1). In the future more sites could be added to each community to create a more evenly distributed sample of aspects.

In this study, we focused on constancy, general growth forms, and the relative abundance of the most common species occurring within each community in both surveys in order to reduce the chance of false inference. To reflect the original survey, the new dataset was modified by combining species within genera with high uncertainty of correct species-level identification. Identification issues in future efforts will be diminished by the expanding connectivity of herbaria and herbarium databases, continued collection of voucher specimens, and high-quality specialized plant keys (Shaw, 2008; Weber & Wittmann, 2012).

Inferences concerning long term trends will also be affected by variations in weather patterns and conditions during the survey periods. Langenheim's survey occurred not long after the severe drought conditions of the 1930s and plant communities could have still been recovering (Western Regional Climate Center, 2014). The reported increases in species richness and abundance may be due to this effect. After approximately 50 years of gradually warmer but wet conditions, the western slope of the Colorado Rocky Mountains has returned to an approximately decade long drought cycle (Western Regional Climate Center, 2014). Unfortunately, no long-term precipitation and temperature data are available for most of the study area. Both stations occur at around approximately 3000 m, data from the Crested Butte NOAA weather station does not show consistent trends like the Cochetopa Creek station in terms of decadal temperature increase (Figure 6 and 7). Current studies, however, like GLORIA (Grabherr et al., 2000), are improving the coverage of climate data at high-elevation, particularly at mountain summits, and will provide valuable resources for comparing rates of temperature and precipitation change and their effect along an elevation gradient.

## Conclusions

This comparative study using historical data is in agreement with many others that demonstrate significant and rapid change in the species abundance and composition of high-elevation plant communities (Pauli et al., 1996; Schob, 2007; Gottfried et al., 2012; Wipf et al., 2013; Sproull et al., 2015). Given continued temperature increases, we predict alterations to plant community composition to continue. Many models predict that increased rates of rising global temperature will cause shifts in species composition, with some species expanding upwards and others adapting or becoming extirpated (Pauli et al., 1996; Grabherr et al., 2001; Pauli et al., 2003; Peter et al., 2007). Although it is unclear exactly how such unprecedented increases in annual temperature will affect plant communities, the use of historical ecological data for comparative studies is a valuable tool for assessing and predicting change. This is particularly true for our dataset in which climatic variation occurs along an elevation gradient (Swetnam et al., 1999; Peter et al., 2007; Zhu et al., 2009; Sproull et al., 2015). Future studies could employ the entire dataset from this new survey for further increase the resolution of results that could then be used for plant community analysis within the study area or be applied to similar ecosystems worldwide (Swetnam et al., 1999; Peter et al., 2007).

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## Tables and Figures

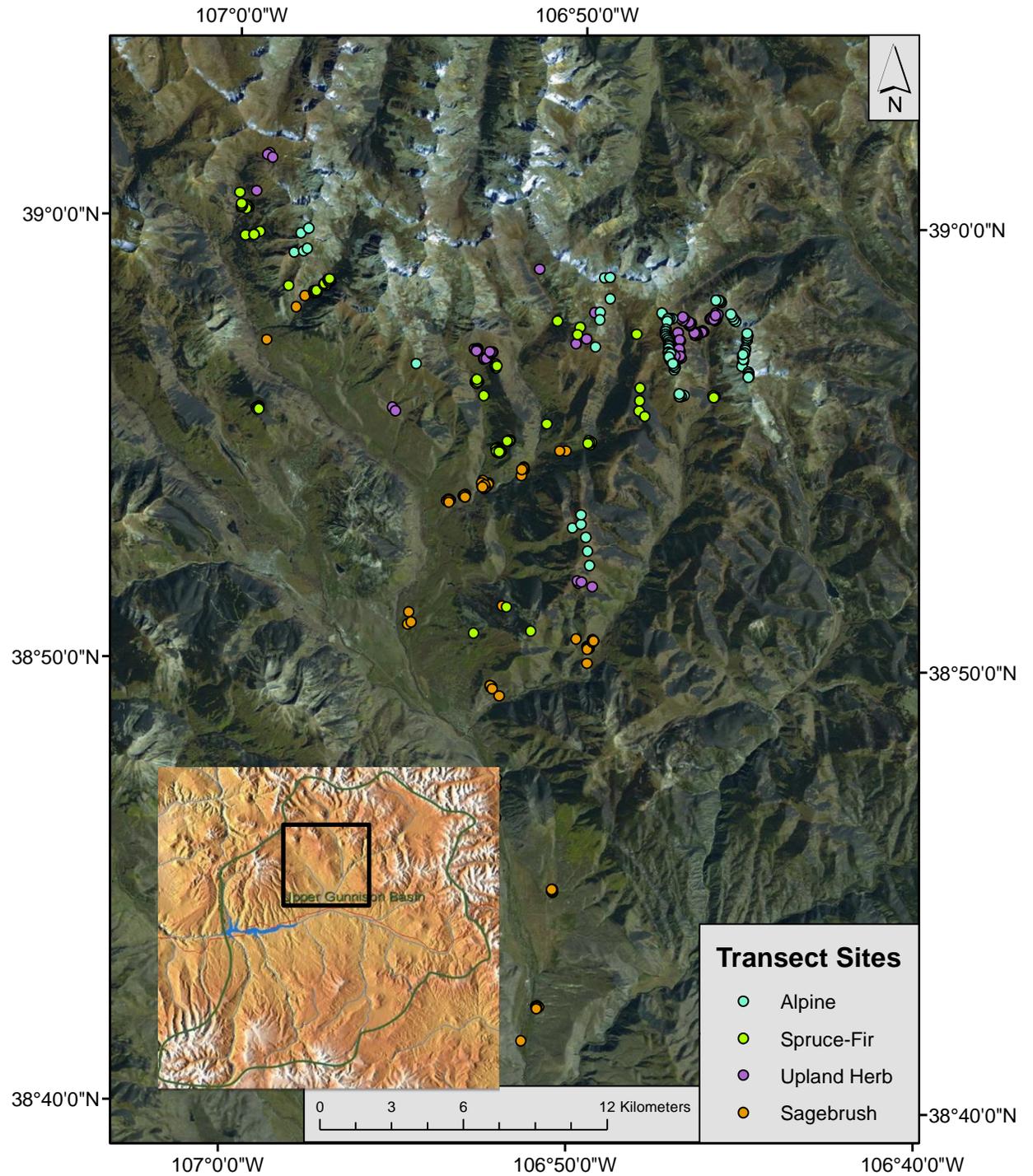


Figure 1. Aerial photo of the 236 km<sup>2</sup> study area in the upper Gunnison Basin, CO

Table 1. Summary statistics of total richness, average Bray-Curtis dissimilarity, and average Shannon-Weiner diversity. Original data (Langenheim, 1953), is named *1950*, and the resurvey, is *2015*. The total number of sites in the original survey is given first, followed by the sites successfully resampled. Asterisks denote significant difference between study periods for richness and Shannon-Weiner via Welch's T-test. Bray-Curtis values are presented for both survey periods and from pairwise comparisons between communities for both communities. Three sites from the original survey (SF24, A1, A35) were excluded. Bray-Curtis dissimilarity was significantly different between survey periods (Welch's T-test:  $T\text{-stat}_{(4)} = -8.05$ ,  $p\text{-value} = 1.30 \times 10^{-4}$ ).

Community	Sites (1950/2014)	Richness		Bray-Curtis			Shannon-Weiner	
		1950	2015	1950	2015	1950 v. 2014	1950	2015
Sagebrush	27/27	43	84*	0.358	0.708	0.74	2.30	2.42
Spruce-Fir	32/31	43	69*	0.408	0.562	0.73	2.21	2.17
Upland-herb	31/31	59	88*	0.495	0.716	0.87	2.68	3.07*
Alpine	35/33	51	65*	0.413	0.514	0.69	2.62	2.04*

Table 2. Paired *t*-test summary statistics of plant communities from both survey periods compared for differences in richness, and Shannon-Weiner Index values.

Community	Shannon-Weiner			Richness	
	df	<i>t</i> -stat	<i>P</i> ( <i>T</i> < <i>t</i> )	<i>t</i> -stat	<i>P</i> ( <i>T</i> < <i>t</i> )
Sagebrush	26	0.642	0.263	-2.368	0.0128
Spruce-Fir	30	-0.301	0.382	-1.769	0.0435
Upland-herb	30	5.519	3.01x10 <sup>-6</sup>	-9.482	1.09x10 <sup>-10</sup>
Alpine	32	-7.346	4.18x10 <sup>-6</sup>	4.106	1.30x10 <sup>-4</sup>

Table 3a. The fifteen most abundant species for the sagebrush and spruce-fir communities as described by Langenheim (1962) in the original (1950) and new survey (2014). Relative abundance and constancy are given for each species.

Sagebrush						Spruce-Fir					
1950	Rel. Abd.	Const.	2014	Rel. Abd.	Const.	1950	Rel. Abd.	Const.	2014	Rel. Abd.	Const.
<i>Artemisia tridentata</i>	32.52	100	<i>Artemisia tridentata</i>	16.48	52.94	<i>Vaccinium</i> spp.	22.77	96.77	<i>Vaccinium</i> spp.	18.43	77.42
<i>Festuca thurberi</i>	6.09	96.3	<i>Festuca thurberi</i>	6.26	38.24	<i>Pedicularis</i> spp.	8.55	93.55	<i>Arnica cordifolia</i>	8.73	87.10
<i>Ericameria</i> spp.	4.15	81.48	<i>Achillea millefolium</i>	3.94	58.82	<i>Arnica cordifolia</i>	7.53	96.77	<i>Carex geyeri</i>	2.89	58.06
<i>Arenaria congesta</i>	3.89	81.48	<i>Artemisia frigida</i>	3.84	17.65	<i>Lupinus</i> spp.	5.22	61.29	<i>Fragaria virginiana</i>	2.09	74.19
<i>Eriogonum umbellatum</i>	2.35	92.59	<i>Lupinus</i> spp.	3.36	52.94	<i>Polemonium pulcherrimum</i>	4.03	74.19	<i>Paxistima myrsinites</i>	1.91	51.61
<i>Lupinus</i> spp.	2.35	59.26	<i>Artemisia dracunculus</i>	3.31	41.18	<i>Ribes montigenum</i>	3.5	70.97	<i>Ribes montigenum</i>	1.57	54.84
<i>Symphoricarpos</i> spp.	2.06	44.44	<i>Lathyrus lanswertii</i>	3.16	50.00	<i>Fragaria virginiana</i>	2.69	96.77	<i>Pseudocymopterus montanus</i>	1.28	45.16
<i>Rosa</i> spp.	2.02	66.67	<i>Elymus scribneri</i>	3.10	41.18	<i>Paxistima myrsinites</i>	2.03	29.03	<i>Carex</i> spp.	1.20	35.48
<i>Agastache urticifolia</i>	1.67	51.85	<i>Eriogonum umbellatum</i>	3.02	41.18	<i>Mertensia ciliata</i>	1.91	74.19	<i>Osmorhiza depauperata</i>	1.11	61.29
<i>Bromus frondosus</i>	1.67	51.85	<i>Erigeron speciosus</i>	2.70	47.06	<i>Koeleria macrantha</i>	1.59	38.71	<i>Geranium richardsonii</i>	1.05	48.39
<i>Potentilla pulcherrima</i>	1.63	77.78	<i>Potentilla gracilis</i>	2.58	35.29	<i>Carex geyeri</i>	1.38	61.29	<i>Ligusticum porteri</i>	0.96	45.16
<i>Erigeron speciosus</i>	1.61	85.19	<i>Ericameria</i> spp.	1.62	38.24	<i>Pseudocymopterus montanus</i>	1.31	67.74	<i>Epilobium angustifolium</i>	0.84	48.39
<i>Potentilla gracilis</i>	1.57	85.19	<i>Koeleria macrantha</i>	1.47	44.12	<i>Ligularia amplexans</i>	1.28	58.06	<i>Lathyrus lanswertii</i>	0.82	25.81
<i>Achillea millefolium</i>	1.54	92.59	<i>Castilleja linariaefolia</i>	1.40	52.94	<i>Ribes wolfii</i>	1.16	61.29	<i>Pedicularis racemosa</i>	0.78	54.84
<i>Lathyrus lanswertii</i>	1.5	81.48	<i>Festuca idahoensis</i>	1.33	14.71	<i>Osmorhiza depauperata</i>	1.13	48.39	<i>Lupinus</i> spp.	0.73	41.94

Table 3b. The fifteen most abundant species for the upland-herbaceous and alpine communities as described by Langenheim (1962) in the original (1950) and new survey (2014). Relative abundance and constancy are given for each species.

Upland-herbaceous						Alpine					
1950	Rel. Abd.	Const.	2014	Rel. Abd.	Const.	1950	Rel. Abd.	Const.	2014	Rel. Abd.	Const.
<i>Ligusticum porteri</i>	9.42	90	<i>Ligusticum porteri</i>	4.41	50.00	<i>Oxytropis deflexa</i> var. <i>sericea</i>	4.01	82.35	<i>Elymus trachycaulus</i>	2.31	52.94
<i>Lupinus</i> spp.	9.18	83.33	<i>Bromelica spectabilis</i>	4.14	66.67	<i>Dryas octopetala</i>	3.88	44.12	<i>Elymus scribneri</i>	2.10	52.94
<i>Senecio crassulus</i>	6.3	96.67	<i>Fragaria virginiana</i>	3.94	80.00	<i>Tetranneuris grandiflora</i>	3.76	85.29	<i>Geum rossii</i>	1.76	44.12
<i>Carex</i> spp.	4.48	86.67	<i>Achillea millefolium</i>	3.18	83.33	<i>Artemisia scopulorum</i>	3.66	82.35	<i>Salix arctica</i>	1.26	41.18
<i>Delphinium barbeyi</i>	3.58	66.67	<i>Salix drummondiana</i>	3.10	50.00	<i>Kobresia sibirica</i>	3.53	79.41	<i>Achillea millefolium</i>	1.25	35.29
<i>Bistorta bistortoides</i>	3.08	63.33	<i>Festuca thurberi</i>	3.01	53.33	<i>Ivesia gordonii</i>	3.21	50	<i>Silene acaulis</i>	1.20	52.94
<i>Phleum commutatum</i>	2.98	76.67	<i>Lupinus</i> spp.	2.48	53.33	<i>Silene acaulis</i>	3.01	76.47	<i>Astragalus alpinus</i>	1.18	41.18
<i>Helianthella quinquenervis</i>	2.97	63.33	<i>Carex</i> spp.	2.31	73.33	<i>Oxytropis podocarpa</i>	2.9	58.82	<i>Potentilla quinquefolia</i>	1.12	32.35
<i>Castilleja sulphurea</i>	2.92	73.33	<i>Bromopsis ciliata</i>	2.26	60.00	<i>Polemonium viscosum</i>	2.69	76.47	<i>Trifolium dasyphyllum</i>	1.03	41.18
<i>Vaccinium</i> spp.	2.32	43.33	<i>Helianthella quinquenervis</i>	2.20	60.00	<i>Erigeron pinnatisectus</i>	2.65	82.35	<i>Erigeron compositus</i>	0.95	29.41
<i>Achillea millefolium</i>	1.98	73.33	<i>Potentilla quinquefolia</i>	1.96	43.33	<i>Geum rossii</i>	2.44	64.71	<i>Oxytropis deflexa</i> var. <i>sericea</i>	0.95	26.47
<i>Sibbaldia procumbens</i>	1.9	46.67	<i>Potentilla gracilis</i>	1.92	46.67	<i>Carex drummondiana</i>	2.37	29.41	<i>Agrostis scabra</i>	0.89	32.35
<i>Erigeron elatior</i>	1.62	56.67	<i>Delphinium barbeyi</i>	1.90	56.67	<i>Trisetum spicatum</i>	1.6	82.35	<i>Dryas octopetala</i>	0.85	35.29
<i>Potentilla gracilis</i>	1.62	76.67	<i>Mertensia ciliata</i>	1.77	60.00	<i>Festuca ovina</i>	1.59	76.47	<i>Oxytropis podocarpa</i>	0.78	64.71
<i>Festuca thurberi</i>	1.55	26.67	<i>Bromis inermis</i>	1.72	50.00	<i>Potentilla</i> spp.	1.54	70.59	<i>Eleocharis palustris</i>	0.76	38.24

Table 4. Average density of tree species for 100 m<sup>2</sup> by diameter classes based on 31 quadrants in 2014 and 24 quadrants in 1950 (Langenheim, 1962). Size classes were converted from inches (Langenheim, 1962) to cm.

Size Class	<i>Picea engelmannii</i>		<i>Abies lasiocarpa</i>		<i>Pinus contorta</i>	
	1950	2014	1950	2014	1950	2014
>40cm	x	2	0	0	x	0
25-40cm	x	1	x	1	3	x
13-24cm	x	1	2	2	9	x
2.5-12.8	x	0	x	1	4	x
Saplings	2	1	4	1	4	x

Table 5. Multiple regression of growth form proportions against each community type simultaneously for both surveys.

Community	Forb		Graminoid		Shrub		Bare	
	$R^2$	$p$ -value	$R^2$	$p$ -value	$R^2$	$p$ -value	$R^2$	$p$ -value
Sagebrush	0.246	0.002	0.727	0.001	0.370	0.109	0.658	0.001
Spruce-fir	0.643	0.001	0.179	0.002	0.268	0.001	0.631	0.001
Upland-herb	0.645	0.001	0.288	0.001	0.355	0.001	0.484	0.001
Alpine	0.728	0.001	0.360	0.001	0.378	0.001	0.798	0.001

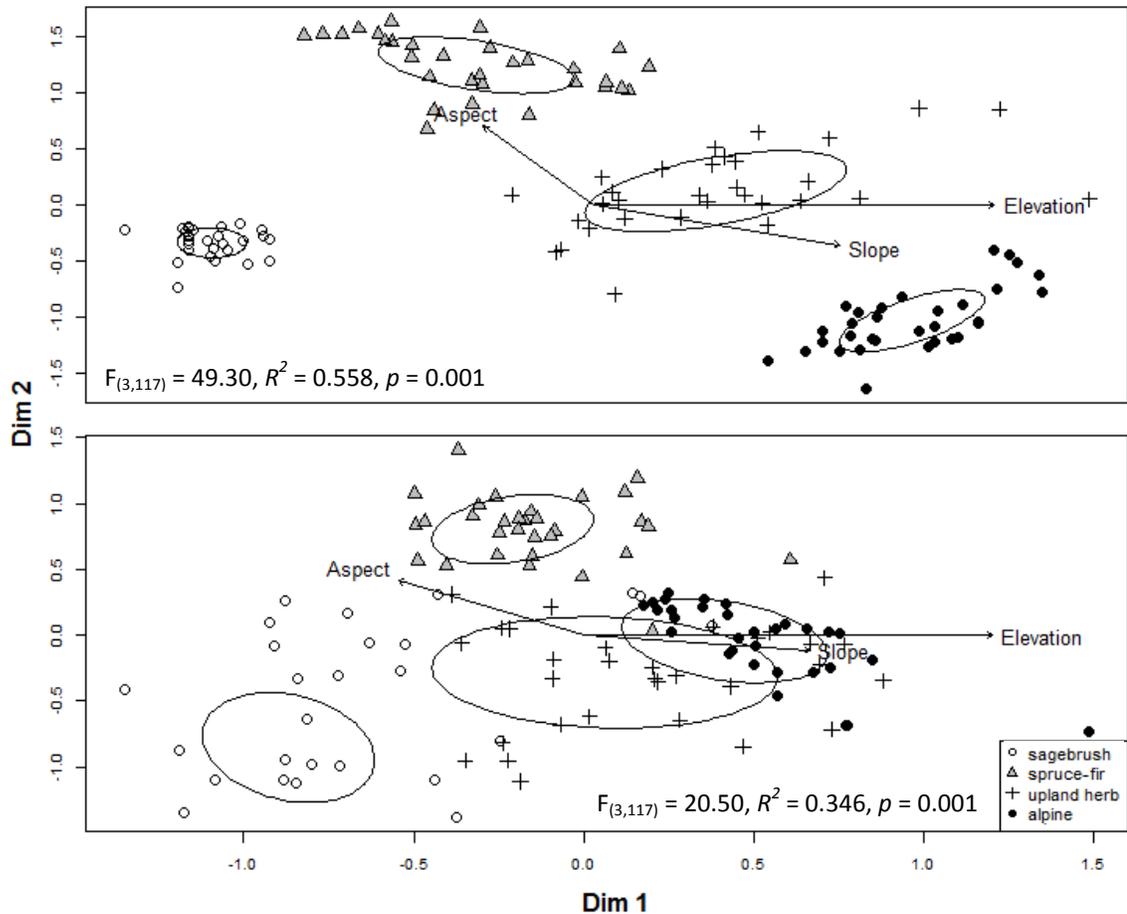


Figure 2. NMDS ordinations of dimension 1 and 2 and regression results for environmental variables for a) Langenheim (1953) and b) new survey data with 95% confidence ellipses. Arrows indicate increasing slope and elevation, and western-facing aspects. Red, black, blue, and green represent sagebrush, alpine, upland-herbaceous, and spruce-fir, respectively. Substrate was not included due to low significance of vector fit values from multiple regression. Final stress for 3D NMDS solution = 0.10 and 0.13 for original and new survey data, respectively. Permutational ANOVA (PERMANOVA) results are shown for both survey periods.

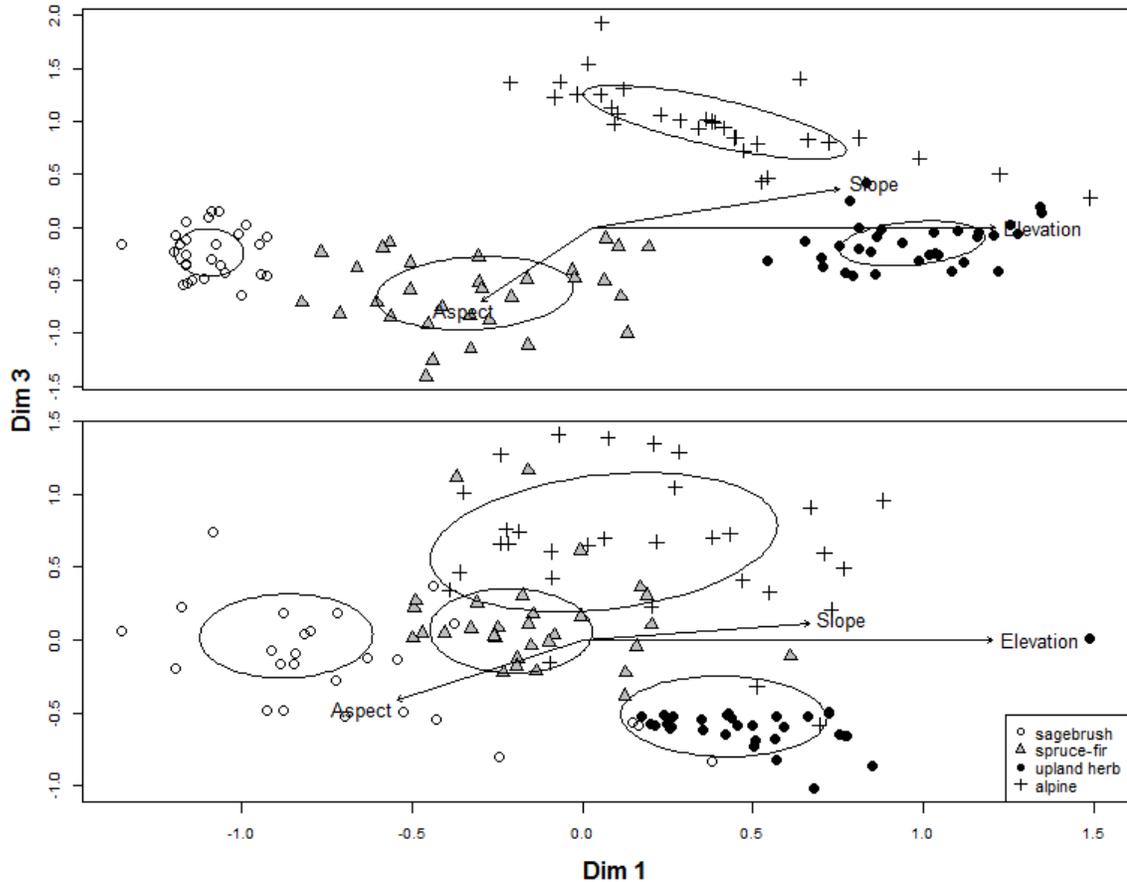


Figure 3. NMDS ordinations of dimension 1 and 3 and regression results for environmental variables for a) Langenheim (1953) and b) new survey data. Arrows indicate increasing slope and elevation, and western-facing aspects. Red, black, blue, and green represent sagebrush, alpine, upland-herbaceous, and spruce-fir, respectively. Substrate was not included due to low significance of vector fit values from multiple regression. Final stress for 3D NMDS solution = 0.10 and 0.13 for original and new survey data, respectively.

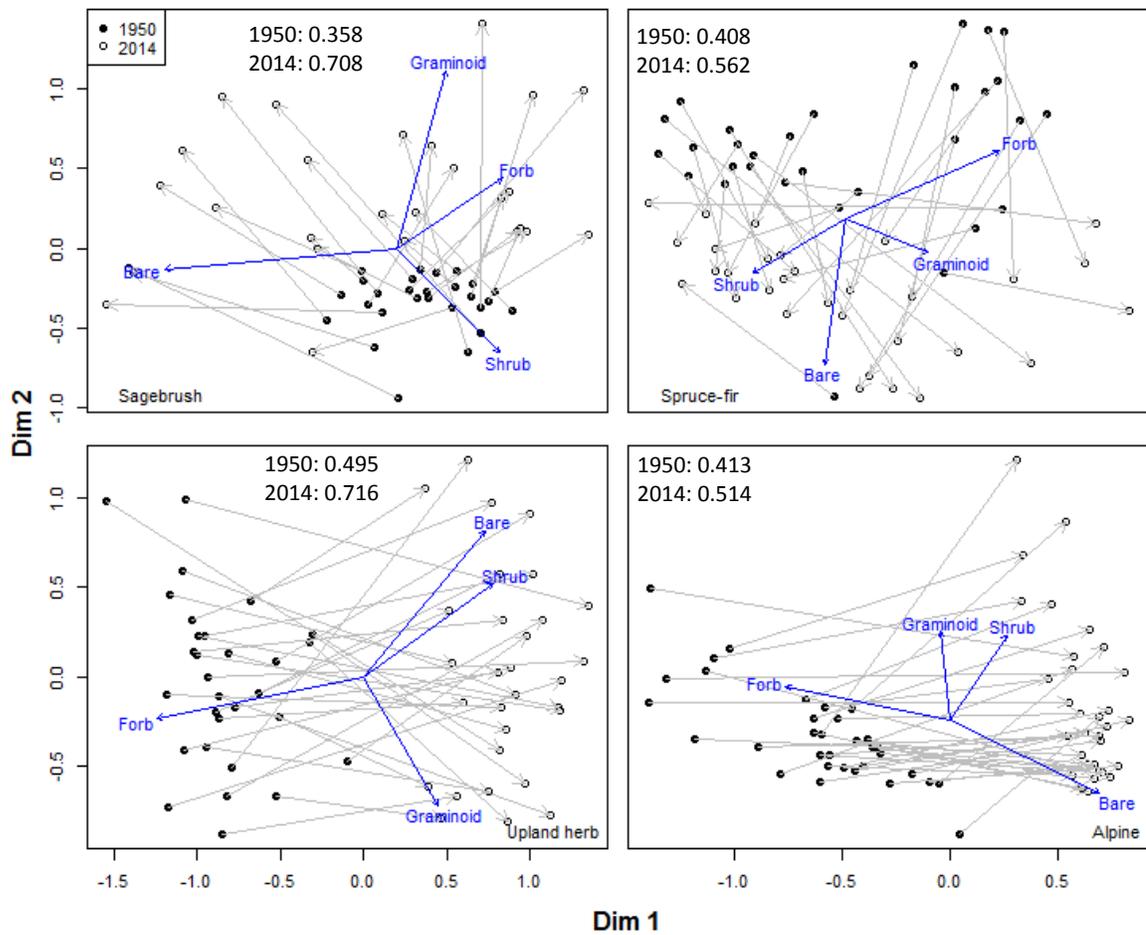


Figure 4. NMDS ordinations in dimension 1 and 2 for each community type. Regression results for the proportion of three growth forms (forbs, graminoids, and shrubs) and bare area for each community from the resurvey are fit on each ordination. Sites from the original survey are black circles, the new survey is denoted with open circles. Length of connecting arrows correspond to Bray-Curtis dissimilarity. Arrows indicate increasing proportions of growth forms and bare area. Bray-Curtis index values (indicator of beta-diversity) are included for both survey periods for each community type.

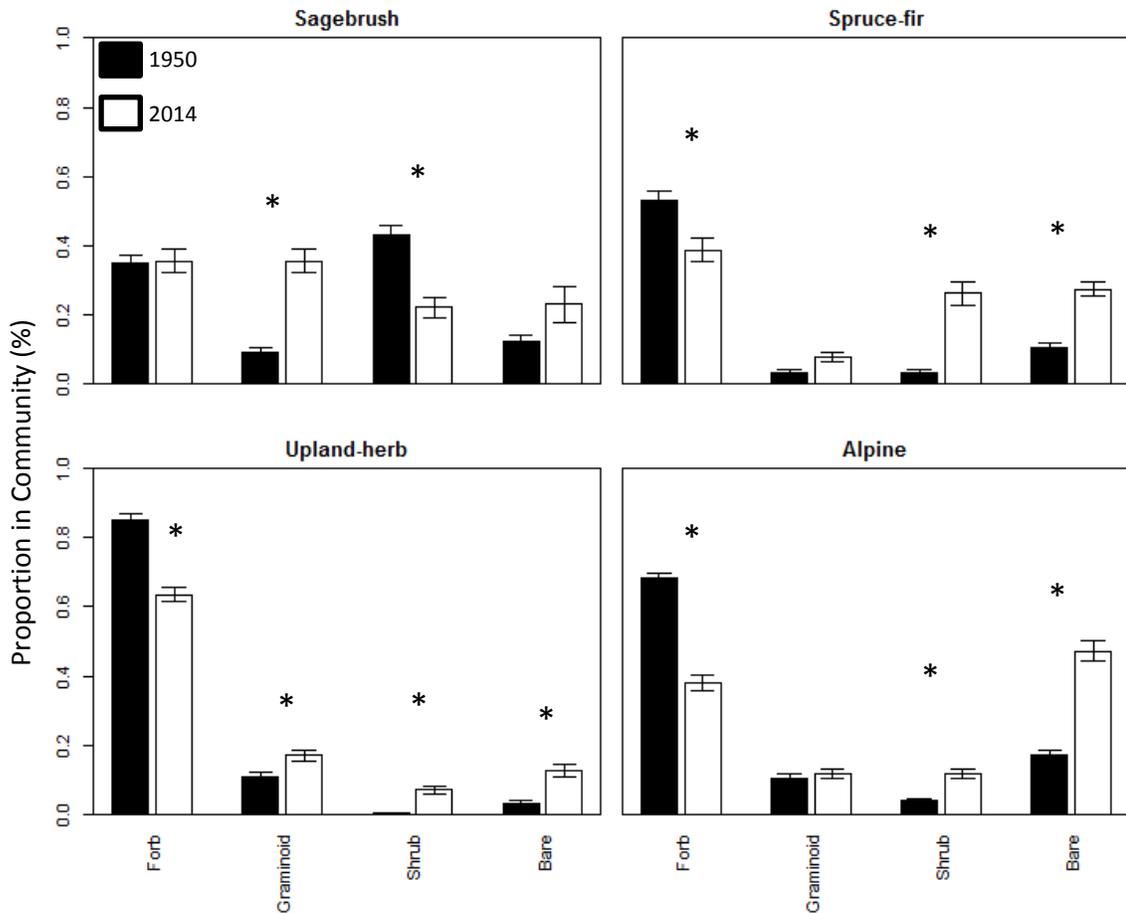


Figure 5. Proportion of bare area, and forb (herbaceous), shrub, and graminoid (grasses, rushes, and sedges) species in each community type from Langenheim (1953) and the new survey. Black bars represent the original survey (1950), and white bars denote the new survey (2014). Heights of bars are based on average relative abundance. Standard error is displayed. Asterisks denote significant difference between pairs by paired *t*-tests.

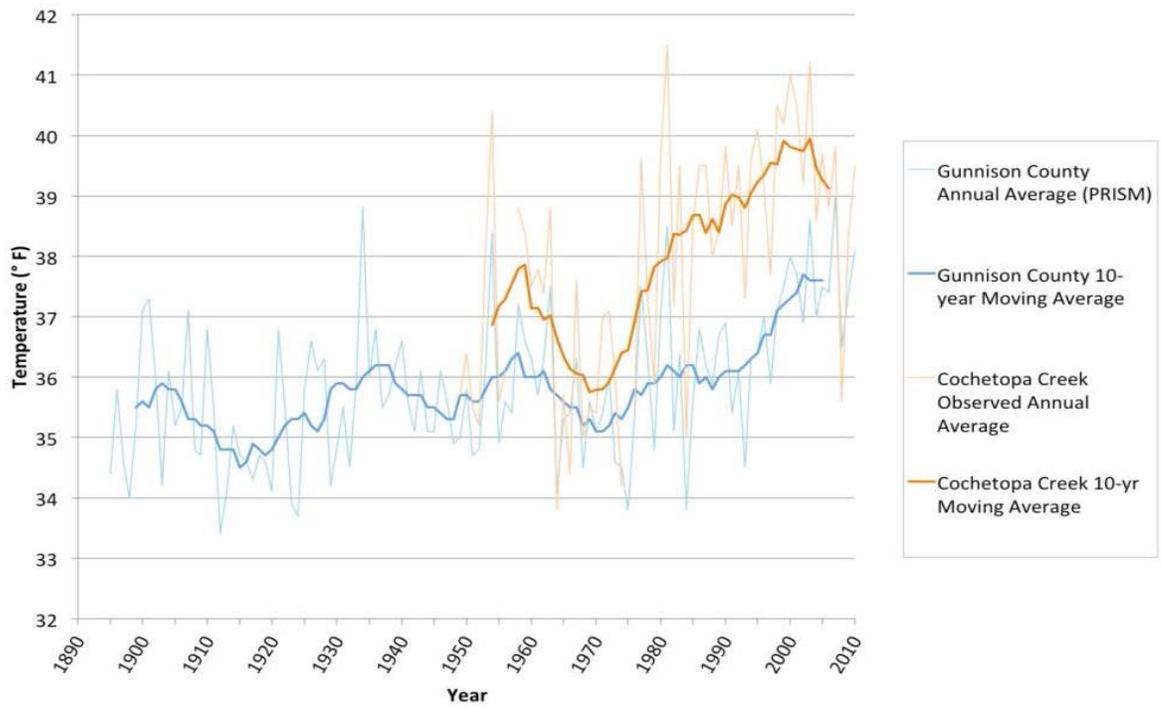


Figure 6. The Cochetopa Creek weather station (~3000 m) and the Gunnison County average displaying average increase in temperature since the late 1800s (Western Regional Climate Center, 2014).

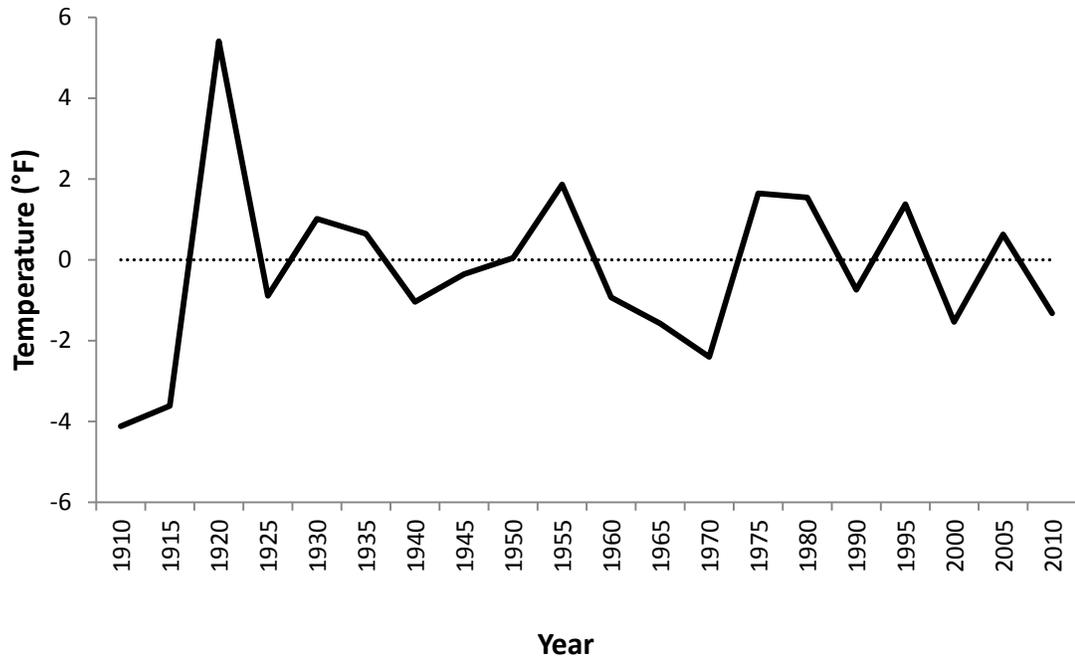


Figure 7. The Crested Butte weather station (~3000 m) displaying average change in temperature since the late 1915s (NOAA, 2015). Temperatures are reported in Fahrenheit for comparison with Cochetopa Creek weather station data.

## Appendix A: Species List

Table 1A. Species detected in Zorio et al. (2014) in four high-elevation pant communities in the East River Basin, CO, USA. Species are arranged alphabetically by family. Weber and Wittmann (2012) and Shaw (2008) were used for plant identification. The presence (x) or absence (0) of each species in each community type from both the original (Langenheim, 1962), denoted 1950, and the new survey, denoted 2014, are included. Community abbreviations appear in order of the lowest elevation to highest elevation community type. SB: sagebrush, SF: spruce-fir, UH: upland-herbaceous, AL: alpine. Species names in bold have expanded upwards. Underlined species names have expanded downwards. Underlining and bold type represent concurrent upward and downward expansion. Asterisks denote species that have contracted their range.

	1950				2014			
	SB	SF	UH	AL	SB	SF	UH	AL
<b>Amaranthaceae</b>								
<i>Chenopodium atrovirens</i>	0	0	0	0	x	0	x	0
<b>Asteraceae</b>								
<i>Achillea millefolium</i>	x	x	x	x	x	x	x	x
<i>Agoseris aurantiaca</i>	0	0	0	0	x	x	x	0
<i>Agoseris glauca</i>	0	0	0	0	x	x	0	x
<i>Antennaria spp.</i>	x	0	x	x	x	0	x	x
<i>Arnica chamissonis</i>	0	0	0	0	x	0	0	0
<b><i>Arnica cordifolia</i></b>	0	x	0	0	0	x	x	x
<b><i>Arnica latifolia</i></b>	0	x	0	0	0	0	x	x
<i>Arnica mollis</i>	0	0	0	0	0	x	x	0
<i>Arnica parryi</i>	0	0	x	0	0	0	x	0
<b><i>Arnica rydbergii</i></b>	0	0	x	0	0	0	0	x
<i>Artemisia dracuncululus</i>	0	0	0	0	x	0	0	0
<i>Artemisia frigida</i>	x	0	0	0	x	0	0	0
<i>Artemisia ludoviciana</i>	x	0	0	0	x	0	0	0
<u><i>Artemisia scopulorum</i></u>	0	0	0	x	0	0	x	x
<i>Artemisia tridentata</i>	x	0	0	0	x	0	0	0
<i>Aster spp.</i>	0	0	0	0	0	0	x	0
<i>Chaenactis alpina</i>	0	0	0	0	0	0	0	x
<i>Chrysothamnus spp.</i>	x	0	0	0	x	0	0	0
<i>Cirsium arvense</i>	0	0	0	0	x	x	x	x
<i>Cirsium hookerianum</i>	0	0	0	0	x	x	x	x
<b><i>Cirsium spp.</i></b>	0	0	x	0	0	x	x	x
<i>Crepsis tectorum</i>	0	0	0	0	x	0	x	0
<i>Dugaldia hoopsii</i>	0	0	0	0	x	x	x	0
<i>Erigeron caespitosus</i>	0	0	0	0	0	0	0	0

<i>Erigeron canus</i>	0	0	0	0	x	0	0	0
<i>Erigeron compositus</i>	0	0	0	x	0	0	0	0
<u><i>Erigeron coulteri</i></u>	0	0	x	0	x	0	x	0
<u><i>Erigeron elatior</i></u>	0	0	x	0	x	0	x	0
<i>Erigeron formosissimus</i>	0	0	0	0	0	0	0	0
<i>Erigeron glabellus</i>	0	0	0	0	x	x	x	0
<u><i>Erigeron glacialis</i></u>	0	x	x	x	0	0	0	x
<i>Erigeron grandiflorus</i>	0	0	0	0	0	0	x	x
<i>Erigeron leiomerus</i>	0	0	0	0	0	0	0	x
<i>Erigeron peregrinus</i>	0	0	0	0	0	x	0	0
<i>Erigeron simplex</i>	0	0	0	0	0	0	x	0
<b><i>Erigeron speciosus</i></b>	x	0	0	0	x	x	x	x
<i>Erigeron subtrinervis</i>	0	0	0	0	x	0	x	0
<i>Helianthella parryi</i>	0	0	0	0	x	x	x	0
<b><u><i>Helianthella quinquenervis</i></u></b>	x	0	x	0	x	x	x	0
<i>Heliomaris grandifolia</i>	0	0	0	0	0	0	x	0
<i>Heliomaris multiflora</i>	0	0	0	0	x	0	0	0
<b><i>Heterotheca villosa</i></b>	x	0	0	0	x	0	x	0
<i>Lactuca serriola</i>	0	0	0	0	x	0	0	0
<u><i>Ligularia holmii</i></u>	0	0	0	x	0	0	x	0
<i>Ligularia porteri</i>	0	0	0	0	0	0	0	0
<i>Ligularia soldanella</i>	0	0	0	0	0	0	x	0
<i>Machaeranthera bigelovii</i>	0	0	0	0	0	x	0	0
<i>Oreochrysum parryi</i>	0	0	0	0	0	x	x	0
<i>Packera cana</i>	0	0	0	0	0	0	0	0
<i>Packera werneriiifolia</i>	0	0	0	x	0	0	0	x
<i>Senecio amplexans</i>	0	0	0	0	0	0	0	x
<i>Senecio canus</i>	0	0	0	0	x	0	x	0
<i>Senecio crassulus</i>	0	0	x	0	0	0	x	0
<i>Senecio fremontii variety blitoides</i>	0	0	0	0	0	0	0	0
<i>Senecio integerrimus</i>	0	0	0	0	x	x	x	x
<i>Senecio serra</i>	0	0	0	0	0	x	x	0
<i>Senecio spp.</i>	0	0	0	0	x	0	x	0
<b><i>Senecio triangularis</i></b>	0	x	0	0	0	x	x	0
<i>Senecio wootonii</i>	0	0	0	0	0	0	x	x
<b><u><i>Solidago spp.</i></u></b>	0	x	0	x	x	x	x	x
<b><i>Taraxacum officinale</i></b>	x	0	x	0	x	x	x	x
<i>Tetradymia canescens</i>	0	0	0	0	x	0	0	0
<b><i>Tonestus lyallii</i></b>	x	0	0	0	0	0	x	x
<b><i>Townsendia spp.</i></b>	x	0	0	0	0	0	x	0
<i>Virgulus campestris</i>	0	0	0	0	x	0	0	0

<i>Wyethia amplexicaulis</i>	0	0	0	0	x	0	x	0
<b>Apiaceae</b>								
<i>Angelica grayi</i>	0	x	0	0	0	0	0	0
<i>Heracleum maximum</i>	0	0	0	0	x	x	0	0
<i>Ligusticum porteri</i>	0	x	x	0	x	x	x	0
<i>Lomatium dissectum</i>	0	0	0	0	x	0	0	0
<i>Oreoxis alpina</i>	0	0	0	x	0	0	0	x
<i>Osmorhiza berteroi</i>	0	0	0	0	0	0	0	x
<i>Osmorhiza depauperata</i>	0	x	0	0	0	x	0	0
<i>Osmorhiza occidentalis</i>	0	0	0	0	0	0	x	0
<b><u>Pseudocymopterus montanus</u></b>	0	x	x	0	x	x	x	x
<b>Berberidaceae</b>								
<i>Mahonia repens</i>	x	0	0	0	x	x	0	0
<b>Boraginaceae</b>								
<i>Hackelia floribunda</i>	0	0	0	0	x	0	0	0
<b><i>Mertensia ciliata</i></b>	0	x	0	0	0	x	x	x
<i>Mertensia fusiformis</i>	0	0	0	0	0	x	x	0
<i>Mertensia lanceolata</i>	0	0	0	0	0	x	0	0
<i>Mertensia paniculata</i>	0	0	0	0	x	x	0	0
<i>Mertensia spp.</i>	0	0	0	0	x	0	0	0
<i>Mertensia oblongifolia</i>	0	0	0	x	0	0	0	0
<i>Myosotis asiatica</i>	0	0	0	0	0	0	0	x
<i>Phacelia sericea</i>	0	0	0	x	0	0	x	x
<b>Brassicaceae</b>								
<i>Boechera drummondii</i>	0	0	0	0	x	0	0	0
<i>Boechera holboellii</i>	0	0	0	0	x	0	0	0
<b><i>Boechera stricta</i></b>	0	x	0	0	x	x	x	x
<i>Cardamine cordifolia</i>	0	0	0	0	x	x	x	0
<i>Descurainia sophia</i>	0	0	0	0	x	0	x	0
<b><u>Draba spp.</u></b>	0	x	0	x	x	x	x	x
<i>Erysimum capitatum</i>	0	0	0	0	0	0	0	x
<i>Lesquerella acutifolia</i>	0	0	0	x	0	0	0	0
<i>Lesquerella alpina</i>	0	0	0	0	0	0	0	x
<i>Noccaea montana</i>	0	0	0	0	0	x	x	0
<i>Smelowskia calycina</i>	0	0	0	x	0	0	x	x
<i>Thlaspi arvense</i>	0	0	0	0	x	0	0	0

<b>Campanulaceae</b>								
<i>Campanula parryi</i>	x	0	0	0	x	0	0	0
<i>Campanula rotundifolia</i>	x	0	0	x	x	0	x	0
<b>Caprifoliaceae</b>								
<i>Distegia involucrata</i>	0	x	0	0	x	x	0	0
<i>Sambucus racemosa</i>	0	0	0	0	x	x	x	0
<i>Symphoricarpos spp.</i>	x	0	x	0	0	x	0	0
<b>Caryophyllaceae</b>								
<i>Arenaria congesta</i>	x	0	x	x	x	x	x	x
<i>Cerastium beeringianum</i>	0	0	0	x	0	0	0	x
<i>Minuartia obtusiloba</i>	0	0	0	0	0	x	0	x
<i>Minuartia rubella</i>	0	0	0	0	0	0	0	x
<i>Silene acaulis</i>	0	0	0	x	0	0	x	x
<b>Celastraceae</b>								
<i>Paxistima myrsinites</i>	x	x	0	0	x	x	0	0
<b>Crassulaceae</b>								
<i>Rhodiola integrifolia</i>	0	0	x	0	0	0	x	x
<i>Sedum spp.</i>	0	0	0	x	x	0	0	x
<b>Cupressaceae</b>								
<i>Juniperus communis</i>	0	0	0	0	x	x	x	0
<b>Cyperaceae</b>								
<i>Carex geyeri</i>	0	x	0	0	0	x	x	0
<i>Carex siccata</i>	x	0	0	0	0	0	x	0
<i>Carex spp.</i>	0	0	x	x	x	x	x	x
<i>Eleocharis palustris</i>	0	0	0	0	0	0	0	x
<i>Kobresia sibirica</i>	0	0	0	x	0	0	0	0
<i>Scirpus tabernaemontani</i>	0	0	0	0	x	0	0	0
<b>Elaeagnaceae</b>								
<i>Shepherdia canadensis</i>	0	0	0	0	x	0	0	0
<b>Equisetaceae</b>								
<i>Equisetum arvense</i>	0	0	0	0	0	x	0	0
<i>Equisetum palustre</i>	0	0	0	0	x	0	0	0
<i>Equisteum hyemale</i>	0	0	0	0	0	x	0	0

**Ericaceae**

<i>Arctostaphylos uva-ursi</i>	0	0	0	0	0	x	0	0
<i>Pyrola chlorantha</i>	0	0	0	0	0	x	0	0
<i>Pyrola rotundifolia</i> ssp. <i>Asarifolia</i>	0	0	0	0	0	x	0	0
<i>Pyrola uniflora</i>	0	x	0	0	0	x	0	0
<i>Vaccinium</i> spp.	0	x	x	x	0	x	x	x

**Fabaceae**

<i>Astragalus alpinus</i>	0	0	0	0	x	0	0	x
<i>Astragalus americanus</i>	0	0	0	0	0	x	0	0
<i>Hedysarum alpinum</i>	0	0	0	0	0	0	x	0
<i>Lathyrus lanszwertii</i>	x	0	0	0	x	x	x	0
<b><i>Lupinus</i> spp.</b>	x	0	0	0	x	x	x	x
<i>Oxytropis fendleri</i>	0	0	0	0	0	x	0	0
<i>Oxytropis campestris</i>	0	0	0	0	0	0	x	0
<i>Oxytropis deflexa</i> var. <i>sericea</i>	0	0	x	x	0	0	x	x
<i>Oxytropis lambertii</i>	0	0	0	0	0	0	x	0
<i>Oxytropis podocarpa</i>	0	0	0	x	0	0	x	x
<i>Trifolium dasyphyllum</i>	0	0	0	0	0	0	0	x
<i>Trifolium parryi</i>	0	0	0	0	0	0	0	x
<i>Trifolium repens</i>	0	0	0	0	x	0	x	0
<i>Vicia americana</i>	x	0	0	0	x	x	x	0

**Gentianaceae**

<i>Frasera speciosa</i>	0	0	x	0	x	x	x	0
<i>Gentianella acuta</i>	0	0	0	0	0	x	0	0
<i>Gentianella amarelle</i>	0	0	0	0	0	x	x	0

**Geraniaceae**

<b><i>Geranium richardsonii</i></b>	0	x	0	0	x	x	x	0
<b><i>Geranium</i> spp.</b>	x	0	x	0	x	x	0	0
<i>Geranium visicossium</i>	0	0	0	0	x	0	0	0

**Grossulariaceae**

<i>Ribes cereum</i>	0	0	0	0	x	0	x	0
<i>Ribes montigenum</i>	0	x	0	0	x	x	0	0
<i>Ribes</i> spp.	0	0	0	0	0	0	x	0
<i>Ribes wolfii</i>	0	x	0	0	0	x	0	0

<b>Hydrophyllaceae</b>									
<i>Hydrophyllum capitatum</i>	0	0	0	0	0	x	x	0	
<b>Iridaceae</b>									
<i>Iris missouriensis</i>	x	0	x	0	x	0	x	0	
<b>Juncaceae</b>									
<i>Juncus balticus</i>	0	0	0	0	x	0	0	0	
<i>Juncus</i> spp.	0	0	0	0	x	x	0	0	
<i>Luzula parviflora</i>	0	0	0	0	0	x	0	0	
<b>Lamiaceae</b>									
<i>Agastache urticifolia</i>	x	0	0	0	x	0	x	0	
<b>Liliaceae</b>									
<i>Allium geyeri</i>	0	0	0	0	x	0	0	0	
<i>Calochortus gunnisonii</i>	0	0	0	0	x	0	x	0	
<i>Erythronium grandiflorum</i>	0	0	x	0	0	x	x	0	
<i>Lloydia serotina</i>	0	0	0	0	0	0	x	x	
<i>Veratrum californicum</i>	0	0	0	0	0	0	x	0	
<i>Zigademus elegans</i>	0	x	x	0	x	x	x	0	
<b>Linaceae</b>									
<i>Linum lewisii</i>	x	0	0	0	x	x	x	0	
<b>Montiaceae</b>									
<i>Claytonia lanceolata</i>	0	0	0	0	0	x	x	0	
<i>Claytonia megarhiza</i>	0	0	0	0	0	0	0	x	
<b>Nolinoideae</b>									
<i>Maianthemum stellatum</i>	x	0	0	0	x	x	0	0	
<b>Onagraceae</b>									
<i>Epilobium angustifolium</i>	0	x	0	0	0	x	0	0	
<i>Epilobium ciliatum</i>	0	0	0	0	0	x	x	0	
<i>Gayophytum diffusum</i>	0	0	0	0	x	0	0	0	
<b>Orchidaceae</b>									
<i>Goodyera oblongifolia</i>	0	0	0	0	0	x	0	0	
<b>Plantaginaceae</b>									

<i>Besseya alpina</i>	0	0	0	0	0	0	0	x
<i>Penstemon caespitosus</i>	0	0	0	0	x	0	0	0
<b><i>Penstemon strictus</i></b>	x	0	0	0	x	0	x	0
<b><i>Penstemon whippleanus</i></b>	0	x	x	0	0	0	x	x
<b>Poaceae</b>								
<i>Achnatherum hymenoides</i>	0	0	0	0	x	0	0	0
<b><i>Agrostis scabra</i></b>	0	0	x	0	0	0	0	x
<i>Alopecurus aequalis</i>	0	0	0	0	x	0	0	0
<u><i>Bromelica spectabilis</i></u>	0	0	x	0	x	x	x	0
<i>Bromis ineris</i>	0	0	0	0	x	x	x	0
<i>Bromopsis ciliata</i>	0	0	0	0	x	x	x	0
<i>Bromopsis richardsonii</i>	0	0	0	0	x	x	x	0
<i>Bromus frondosus</i>	x	0	0	0	x	0	0	0
<i>Bromus tectorum</i>	0	0	0	0	x	0	0	0
<i>Calamagrostis purpurascens</i>	0	0	x	0	0	0	x	0
<u><i>Deschampsia caespitosa</i></u>	0	x	0	0	x	0	0	0
<i>Elymus glaucus</i>	0	0	0	0	x	0	0	0
<u><i>Elymus scribneri</i></u>	0	0	0	x	x	0	x	x
<i>Elymus trachycaulus</i>	x	0	x	x	x	0	x	x
<i>Festuca idahoensis</i>	0	0	0	0	x	0	0	0
<i>Festuca ovina</i>	0	0	x	x	0	0	0	0
<b><i>Festuca thurberi</i></b>	x	0	x	0	x	x	x	x
<b><i>Koeleria macrantha</i></b>	x	x	0	0	x	0	x	x
<i>Leymus innovatus</i>	0	0	0	0	0	0	0	0
<i>Pascopyrum smithii</i>	0	0	0	0	x	x	x	0
<b><i>Phleum commutatum</i></b>	0	0	x	0	0	x	x	0
<i>Phleum pratense</i>	x	0	0	0	x	0	0	0
<u><i>Poa alpina</i></u>	0	0	x	x	x	0	x	x
<i>Poa arctica</i>	0	0	0	x	0	0	0	0
<i>Poa fendleriana</i>	0	0	0	0	x	0	x	0
<i>Poa interior</i>	x	0	0	0	0	0	0	0
<b><i>Poa leptocoma</i></b>	0	x	0	0	0	x	x	0
<i>Poa occidentalis</i>	0	0	x	0	0	0	0	0
<i>Poa pratensis</i>	0	0	0	0	0	0	x	0
<i>Poa reflexa</i>	0	0	0	0	x	0	x	0
<i>Poa secunda</i>	0	0	0	0	0	x	0	0
<i>Poa glauca</i>	0	0	x	x	0	0	0	0
<i>Stipa comata</i>	0	0	0	0	0	0	0	x
<i>Trisetum spicatum</i>	0	0	x	x	0	0	0	0

<b>Polemoniaceae</b>								
<i>Collomia linearis</i>	0	0	0	0	x	x	x	0
<i>Ipomopsis aggregata</i>	x	0	0	0	x	0	x	x
<u><i>Phlox hoodii</i></u>	0	0	0	x	x	0	x	0
<b><i>Polemonium pulcherrimum</i></b>	0	x	0	0	0	x	x	x
<u><i>Polemonium viscosum</i></u>	0	0	0	x	0	x	0	0
<b>Polygonaceae</b>								
<u><i>Bistorta bistortoides</i></u>	0	0	x	x	x	0	x	x
<b><i>Eriogonum umbellatum</i></b>	x	0	0	0	x	0	x	x
<i>Polygonum douglasii</i>	0	0	0	0	x	0	x	0
<i>Polygonum viviparum</i>	0	0	0	x	0	0	0	0
<i>Rumex densiflorus</i>	0	0	0	0	x	0	x	0
<b>Pyrolaceae</b>								
<i>Moneses uniflora</i>	0	0	0	0	0	x	0	0
<i>Orthilia secunda</i>	0	x	0	0	0	x	0	0
<b>Primulaceae</b>								
<i>Androsace septentrionalis</i>	0	0	0	0	x	x	x	x
<b>Ranunculaceae</b>								
<u><i>Aconitum columbianum</i></u>	0	0	x	0	x	x	x	0
<i>Anemone parviflora</i>	0	x	0	0	0	0	0	x
<u><i>Aneome multifida</i> ssp. <i>Saxicola</i></u>	0	0	0	x	0	0	x	x
<b><i>Aquilegia caerulea</i></b>	0	0	x	0	0	x	x	x
<i>Aquilegia canadensis</i>	0	0	x	0	0	x	0	0
<i>Caltha leptosepala</i>	0	x	x	0	0	x	x	0
<u><i>Delphinium barbeyi</i></u>	0	x	x	x	x	x	x	0
<i>Delphinium nelsonii</i>	0	0	0	0	x	0	x	0
<i>Pulsatilla patens</i> ssp. <i>multifida</i>	0	0	0	0	0	0	0	x
<i>Ranunculus inamoenus</i>	0	0	0	0	0	x	x	0
<b><u><i>Thalictrum fendleri</i></u></b>	0	x	x	0	x	x	x	x
<i>Thalictrum occidentale</i>	0	0	0	0	0	x	0	0
<u><i>Trollius laxus</i></u>	0	0	x	0	0	x	x	0
<b>Rosaceae</b>								
<i>Amelanchier alnifolia</i>	x	0	0	0	x	0	0	0
<i>Dryas octopetala</i>	0	0	0	x	0	0	0	x
<b><u><i>Fragaria virginiana</i></u></b>	0	x	x	0	x	x	x	x

<i>Geum rossii</i>	0	0	x	x	x	0	x	x
<i>Ivesia gordonii</i>	0	0	0	x	0	0	x	x
<i>Pentaphylloides floribunda</i>	0	0	0	0	x	0	x	0
<i>Potentilla arguta</i>	0	0	0	0	x	0	0	0
<i>Potentilla diversifolia</i>	0	0	x	x	x	x	0	x
<b><i>Potentilla gracilis</i></b>	x	0	x	0	x	x	x	0
<i>Potentilla hippiana</i>	0	0	0	0	0	0	x	x
<i>Potentilla nivea</i>	0	0	0	x	0	0	0	x
<b><i>Potentilla pulcherrima</i></b>	x	0	0	0	x	0	x	x
<i>Potentilla quinquefolia</i>	0	0	0	0	0	x	x	x
<i>Potentilla rubricaulis</i>	0	0	0	x	0	0	0	x
<i>Prunus virginiana</i>	0	0	0	0	x	0	0	0
<b><i>Rosa woodsii</i></b>	x	0	0	0	x	x	x	0
<i>Sibbaldia procumbens</i>	0	0	x	x	0	0	x	x
<b>Rubiaceae</b>								
<b><i>Galium boreale</i></b>	x	0	0	0	0	x	0	0
<i>Galium septentrionale</i>	0	0	0	0	x	0	0	0
<b>Salicaceae</b>								
<i>Salix arctica</i>	0	0	0	x	0	0	0	x
<i>Salix brachycarpa</i>	0	0	0	x	0	0	0	0
<i>Salix drummondiana</i>	0	0	0	0	0	0	x	x
<i>Salix geyeriana</i>	0	0	0	0	0	0	x	x
<b><i>Salix glauca</i></b>	0	0	x	0	x	0	0	0
<i>Salix nivalis</i>	0	0	0	0	0	0	x	0
<i>Salix planifolia</i>	0	0	0	0	0	0	0	0
<i>Salix scouleriana</i>	0	0	0	0	x	0	0	0
<b>Santalaceae</b>								
<i>Comandra umbellata</i>	0	0	0	0	x	0	0	0
<b>Saxifragaceae</b>								
<b><i>Heuchera parviflora</i></b>	x	0	0	0	0	x	0	0
<i>Micranthes odontoloma</i>	0	0	x	x	0	0	0	0
<i>Mitella stauropetala</i>	0	x	0	0	0	0	0	0
<i>Saxifraga bronchialis</i>	0	0	0	0	0	x	x	0
<i>Saxifraga occidentalis</i>	0	0	0	0	0	0	0	x
<i>Saxifraga rhomboidea</i>	0	0	0	0	0	0	0	x
<b>Scrophulariaceae</b>								

<i>Castilleja covilleana</i>	x	0	0	0	0	0	0	0
<i>Castilleja linariaefolia</i>	x	0	0	0	x	0	0	0
<i>Castilleja miniata*</i>	x	x	x	x	0	x	x	0
<i>Castilleja occidentalis*</i>	0	0	x	x	0	0	0	x
<i>Castilleja rhexifolia*</i>	x	x	x	x	0	x	x	0
<i>Castilleja spp.</i>	x	x	x	0	0	0	0	0
<i>Castilleja sulphurea *</i>	x	x	x	x	0	0	x	0
<i>Orthocarpus luteus</i>	x	0	0	0	x	0	0	0
<i>Pedicularis bracteosa*</i>	0	x	x	x	0	x	0	0
<i>Pedicularis groenlandica*</i>	0	x	x	x	0	0	x	0
<i>Pedicularis parryi</i>	0	0	0	x	0	0	0	0
<i>Pedicularis procera</i>	0	0	0	0	0	0	x	0
<i>Pedicularis racemosa</i>	0	x	0	0	0	x	0	0
<i>Veronica alpina</i>	0	0	0	0	0	x	x	0
<i>Veronica americana</i>	0	0	0	0	x	0	x	x
<i>Veronica nutans</i>	0	0	0	0	0	x	x	0
<b>Valerianaceae</b>								
<i>Valeriana acutiloba</i>	0	0	0	0	0	0	x	0
<i>Valeriana edulis</i>	0	0	0	0	x	x	x	x
<i>Valeriana occidentalis</i>								
<b>Violaceae</b>								
<i>Viola adunca</i>	0	0	0	0	x	x	x	0
<i>Viola canadensis</i>	0	0	0	0	0	x	0	0
<i>Viola nuttallii</i>	0	0	0	0	0	0	0	0
<i>Viola praemorsa</i>	0	0	0	0	x	x	0	0
<i>Viola renifolia</i>	0	0	0	0	0	x	0	0
<i>Viola repens</i>	0	0	0	0	0	0	x	0
<i>Viola rydbergii</i>	0	0	0	0	0	x	0	0

## Appendix B: Supplementary data

Table 1B. Summary of location (decimal degrees) and environmental variables for each site in the original (Langenheim, 1953) and new survey. Communities are abbreviated as follows: sagebrush (SB), spruce-fir (SF), upland-herbaceous (U), alpine (A).

Site #	Lat	Long	Aspect	Slope (%)	Elevation (m)	Substrate
SB1	38.7312	-106.8481	SW	7	2583	Sandstone
SB2	38.7903	-106.8698	SW	2.78	2598	Shale
SB3	38.7895	-106.8725	SW	5.18	2586	Alluvium
SB4	38.8211	-106.8689	SE	21.65	2909	Landslide
SB5	38.8215	-106.8693	SE	15.42	2683	Sandstone
SB6	38.8343	-106.8273	E	19.17	2838	Glacial Drift
SB7	38.8340	-106.8270	E	27.65	2878	Gravel
SB8	38.8343	-106.7726	SE	22.35	2876	Glacial Drift
SB9	38.8485	-106.1465	E	0.56	2439	Shale
SB10	38.8480	-106.9139	SE	1.66	2722	Sandstone
SB11	38.8524	-106.9135	SW	2.42	2735	Sandstone
SB12	38.8487	-106.9123	E	7.4	2712	Sandstone
SB13	38.8553	-106.8685	NW	7.46	3121	Gravel
SB14	38.8824	-106.8905	SE	13.34	2805	Sandstone
SB15	38.8997	-106.8781	S	10.07	2818	Sandstone
SB16	38.9007	-106.8780	SE	6.47	2237	Shale
SB17	38.9001	-106.8792	W	2.08	2791	Sandstone
SB18	38.9142	-106.8393	S	17.72	2975	Limestone
SB19	38.9141	-106.8424	S	20.23	2961	Granitoid
SB20	38.9240	-106.8549	SE	15.56	2873	Glacial Drift
SB21	38.9269	-106.8531	SE	9.66	2808	Landslide
SB22	38.6918	-106.8553	SW	0.41	2468	Sandstone
SB23	38.7048	-106.8493	W	13.39	2528	Sandstone
SB24	38.9664	-106.9708	SE	17.18	3074	Limestone
SB25	38.9708	-106.9666	SE	15.52	3080	Gravel
SB26	38.9718	-106.9624	W	22.81	3109	Rhyolite
SB27	38.9538	-106.9845	SW	4.02	2928	Limestone
SF1	38.9671	-106.9604	NW	16.07	3119	Sandstone
SF2	38.9709	-106.9589	W	14.65	3131	Sandstone
SF3	38.9719	-106.9579	W	24.9	3164	Sandstone
SF4	38.9743	-106.9745	W	29.51	3537	Sandstone
SF5	38.9946	-106.9890	W	15.59	3316	Shale
SF6	38.9929	-106.9910	W	14.15	3265	Shale
SF7	39.0037	-106.9956	W	12.52	3214	Sandstone
SF8	39.0041	-106.9985	W	7.81	3146	Glacial Drift
SF9	39.0090	-106.9991	S	7.74	3154	Glacial Drift
SF10	38.8462	-106.8546	W	7.31	3379	Sandstone
SF11	38.8450	-106.8821	SW	8.19	2038	Shale

SF12	38.8550	-106.8665	E	7.93	3105	Sandstone
SF13	38.9353	-106.7733	SW	21.82	3266	Sandstone
SF14	38.9385	-106.8043	SE	11.29	3486	Sandstone
SF15	38.9337	-106.8043	E	9.28	3397	Sandstone
SF16	38.9280	-106.8022	SW	1.06	3435	Sandstone
SF17	38.9298	-106.8046	E	4.22	3435	Sandstone
SF18	38.9278	-106.8018	NE	2.99	3435	Sandstone
SF19	38.9388	-106.8145	S	8.97	3082	Sandstone
SF20	38.9241	-106.8489	W	25.11	3041	Sandstone
SF21	38.9306	-106.8198	W	6.27	3041	Sandstone
SF22	38.9632	-106.8448	W	15.61	3323	Sandstone
SF23	38.9609	-106.8337	W	15.59	3519	Sandstone
SF24	38.9581	-106.8349	W	13.52	3506	Sandstone
SF25	38.9586	-106.8066	W	14.31	3485	Sandstone
SF26	38.9111	-106.8713	W	15.21	3154	Sandstone
SF27	38.9114	-106.8719	W	24.1	3165	Sandstone
SF28	38.9122	-106.8701	W	26.1	3218	Sandstone
SF29	38.9185	-106.8660	W	13.13	3272	Sandstone
SF30	38.9345	-106.8794	E	9.28	3052	Sandstone
SF31	38.9302	-106.8775	W	15.21	3001	Sandstone
SF32	38.9288	-106.9878	W	29.51	3113	Sandstone
U1	38.9639	-106.7658	S	9.23	3553	Sandstone
U2	38.9664	-106.7706	S	11.6	3523	Sandstone
U3	38.9638	-106.7720	SW	22.77	3611	Sandstone
U4	38.9607	-106.7746	E	21.65	3563	Sandstone
U5	38.9603	-106.7781	S	27.22	3537	Sandstone
U6	38.9609	-106.7850	SE	10.36	3615	Sandstone
U7	38.9595	-106.7867	SE	7.05	3657	Sandstone
U8	38.9561	-106.7872	E	9.98	3594	Sandstone
U9	38.9538	-106.7859	N	8.18	3618	Sandstone
U10	38.9508	-106.7847	E	7.24	3618	Sandstone
U11	38.9513	-106.7843	N	16.19	3671	Sandstone
U12	38.6170	-106.7847	NW	7.13	2936	Sandstone
U13	38.8644	-106.8321	SE	21.37	3461	Sandstone
U14	38.8654	-106.8327	S	24.81	3503	Sandstone
U15	38.8649	-106.8307	SE	24.37	3458	Sandstone
U16	38.8632	-106.8255	SE	32.26	3334	Sandstone
U17	38.9510	-106.8880	S	28.04	3440	Sandstone
U18	38.9512	-106.8836	S	29.06	3403	Sandstone
U19	38.9513	-106.8786	S	22.88	3331	Sandstone
U20	38.9501	-106.8782	S	22.83	3471	Sandstone
U21	38.9665	-106.8269	SW	28.02	3800	Plutonic
U22	38.9546	-106.8356	NE	26.89	3604	Sandstone
U23	38.9565	-106.8306	NW	14.4	3609	Sandstone
U24	38.9824	-106.8539	SW	23.35	3484	Plutonic

U25	38.9294	-106.9235	SE	2.4	3044	Shale
U26	38.9281	-106.9220	E	1.29	3037	Shale
U27	39.0098	-106.9911	S	26.66	3369	Glacial Drift
U28	38.9973	-106.9800	S	25.71	3374	Sandstone
U29	39.0236	-106.9861	SW	7.13	3515	Sandstone
U30	39.0226	-106.9836	SW	10.48	3367	Sandstone
U31	39.0215	-106.9795	SW	12.35	3509	Sandstone
A1	38.9720	-106.8195	N	22.48	3777	Sandstone
A2	38.9719	-106.7660	N	23.96	3775	Limestone
A3	38.9650	-106.7588	E	34.73	3834	Sandstone
A4	38.9595	-106.7541	SW	28.83	3871	Plutonic
A5	38.9480	-106.7539	E	32.66	3897	Plutonic
A6	38.9429	-106.7520	S	26.69	4003	Plutonic
A7	38.9498	-106.7529	E	27.56	3880	Plutonic
A8	38.9534	-106.7521	E	36.98	3894	Plutonic
A9	38.9662	-106.7917	N	28.14	3763	Sandstone
A10	38.9641	-106.7899	SE	31.76	3800	Sandstone
A11	38.9596	-106.7916	E	28.05	3778	Sandstone
A12	38.9570	-106.7912	NE	17.91	3831	Sandstone
A13	38.9555	-106.7899	E	21.9	3849	Sandstone
A14	38.9537	-106.7899	E	38.2	3815	Sandstone
A15	38.9515	-106.7899	E	31	3750	Sandstone
A16	38.9478	-106.7885	NE	27.55	3781	Sandstone
A17	38.9457	-106.7874	E	24.55	3830	Sandstone
A18	38.9420	-106.7871	E	27.37	3757	Sandstone
A19	38.8713	-106.8269	E	21.38	3435	Sandstone
A20	38.8766	-106.8281	E	23.69	3658	Sandstone
A21	38.8819	-106.8292	N	3.23	3662	Sandstone
A22	38.8853	-106.8355	E	15.34	3650	Sandstone
A23	38.8867	-106.8315	SW	5.98	3673	Sandstone
A24	38.8902	-106.8315	E	8.85	3666	Sandstone
A25	38.9797	-106.8225	N	20.59	3870	Plutonic
A26	38.9798	-106.8199	S	17.22	3897	Plutonic
A27	38.9667	-106.8241	E	27.69	3811	Sandstone
A28	38.9640	-106.8243	E	28.37	3829	Plutonic
A29	38.9535	-106.8261	SE	31.53	3739	Sandstone
A30	38.9458	-106.9124	S	30.28	3628	Sandstone
A31	38.9998	-106.9750	W	32.88	3872	Sandstone
A32	38.9961	-106.9656	W	28.64	3823	Sandstone
A33	38.9845	-106.9717	SE	38.26	3733	Sandstone
A34	38.9859	-106.9689	E	25.14	3694	Sandstone
A35	38.9848	-106.9699	E	34.92	3627	Sandstone

## Appendix C: Community Transect Data

Table 1C. Summarized transect data of plant counts (including bare ground) detected in the sagebrush community.

Species / Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
<i>Achillea millefolium</i>	0	4.7	0	7	9.7	0.7	0	6.7	6.7	0.3	13	8.3	1.3	6.3	10	2.3	8	5.3	5.3	5.3	2.7	1.3	0	0	0	0	1.3
<i>Achnatherum hymenoides</i>	0	0	0	2.7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7	4	1	0.7	0	0
<i>Aconitum columbianum</i>	0	0	0	1.3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Agastache urticifolia</i>	0	0.3	0	0	0	3.3	0	0	0	0.3	0	0	0	2	0	0	0	0	0	0	0	7.3	0	0	0	0	0
<i>Agoseris aurantiaca</i>	0	0	0	0	0	0	0	0	0	0	0	1.3	2	3.7	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Agoseris glauca</i>	2.3	4.3	0	0	0	4	0	0	0	0	0.7	0	0	13	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Allium geyeri</i>	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7
<i>Alopecurus aequalis</i>	0	1	0	0	0	0	0	3	3	5	15	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0
<i>Amelanchier alnifolia</i>	0.3	0	0	4.3	0.7	2	0.3	0	0	0	0	2	0.7	0	0	0	0	0	0	0	0	0	0	4.7	0	0	3.3
<i>Androsace septentrionalis</i>	0	3.7	0	0	1	0	0	0.7	0	0.3	0.3	0	0	0	1.3	4	0	0	0	0.3	0	0	0	0	0	0	0.3
<i>Angelica grayi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Antennaria pulcherrima</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Antennaria spp.</i>	2	0	0	0	0.7	0.3	0	0	0	1	0.7	0.3	0	0	0	0	0	0	0	0	0	0	0	1.7	0	0	0
<i>Arctostaphylos uva-ursi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
<i>Arenaria congesta</i>	0.7	0	0	0	0	0	0	1.3	0	0	1.3	2	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	6
<i>Arnica chamissonis</i>	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Artemisia dracunculul</i>	12	16	26	0	0	2	0	9	0	6.3	7.7	5.7	0	0	1	2.3	0.3	0.7	0.3	0	0	0	0	0	0	0	0.3
<i>Artemisia frigida</i>	0	0	5.3	11	8.3	30	0	0	0	0	0	0.3	0	0	49	0	0	0	0	0	0	0	0	0	0	0	0
<i>Artemisia ludoviciana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Artemisia tridentata</i>	0	0	12	16	2.3	40	10	20	0	25	23	10	17	0	0	23	54	54	42	25	0	43	27	0	0	0	1
<i>Astragalus americanus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	2.7
<i>Bare</i>	24	22	30	5.7	23	26	6.7	21	21	22	14	8.7	9	9	2.3	10	9	11	7.7	2.3	6	20	39	18	10	17	23
<i>Bistorta bistortoides</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
<i>Boechera drummondii</i>	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Boechera holboellii</i>	0	0	0	0.3	5	2	0	0	0	0	0	0.3	0.7	0	0	0	0	0	0	0	0	0	1.3	0	0	0	1
<i>Boechera stricta</i>	0	0	0.3	0	2.7	0	0	0	0	0	0	3.3	1.7	0.3	0	0.7	0.7	0.7	0.7	0.7	0	0	0	0	0	0	0
<i>Bromelica spectabilis</i>	0	0	0	0	0	0	0	0	0	0	0	1.7	0	1.3	0.7	1.7	0	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
<i>Bromis ineris</i>	0	0	4.3	0.7	5	2.7	0.7	0.3	0	0	0.7	3.3	1.3	0	1.7	1	0.7	1.3	1.3	0	0	0	0	0	0	0	0	0
<i>Bromopsis ciliata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	8.7	1.3	0	1	1.7	2	3.3	0	0	0	0	0	0	0	0
<i>Bromopsis richardsonii</i>	0	0	3.7	1.7	0.3	6.3	0	0	0	0	0	1.7	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bromus frondosus</i>	0	0	0	0	0	0	0.7	2	5	0	0	4	2.3	0.7	0.7	0.7	1.7	2.7	2.3	0.7	0	0.3	0	0	0	0	1	0
<i>Bromus tectorum</i>	0	0	0	0.3	0	0.7	0	0	0	0	0	0.7	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Calochortus gunnisonii</i>	0	0	0	1	0	0.3	0	0	0	0	0	1	2	0.7	3.7	5	0	0	0	0.3	1.3	0	0	0	0	0	0	0
<i>Campanula parryi</i>	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0.3	0.3	0.3	0.3	0.3	1	0	0	0	0	0	0	0	0
<i>Campanula rotundifolia</i>	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0.3	0.7	0	0	0	0.7	0	0	0	0	0	0	0	0.3
<i>Cardamine cordifolia</i>	0	0	0	3.3	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Carex spp.</i>	0	3.7	0.3	2.3	0.3	2.7	0	0	0	1	1.7	1.7	2.7	0	0	0	0.3	0.3	0.3	0	0	0	0.3	0	0	0	0	0
<i>Castilleja covilleana</i>	0	0	0	0.3	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0	0
<i>Castilleja linariaefolia</i>	1	2.7	0.7	5	4.7	4	0.7	0	1.7	0.7	0.7	1.7	0	0	1.7	3.3	0	0	2.7	0.3	2	2.7	0	0	1.7	0	0	
<i>Castilleja miniata</i>	0	0	0	0	0	3.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Castilleja rhexifolia</i>	0	0	0	0	0	0.7	0	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3
<i>Castilleja spp.</i>	0	1	0	0	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Castilleja sulphurea</i>	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chenopodium atrovirens</i>	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	10	4	0	0	0	0	0	0
<i>Chrysothamnus spp.</i>	0	0	0	0	2	0	0	0	0	2	0	0.7	3.3	3.7	1	0	2.7	1.7	2.3	3.7	10	2.7	7.7	0	0	0	0	0
<i>Cirsium arvense</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.3	0	0	0	0	0	0	0
<i>Collomia linearis</i>	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0.3	0	2	0	0	0	0.3	0.3	2.7	0	0	0	0	0	0
<i>Comandra umbellata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Crepsis tectorum</i>	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Delphinium barbeyi</i>	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	3.7	0	0	0	0	0	0	1
<i>Delphinium nelsonii</i>	0	0	0	0	0	0	0	0	2	0	0.7	0.7	0	0	0	0.3	0	0	0	0	0.3	0	0	0	0	0	0	1.7
<i>Delphinium nuttallii</i>	0	0	0	0	0	0	0	0	1	0	0.7	0	0	0.3	0	0	0	0	0	0	1	0	0	0	0	0	0	0.3
<i>Deschampsia caespitosa</i>	0.3	0	16	1.3	0	3	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	1.3
<i>Descurainia sophia</i>	0	0	1.7	3	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0.7
<i>Distegia involucrata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0
<i>Draba spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
<i>Dugaldia hoopsii</i>	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elymus glaucus</i>	0	0	0	8.7	0	13	0.3	0	1	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elymus scribneri</i>	0	0	0	0	0	0	0	0	2	2.7	0.7	4.3	6.3	9	1.3	8.3	11	9	9.7	7.3	12	0.7	0	0	0	0	0
<i>Elymus trachycaulus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0
<i>Equisteum hyemale</i>	0	0	0	2.7	0	2	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ericameria nauseosa</i>	0.7	0	0	6.7	0.7	7.7	1	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
<i>Ericameria spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erigeron caespitosus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
<i>Erigeron canus</i>	0	0	0	0	1.3	0	0	0	0	0	0	1.3	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erigeron glabellus</i>	2	0	0.7	2.7	0	0.3	0	0	1	1.7	0	1	0	1	0	0	0	0	0	0	0	0	0	1.3	0	0	2.7
<i>Erigeron speciosus</i>	0	0.7	0	6.3	1.7	13	2.3	0	0.3	4.3	2.3	1.3	7.7	11	2.3	7.3	0	0	0	1.7	7.7	3	0	0	0	0	0
<i>Erigeron subtrinervis</i>	0	0	0	0	5	0	0	0	0.3	0.3	0	0.3	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0.7
<i>Eriogonum umbellatum</i>	0	0	0	1.3	0	11	0	0	10	3.7	3	8.7	13	1	8.7	13	0	0	0	5.3	1	0.3	1.7	0	0	0	0
<i>Festuca idahoensis</i>	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	19	0.7	0	0	0	0	0	3
<i>Festuca thurberi</i>	0	0	0	0.3	0	29	5	0	9.3	1.3	11	14	30	13	0	16	0	0	0	34	5.3	0	0	0	0	0	0.7
<i>Fragaria virginiana</i>	0	0	0	2	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3
<i>Frasera speciosa</i>	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
<i>Galium boreale</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Galium septentrionale</i>	0	0	0	0	0	0	0	0	1.3	0	0	3	0	0	0	0.3	1.3	1.3	1.3	0.3	0	0.7	0	0	0	0	0
<i>Gayophytum diffusum</i>	0	0	0	0	0	0	0	0	0	0	0	0	1.3	5.3	0	0	0	0	0	0	0	0	0	0	0	0	3.3
<i>Geranium richardsonii</i>	0	0	0	0	0	0	0	0	0	0	0	0.3	1	0	0	0	0.3	0.3	0.3	0	0	0	0	0	0	0	0
<i>Geranium spp.</i>	0	0	0	0	0	0	0	0	1.3	3.7	1.7	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geranium viscosissimum</i>	0	0	0	0	0	0	0	0	1.3	3.7	1.7	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geum rossii</i>	0	0	0	0	0	0	0	0	0.3	0	0	1.3	0	0	0	0	2	2.7	1.7	0	0	0	0	0	0	0	0
<i>Hacklelia floribunda</i>	0	0.3	0.3	0	0.3	0.3	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Helianthella parryi</i>	0	2.7	0	0	0	0	0	0	0	0	0	0.3	0	4	0	0.3	0	0	0	0	3	0.7	0	0	0	0	0
<i>Helianthella quinquenervis</i>	0	0	0	0	0	0	0	0	0.3	0	0	0.3	0	0.3	0	0	0	0	0	0.3	11	1.3	0	0	0	0	0
<i>Heliomaris multiflora</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Heracleum maximum</i>	0	1	0	0.7	1.3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
<i>Heterotheca villosa</i>	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Heuchera parviflora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ipomopsis aggregata</i>	0	0	0	0	0.3	1	0	0	0	0.7	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	7.7
<i>Iris missouriensis</i>	0	0	0	3.3	3.7	0	0	0	0	0.7	0.3	3.7	0	0	0	0	0.3	0.3	0.3	0	0	0	0	0	0	0	0.3
<i>Juncus balticus</i>	0	4.3	0	0	4.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
<i>Juncus spp.</i>	1.7	0.7	0	0	4.3	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Juniperus communis</i>	0	0	0	0	1.7	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
<i>Koeleria macrantha</i>	3	3	0	1.3	1.7	1.3	0	0	0	0	0	1	1.3	3	2.3	0	4.7	4	5	0	3.7	0.7	3.7	0	0	0	0
<i>Lactuca serriola</i>	0	2.3	0	0	0	0	0	0	0	0	0	2.7	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	2
<i>Lathyrus leucanthus</i>	0	1	0	0.7	0.7	7.3	0.3	0	0	0.3	3	0.7	9	0	4.7	13	4.7	5.7	6	15	8	4.7	0	0	0	0	0
<i>Leymus innovatus</i>	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ligusticum porteri</i>	0	0.7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Linum lewisii</i>	0	0	0	0.3	0.3	2	0	0	0	0	0	0	0.7	4.7	0	0	0.7	0	0.3	11	0	0	0	0	0	0	4.3
<i>Lomatium dissectum</i>	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lupinus spp.</i>	1	7	0	0.7	0.3	0.3	0	0	3.7	11	3.7	0.3	3.7	12	12	12	7.3	6	5	0	1.3	3.7	0	0	0	0	0
<i>Mahonia repens</i>	0.3	0	0.3	1.7	0	9.3	0.3	0	1	0.3	0.7	2	1.3	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0
<i>Maianthemum stellatum</i>	0	0	0	0	2.7	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3
<i>Mertensia paniculata</i>	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
<i>Mertensia spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
<i>Orthocarpus luteus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pascopyrum smithii</i>	0	0	0	0	4.3	2.7	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3
<i>Paxistima myrsinites</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Penstemon caespitosus</i>	0.7	10	0.3	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	6
<i>Penstemon strictus</i>	0	0.3	0	0.3	0.3	1	0	0	0	0	0	2	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pentaphylloides floribunda</i>	0	0	0.3	0.3	0.7	0	0	0	0	0	2	8.3	0	0	0.3	0	0	0	0	0	0	0	0	5	0	0	1.3
<i>Phleum pratense</i>	0	0	0	0	7.7	0	0	0	0	2	0.3	1	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Phlox hoodii</i>	3.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	1
<i>Poa alpina</i>	0	0	0	0	4.7	0	0	0	0.3	1.7	0	1.3	0	5	0.3	1.3	0	0	0	0	0	0	1.7	0	0	0	0
<i>Poa fendleriana</i>	0	0	0	0	0	0	0	0	5	11	1	0	0	0	1.7	0.3	0	0	0	0	0	0.3	1.3	0	0	0	0.7

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
<i>Poa reflexa</i>	0	0	0	0	0.3	0	0	0	0	0.3	0	0	0	4	3	0	0.3	0.3	0.3	0	0	0	0	0	0	0	0	0
<i>Poa spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polygonum douglasii</i>	0	0	0	0.3	0	1	0	0	4.3	1	0.7	0	0	1	0	0	0	0	0	0	1	0.3	0	0	0	0	0	0
<i>Polygonum viviparum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Potentilla arguta</i>	0	0	0.3	0	1	0	0	0	0	0	0	0	0	0	0	0	0.7	0.7	0.7	0	0	0	0	0	0	0	0	0
<i>Potentilla diversifolia</i>	0	1.3	0.7	0	0.3	0	0	0	0	4	7	0	0	1	3.3	2.3	3.7	3.7	3.7	0.3	0	0.7	0	0	0	0	0	0
<i>Potentilla gracilis</i>	0	0	0	0	0	0	0	0	0.3	6	5.3	3.3	1.3	0	8.3	0	12	13	17	0.7	0.3	0	0	0	0	0	0	1.7
<i>Potentilla pulcherrima</i>	0	0	0	0	3	0	0	0	0.7	0	0.3	0	0	0	0	0	3	4.7	2.3	0	0	0	0	0	0	0	0	0
<i>Potentilla spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Prunus virginiana</i>	0	0	0	1.7	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pseudocymopterus montanus</i>	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ribes cereum</i>	0.3	0	0	0.3	0.3	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
<i>Ribes montigenum</i>	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rosa spp.</i>	0	0	0	0	2.3	1.7	0	0	0	2.7	4	3.3	0	0	0	0.3	0	0	0	0	0	0	0	0.3	0	0	0	0
<i>Rumex densiflorus</i>	0	0	0	0	1	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	1.3
<i>Salix drummondiana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
<i>Salix glauca</i>	0	0	0.7	0	1	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3
<i>Salix scouleriana</i>	0	0.7	0	0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sambucus racemosa</i>	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Scirpus tabernaemontani</i>	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sedum spp.</i>	0	6.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
<i>Senecio canus</i>	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Senecio integerrimus</i>	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0.7
<i>Senecio spp.</i>	1.7	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	1
<i>Solidago spp.</i>	0	0	0	0	2	2.3	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7
<i>Symphoricarpos spp.</i>	0	0	0	2.3	0.3	0	1.7	0	0.3	0	0	3.7	0	0	0	0	0	0	0	0	0	0.3	1	0	0	0	0	0
<i>Taraxacum officinale</i>	0	0	0	0	1.7	0	0	0	0.7	4.3	13	1.3	0	0	0.3	0.7	0	0	0	0	0	0	0	0	0	0	0	0.7
<i>Tetradymia canescens</i>	0	5	0	0	0.3	0	0	0	0.7	0.7	0	0	0	0	0	0	0.7	0	0	0	1	0.7	0	0	0	0	0	2.3
<i>Thalictrum fendleri</i>	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
<i>Thlaspi arvense</i>	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Tragopogon dubius</i>	0	0	0	0	0	0	0	0	0	0	0.3	0	2.3	0	0	2.3	4.3	3.3	0	0	0	0	0	0	0	0	0
<i>Trifolium repens</i>	0	0	0	0.3	0.7	0	0	0	0	0.7	1.3	0.3	0	0	0	0	0	0	0	0	0	0	1.7	0	0	0	0
<i>Vaccinium spp.</i>	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Valeriana edulis</i>	0	0	0	0	0	0	0	0	0	0	0.7	0.3	0	0	0	0.3	0.7	0.3	0	0	0	0	0	0	0	0	0
<i>Veratrum californicum</i>	0	0	0	0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Veronica americana</i>	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0	0	0.3
<i>Vicia americana</i>	3	0	0	1.3	0.3	0	0	0	0	0	1	3	0	2.3	6	3.3	0	0	0	4.3	0	0	0	0	0	0	2
<i>Viola adunca</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viola nuttallii</i>	0	0	0	0	0	0	0	0	0	0	0	3.3	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Virgulus campestris</i>	1.7	0	0	0	3.7	0.7	0	0	0.7	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0.3	0	0	0	0
<i>Wyethia amplexicaulis</i>	0	0	0	0	0	8.7	0.7	0	0	0	0	1	0	1.3	0.3	10	0.3	0.3	0.3	0	2	1.3	0	0	0	0	0.3
<i>Zigademus elegans</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3

Table 2C. Summarized transect data of plant counts (including bare ground) detected in the spruce-fir community.

Species / Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	25	26	27	28	29	30	31	32
<i>Achillea millefolium</i>	0	0.7	1	0	1.3	0.7	0	0	0.3	0	0.7	0	2	0	0	4.7	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0
<i>Aconitum columbianum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Agoseris glauca</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Androsace septentrionalis</i>	0	0	0	0	0	0.3	0	0	0	0	0	0	0.3	0.7	0	0.3	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Angelica grayi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Aquilegia caerulea</i>	0	2	0	0	0	0	0.3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0
<i>Aquilegia canadensis</i>	0	0.3	0.7	0	0	0	0	0	0	0	0	0	0	0.7	1.7	0	0.3	0.3	0	0.7	0.3	0	0	0	0	0	0	0	0	3	0
<i>Arctostaphylos uva-ursi</i>	0	0	0.3	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arenaria congesta</i>	0	0	0	0	1.3	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arnica cordifolia</i>	8.7	6.3	24	16	5.3	3.7	7	7.7	1.3	10	12	4.3	13	8	7.3	0	26	0	10	9.3	8.7	8	5.7	0	4.3	4.7	18	18	23	0	0
<i>Arnica latifolia</i>	0	0	0	0	4	0	0.3	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arnica mollis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
<i>Arnica parryi</i>	0	0	0.3	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Astragalus alpinus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bare</i>	44	9.3	26	0	25	26	41	43	27	29	15	26	17	29	30	14	14	18	31	30	29	27	31	13	27	25	19	9.3	18	21	13
<i>Bistorta bistortoides</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Boechera stricta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bromelica spectabilis</i>	0	0	0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bromis ineris</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bromopsis ciliata</i>	0	4	0	0	0	0	0	0	0	0	0	0.7	0	5	0	2.7	2	0	0	0	0	0	0	0	0	0	0.7	0	0	0	
<i>Bromopsis richardsonii</i>	0	3.3	2.7	2	0	0	0	0	0	0	0.3	0	6	0	0	0.7	0	0	2.7	0	0	0	0	1	0	0	0	0	0.3	1	0
<i>Caltha leptosepala</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	4.3	1.7	0	0	0	0	0	5.3	0	0
<i>Cardamine cordifolia</i>	2	0	0	0.3	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0.3	0.7	0	0	0	0	0	0	0	0
<i>Carex geyeri</i>	0	3	5	3.7	9.7	3.3	0.3	0	0.7	0.7	9.7	8	0	9.3	14	3	2.3	3.7	0	0	0	1.3	0	12	0	0	0	0	0	0	0
<i>Carex spp.</i>	1.3	0	0	0	0	0	0	0	0	0	0	0	7.7	0	0	0	0	0	2.3	3.3	2	0	1.3	0	0.7	7.3	7.3	0	0	4	0
<i>Castilleja miniata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Castilleja rhexifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Castilleja spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	25	26	27	28	29	30	31	32
<i>Castilleja sulphurea</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0
<i>Cirsium arvense</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0	0	0	0	0	0	0
<i>Cirsium hookerianum</i>	0	2.7	0.3	1	0	0	3.3	1	0.3	0	0	0	0	0	0	0.3	0.3	0	0	0	0	0	0	4.3	0	0	0.3	0	1.3	0	0
<i>Claytonia lanceolata</i>	0	0	0	0.7	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Collomia linearis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Delphinium barbeyi</i>	0.7	1.3	0	0	0	0	1.7	0.7	0	0	0	0	3.3	0	0.3	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Deschampsia caespitosa</i>	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Distegia involucrata</i>	0	0	0.3	0	0	0	0.7	0	1	0	0	0	1.7	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
<i>Draba spp.</i>	0.3	0	0	0	0	0	4	2.3	3.3	0	0	0	1.7	0.3	0	1.3	0.3	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Dugaldia hoopsii</i>	12	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Epilobium angustifolium</i>	2.7	0	2.7	2.3	2.3	0.7	1.7	0.3	5	0.7	1.7	0.7	0	2.7	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0
<i>Epilobium ciliatum</i>	0.7	6.3	0	0	0	0	0	0	5	0	0	1.3	0	0	1.3	0	1.3	0	0.3	0	0	0	0	0	0	0	1.3	0	0	0	0
<i>Equisetum arvense</i>	0.7	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Equisetum palustre</i>	1	0	0	0.7	0	0	0	0	5	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.3	0	0
<i>Erigeron elatior</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0.7	0	0	0	0	0.7	0	0
<i>Erigeron glabellus</i>	1	0	3.7	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0.7	2	0	0	0	0	0	0	0	0	0	0	3	0
<i>Erigeron glacialis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erigeron peregrinus</i>	0	0	0.3	0	9.3	4.3	0	0	0	0	0	0	0.3	0	0	1	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erigeron speciosus</i>	0.3	2	0	0	2	2.7	0.7	2	0	0	0	0	1.7	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0.3
<i>Erigeron subtrinervis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Eriogonum umbellatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erysimum capitatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erythronium grandiflorum</i>	0	2.3	0	0.3	0	0.3	3.7	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Festuca thurberi</i>	0	2	0	0.3	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Fragaria virginiana</i>	0	14	4.3	1.7	2.7	0.7	0	0	4	0.3	3.3	3	4.7	0	0.7	2.7	2	1.7	4.7	3	4.3	0.3	1.7	1.3	0	0	0	0	2.7	1.3	0
<i>Frasera speciosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0
<i>Galium boreale</i>	0	0	1.3	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gentianella acuta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gentianella amarella</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	25	26	27	28	29	30	31	32
<i>Geranium richardsonii</i>	0	0	0	6	4.7	1.3	3.3	1.3	1.3	0	0	0.7	0	2.7	0	0.7	0	0	1	2.7	4	0	0	1	0	0	0	0	2	0	0
<i>Geranium spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	1	0	3.3	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0
<i>Geranium viscosissimum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0
<i>Goodyera oblongifolia</i>	0.3	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Helianthella parryi</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Helianthella quinquenervis</i>	0	1	0	0	0	0	0	0	0	0	0	0	0.7	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Heracleum maximum</i>	0	5.3	0	1	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Heuchera parviflora</i>	0	4.3	0	0.7	0	0	0	0	0	0	0	0	3.3	0.7	3.7	0	1.3	0	0	0	0	3.3	1.3	0	0	0	0.7	0	0	0	0
<i>Hydrophyllum capitatum</i>	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Juniperus communis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	0	0	1	0	0	0
<i>Koeleria macrantha</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lathyrus lanszwertii</i>	0	0	0	0	0	0	4.7	2	0.3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0
<i>Lathyrus leucanthus</i>	0	2	0	1.7	11	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	4	0	0	0	0	0	0	0	1	0	0
<i>Ligularia amplexens var. Holmii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ligusticum porteri</i>	0	6.3	1.7	0	0	0	0	0	0.7	0.3	5	5.7	0	1	1.7	2	0	0	2.3	1.7	0	0	0	0	0	0	0	0	1	0.3	0
<i>Linum lewisii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lupinus parviflorus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	1	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lupinus spp.</i>	0	0	0	0	0	0	4.7	3	0.7	0.7	0.3	0.3	4	2	0	5.7	0.3	0.7	0.3	0	0	0	0	0	0	0	0	0	0	0	0
<i>Luzula parviflora</i>	0	0	0	0	0	0	0	0	0	0.3	1.3	0	3	1.3	3	0	0	0	0	0	0	0	0	0	0.7	0	0	0	1.3	0	0
<i>Machaeranthera bigelovii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0
<i>Mahonia repens</i>	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3	0	0	0	0
<i>Maianthemum stellatum</i>	0	1.7	0	0.3	0	0	5	2	1	0	0	0	1.7	0	0	0	0	0	2	0	0	0	0	1.7	0	0	0	0	0	0	0
<i>Mertensia ciliata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	3	0	0	0	0	0	4.7	2.7	1.7	0	0	0	0	0	0	0
<i>Mertensia fusiformis</i>	0	0	0	0	0	0	0	0	0.7	0	0	1.7	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0.7	0	0
<i>Mertensia lanceolata</i>	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mertensia paniculata</i>	0	9	0.3	1.7	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Micranthes odontoloma</i>	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Minuartia obtusiloba</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0
<i>Mitella stauropetala</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0.7	0	0	0	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	25	26	27	28	29	30	31	32		
<i>Moneses uniflora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.7	0	0	0	0	1.7	0	0	0		
<i>Noccaea montana</i>	1.3	0.3	0	0.3	0	0	0.7	1.3	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Oreochrysum parryi</i>	0.7	0	0	0.7	0	0	0	0	0	0	1	0	0	0	1	0	0.7	0	3.3	1.3	4.3	0	0	0	0.7	0	0	0	2	2.7	0		
<i>Orthilia secunda</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	1	0	0.3	1	0	0	0	0	0	0		
<i>Osmorhiza depauperata</i>	0	2.7	0.7	2.3	2	1.7	2.3	1.7	1.3	0.7	0	0	2	1	0	0	0.7	0	0	2	1.3	6.7	4	0	0	0	0	1	0	0.3	0		
<i>Oxypolis fendleri</i>	0	0	0	0.7	0	0	0	0	0	0	0.3	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0		
<i>Pascopyrum smithii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	
<i>Paxistima myrsinites</i>	13	0.3	12	2.3	1.3	0.7	0.3	0	3.3	0	1.3	0	0	0	0	0	0	0	6.7	0	0.3	0	0	0	2	8.3	5	0	2	0	0		
<i>Pedicularis bracteosa</i>	0	1	0.3	0	0	3.7	0	0	3.3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Pedicularis groenlandica</i>	0	0	0	1	0	0	0	0	2.3	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	
<i>Pedicularis racemosa</i>	0	0.3	1.7	0.3	2.3	3.7	0.3	0	0	1	0	0	0	1.3	2	0	0	1.7	0.3	0	1.7	4.3	0	0	1.7	0	0.3	0	1.3	0	0		
<i>Pedicularis spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Phleum commutatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Poa leptocoma</i>	0.3	4.7	0	0.7	5.3	3.3	2.7	1.7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Poa secunda</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Poa spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polemonium pulcherrimum</i>	0	4.3	0	0	1.3	0.3	0	1	1.3	0.3	0	0	4.7	0	4.7	0	0	0.3	0	0	0	0	0	2.7	0	0	0	0	0	0	0	0	
<i>Polemonium viscosum</i>	0	0	0	0	0	0	3.7	0	0	0	0	0	0	1	0	1.7	0	2	0	1	0.3	0	0	1.3	0	0	0	0	0	0	0	0	
<i>Potentilla diversifolia</i>	0.3	1.3	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Potentilla gracilis</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0
<i>Potentilla quinquefolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pseudocymopterus montanus</i>	0	0	0	1	2.7	0.7	4	5	0.7	0	1	0.3	0	2	1.3	0	0	0	0	0	0	0	13	7.3	0	0	0	0	0	1	0	0	0
<i>Pyrola chlorantha</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	2	0	0	0	0	0.3	0	0	0	0	0	0
<i>Pyrola rotundifolia ssp. Asarifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0.3	0	0	0	0	0	0
<i>Pyrola uniflora</i>	0	1.7	0.3	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ranunculus inamoenus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0
<i>Ribes montigenum</i>	0	7	0.7	0.3	4.7	2.3	2.3	1.3	6.3	1	0	0	2.7	0	7.3	0	5.3	3	0	0	0	0.7	1.7	2	0	0	0	0	0	0	0	0	0
<i>Ribes wolfii</i>	0	0	0	1	0	0	0	0	5.7	0	0	0	1.7	0	1.7	0	0	0	0	0	0	1.3	0.3	0	0	0	0	0	0	0	0	0	0
<i>Rosa spp.</i>	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0.7	0	0	0	0	0	1	2.7	4	0	0	0	0	0	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	25	26	27	28	29	30	31	32			
<i>Sambucus racemosa</i>	0	1	0	0	0	0	0	0	0.7	0	0.3	0	0	0.3	0	0	0.7	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0		
<i>Saxifraga bronchialis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.7	0	0	0	0	0	0	0	0	0		
<i>Senecio amplexans</i>	0	0	0	0	1.3	0	0.3	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Senecio crassulus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Senecio integerrimus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		
<i>Senecio serra</i>	0	0.3	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	2.7	0	0	0	0	0	0	0	0	0	0		
<i>Senecio spp.</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Senecio triangularis</i>	0	0	0	0	0	0.3	1	0.3	0	0	0	0	0.3	0	0	0	0.7	0	0	0	0	0.7	0	0	0	0	0	0	2	0	0	0		
<i>Shepherdia canadensis</i>	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.7	0	0	0		
<i>Solidago spp.</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0		
<i>Symphoricarpos spp.</i>	0	4	0	0	0	1.3	0.3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0	0	0	0	0		
<i>Taraxacum officinale</i>	0.7	4.3	1.3	0	0	0	0	0	0	0	0	0.3	0	0.3	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0.7	0	0	0		
<i>Thalictrum fendleri</i>	0	0	0	0	0	0	1.7	0.7	0	0	0.7	0	5.7	0.7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Thalictrum occidentale</i>	0	6.7	1.3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7	2.3	0	0	0	0	0	0	0	0	0	0	0	
<i>Thlaspi arvense</i>	0	1.3	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Trollius laxus</i>	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0.7	1.3	0	0	0	0	0	2.3	0	0	0	0	
<i>Vaccinium spp.</i>	52	0	27	6.7	32	48	0	0	9.3	29	35	22	0	14	5.3	0	13	12	19	0	0.3	26	11	0	30	22	30	32	0	45	52	0	0	
<i>Valeriana edulis</i>	0	0	0.3	7	0	0	0	0	0	0	0	0	1.7	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Veronica nutans</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vicia americana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0.3	0	0	0	0	
<i>Viola adunca</i>	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viola canadensis</i>	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1.7	0	0	0	0	
<i>Viola nuttallii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viola praemorsa</i>	0	4.3	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	1.3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viola renifolia</i>	0	6	1	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viola rydbergii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	2.3	0.3	0.3	0.7	0	0	0	0.3	0	0	0	0	
<i>Zigademus elegans</i>	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	

Table 3C. Summarized transect data of plant counts (including bare ground) detected in the upland-herbaceous community.

Species / Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
<i>Achillea millefolium</i>	5	1	2.3	5	3.7	1.7	1.7	0.3	0.7	0	0	9	10	5	3.7	3.7	8	8.7	2	6	0	0	0	4.3	5	2	2.3	1	2	1.3
<i>Aconitum columbianum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0.3
<i>Agastache urticifolia</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.3	0.7	0	0	0	0	0	0	0	0	0	0
<i>Agoseris aurantiaca</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0
<i>Agoseris glauca</i>	0	0	0	0	0	0	0	0	0.7	1.3	0	3.3	2.3	2.3	2	0.7	0	0	0	0.3	0	0	0	0	0	0.3	0	0	0	0
<i>Agrostis scabra</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Androsace septentrionalis</i>	1	0.3	0	0	0	0	0	0.7	0.7	1.3	0.3	1.3	1.3	0.7	0	0	0.7	1.3	0	0.7	1	0	2.7	1	0	0.7	1.3	1.3	1.3	1
<i>Aneome multifida ssp. Saxicola</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Antennaria spp.</i>	0	0	0	0	0	0	0	0	0	0	0.3	1.3	1.3	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Aquilegia caerulea</i>	0	0	0.3	0.3	0.3	0	0.3	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0.3	0
<i>Aquilegia canadensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arenaria congesta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arnica cordifolia</i>	0	0	1	0	0	0.3	0	0	0.7	0	0	0	0	0	0.7	1.3	0.7	2	0	1.3	0	0	1	0	0	0	0	0	1.3	0
<i>Arnica mollis</i>	1.7	3.7	0.7	0	0	0	0	2	0	0	0	2	2	0	3	4.7	0.3	1.3	0	3.3	0	0	0.7	0	0	0	0	0.3	0	0.3
<i>Arnica parryi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Artemisia ludoviciana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	1.7	0	0	0	0	0	0	0	0	0	0	0	0
<i>Artemisia scopulorum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	1	0.3	0	0	0	0	0	0	0
<i>Aster spp.</i>	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Astragalus alpinus</i>	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bare</i>	15	9.7	10	2.3	4.7	6.7	50	12	15	5.3	8.7	20	19	2.3	7	18	6	6.7	9.3	3.3	30	12	12	23	14	2.7	12	11	11	13
<i>Besseyia alpina</i>	0.7	0	0	0	0	1	0.7	0	5.3	0.7	3	0	0	0	0	0	0	0	0	0	0	0	2	0.3	0	0	0	0.3	0.7	0
<i>Bistorta bistortoides</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Boechera stricta</i>	0	0	0.7	0	0.3	1.7	0	2	0.7	3.3	0.7	0	0	0	0	0	0	0	0	0	0	0	1	0	2.3	0	0.7	0	1	0.7
<i>Bromelica spectabilis</i>	0	0	0	8.7	3.3	5.3	3.3	8.7	4.7	2	8.7	8.7	6.3	18	12	15	0	0	0	0	0	0	0	3.3	1.7	6.3	1.7	1.7	1.3	3.7
<i>Bromis inermis</i>	4	5	1.7	0	0	0	1.7	1.3	0	0	0	7	6.7	0	0.3	0.3	0.7	2	1	0	0	0	0	2.3	0	7.7	10	0	0	
<i>Bromopsis ciliata</i>	3.7	0	0	0.7	0.7	0	1.3	1	10	4.7	3.3	0	0	4.3	0	1	5.3	6	8.7	3.7	0	0	0	0	3.7	0	1.7	0	3	5
<i>Bromopsis richardsonii</i>	0	0	0	0	0	0	0	0	0	1	4	1.7	5	9	0	2.3	3.3	2.7	0.7	1.3	0	0	0	0.7	0	2.3	4	0	1.3	0
<i>Bromus tectorum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
<i>Calamagrostis purpurascens</i>	2	2.7	0.3	0	0.2	1	2.3	2.3	0	0.7	1	0.3	0.3	0	0	1.3	0	0	0	0	1	1.7	0.7	1.3	0	0.7	0.3	0	0	0	
<i>Calochortus gunnisonii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	
<i>Caltha leptosepala</i>	0	0	0	0	0	0	1.7	0.7	2	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Campanula parryi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Campanula rotundifolia</i>	0	0	0	0	0	0	0	6	0	0	2.7	0.3	1.3	0	1.3	0.7	5.7	4	0	3.7	0	0	0	0	0	0	0	0	0	0	
<i>Cardamine cordifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	
<i>Carex geyeri</i>	0	0	0	0	0	0	0	0	0	6.3	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	
<i>Carex siccata</i>	0	0.7	0	0	0	0	0	0	5.3	0	0	3.7	3.3	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3	1	1.7	0.3
<i>Carex spp.</i>	0	2.3	2.3	2	1.3	2.3	0	0	8	1.7	9	6	3.7	2	0	4.7	1.7	0.7	0	0	2.3	0.3	0	2	2.7	3.3	6.3	3.7	0	1	
<i>Castilleja linariaefolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Castilleja miniata</i>	0	0	0.7	2.7	2	1.3	0.3	0	0	0	0.3	0	0.3	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Castilleja occidentalis</i>	0	0	0	0	0	0	0	0	1	0.3	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Castilleja rhexifolia</i>	0.3	0	2	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3
<i>Castilleja spp.</i>	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.3
<i>Castilleja sulphurea</i>	0	2.3	1.7	1.3	0.3	3.7	1.3	3	0	0	4.7	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0.3	0.3	0	
<i>Cerastium beeringianum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0
<i>Chenopodium atrovirens</i>	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cirsium arvense</i>	0	0.7	0	0	0.7	1	0.7	0	1.3	0	0	0	0	1.7	0	0	0.3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cirsium hookerianum</i>	1.3	0	3	0	0	0	0	0	0	1.3	0	2	2	0.7	0	0	0	0	0	0	0	0	0	1	0	0	0	2.3	0.7	0	
<i>Cirsium spp.</i>	0	0	0	0	0.3	3	0.7	1	4.7	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
<i>Claytonia lanceolata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	1.7	0	0	0	0	0	0	1	0	0.3	
<i>Collomia linearis</i>	0	0	0	0	0	0	0	0	0.3	0	0	1.7	1.7	2.3	0	0	0	0	1.7	0	0	0	0	0	0	4	0	0	0	0	
<i>Crepsis tectorum</i>	0	0	0	0.3	0	0.3	0	0	0	0	0	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Delphinium barbeyi</i>	2.3	4	1.7	0	5	13	0	0.3	1.3	11	0.7	0	0	0	0	0	0	0	0.7	0	0	0	0.3	0.3	1.7	5.7	2	0	5	2.7	
<i>Delphinium nelsonii</i>	0	0	2	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0
<i>Descurainia sophia</i>	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0.7	0	0	0	0
<i>Draba spp.</i>	0	1	0	0	2	1	3.7	5	1.3	3.7	0	0	0	0	0	0	0.7	1.3	1.3	0	0.7	0	10	0.7	2.3	0	0.3	0	1.3	0	
<i>Dugaldia hoopsii</i>	0	0	0	5.7	0	5.3	0	0	0	0	1	0	0	0	0	2.3	3	0	0	0	0	0	0	0	0	1.3	0	3.3	4.7	5	
<i>Elymus scribneri</i>	1.3	5	0	0	0	0	0	0	0	0	0	0	0	1.3	0.3	0	1.7	2	0	1.7	0	0	0	0	0.3	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
<i>Elymus trachycaulus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0	0	2	0	5.3	0	2.3	0	15	
<i>Epilobium ciliatum</i>	0	1.3	2	0	1.7	11	0	2	0	0	0.3	5	5	0	0	0	0	0	0	0	0	0	0.3	0	0.3	0	1	0	0	2.7	
<i>Erigeron caespitosus</i>	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	
<i>Erigeron canus</i>	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0.3	0	
<i>Erigeron compositus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	1.7	2	0	0	0	0	0	0	0	
<i>Erigeron coulteri</i>	1.7	3	1	3	1	1.7	1.7	1.7	0.3	0	0	0.3	0	0	0	0	0	0	0.3	0	1.3	2.7	1	0.3	0	1	2	2	0	0	0
<i>Erigeron elatior</i>	0	0	0	0	0	0	0	0	0.3	0	0	0	0	1	0	0	0	0	0	0	0	0.7	0	2	0	0	0	0.3	0	0	0
<i>Erigeron formosissimus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0
<i>Erigeron glabellus</i>	0	0	0	0	0	0	0	0	1	0.7	2.3	5	5	1.7	0	0	6.3	2	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erigeron glacialis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1.3	0.7	0	0	0	1.3	
<i>Erigeron leiomerus</i>	0	0	0	0.3	0	0	0.3	0	4	0	1	1	1	0	1.3	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erigeron simplex</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0.3	0	0	0	0	0	0	0	0	0	0
<i>Erigeron speciosus</i>	3.7	3.7	1.3	1	1.7	1.3	0	0	0	0	1.7	0	0	4.7	1.7	0	8	8.7	0.7	4	0	0	0	1.3	0	4	0	0	0	0	
<i>Erigeron subtrinervis</i>	0	1	0.3	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Eriogonum umbellatum</i>	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	1.3	2.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erythronium grandiflorum</i>	0	0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0.3	9.7	0	0	0	0	0	0	1.7
<i>Festuca idahoensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Festuca ovina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Festuca thurberi</i>	0	4.3	2	5	2	7.3	0.3	1	0	0	0	0	0	1.7	0	0.3	21	18	0	14	0	0	0	3	2.7	0	4.3	0	0	3.3	
<i>Fragaria virginiana</i>	8.3	6	7.7	3.7	11	8	0.3	1.7	7.7	0.7	8.7	10	10	3.3	0.7	0.3	1.7	2.7	0	3.3	0	0	1.3	16	0	0	2	1	0	1.3	
<i>Frasera speciosa</i>	0.3	0.3	2.7	0.7	0.7	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
<i>Galium septentrionale</i>	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0.3	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0.3	0	0	0
<i>Gentianella amarella</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0
<i>Gentianopsis barbellata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geranium viscosissimum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geranium spp.</i>	2	1.7	4.7	1	1.7	0	0	0	0	0	0	2.3	2.3	0.3	0	0	0	0	12	0	0	0	0	2.7	0	0	0	0	0.3	0	
<i>Geum rossii</i>	0	0	0	0	0	0	2.3	5	6.3	3	1.3	0.3	0.3	2	0	0	0	0	0	0	0	0	1	0	3	0.7	0	0	0	0	
<i>Hedysarum alpinum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	20	0	0	0	0	0	0	1	0	0	0	0	
<i>Helianthella parryi</i>	0	0	0.3	1	0.7	0	0	0	0	0	0	0	0	0.7	0.7	0	4	3.3	1	0	0	0	0	0	0	0	0	0	0	0	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
<i>Helianthella quinquenervis</i>	1.7	1.3	4.7	5	7.7	2.7	0.3	0.3	0	0	4.3	0.7	0.7	2.7	1.3	4.3	0	0	0	8	0	0	0	0	0	3.7	8	0	0	8.7	
<i>Heliomaris grandifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	1.3	0	0	0	0	
<i>Heterotheca villosa</i>	3.3	1	1.7	0	2	0	0.3	0	0	0	0	0	0	0	3	9.7	6.7	5	2.7	9	0	0	0	0	0	0	0	0	0	0	
<i>Heuchera parviflora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0.3	0	0	1.7	0	0
<i>Hydrophyllum capitatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	1.3	
<i>Ipomopsis aggregata</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.3	1	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0.3
<i>Iris missouriensis</i>	0.7	1	2.3	2.7	1	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
<i>Ivesia gordonii</i>	0	0	0	0.7	0	0	4	0	0.3	0	0	0	0	0	0	0.3	0.3	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0
<i>Juncus spp.</i>	0	0	0	0	0	0	0	0	1.7	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0
<i>Juniperus communis</i>	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0
<i>Koeleria macrantha</i>	0	0	0	0	0	0.3	0	0	0	0	0	2.7	2.7	0	0	0	2.7	2	0	2	0	0	0	0	0	0	3	0	0	0	0
<i>Lathyrus leucanthus</i>	3.7	3.7	3.3	5.3	0	0.3	2	0.7	0	0	0.7	0	0	10	0	0	0	0	0	0	3.3	0	0	0	0	0	0	0	0	0	0
<i>Ligularia soldanella</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	10	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ligusticum porteri</i>	0	0	0	5.3	32	16	0	0	0	0	0	6	6	1.7	0.7	0.7	0	0	0	12	0	0	4.3	0.3	0	17	8	0	1	21	
<i>Linum lewisii</i>	0	0	0	0	0	0	0	0	0	0	0	4.3	4.3	0.7	0	4.3	9.3	8.7	0.3	2	0	0	0	0	0	3.3	0	0	0	0	
<i>Lloydia serotina</i>	0.7	1	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	4.3	3	0	0	0	0	0	0	0	
<i>Lupinus parviflorus</i>	0	0	0	1	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lupinus spp.</i>	0	0	0	4.7	7.3	7	1	3	8	4.3	14	0.3	0.3	2.3	0	4	0	0	0	11	0	0	0	0	0	0	5.3	0	1	1	
<i>Mertensia ciliata</i>	1.7	0.7	1	0	4.7	10	0	7	0.7	0.7	0.7	0.3	0.3	0	0	0	0.7	0	0	0	0.3	0	0	0	1.3	0	1.3	14	7.3	0.7	
<i>Mertensia fusiformis</i>	0	0	0	0	0	1.3	0	0.7	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	
<i>Mertensia spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Noccaea montana</i>	0	0	0	0.7	0.3	0.3	0	2.3	0	0.3	1.7	0	0	0	0	0	0	0	0	0.3	0	0	4.3	1	3	0	0.3	4.3	0	1.3	
<i>Oreochrysum parryi</i>	0	0.3	0	1	0.7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Osmorhiza occidentalis</i>	0	0.7	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	
<i>Oxypolis fendleri</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Oxytropis campestris</i>	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Oxytropis deflexa var. sericea</i>	0.7	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	1.7	1.7	0	0	0	0	0	0	0	
<i>Oxytropis lambertii</i>	0	1.3	0.3	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	
<i>Oxytropis podocarpa</i>	2	0	2.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.7	4	0	0	0	0	0	0	0	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
<i>Packera cana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Pascopyrum smithii</i>	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Pedicularis bracteosa</i>	0	0.3	0	0	0	1	0.3	0	1	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	
<i>Pedicularis groenlandica</i>	0	0	0	0	0	0.3	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Pedicularis racemosa</i>	0	0	0	0	0	0.3	0	0	0	0	0	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Pedicularis spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Penstemon strictus</i>	0	0	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0.3	0	0	
<i>Pentaphylloides floribunda</i>	0.7	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0.7	1	1.7	0	0	0	0	0	0	0	0	0.7	0	0.3	0	0
<i>Phacelia sericea</i>	0	2.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	
<i>Phleum commutatum</i>	0	0	0	0	0	0	0	0	0.3	1	0	0.7	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7	0.7	0	0
<i>Phlox hoodii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	1	0	0	0	0	0	
<i>Poa alpina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	
<i>Poa fendleriana</i>	2	1	0	0	0	0	0	0	0	0	1.3	1	1	0	0	0	0	0	0	0	1.7	0.7	1.3	0	0.7	0	0	0	0	0	
<i>Poa leptocoma</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.7	0	0	0	0	
<i>Poa reflexa</i>	0	0	0	0	0	0	0	0	0	0	0	0.7	0.7	0.3	0	0	0	0	0	0	0	0	0	0.7	2.7	0	1.7	0	0	0	
<i>Poa spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Polemonium viscosum</i>	0	0	0	0	0	0	0	0	0	0	0	1.7	1.7	2	0.7	0	0	0	0	0	0	3	0.7	0.3	0	0	0	0	0	0.3	0
<i>Polygonum douglasii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	
<i>Potentilla gracilis</i>	3.7	9	2	0	0	0.7	0	0	0	0	0	2.3	2.3	0.7	0	0	0	0	2.7	0	2.3	1	2.7	18	0	0	0	1.3	0	9.3	
<i>Potentilla hippiana</i>	1.3	1.3	1	0.7	0	0	0	0	0	0	0	0	1.3	3.7	1	0.3	0	0	1.7	0	0	0	0	4	0	3.3	3.3	1	0	0	
<i>Potentilla pulcherrima</i>	0	0	1.7	0	0	0	2.7	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Potentilla quinquefolia</i>	0	0	0	22	6.3	3	0.3	1.7	3.3	0.7	8	0	0	0	0	2.3	2.7	3.7	0	4.3	0	0	0.7	0	0	0	0	0	0	0	
<i>Potentilla spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Pseudocymopterus montanus</i>	3	0.3	1	2	1	3	7	0.3	1.7	0.3	4	2.3	2.3	1	0	0	0	0	0	0	0	0	0	2.3	2	0	0.3	0.3	0	0.7	
<i>Pyrola uniflora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Ranunculus inamoenus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1.7	0	0	
<i>Rhodiola integrifolia</i>	0.7	0.3	0.7	0	0.7	1	0	0.3	0	0.7	0.7	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0.3	1.7	0	0.3	
<i>Ribes cereum</i>	0.3	0	1.7	0	1	0.3	0	0	0	0	0	1	1	1	0.3	0	0	0	0.3	0.3	0	0	4	0	0	0	0	1.3	1	0	
<i>Ribes spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2.7	0	0	0	



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
<i>Valeriana acutiloba</i>	0	2	0.3	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
<i>Valeriana edulis</i>	7	6.3	5.7	0	0	17	1.7	0.3	0	0.7	0.7	0	0	5.7	0	0	0	0	0	0	0	0	1.7	0	0	0.7	0	0.7	0	0
<i>Valeriana occidentalis</i>	0	6.3	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
<i>Veratrum californicum</i>	0	0	0	0	1.7	0	0	0	0	0	0	1.7	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1.3
<i>Veronica americana</i>	0	0	0	0.3	0	0	0	0.3	1	1.7	0	1	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Veronica nutans</i>	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vicia americana</i>	0	0	0	0	0	0	0.7	0	0	0	0	0	0	13	0	6.3	0	0	0	0	0.3	0	0	1.7	0	0	0	2	0.3	0
<i>Viola adunca</i>	0	0	0	0	0	0	0	0	0.7	0	0	0.3	0.3	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viola nuttallii</i>	0	0	0	0	0	0	0	0	1	0.3	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0.3	0.7	1.7	0	0.7
<i>Viola repens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.7	0	0.7	0	0	0	0.3
<i>Wyethia amplexicaulis</i>	0	0	0	0	0	0	0	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.7	0	0	0	0	0	0
<i>Zigademus elegans</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0



	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
<i>Carex siccata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	0.3	0	0	0	0	0	2	0.3	1.7	0	0.7	0	
<i>Castilleja miniata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Castilleja occidentalis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Castilleja rhexifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	
<i>Castilleja sulphurea</i>	0	0	0	0	0	2.7	0.7	0.3	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Cerastium beeringianum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	6.3	0	0	0	0	0	
<i>Chaenactis alpina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0		
<i>Circium sp.</i>	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	1	
<i>Claytonia megarhiza</i>	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Draba albertina</i>	1.3	0	0	3	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	2	1.3	1.3	1	0	2.3	0	0	0	0	0.3	0		
<i>Draba aurea</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	2.3	0.7	0	0.7	0	0	0	0	0	0	0	0		
<i>Draba spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Dryas octopetala</i>	0	3	0.3	0	0	2	0	0	1	7.3	0	0	0	0	10	1.7	0	0	0	0	0	0	0	4.3	0	0	0	3.7	0	0	0	0	0	
<i>Dugaldia hoopesii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0.3	0	0	0	
<i>Eleocharis palustris</i>	0	0	2.3	0	1.3	1.7	10	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	1.7	0	1.7	0	0	
<i>Elymus glaucus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Elymus scribneri</i>	3	0	0	6.3	6	0	0	2.7	11	1.7	6.7	5.3	1.3	5	2.7	0	0	0	0	1	3.3	2.7	0	0	0	0	2.3	0	3.7	2.7	3.3	0	0	
<i>Elymus trachycaulus</i>	2.3	0	8.7	0	4.7	9	0	0.3	6.3	3	0.3	3	18	8.3	3	0	1.7	0	0	0	0	0	0	0	0	0	0	4	2.7	0.3	0	0	0	
<i>Erigeron compositus</i>	1	0	0.3	0	0	0.3	0	1.3	7.7	1	1.3	2.3	0	0	11	0	0	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0	1.7	1.3
<i>Erigeron glabellus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Erigeron glacialis</i>	0	6.7	2	2	0	0	0	0	0	0	0	0	0	0	0.7	0.3	0	0	0	0	6.7	2.7	0	0	0	0	0	0	0	0	0.3	1		
<i>Erigeron grandiflorus</i>	0	0	0	0	1.3	0	0	0	0.3	0	0	0	0	0	0	0	1.7	0.7	0	0	0	0	0	0	2.7	0	0	0	0	0	0	0	0	
<i>Erigeron leiomerus</i>	0	2	0.7	0	3	0.7	0	0.7	1.3	2.3	0	0.7	0	0	0	0	0.7	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0.7	0	
<i>Erigeron peregrinus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Erigeron simplex</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	
<i>Erigeron speciosus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Eriogonum umbellatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Erysimum capitatum</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Festuca idahoensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
<i>Festuca thurberi</i>	0	0	0	0	0	0	0	0	0.3	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	1.7	0	0.3	2.3	1.7	0	0	
<i>Fragaria virginiana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0
<i>Galium septentrionale</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gayophytum diffusum ssp. Parviflorum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geranium viscosissium</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geum rossii</i>	0.3	4	6.7	0	0	0	0	0.7	4.3	2	0	0	0	0.3	0	0.7	0	0	0	0.3	0	1.7	0	0	2.3	1.3	16	18	0	0	0	1.3	0	
<i>Goodyera oblongifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.7	0	0	0	0	0	0	0	0	0	0
<i>Helianthella quinquenervis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ipomopsis aggregata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
<i>Iris missouriensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Juncus spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Koeleria macrantha</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
<i>Lesquerella alpina</i>	0	0	0	0	0	0	0.3	0	0.3	0	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ligularia holmii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lloydia serotina</i>	0	1.3	0	0	0.7	0	0.7	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.7	1	0.7	3.3	0	0	0	1.3	0	
<i>Lupinus argenteus</i>	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0.7	0	0	0	0	0	0	0	1.3	0	0	0	0	0
<i>Lupinus parviflorus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lupinus sericeus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lupinus spp.</i>	0	0.3	0.2	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0.4	0	0.3	0	0	
<i>Mertensia fusiformis</i>	0	0.3	2.3	1.3	1.3	0	0	1	0	0	1.3	0.3	0.7	1	0	0	0	0	0	0	0	0	0	1	3.7	1.7	0	1.3	0	0	0	0.7	0	
<i>Mertensia spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Minuartia obtusiloba</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	5	0	0	0	0	0	
<i>Minuartia rubella</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0.7	2.3	0	0	0	0	1.3	0	
<i>Myosotis asiatica</i>	0	0	0.3	2.3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	1	0	0	1	0	0	0.13	0	0	0	
<i>Oreochrysum parryi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Oreoxis alpina</i>	0	0	0	0	0	0.7	2.3	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0.3	
<i>Orthilia secunda</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Orthocarpus luteus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34			
<i>Osmorhiza berteroi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	
<i>Osmorhiza depauperata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Oxypolis fendleri</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Oxytropis deflexa var. sericea</i>	0.3	1	0.3	1.3	0	0	0	2	2	1.7	1	10.7	1	3	1	1	0	0	0	0	0	0	2.7	0	1.7	2.3	0	0	10.7	1.3	0.30.3					
<i>Oxytropis podocarpa</i>	0	0	0	0	0	0	0	0	1.6	1	0.4	0.6	1.1	0.7	1.2	0.2	0.1	0	0	0	0	0	1.1	0	0	0.8	0	0	0.3	0.7	0.8	00.4				
<i>Packera cana</i>	0.7	2	0	0.7	3.3	1.3	1.3	1.3	2.3	0	1.7	2.3	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Packera wernerifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	1	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1.3	
<i>Pedicularis bracteosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0
<i>Pedicularis groenlandica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0
<i>Pedicularis parryi</i>	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0.3	0	0	0	
<i>Penstemon whippleanus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0.7	0	0.7	0	0	0	0	
<i>Pentaphylloides floribunda</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0
<i>Phacelia sericea</i>	0	1.3	0	0	0	0	0	0	0	0	0	0.3	0.3	0	0.7	0	0	0	0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0	0	
<i>Phleum pratense</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Phlox hoodii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Poa spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polemonium viscosum</i>	0	2.3	1	1.7	4.7	1.7	0	0	0	0	0.3	0	0	0	0	0.3	0	0	0	0	0	0	0	3.3	5	3.7	0	1.7	0	0	0	0	0	0	0	0
<i>Polygonum douglasii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Potentilla diversifolia</i>	1	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1.3	0	7	0	0	1.3	1.3	0	0	0	0	0	0	0	0	0
<i>Potentilla hippiana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3.3	2.7	5.3	4.7	0	0	0	0	0	0	0	0	0	0.3	0	0
<i>Potentilla nivea</i>	0.3	0.7	0	0	0	0	0	0.7	0	0.7	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Potentilla pulcherrima</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.7	3.3	8.3	3.7	0	0	0	0	0	0	0	0
<i>Potentilla quinquefolia</i>	0	5.7	6.3	5.7	0	0	0	0	4.3	0	0.7	2.7	1	1.3	5.3	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Potentilla spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pseudocymopterus montanus</i>	0	0	1.3	0	0	0	0	0	1	1	0	1	0	0	0	0	3	0	0	0	0.7	1	0	1.7	0	0	0	1.7	1.7	0.7	2.7	1	1	1	1	1
<i>Pulsatilla patens subspecies multifida</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0
<i>Rhodiola integrifolia</i>	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0.3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34			
<i>Rumex densiflorus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Salix arctica</i>	0.3	1.7	7.3	4.3	4	1	0.3	2.3	0	4.3	2.7	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	3.3	0	5	0	0	0	5.7	0		
<i>Salix brachycarpa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Salix drummondiana</i>	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	
<i>Salix geyeriana</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Salix planifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	
<i>Saxifraga occidentalis</i>	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
<i>Saxifraga rhomboidea</i>	0	3	3	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	3.3	0	0	0	0	1	0	0	0	0	2.7	3.3	0	0.7	0	0		
<i>Sedum lanceolatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	2.7	0.7	1.7	0	0	0	0	0	1.3	2.7	0.7	0	0	0	0		
<i>Sedum stenopetalum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Senecio amplexans</i>	0	0	0	0	0	0	0	0.3	1.7	0	1	2.7	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Senecio integerrimus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	1
<i>Senecio wootonii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sibbaldia procumbens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0.3	0
<i>Silene acaulis</i>	0	0.7	2.3	4.3	0	0	3	0	2.7	1	1	1	1	1.7	0	0.3	0	0	0	4	8	4	0	0	1	2	3.3	0	0	0	0	0	0	0	0.7	
<i>Solidago simplex</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	0	0.3	2.7	1.3	2	0	0	0	0	0	1	1	1	0	0	0		
<i>Stipa comata</i>	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	1	0	0	0	0	0	0	0	0	0	0	0	
<i>Symphoricarpos rotundifolius</i>	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Taraxcum officinale</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0
<i>Tetradymia canescens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trifolium dasyphyllum</i>	0	0.6	0.4	0.1	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.4	0	0	0	0.7	0.7	1.6	3.7	1	0	0.8	0	0	0	
<i>Trifolium parryi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	
<i>Trifolium repens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trollius laxus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vaccinium scoparium</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
<i>Vaccinium spp.</i>	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vaccinium uliginosum</i>	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Valeriana edulis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
<i>Veronica americana</i>	0	0.7	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	3	0	0	0	0	0.7	0
<i>Zigademus elegans</i>	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0