

PLANT COMMUNITY COMPOSITION WITH RESPECT TO SPECIES RICHNESS ALONG AN ALTITUDINAL GRADIENT IN GUNNISON COUNTY, CO

Josh Davendonis, Beloit College

Structured Undergraduate Research Program, Field Botany Course

Rocky Mountain Biological Laboratory

Introduction

Due to their extreme nature, alpine environments provide ideal locations to study the effects of extreme conditions on organisms (Douglas and Bliss 1977). Specifically, the effect of altitude and the associated climate differences as altitude increases dramatically alters plant species composition with respect to montane forests (Allen et al. 1991). While this observation is well established in forests, altitudinal effects on plant species composition in dry meadows is the focus of this project.

Langenheim (1962) performed extensive surveys of the vegetation in and around the Crested Butte area in an attempt better understand the local plant communities. In these surveys, Langenheim notes that varying exposure to solar radiation resulted in differing community structures on various mountain slopes. Furthermore, she states that historical and present day human activity in this area has the potential to alter habitat structure. Her identification of discontinuous community types across meadows occurring at different altitudes supports the hypothesis that altitude has an effect on species richness.

The Gothic town site, the location of the Rocky Mountain Biological Laboratory (RMBL), is located at approximately 9500' above sea level. At this subalpine altitude, there is a staggering amount of plant diversity in the meadows and hill slopes in and around the town site (*personal observation*). On Field Botany's first field excursion up towards Queen's Basin, our class witnessed different populations of flowering plants, coniferous forests, wet and dry meadows, and isolated patches of plant species rarely

found elsewhere in the state. This demonstrates that at more extreme elevations, plant diversity, though phenologically different than at lower locations, is maintained. However, we are interested in determining if community structure changes along an altitudinal gradient with respect to species richness. To further this goal, we investigated species/area relationships along an altitudinal gradient as well.

Based on Langenheim's (1962) wide-ranging work, as well as our own personal observations, we predict that as elevation increases, species richness will decrease as growing conditions, such as light intensity, growing season, and temperature will fall beyond many plant species tolerance zones.

Methods

Study sites

We measured species diversity at four different locations at varying locations and altitudes in Gunnison County, Colorado, USA. The plot locations are listed in Table 1 below.

Locality	Altitude	Latitude	Longitude
Friends Pond, Gothic Research Natural Area, Colorado, USA	3108m	N 39° 00'	W 107°
Coal Creek, Colorado, USA	1956m	N 38 ° 33.025'	W 107 ° 20.090'
Adobe Hills, Colorado, USA	1726m	N 38 ° 46.875'	W 107 ° 39.113'
Virginia Basin, Colorado, USA	3413m	N 38°52.414	W 106°57.220

Table 1: Plot locations.

Plot Design and Species Collection

Using a compass and measuring tape, we established nested plots up to 50 x 50 m in the meadow at Friends Pond. In the interests of time and efficiency, we set up nested plots up to 20 x 20 m in the meadows at Adobe Hills and Coal Creek. Additionally, the meadow at Virginia Basin consisted of a single, non-nested 20 x 20 m plot. We marked the corners of the plots with yellow flags and collected voucher

specimens of every plant observed inside the square plot. Plants present along the edges of the plot with >50% of biomass inside the plot were considered inside the plot and also collected.

Voucher specimens from Virginia Basin were pressed at the time of collection and later identified at RMBL through the use of Weber and Wittman's Colorado Flora: Western Slope, Third Edition. Additional identification was supplemented by Darrow's Wild about Wildflowers, Second Edition as well as RMBL Herbarium specimens. A wooden press, newspaper, and cardboard were used for proper preservation of the specimens. Adobe Hills, Coal Creek, and Friends Pond specimens were kept damp in newspaper and plastic bag until pressed at a later time.

Analysis

To examine the plant community structure, we generated log species vs. log area curves for the Friends Pond, Adobe Hills, Coal Creek plots in order to determine to what extent species/area relationships differed between locations. We used the slope and intercept values of these curves to satisfy the equation $S=cA^z$, where S is the total number of species, A is the area, and c and z are solvable constants. This power function describes species-area relationships.

Species richness at each altitudinal plot was correlated with elevation as well as mean annual rainfall. Pairwise community similarities were then calculated by taking the number of shared species of two plots and dividing this value by the total number of combined species of the two plots of interest. The effects of altitude, mean annual rainfall, as well as geographic distance between plots on community composition were further evaluated through the use of the Mantel test (Mantel Nonparametric Test Calculator Version 2.00 for Windows 1997-2000. Written by A. Liedloff).

Results

We encountered a total of 129 species across the four plots, with the families Asteraceae, Brassicaceae, and Poaceae containing the highest numbers of specimens (see Appendix for more detailed information).

Species-Area Relationships

From the nested plot data gathered at Friends Pond, Adobe Hills, and Coal Creek, we generated log (number of species) vs. log (area m²) curves (Figure 1). We then used the slope and y-intercepts of these curves, displayed in Table 1, to calculate the constants c and z of the power function $S=cA^z$ to generate predicted species-area relationship curves (Figure 2).

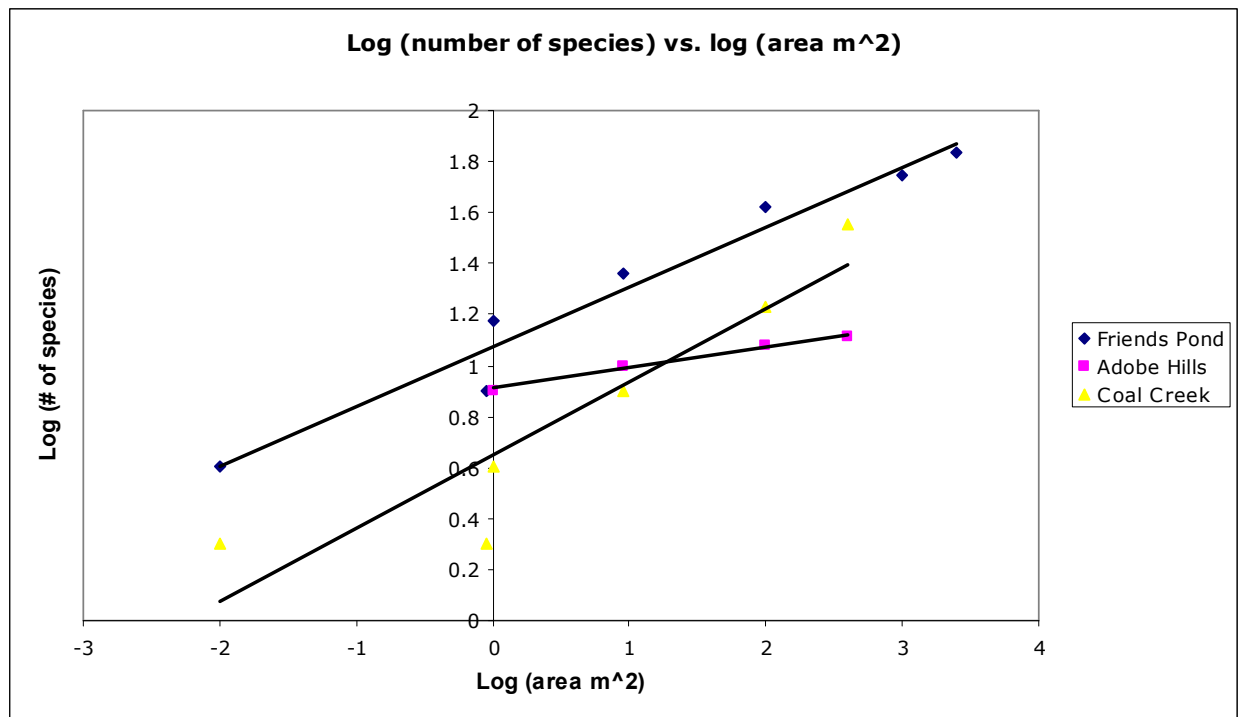


Figure 1: Log (number of species) vs. Log (area m²) data with fitted linear curves.

Plot	S	c	z
Friends Pond	70	11.9179072	0.2344
Coal Creek	36	2.93359394	0.4094
Adobe Hills	13	8.15642787	0.081

Table 2: Constants c and z derived from the log (number of species) vs. log (area m²) curves.

The species-area relationship curves displayed below in Figure 2 predict the number of species present as plot area increases. As the curves approach a horizontal asymptote, the number of new species encountered diminishes. This indicates how large of an area a sampling plot must be in order to accurately survey the assemblage of plant species present in a specific continuous habitat.

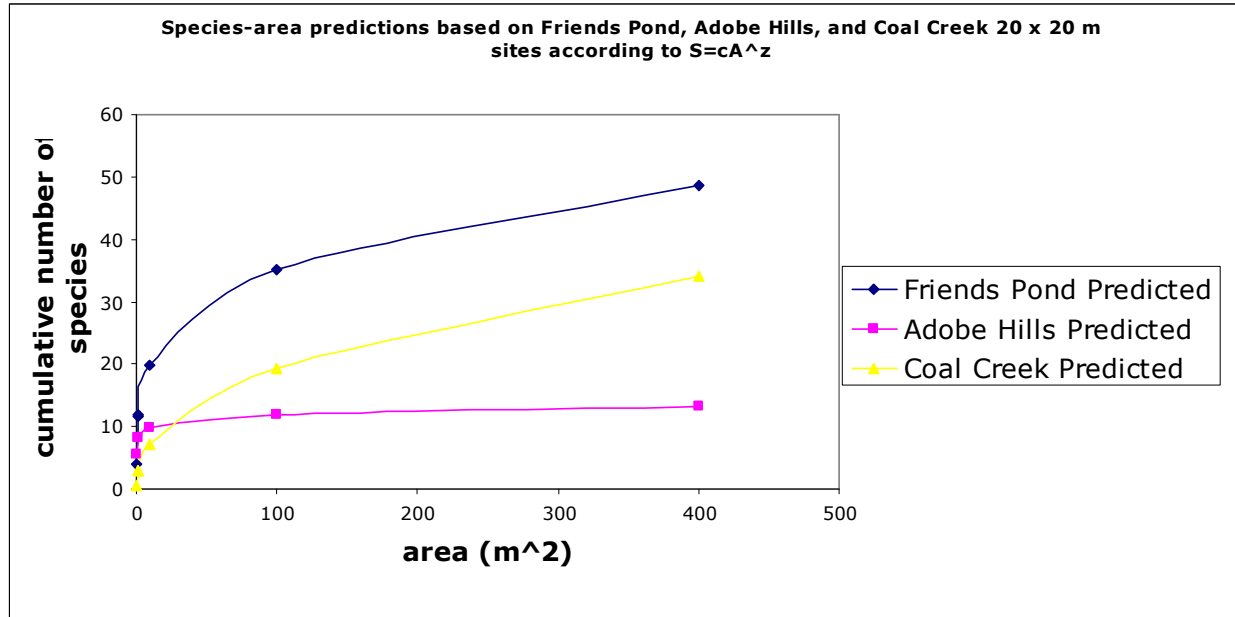


Figure 2: Species-area relationship prediction curves for the Friends Pond, Adobe Hills, and Coal Creek sites

Community Composition Comparisons

With respect to pairwise community similarity, we found that the community composition of Virginia Basin and Friends Pond were the most similar, both sharing 26.10% of the same species (Table 3). Adobe Hills shared only 2% of plant species with the plot at Coal Creek and was completely dissimilar to all other plots. Complete community composition data is displayed below in Table 3.

	Friends Pond	Virginia Basin	Coal Creek	Adobe Hills
Friends Pond	--	26.10%	6.30%	0%
Virginia Basin		--	7.00%	0%
Coal Creek			--	2%
Adobe Hills				--

Table 3: Results of pairwise community comparisons of 20x 20 m plots displayed as percent similarity.
Species Richness vs. Altitude and Rainfall

We observed that species richness did not decline as altitude increased. Rather, we observed a positive correlation between altitude and species richness ($R=0.7839$,

Figure 4). Furthermore, we observed an additional positive correlation between mean annual rainfall and species richness ($R=0.8155$, Figure 5).

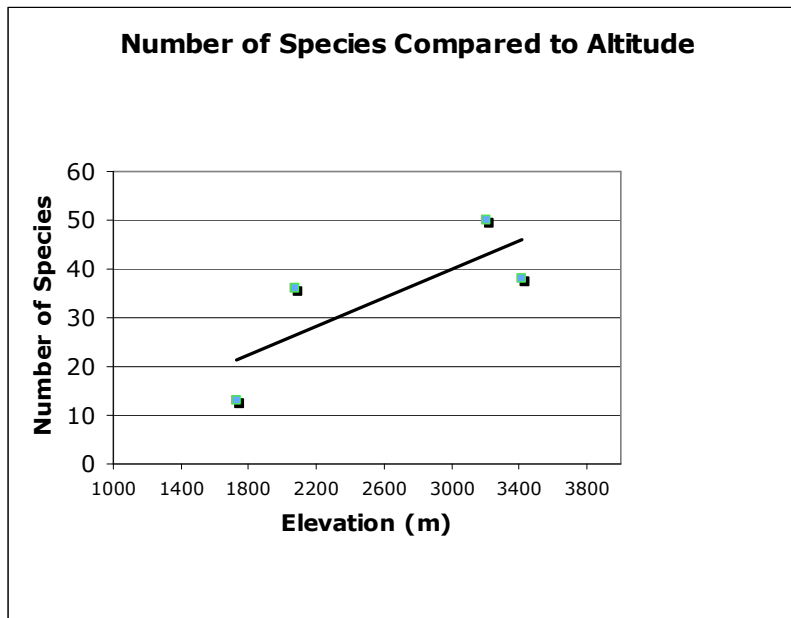


Figure 4. Altitude correlated with species richness, $R=0.739$.

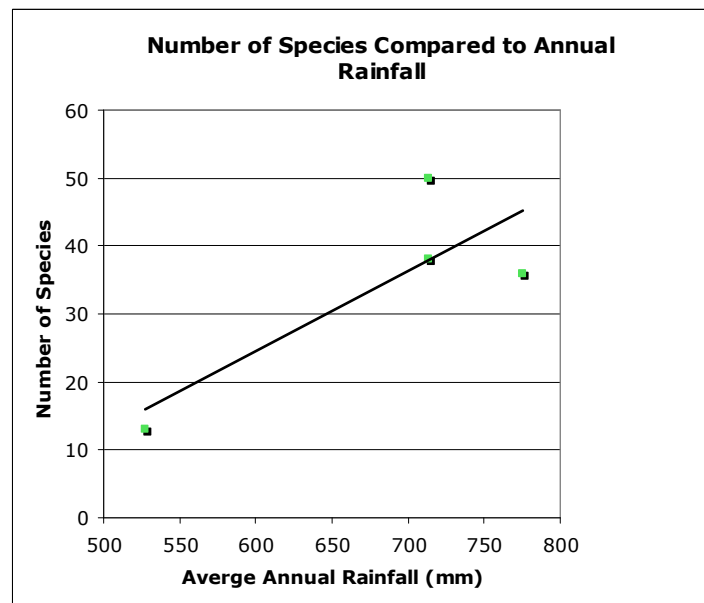


Figure 5: Rainfall correlated with species richness, $R=0.8155$

Mantel Test for Effect on Community Composition

Results of the Mantel test revealed that geographic distance between plots has significant effect on community similarity of the factors tested ($p<0.05$, $r = -0.8767$, Table

4). This also revealed that a negative correlation exists between geographic distance and community similarity. While there was a significant effect of mean annual rainfall, the r-value produced by the test (-0.7997) was not as robust as that of geographic distance.

Mantel Test			
	r-value	Critical Value	Accept or Reject Null Hypothesis
Community Structure x Difference in Annual Mean Rainfall	-0.7997	$p < .05$	Reject
Community Structure x Geographical Distance	-0.8767	$p < .05$	Reject
Community Structure x Difference in Altitude	-0.556	$p > .05$	Accept

Table 4: Results calculated using the nonparametric Mantell test.

Discussion

As Langenheim (1962) observed, the Crested Butte area is a host to a wide variety of habitats, each with their own specific community compositions. Moreover, Gunnison County, rich in extremes of altitude and rainfall, provides an excellent setting to perform species richness surveys.

The results of our own species-area relationship surveys suggest that we sampled a large enough area to accurately represent the species assemblages specific to dry meadows in Adobe Hills and Coal Creek. These two curves in Figure 2 approach a horizontal asymptote more rapidly than the curve representing Friends Pond. In the case of Friends Pond, the curve continues to increase and does not level off. This indicates that in future endeavors to evaluate species-area relationship, we should sample a larger area to better portray the species richness unique to this dry meadow.

Although the community compositions of the four plots sampled exhibited their own unique richness levels, many locations shared anywhere from 2-26.10% of similar species (Table 3). The plots that shared the highest numbers of species in common,

Virginia Basin and Friends Pond, were also the closest geographically. This relationship between geographic distance and pairwise community similarity is further supported by the results of the nonparametric Mantel test, which revealed that out of the three factors tested, geographic distance had both a significant as well as the most robust effect on community similarity ($p < 0.05$, $r = -0.8767$, Table 4). Additionally, these ecosystems were very similar to each other with respect to weather conditions. On the other hand, in the case of the sagebrush community at Adobe Hills, both the large geographical distance from the other plots as well as its unique alkaline soil may have contributed to the small levels of similarities between the other plots.

Though we hypothesized that species richness would decrease as elevation increased, results of the correlation test between species richness and altitude do not support our original hypothesis. Rather, we observed a positive correlation between species richness and altitude (Figure 4). However, the analysis suffers from a small number of data points. Additionally, we found that the relationship between species richness and mean annual rainfall, rather than altitude, produced a more robust correlation coefficient ($R = 0.8155$, Figure 5). In future research concerning species richness, investigators would benefit from collecting rainfall data, as this variable exhibits a stronger correlation with species richness.

Close observation of the abundant flora in varying locations throughout Gunnison, Colorado area provides compelling support for many hypotheses concerning species richness relationships. Although the data we collected and analyzed did not support our original hypothesis, we were able to increase our understanding of how environmental factors other than altitude affect species richness.

Acknowledgements

I would like to thank the Rocky Mountain Biological Laboratory for the use of its facilities as well as our instructor George Weiblen for his constructive criticism and advice. I would also like to thank my classmates for their input and support. Most

importantly, I would like to thank Sarah Onstad, Mitch, Lopez, and Amy Miller for collaborating with me on this project.

Works Cited

Bryant J. A., C. Lamanna, H. Morlon, A.J. Kerkhoff, B. J. Enquist, J. L. Green. 1991. Gradient analysis of latitudinal variation in southern Rocky Mountain forests. *Journal of Biogeography* **18**:123-139

Douglas, G. W. and L. C. Bliss. 1977. Alpine and high subalpine plant communities of the north cascades range, Washington and British Columbia. *Ecological Monographs* **47**:113-150

Langenheim, J. H. 1962. Vegetation and environmental patterns in the Crested Butte area, Gunnison County, Colorado. *Ecological Monographs*. **32**: 249-285

Appendix: Note: "ns" = no species

Genus	Species	Family	Virginia Basin (VB)	Friends Ponds (FP)	Coal Creek (CC)	Adobe Hills (AH)
Abies	lasiocarpus	Pinaceae		FP67		
Achillea	millefolium	Asteraceae	VB13	FP19	CC11	
Adenolinum	lewisii	Linaceae	VB3			
Agrostis		Poaceae			CC2	
Alyssum	parviflorum	Brassicaceae				AH8
Amelanchier	ainifolia	Rosaceae			CC27	
Androsace	septentrionalis	Primulaceae	VB9	FP2		
Anisantha	diandra	Poaceae				AH3
Anisantha		Poaceae			CC3	
Antennaria		Asteraceae	ns			
Aquilegia	coerulea	Ranunculaceae		FP78		
Arabis		Brassicaceae	VB34			
Arnica	rydbergii	Asteraceae			CC14	
Arnica	cordifolia	Asteraceae	VB27	ns		
Artemisia	novum	Asteraceae				AH14
Artemisia	tridentata	Asteraceae			CC40	
Astragalus	alpinis	Fabaceae	VB26			
Atriplex	canescens	Chenopodiaceae				AH5
Atriplex	confertifolia	Chenopodiaceae				AH7
Atriplex	gardneri	Chenopodiaceae				AH11
Boechea	divaricarpa	Brassicaceae	VB32	FP18		
Bromelica	spectabilis	Poaceae		FP83		
Bromopsis	pubescens	Poaceae		FP62		
Carex	egglesoni	Cyperaceae		FP16		

Castilleja	miniata	Orobanchaceae		FP59	CC19	
Castilleja	occidentalis	Orobanchaceae	VB15			
Ceanothus	martinii	Rhamnaceae			CC31	
Ceratochloa	carinata	Poaceae		FP1		
Chamerion	angustifolium	Onagraceae		ns		
Chenopodium		Chenopodiaceae		FP3		
Chrysothamus	viscidiflorous	Asteraceae				AH6
Cirsium	hesperium	Asteraceae	VB6			
Cirsium	parryi	Asteraceae		FP75		
Cirsium	tioganum	Asteraceae			CC10	
Collomia	linearis	Polemoniaceae			CC39	
Delphinium	barbeyi	Ranunculaceae		FP38		
Draba	albertina	Brassicaceae		FP45		
Draba	aurea	Brassicaceae	VB7			
Draba	crassifolia	Brassicaceae		FP25		
Draba	ventosa	Brassicaceae		FP29		
Dugaldia	hoopsii	Asteraceae		FP22		
Elymus	glaucus	Poaceae			CC5	
Elymus		Poaceae				AH12
Eremogone	congesta	Alsiniaceae	VB21			
Eremogone	fendleri	Caryophyllaceae		FP71		
Erigeron	coulteri	Asteraceae	VB30	FP79		
Erigeron	elator	Asteraceae	VB23	FP40		
Erigeron	flagellaris	Asteraceae			CC30	
Erigeron	speciosus	Asteraceae			CC13	
Erigeron	subtrinervis	Asteraceae		FP64		
Eriogonum	gordonii	Polygonaceae				AH13
Eriogonum	umbellatum	Polygonaceae	VB20		CC17	
Festuca	thurberi	Poaceae	VB12	FP12		
Fragaria	virginiana	Rosaceae	VB1	FP34	CC38	
Galium	septentrionale	Rubiaceae			CC36	
Gastrolychnis	drummondii	Caryophyllaceae		FP39		
Gentianopsis	thermalis	Gentianaceae	VB24			
Geranium	caespitosum	Geraniaceae			CC7	
Geranium	richardsonii	Geraniaceae	VB17	FP33		
Helianthella	quinquenervis	Asteraceae		FP32		
Heliomeris	multiflora	Asteraceae			CC9	
Heracleum	sphondylium	Apiaceae		FP49		
Heterotheca	pumilla	Asteraceae		ns		
Heterotheca	villosa	Asteraceae	VB25			
Hydrophyllum	capitatum	Boraginaceae		FP36		
Indetermined 1						AH1
Indetermined 1					CC4	
Indetermined 1			ns			
Indetermined 1				FP14		
Indetermined 2		Asteraceae				AH10
Indetermined 2					ns	
Indetermined 2				FP27		

Indetermined 3					ns	
Indetermined 3				FP44		
Indetermined 4		Polygonaceae			CC33	
Indetermined 4		Asteraceae		FP63		
Ipomopsis	aggregata	Polemoniaceae		FP53		
Juniperis	communis	Cupressaceae		FP56		
Juniperis	coniferus	Cupressaceae			CC18	
Lathyrus	leucanthus	Fabaceae	VB2	FP47		
Ligularia	bigelovi	Asteraceae		FP7		
Ligusticum	porteri	Apiaceae		FP46		
Ligusticum		Apiaceae	VB31			
Lonicera	involucrata	Caprifoliaceae		FP70		
Lupinus	bakeri	Fabaceae		FP58		
Mahonia	repens	Berberidaceae			CC28	
Medicago	lupuina	Fabaceae			CC34	
Mertensia	ciliata	Boraginaceae	VB4	FP9		
Oligosporous	dracunculus	Asteraceae		ns	CC1	
Osmorhiza	occidentalis	Apiaceae		FP35		
Pedicularis	racemosa	Scrophulariaceae	FP73			
Penstemon	whippleanus	Plantaginaceae			FP37	
Phleum	alpinum	Poaceae		FP82		
Phleum	pratense	Poaceae			CC16	
Pneumonanthe	affinis	Gentianaceae	VB16			
Poa	alpina	Poaceae	VB11			
Poa	bigelovi	Poaceae	VB36			
Poa	pratensis	Poaceae		FP5		
Poa	aretica	Poaceae	VB18	FP6		
Polemonium	pulcherrimum	Polemoniaceae		FP66		
Potentilla	gracilis	Rosaceae	VB8	FP15	CC6	
Prenanthes	racemosa	Asteraceae		FP42		
Promopsis	inermis	Poaceae		FP81		
Prunis	virginiana	Rosaceae			CC23	
Pseudocymopterus	montanus	Apiaceae	VB37	FP72		
Pseudorogeneria		Poaceae				AH9
Ranunculus	uncinatus	Ranunculaceae		FP43		
Ribes	montigenum	Grossulariaceae	VB19	FP65		
Ribes	wolfii	Grossulariaceae		FP74		
Rumex	crispus	Polygonaceae		FP52		
Sambucus	microbotrys	Caprifoliaceae		FP68		
Sceleropogon	brevifolius	Poaceae			CC25	
Silene	dichotona	Caryophyllaceae			CC32	
Symphoricarpos	rotundiflorous	Caprifoliaceae			CC21	
Taraxacum	eriophorum	Asteraceae	VB33			
Taraxacum	officinale	Asteraceae	VB5		CC8	
Thalictrum	fendleri	Thalictraceae	VB10	FP8		
Tragopogon	dubius	Asteraceae			CC22	AH2
Vaccinium	cespitosum			ns		
Vaccinium	myrtillus	Ericaceae	VB28	FP77		

Valeriana	edulis	Valerianaceae	VB22	FP11		
Veratrum	californicum	Lilaceae		FP23		
Vexibia	nuttalliana	Fabaceae			CC37	
Vicia	americana	Fabaceae		FP17		
Viola	nuttalli	Violaceae		ns		
Viola		Violaceae		ns		
Wyethia	amplexicaulis	Asteraceae			CC12	
Zigadenus	elegans	Lilaceae	VB35			

$$\% \text{ Similarity} = \frac{\# \text{ species shared}}{\text{total \# of species in paired plots}}$$