

Possible Influence of Altitude, Geographical Distance Between sites and Annual precipitation rates on Species Richness

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Abstract

One of the most interesting questions that ecologists strive to answer is how and why species diversity and richness amongst organisms varies across geographical regions. Of course, there are multiple possible factors that impact the patterns of species diversity but this study compounds data from high alpine wet regions, to low dry desert planes in order to build a species richness curve for each site. With this compounded data we strive to answer the question: how is species richness correlated to altitude, geographical distance between sites, and annual precipitation rates.

Introduction

Several factors impact the patterns of species richness. For example: latitudinal gradients, environmental stress, temporal variation, productivity gradients, altitude gradients, heterogeneity gradients, long-term fertilization variations, overall sample area, frequency and severity of disturbances

are all known to impact the species diversity and richness of a site (Stohlgren, 2007). One of the most interesting questions that ecologists strive to answer is how and why species richness and diversity amongst organisms varies across geographical regions.

This particular topic has gathered much attention because similar geographical regions can differ profoundly in their species richness (Rabosky 2009). In order to measure the species richness many ecologists utilize a mathematical tool known as the species area relationship curve in conjunction with quantitative sampling methods. This theoretical model varies widely depending on the habitat, taxa as well as overall scale of the sampled region (Harte et. al. 2009).

There are three distinct processes involved in order to calculate the species area curve. First one must sample small areas, leading up to larger areas and record where each new species occurs firstly in the area. Then, use Arrhenius power law (Arrhenius, 1921) and lastly undergo a “continental” phase which consists of making sure regions that are separated by large areas contain non overlapping species (Preston, 1960). This model is appropriate for studying the spatial phenomena of beta diversity on a small scale; however, this model fails to accurately simulate the large scale landscapes. Thus, the species area curve makes it possible to measure the species diversity of smaller and larger regions than the area samples, but not infinitely small nor infinitely large sized samples (Rosindell and Cornell, 2009).

It is commonly assumed that plant diversity decreases with increasing elevation, due to the decrease in air temperature. This seems logical, however there are regions which are located within close proximity to the higher altitudes that decrease in elevation and decrease in annual rainfall (Stohlgren 2007). Being that species richness plays a key role in species diversity and due to our temporal limitations we sought out to measure species richness in 4 sites all variable in elevation, and 3 sites variable in rainfall, in order to strengthen or weaken our hypothesis that species diversity increases as altitude decreases.

Methods

Sites: Due to temporal limitations only 4 sites were measured. Each varied in elevation, annual rain fall and other physical attributes

Table 1

Site Location	Altitude	Latitude	Longitude
Friends Pond (GRNA) 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

Equations Used

% community similarity = (# of species common to A & B) / total number of species in plots A & B combined)

$$S=CA^z$$

S=predicted species A=Area sampled c=constant z=constant

Materials: Compass, 50m measuring tape, Survey Flags, Bed sheet , Sharpie, Field guides, newspaper, Plant press, large plastic bag

Procedure

At the Virginia Basin site we created a 20x20 plot, collected a sample of each vascular plant species, labeled it, pressed it and identified it using Weber, Darrow and Shaw.

At the Coal Creek and Adobe Hills sites we created 10cmx10cm, 30cmx30cm, 1mx1m, 3mx3m, 10mx10m, 20mx20m area plots. In each plot we collected a sample of each vascular plant, labeled it, pressed it and identified it using Weber, Darrow and Shaw.

At the Friends Pond site we created a 1cmx1cm, 3cmx3cm, 30cmx30cm, 1mx1m, 30mx30m and a 50mx50m plot. Similarly like the others we collected a sample of each vascular plant species, labeled it, pressed it and identified it using Weber, Darrow and Shaw.

Results

During this experiment we encountered a total of 130 different plant species of which can be viewed in Appendix A

For the charts below the following abbreviations are used:

AH (Adobe Hills)

GNA(Gunnison Natural Research Area)

VB (Virginia Basin)

CC (Coal Creek)

Figure 1

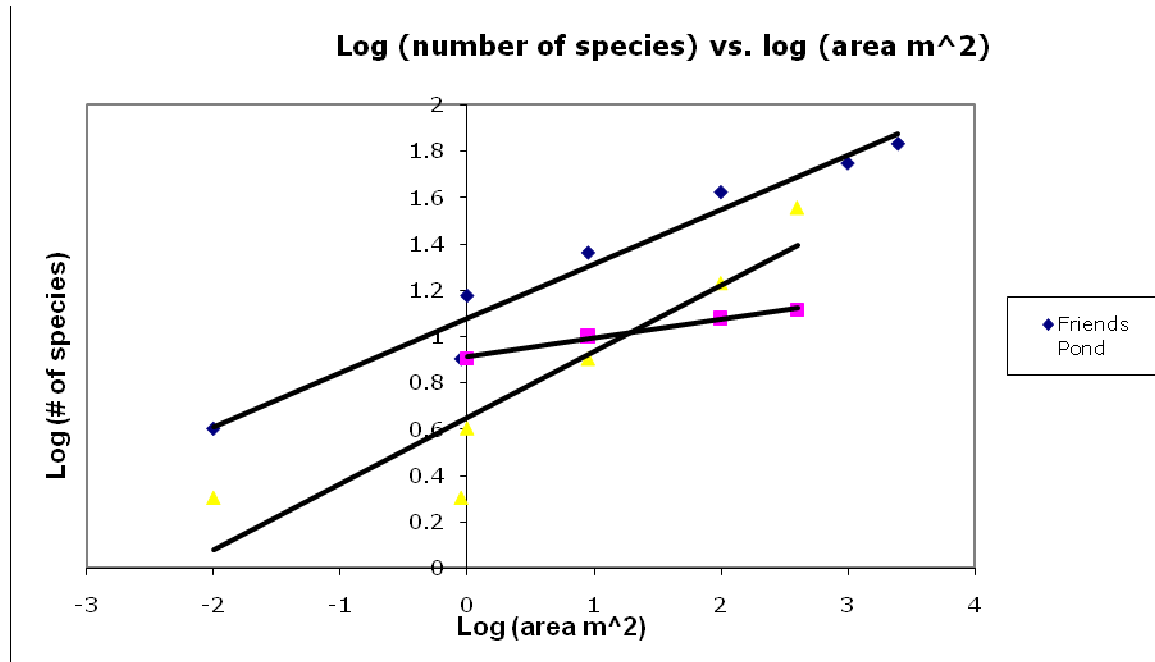


Figure 1 is an analysis of the log (#species) by the log (area m²) for Friends Pond, Adobe Hills and Coal Creek. The plot of Friends Pond has a r² correlation of 0.9608, the plot of Coal Creek has a correlation r² value of 0.853 and the correlation of Adobe hills has a r² value of 0.9887, as illustrated in Table 1

Table 2

Plot	c (intercept ¹⁰)	z (slope)	R ²
Friends Pond	2.08415434	0.2344	0.9608
Coal Creek	0.01315527	0.2856	0.853
Adobe Hills	0.39588289	0.081	0.9887

The information in Table 2 was calculated from the line of best fit from data compounded at each site. The constants z and c were found using the Arrhenius power law in the species area equation.

Figure 2

Species-area predictions based on Gothic Research Natural Area (GRNA), Adobe Hills, and Coal Creek 20 x 20 m sites according to $S=cA^z$

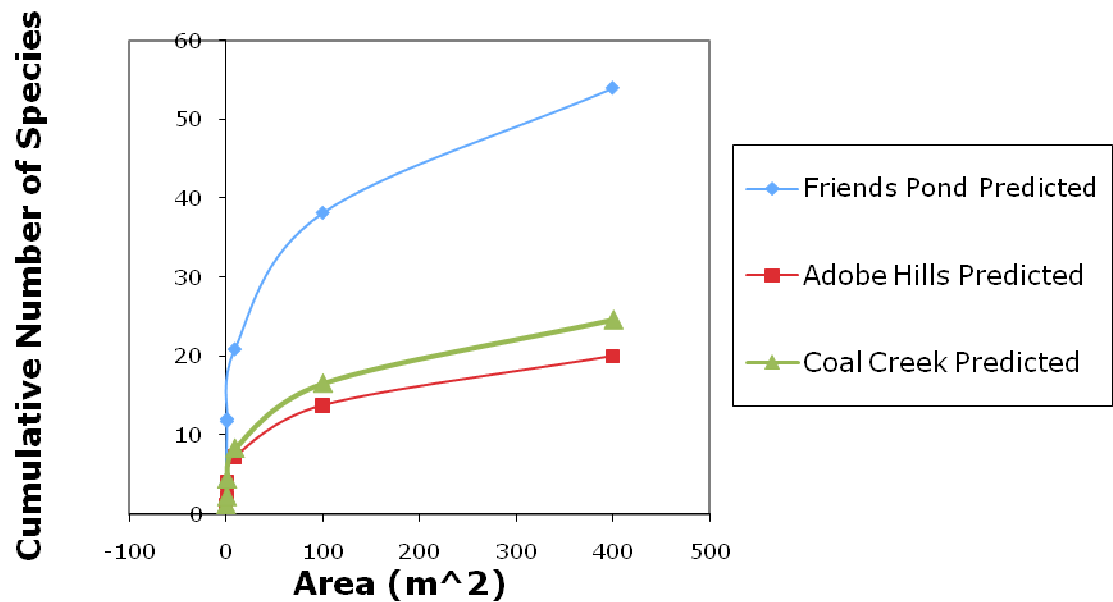


Figure 2 is a collaboration of graphs from the species-area predictions from 3 sites (Friends Pond, Adobe Hills and Coal Creek). The Friends Pond has the steepest slope as the area reaches infinity, followed by Coal creek and Adobe hills.

Figure 3

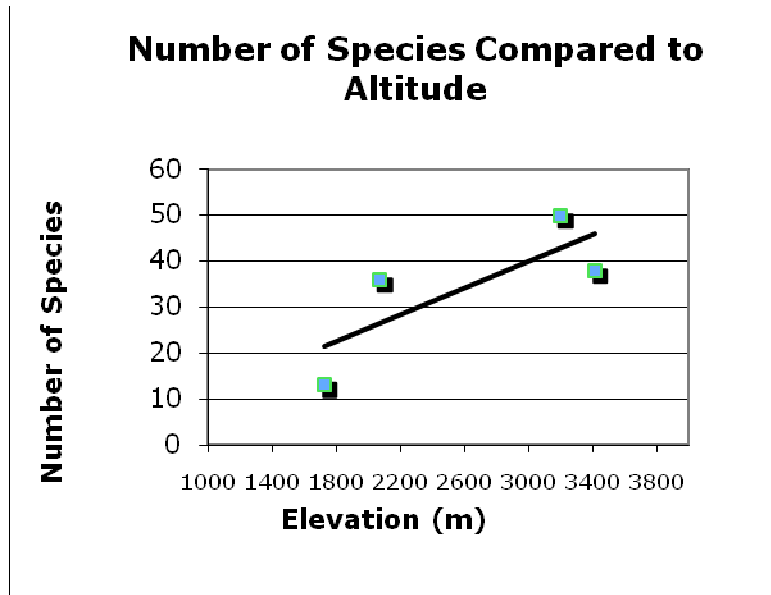


Figure 3 is a graphical representation of the number of species collected as elevation increases. The r value for this graph is 0.7890

Figure 4

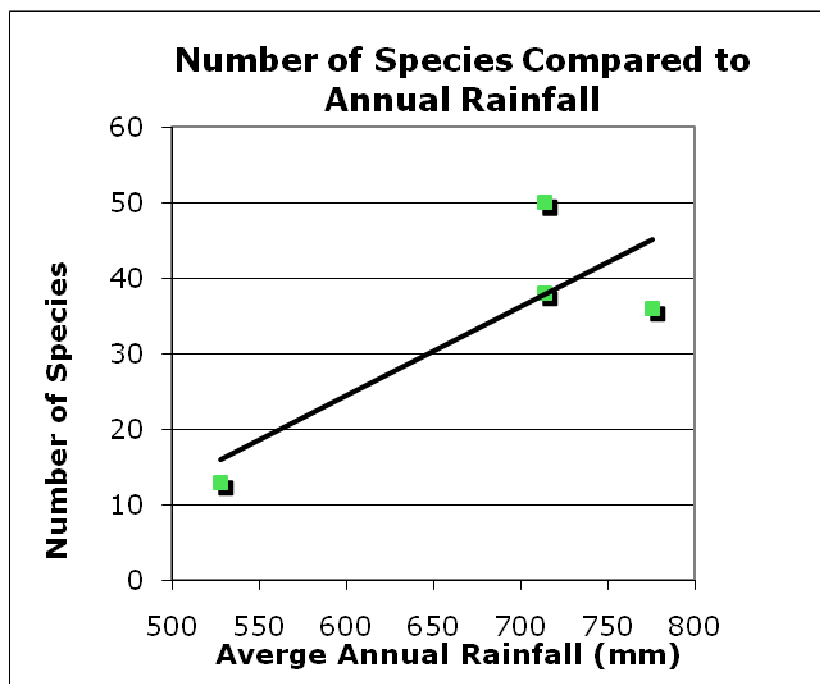


Figure 4 is a graphical representation of the number of species collected as annual rainfall at the site increases. The r value for this graph is .81556

Table 3

FP/CC	FP/VB	CC/VB	CC/AH
Castilleja miniata	Androsace septentrionalis	Eriogonum umbellatum	Tragopogon dubius
Oligosporous dracunculus	Arnica cordifolia	Taraxacum officinale	
Achillea millefolium	Boechera divaricarpa	Achillea millefolium	
Fragaria virginiana	Erigeron coulteri	Fragaria virginiana	
Potentilla gracilis	Erigeron elatior	Potentilla gracilis	
	Festuca thurberi		
	Geranium richardsonii		
	Lathyrus leucanthus		
	Mertensia ciliata		
	Poa aretica		
	Pseudocymopterus montanus		
	Ribes montigenum		
	Thalictrum fendleri		
	Vaccinium myrtillus		
	Achillea millefolium		
	Fragaria virginiana		
	Potentilla gracilis		
	Valeriana edulis		
5 species	18 species	5 species	1 species

Table 3 is a pair-wise comparison of elevation plots showing similar species between sites. Note, Adobe Hills shares no similarities with any other plot and therefore is not included in this table.

Table 4

Coal Creek	Adobe Hills	Total Overall	Shared	% Similar
36	13	48	1	0.02083333
Friends Pond	Virginia Basin			
50	38	70	18	0.25714286
Friends Pond	Coal Creek			
50	36	81	5	0.0617284
Virginia Basin	Coal Creek			
38	36	71	5	0.07042254

Table 4 is associated with Table 3, yielding the total species overall, the percentage of similar species and the number of shared species.

Table 5

Community similarity of 20x20 meter vegetation plots at four sites.				
	FP	VB	CC	AH
FP	--	25.70%	6.20%	0%
VB		--	7.00%	0%
CC			--	2%
AH				--

Table 5 shows the community similarity across four sites at the 200m² area

Table 6

Mantell Test			
	r value	Critical Value	Accept or Reject Null Hyp
Community Structure X Difference in Annual Average 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 6 shows the results calculated using Mantel Nonparametric Test Calculator Version 2.00 for Windows 1997-2000. Written by Adam Liedloff.

Discussion

Several measurable and immeasurable factors impact the patterns of species richness. In this study we sought out to answer the question: of the many factors that impact species richness, how does altitude, annual rainfall and geographical distance influence species richness. In order to do this we collected data from 3 environmentally variable sites and used species richness curves to determine how annual precipitation rates and elevation correlate to species richness. We also used community similarities, and the mantel statistical test to determine which factors correlate to variations in community structure.

The species area curve provides researchers with the tools essential to predict the number of species in a given area. Figure 2 illustrates three curves representing each site. The Adobe hills site had a r value of 0.9887, suggesting that the predicted graphical representation was closest to the actual measurement of species. This is clear when analyzing the graph because this line appears to reach a horizontal asymptote quicker than the other two sites. The Friends Pond site predicted value has a correlation factor of $r=0.9608$, and does not appear to reach a horizontal asymptote. This means that although there is a strong correlations to actual and predicted species richness curves, more plots calibrated at greater areas would increase the accuracy of the predicted species-area equation. The Coal Creek correlation factor was $r^2= 0.853$ and although the individual points were less correlated to the r^2 value the predicted graphical representation appears to approach a horizontal asymptote quicker than the Friends Pond Site. If this experiment was repeated the species richness at the Friends pond site and the Coal Creek site should be calibrated at a larger sample size then they were in this particular experiment.

There are many factors that influence species richness. In this study we took into account altitude and average annual rainfall at each of our sites, this is illustrated in Figure 3 and Figure 4. Average annual rain fall had an r value of .815566 and altitude had an r value of .7890. This suggests that the average annual rainfall might have a greater influence on species richness then altitude. I would suggest that more plots be made in greater geographically distant regions, in order to solidify this assumption.

When comparing community structure we took into account the similarity amongst 4 sites (CC, AH, VB, FP). We then created matrixes of annual average rainfall, geographical distance between sites and community structure in order to use a Mantell test to test how correlated the community structure matrix is to the others. We found that community structure is correlated least by the difference in

altitude and most with the geographical distance. Average annual rainfall had a significant correlation of ($r=-.7997$) but not as great a statistical significance as geographical distance ($-.8767$). Although, our original hypothesis that species richness increases as altitude decreases was not strengthened in this study, further research would need to be conducted to secure or fully dismiss it.

References

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Appendix A

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
Boechera	divaricata	Brassicaceae	VB32	FP18		
Bromelica	spectabilis	Poaceae		FP83		
Bromopsis	pubescens	Poaceae		FP62		
Carex	egglestonii	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	viscidiflorus	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	subtrineris	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	thermalsis	Gentianaceae	VB24			
Geranium	caespitosum	Geraniaceae			CC7	
Geranium	richardsonii	Geraniaceae	VB17	FP33		
Helianthella	quinque nervis	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				FP55		
Indetermined 5		Asteraceae		FP63		
Ipomopsis	aggregata	Polemoniaceae		FP53		
Juniperis	commun	Cupressa		FP56		

	is	ceae				
Juniperis	coniferus	Cupressaceae			CC18	
Lathyrus	leucanthus	Fabaceae	VB2	FP47		
Ligularia	bigelovii	Asteraceae		FP7		
Ligusticum	porteri	Apiaceae		FP46		
Ligusticum		Apiaceae	VB31			
Lonicera	involuta	Caprifoliaceae		FP70		
Lupinus	bakeri	Fabaceae		FP58		
Mahonia	repens	Berberidaceae			CC28	
Medicago	lupulina	Fabaceae			CC34	
Mertensia	ciliata	Boraginaceae	VB4	FP9		
Oligosporus	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	bigelovii	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		
Prunus	virginiana	Rosaceae			CC23	
Pseudocymopterus	montanus	Apiaceae	VB37	FP72		
Pseudorogneria		Poaceae				AH9
Ranunculus	uncinatus	Ranunculaceae		FP43		
Ribes	montigenum	Grossulariaceae	VB19	FP65		
Ribes	wolfii	Grossulariaceae		FP74		
Rumex	crispus	Polygona		FP52		

		ceae				
Sambucus	microbotrys	Caprifoliaceae		FP68		
Sceleropogon	brevifolius	Poaceae			CC25	
Silene	dichotoma	Caryophyllaceae			CC32	
Symphoricarpos	rotundiflorus	Caprifoliaceae			CC21	
Taraxacum	eriphorum	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			