Mining Herbarium Databases to Discover Plant Species Associations in Central Arizona

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Determining Plant Associations

- Traditional methods of determining plant associations include:
- Counting species within roped off plots
- Other field surveys





Mining SEINet

The SEINet database contains information on over 4 million plant specimen records, of which 540,000 are from Arizona

Many of the Arizona records contain associated species and/or coordinate data.

Plant associations can be investigated and quantified with either of these (Associated Species or Coordinate Data)



Associated Species

When collecting a specimen, the collector will often list other species observed nearby, in a field called "associated species" or "associated taxa".

About 30% of Arizona specimens have associated species data.



Coordinates

Similarly, the collector will often record the latitude and longitude.

Many older records have been georeferenced as best we can with available resources such as Google Earth.

About 80% of Arizona specimens have coordinate data.





Typical Plant Specimen Label

Pteridaceae of Arizona

Astrolepis sinuata (Lag. ex Sw.) Benham & Windham

Yavapai County: Overlooking Cottonwood Creek and jeep trail that goes from Gillette Ruins to Boulder Creek. N 34° 2.08', W 112° 12.25' 2480 ft., 756 m.

Sonoran Desert scrub, top of ridge with Canotia holacantha, Ephedra, Cylindropuntia acanthocarpa, Simmondsia chinensis, Calliandra eriophylla, Eriogonum fasciculatum, Gutierrezia sarothrae, Mammillaria grahamii, Abutilon incanum, Physalis, Cercidium microphyllum, Echinocereus engelmannii, Menodora scabra. Local small dense population in what appears to be a preColumbian 2room field house/pit (which overlooks large Agave murpheyi clone).

16 November 2003 Wendy Hodgson 17486 with Kathy and Al Parker Herbarium of Desert Botanical Garden (DES)

Foundation Species

We chose 81 species of trees and shrubs that are found commonly in the vegetation of central Arizona from high to low elevations.

They are often dominants or at least prominent in the vegetation and frequently are listed in the associate species field.







The Proximity Program

The first approach to quantify associations was to simply look at which species were most frequently listed in each others associated species field. For example:



Picea engelmannii (Engelmann spruce) has 59 records in the database for Arizona that list any associated species. These are a few of the plants that were listed:

	Associated Species	Count	Percent
1	Populus tremuloides	20	34 %
2	Pinus ponderosa	17	29 %
3	Pseudotsuga menziesii	16	27 %
4	Abies concolor	12	20 %
5	Juniperus communis	11	19 %
6	Abies bifolia	10	17 %

Desert near Phoenix

But there's a problem with this approach

Large, prominent, well-known species tend to be included in the associated species list much more frequently than small, little known species.



For example, when collecting in the desert near Phoenix, the giant saguaro cactus (*Carnegiea gigantea*) ...

... is much more likely to be listed than the very common, but tiny, *Pectocarya recurvata*



Species are not selected at random for the associated species list.

- Larger better known species are much more likely to be included than smaller ones.
- Rare species are less likely to be included.
- This skews the results, showing stronger associations between well known species and weaker associations with small, less well known or rare species.

The CORRELATION Program

- If a species A grows with an assortment of species in certain frequencies and species B grows with many of the same species in similar frequencies, then it is likely that they grow with each other.
- Comparing their lists of associated species can measure how often two plants are found in the same environment.

Associated Species Graphs for Four Plants





Correlation Values Based on 81 Associated Species

	Acer negundo	Juglans major	Prosopis juliflora	Parkinsonia florida
Acer negundo	1.00			
Juglans major	.86	1.00		
Prosopis juliflora	.20	.36	1.00	
Parkinsonia florida	.09	.21	.87	1.00

Correlation Results Associated Species, All 81 species

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Cristman within	0.00	204 027	0.12 0.10	010 012	62 62	: 0.0	827 030	0.33 0.45	0.22 0.00		0.70 0.02	2.00 2.00 2.1	* 633 63	0 0 0 0		140 0.72	8.42 1.00	0.01 0.00	0.70 0.81	0.00 0.00	0.00 0.01	0.74 0.83		0.27 0.01	0.08 0.79	0.30 0.20 0.	12 0.07 0	ara aa a:		0.22 0.08	0.40 0.27 0.28	0.30 0.33 0	0.44 0.21 0.20	x 0.20 0.2		42 827 847 8	20 040 020 0.0	0.38 0.37 0	2.20 2.21 2.47
The eventual of	0.05	0.00 0.00	0.12 0.11	0.07 0.07	6.00 0.0	1 0.11	842 821	0.27 0.22	0.00 0.40			0.00 0.00 0.0	e lag lag	0.000	er 000 0		842 845	100 0.0	0.70 0.27	0.72 0.72	0.70 0.00	0.0	0.0	0.12 0.41	0.72 0.07	0.22 0.42 0.4	<u>a las la</u>			8.20 8.32		0.22 0.07 0	0.11 0.17 0.22		- 10.1	12 820 814 8	12 027 021 012	0.12 0.00 0	10 AUT AUT
Depletes chesteri	0.00	0.00 0.00	0.02 0.04	0.01 0.00	807 80	6 0.16	8.27 0.10	0.00 0.32	0.32 0.37		0.40 0.94	8.33 8.33 8.4	K 0.12 0.1	0.26 0	30 0.00 0	139 0.24	832 833	0.12 1.00	0.47 0.28	0.72 0.20	0.43 0.39	0.00 0.00	0.00	0.31 0.23	0.40 0.73	0.33 0.20 0.3	10 0.07 0	827 872 84		241 247	0.42 0.44 0.42	0.41 0.40 0	0.20 0.27 0.27		a a za a	22 0.07 0.20 0	22 049 023 022	0.0 0.0 0	1.0 1.1 1.1
Contrast Indiana line	0.00	0.00 0.04	0.13 0.08	0.00 0.07	0.0 0.0	7 0.44	0.77 0.33	0.33 0.27	0.26 0.00			0.75 0.02 0.0	0 0 28 0 3		a: 0.04 0		8.42 8.79	8.78 8.47	1.00 0.47	0.32 0.02	0.72 0.20	0.00 0.70	1 0.28 0.37	0.10 0.41	0.00 0.04	0.32 0.31 0.4	40 0.00 0		1 032 0.41	821 836	0.27 0.22 0.31	0.10 0.07 0	0.12 0.17 0.11	. 0.32 0.2		10 0 22 0 14 0	17 0.32 0.19 0.14	0.16 0.10 0	0.12 0.07 0.14
Lington surgestion	0.00	0.00 0.00	0.01 0.00	0.04 0.00	0.00 0.0	0.00	0.00 0.00	0.00 0.30	0.00 0.00		0.32 0.40	820 848 83	3 0.07 0.5	0 000	26 0.40 0	122 0.00	0.00 0.00	827 8.28	0.47 1.00	0.00 0.29	0.28 0.28	0.79 0.02	0.00 0.42	0.36 0.77	0.21 0.70	0.00 0.00 0.0	40 0.24 0	0.43 0.00 0.		0.00 0.70	8.42 8.45 9.27	0.07 0.00	0.23 0.41 0.44	0 0.36 0.0		20 0.00 0.27 0	27 0.71 0.42 0.24	0.41 0.31 0	8.21 8.43 8.29
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Designation and selections.		205 207	0.17 0.16	0.0 0.12	822 81	2 0.27	0.25 0.22	0.07 0.41	0.42 0.21		10 10	10 12 10	0 0 10 00	0.00		20 0.0	0.00 0.01	842 837	0.00 0.00	0.27 0.00	1.1	8.28 8.22		0.12 0.22	0.01 0.27	242 244 24	c 000 0	827 829 8	0 00 00	12 0.0	232 233 233	0.00 0.10 0	012 017 02			12 0 20 0 14 0	17 042 042 043	0.12 0.11 0	8.10 0.22 0.15
Viene state	0.00	0.0 0.0	0.00 0.00	0.00 0.00	Ber 10.0	: 0.30	8.40 9.20	0.16 0.22	0.27 0.2	-		0.0 0.0 0.0				135 0.70	822 875	0.0 0.0	0.00 0.79	0.70 0.00	0.01 0.27	1.00 0.70		0.00 0.01	0.01 0.76	0.00 0.00 0.0		825 822 84	0 000 007	5.20 D.05	225 222 2.0	0.00 0.00 0	0.00 0.07 0.25		1 427 44	42 822 844 8	44 Dec Dag Deg	0.27 0.28 0	17 122 124
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Personal an optimization		0.00 0.00	0.00 0.00	0.00 0.00	0.01 0.0	. 0.00	0.00 0.01	0.01 0.00	0.00 0.20	- -	0.11 0.10	0.00 0.12 0.0	9 0.02 0.0	010 0		109 0.27	B.11 B.21	0.17 0.27	0.19 0.01	0.39 0.10	031 012	0.0 0.0		0.21 0.29	0.22 0.89	0.30 0.42 0.4		227 2.90 2.	N 0.41 0.72	0.00 0.00	272 2.01 2.34	0.30 0.32 0	0.70 1.00 0.70	0 0.30 0.2		87 0.82 0.96 D	22 0.33 0.74 0.97	0.40 0.90 0	8.92 8.10 8.92
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Capital and the second sec		0.00 0.00	001 0.00	0.00 0.00	204 20	e 0.10	0.12 0.00	0.10 0.17	0.12 0.17	<u> </u>		an an a	a 0.34 0.3				100 1.00	5.0 0.0	0.32 0.34	0.31 0.00	2.07 2.79	842 833	· • • • • •	0.00 0.70	8.12 0.02	0.76 0.00 04		242 <u>24</u> 21	8 872 947	540 540	100 1.02 0.02	0.0 0.0 0	029 030 02	1 1.00 0.0			10 0.7 0.0 0.27	0.31 0.12 0	13 14 13
2100 a junea	0.00	0.00 0.00	0.01 0.00	000 000	0.00 0.0	s 0.05	0.11 0.01	0.01 0.10	0.00 0.00		0.17 0.06	100 100 10	2 0.07 0.1	0.12 0	116 0.12 0	1.12 0.30	P.24 0.40	0.07 0.00	0.37 0.87	0.0 0.0	242 234	8.27 8.81	0.0	0.33 0.73	8.42 8.71	0.40 0.00 0.1	79 007 O	041 079 0 1	E 076 079	0.79 0.90	877 882 871	0.44 0.72		a 0.07 1.0		** *** ***	e 0.00 0.72 0.73	0.48 0.80 0	876 832 833
Cylindropaetia bigeler	0.00	0.00 0.00	000 0.00	0.00 0.00	p.00 0.0	0.01	0.00	0.00 0.00	0.00 0.17	- B OK	0.00 0.11	0.00 0.10 0.0	0 0.00 0.0	: 000 0		1.00 0.10	0.02 0.39	B.11 0.30	0.13 0.03	0.27 0.00	0.10 0.00	837 836	6 B 11 B 12	0.16 0.67	0.12 0.43	0.17 0.27 0.		226 239 23	n <u>Des</u> Dat	0.00	2.09 0.90 0.22	0.17 0.72	096 096 02	1 0.30 0.0	• :	** ** **	8 0.70 0.00 0.90	0.30 0.83 0	192 107 119
Camagina pipanina	0.00	0.00 0.00	0.00 0.00	0.00 0.00	201 20	0.01	B.0K 0.00	0.00 0.00	0.04 0.00		0.07 0.12	200 2.11 2.0	u 0.00 0.0	0.00 0	0. 0.00 0	100 0.20	000 0.02	0.12 0.22	0.10 0.20	0.35 0.07	0.00 0.10	0.0 0.0	0.17	0.30 0.33	0.12 0.40	0.33 0.37 0.	40 0.00 0	0.00 0.00 0.0	1 0.00 0.72	0.72 0.72	177 0.80 0.13	0.00 0.00 0	0.07 0.07 0.00	a 0.27 0.7	a 0.90 1		N 0.75 0.74 0.90	0.40 0.87 0	0.02 0.13 0.94
Contact Descents	0.00	0.00 0.00	0.00	0.00 0.00	201 0.0	· 0.00	0.00 0.00	0.01 0.05	0.07 0.27	- -	0.12 0.19	0.00 0.17 0.1	o 0.00 0.0	1 010 a	0 0 0 0	LII 630	0.12 0.27	0.00 0.07	0.00 0.00	0.03 0.13	0.0 0.00	8.22 8.22	a a a a a a a a a a a a a a a a a a a	0.02 0.27	0.42 0.71	0.32 0.02 0.	18 0.30 0	030 030 03	16 0.77 0.80	0.90 0.00	0.0K 0.0K 0.0D	0.22 0.72 0	0.00 0.00 0.0	n 0.0 01	0.00 0	10 1.00 D.10 D	N 033 031 030	0.81 0.79 0	0.78 0.39 0.86
Seastly Determs	0.00	0.00 0.00	0.00	0.00 0.00	2.01 2.0	0.01	DOX 0.00	0.00 0.04	0.00 0.00		0.05 0.14	1.00 1.12 1.0	u 0.00 0.0	0 000 0	0.000		100 D.C.	0.16 0.30	0.14 0.27	0.34 0.07	0.33 0.14	0.44	0.19 0.21	0.31 0.29	0.33 0.47	0.30 0.61 0.6	er 100 1		1 1 1 1 1 1 1	0.90 0.90	ana 0.00 0.00	0.30 0.31 0	072 070 07	1 0.37 D.3	a a m a	99 P.E. 100 P	PT 0.01 0.71 0.97	0.07 0.01 0	5.90 5.17 5.96
Nuglia amanys	0.00	0.00 0.00	0.00 0.00	0.00 0.00	201 2.0	• • • •	0.01 0.01	0.01 0.01	0.04 0.21	_ 1 02	0.05 0.14	1.00 1.12 1.0	u 0.02 0.0	. 0a7 a		.00 0.23	0.11 0.20	8.12 8.22	0.17 0.27	0.30 0.10	0.23 0.17	0.44 0.43	0.21 0.22	0.17 0.01	0.24 0.47	0.27 0.44 0.4			B 0.28 0.71	0.00 O.00	111 0.00 0.07	0.27 0.30 0	0.90 0.90 0.97	a 0.33 0.8	- 231 2	N 2.N 2.77 1	00 0.01 0.71 0.92	0.00 0.00 0	8.99 8.16 8.99
Terlinamia Carida	0.00	0.00 0.00	0.00 0.00	0.00 0.00	800 80	0.00	8.07 0.00	0.01 0.09	0.07 0.00		0.10 0.17	2.02 2.17 2.1	1 0.00 0.0	0.12 0		112 0.30	0.01 0.00	0.09 0.09	0.00 0.71	0.20 0.21	0.07 0.12	0.00 0.00	0.42 0.37	0.37 0.72	0.23 0.73	0.37 0.76 0.5	n n n	ana ana an	10 0.17 0.19	0.0° 0.00	100 010 070	0.07 0.08	078 080 07	1 0.27 0.2	0 170 1		8 1.00 0.02 0.79	0.71 0.72 0	876 836 832
Cylindrogenia fulgala	a 0.00	0.00 0.00	000 0.00	0.00 0.00	201 0.0	0.00	B 05 0.00	0.01 0.00	0.00 0.07	- 607 (0.11 0.16	0.00 0.16 0.0	0 0.01 0.0	1 007 0	010 0	107 0.33	0.10 0.20	0.21 0.20	0.17 0.20	0.40 0.10	0.41 0.22	8.21 8.23	: 0.40 0.30	0.32 0.23	0.42 0.81	0.37 0.01 0.0	40 0.07 0	0.00 0.00 0.0	00 0.7K 0.8K	0.02 (0.02	5.3K 0.47 0.4K	0.41 0.72 0	0at 0.ts 0.ts	a 0.0 p.	: 0.00 0	76 0.01 0.71 0	N 0.00 1.00 0.00	0.72 0.72 0	0.08 0.23 0.79
Parkingenia minaginyi	a 0.00	0.00 0.00	0.00 0.00	0.00 0.00	2.01 0.0	0.01	8.03 0.00	0.00 0.02	0.00 0.19		0.00 0.11	0.02 0.10 0.0	N 0.00 0.0	0 000 0	.00 0.00 0	1.01 0.20	887 843	8.12 8.22	0.14 0.24	0.32 0.00	0.34 0.13	842 840	0.17	0.10 0.22	0.30 0.42	0.33 0.38 0.4	at 0.00 0	0.22 0.27 0.	1 0.22 0.71	0.90 0.80	ana ana ana	0.22 0.77 0	0.97 0.97 0.90	0 0.37 0.7	1 0.00 0	74 0.20 0.27 D	92 0.79 0.69 1.00	0.41 0.82 0	0.07 0.12 0.90
Angles privarys	0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.0	0.01	0.00 0.00	0.00 0.00	0.04 0.21	. 8.02 P	0.08 0.12	0.00 0.10 0.0	u 0.01 0.0	0 0 0 0	106 0.27 0	1.00 0.17	8.11 0.25	8.13 0.42	0.14 0.01	0.01 0.12	0.30 0.18	8.28 8.24	i 827 030	0.33 0.47	0.30 0.20	0.37 0.23 0.4	er 022 0	8.26 8.26 8.	77 0.00 0.07	0.70 0.07	849 839 831	0.30 0.82 0	0.29 0.44 0.75	2 0.36 D.a	a 0.30 0.		aa 0.71 0.72 0.01	1.00 0.00 0	8.47 8.42 8.72
Laterale damage	0.00	0.00 0.00	0.00 0.00	0.00 0.00	2.01 0.0	0.00	0.00 0.00	0.00 0.02	0.02 0.21	. a.a. a	0.06 0.11	0.01 0.02 0.0	a a.ce a.e	: 000 0	.00 0.10 0	1.00 0.10	8.82 8.37	0.09 0.43	0.10 0.24	0.22 0.04	0.21 0.11	0.38 0.31	1 0.12 0.17	0.17 0.22	0.17 0.30	0.21 0.40 0.	21 0.00 0	0.21 0.72 0.	E 0.24 0.27	0.00 0.70	246 0.76 0.46	0.30 0.90	0.82 0.80 0.82	0.12 0.2	0 0.10 0		II 0.12 0.12 0.II	0.30 1.00 0	0.00 0.14 0.01
Antonia delatas	0.00	0.00 0.00	0.00 0.00	0.00 0.00	8.01 0.0	0.01	0.00 0.00	0.00 0.02	0.02 0.17		0.00 0.11	0.02 0.08 0.0	N 0.00 0.0	: 004 0	.02 0.07 0		0.02 0.39	8.10 8.47	0.12 0.21	0.22 0.00	0.00 0.10	8.37 8.34		0.16 0.23	0.12 0.82	0.21 0.32 0.1	30 0.00 0	0.22 0.01 0.	FT 0.30 0.47	0.90 0.70	8.07 0.83 0.81	0.00 0.00 0	0.92 0.92 0.83	a 0.30 0.5	4 0.92 O		22 0.74 0.48 0.97	0.07 0.00 1	1.00 0.07 0.94
Angles Intillema	0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.0	0.01	0.00 0.00	0.00 0.07	0.00 0.10		0.00 0.14	8.01 8.08 8.0	0 0.02 0.0	0.02 0	0.00 0.00 0	1.00 0.10	0.10 0.24	8.17 8.27	0.07 0.40	0.21 0.19	0.33 0.33	0.23 0.15	0.00 0.00	0.55 0.23	0.32 0.10	0.31 0.12 0.1		a.a a.a a.	80 830 838	0.01 0.02	832 8.18 8.18	0.22 0.11 0	0.11 0.10 0.22	a 0.0 03	2 8.07 S		14 034 033 013	0.42 0.14 0	1.00 0.12
Circles Insula	0.00	0.00 0.00	0.00 0.00	0.00 0.00	201 2.0	0.00	0.00 0.00	0.00 0.00	0.00 0.00	E 104 1	0.00 0.11	0.00 0.10 0.0	0 0.00 0.0	0 000 0	.00 0.07 0	1.06 0.21	000 0.07	8.12 0.20	0.14 0.29	0.32 0.07	0.27 0.14	842 843	: 0.20 0.20	0.30 0.22	0.26 0.46	0.30 0.47 0.4	40 0.00 0	0.22 D.BK D.	17 0.00 0.70	0.70 0.81	177 0.00 0.00	0.27 0.82 0	0.94 0.80 0.97	a 0.32 0.2	a 1.27 1	N 0.04 0.74 0	12 0.02 0.79 0.90	0.72 0.81 0	8.94 8.12 1.00

Correlation Results Associated Species, All 81 species

Constations Finan angularana Litras intibila											
Pres pargen Line constra Pres Omite Presis transiti Della constrato Presidenza		PicEng	AbiBif	PicPun	AbiCon	PinFle	PopTre	SalSco	PseMen	BerRep	QueGam
Salara ngua Densa perinti Pena sidi Pena sidi Ser providenti Serpen depat Conta pas Serpen meng Serpen meng	Picea engelmannii	1.00	0.97	0.82	0.67	0.64	0.72	0.70	0.67	0.48	0.32
Carrys unights Pallagie genetime Loninelegie im ge Parales standards Loninelegie im ge	Abies bifolia	0.97	1.00	0.84	0.64	0.55	0.78	0.65	0.61	0.38	0.28
Las acorda	Picea pungens	0.82	0.84	1.00	0.82	0.74	0.77	0.87	0.78	0.57	0.46
Querras emergis Naciona major Degrama major Desgrama major Descriptos adeste	Abies concolor	0.67	0.64	0.82	1.00	0.87	0.68	0.90	0.93	0.69	0.70
Connection in the second secon	Pinus flexilis	0.64	0.55	0.74	0.87	1.00	0.71	0.94	0.94	0.84	0.68
Presiden videor Viene date Berland kommen Popula demonite Resulta resolution Resulta resolution Resulta resolution Resulta augusta Resulta balanzak	Populus tremuloides	0.72	0.78	0.77	0.68	0.71	1.00	0.77	0.73	0.63	0.50
Inin predaty i Diagon Intern Dramos vann Literatur en de Dan sont Calinado en de Dan sont Calinado en de Preges públice Englas stando Englas stando	Salix scouleriana	0.70	0.65	0.87	0.90	0.94	0.77	1.00	0.93	0.82	0.65
Lanas progs Estas palais Diograma Saan, Energia palaise Progsis palaise Lanas tethnis Lanas tethnis Persona palaise Lanas tethnis Lanas tethnis Lanas tethnis Lanas tethnis	Pseudotsuga menziesii	0.67	0.61	0.78	0.93	0.94	0.73	0.93	1.00	0.83	0.79
Coglectioning were Solition pursues Cylindrogramics by Camergine pignatic Cyntaer Generatic Sanadia Datamas	Berberis repens	0.48	0.38	0.57	0.69	0.84	0.63	0.82	0.83	1.00	0.80
Details former Right seery Perinama famil Ophetingunts for Perinama many Langton perinamy Langton perinamy Langton test	Quercus gambelii	0.32	0.28	0.46	0.70	0.68	0.50	0.65	0.79	0.80	1.00

Correlation Chart

Based on associated species

Colors indicate groups, lines indicate highest correlation





Group 1: (2668 ± 35 m) Abies bifolia 0.97 Picea engelmannii 0.97	Group 2: (2403 ± 132 m) Abies concolor 0.83 Picea pungens 0.79 Pinus flexilis 0.84 Populus tremuloides 0.73 Pseudotsuga menziesii 0.86 Salix scouleriana 0.88	Group 3: (2123 ± 195 m) Berberis repens 0.90 Pinus ponderosa 0.90	Group 4: (2033 ± 228 m) Acer grandidentatum 0.88 Quercus gambelii 0.88
Group 5: (1814 ± 119 m) Fallugia paradoxa 0.89 Juniperus monosperma 0.83 Juniperus osteosperma 0.90 Pinus edulis 0.90 Purshia stansburiana 0.90	Group 6: (1711 ± 22 m) Arctostaphylos pringlei 0.83 Arctostaphylos pungens 0.88 Garrya wrightii 0.86	Group 7: (1698 ± 151 m) Cupressus arizonica 0.73 Juniperus deppeana 0.83 Quercus emoryi 0.85 Quercus grisea 0.85	Group 8: (1504 ± 159 m) Acer negundo 0.75 Alnus oblongifolia 0.77 Fraxinus velutina 0.74 Juglans major 0.86 Platanus wrightii 0.74
Group 9: (1493 ± 116 m) Garrya flavescens 0.90 Quercus turbinella 0.90	Group 10: (1397 ± 136 m) Atriplex canescens 0.71 Yucca baccata 0.76 Yucca elata 0.85	Group 11: (1305 ± 472 m) Allenrolfea occidentalis 0.84 Sarcobatus vermiculatus 0.84	Group 12: (1268 ± 197 m) Berberis haematocarpa 0.79 Canotia holacantha 0.73 Dasylirion wheeleri 0.67 Eriogonum wrightii 0.78 Juniperus arizonica 0.82 Rhus aromatica 0.59 Rhus ovata 0.76
Group 13: (1185 ± 159 m) Celtis reticulata 0.86 Mimosa biuncifera 0.86 Sapindus saponaria 0.88	Group 14: (1066 ± 83 m) Populus fremontii 0.92 Salix gooddingii 0.92	Group 15: (819 ± 132 m) Calliandra eriophylla 0.91 Dodonaea viscosa 0.82 Eriogonum fasciculatum 0.91 Simmondsia chinensis 0.90	Group 16: (791 ± 488 m) Atriplex lentiformis 0.89 Suaeda nigra 0.89
Group 17: (758 ± 166 m) Acacia greggii 0.80 Bebbia juncea 0.72 Celtis pallida 0.74 Cephalanthus occidentalis 0.66 Chilopsis linearis 0.75 Parkinsonia florida 0.79 Prosopis juliflora 0.79 Prosopis pubescens 0.56 Tamarix chinensis 0.72 Ziziphus obtusifolia 0.80	Group 18: (617 ± 115 m) Carnegiea gigantea 0.89 Cylindropuntia bigelovii 0.86 Cylindropuntia fulgida 0.73 Cylindropuntia leptocaulis 0.88 Encelia farinosa 0.90 Ferocactus cylindraceus 0.91 Fouquieria splendens 0.86 Lycium fremontii 0.84	Group 19: (579 ± 49 m) Ambrosia ambrosioides 0.92 Hyptis emoryi 0.95 Lycium berlandieri 0.93	Group 20: (546 ± 85 m) Ambrosia dumosa 0.88 Atriplex polycarpa 0.81 Larrea tridentata 0.88
Group 21: (475 ± 60 m) Ambrosia deltoidea 0.95 Olneya tesota 0.94 Parkinsonia microphylla 0.96			

Correlation Groups Based on Associated Species

		Group 1: (2668 ± 35 m) Abies bifolia 0.97 Picea engelmannii 0.97	Group 2: (240 Abies concolor (Picea pungens (Pinus flexilis 0.8 Populus tremuk	9 3 ± 132 m) 0.83 0.79 94 9ides 0.73	Group 3: (2123 ± 195 m) Berberis repens 0.90 Pinus ponderosa 0.90	Group 4: (2 Acer grandide Quercus gam	033 ± 228 m) entatum 0.88 belii 0.88			
Corre Asso	Group 1: (266 Abies bifolia 0 Picea engelma	8 ± 35 m) .97 nnii 0.97		Group 2: $(2403 \pm 132 \text{ m})$ Abies concolor 0.83 Picea pungens 0.79 Pinus flexilis 0.84 Populus tremuloides 0.73 Pseudotsuga menziesii 0.86 Salix scouleriana 0.88						
	Group 5: (181 Fallugia paraa Juniperus mon Juniperus osteo Pinus edulis 0. Purshia stansb	4 ± 119 m) loxa 0.89 osperma 0.83 osperma 0.90 90 uriana 0.90		Group (Arctosta Arctosta Garrya w	5: (1711 ± 22 m phylos pringle phylos pungen wrightii 0.86	n) i 0.83 s 0.88	91 ± 488 m) rmis 0.89 46 ± 85 m) osa 0.88 rpa 0.81 ta 0.88			
		Ziziphus obtusifolia 0.80 Group 21: (475 ± 60 m) Ambrosia deltoidea 0.95 Olneya tesota 0.94 Parkinsonia microphylla 0.96								

Coordinate based Correlation

Besides using associated species, we also can apply the CORRELATION program using coordinates.

Similar to using associated species, if Species A and Species B are both found near the same sets of species at similar frequencies, then they will probably be frequently found near each other.

This opens up other applications using georeferenced data.

Adding Non-Plants

We can include animals or fungi for instance if we have a list of coordinates for them. For example, we evaluated the following:

A reptile: Heloderma suspectum (Gila Monster)



A mammal: Sciurus aberti (Abert's Squirrel)



Heloderma suspectum (Gila Monster)



Name	Corr
Ambrosia deltoidea	0.78
Larrea tridentata	0.77
Parkinsonia florida	0.75
Atriplex lentiformis	0.74
Encelia farinosa	0.73
Ambrosia dumosa	0.73
Prosopis juliflora	0.73
Ziziphus obtusifolia	0.72
Atriplex polycarpa	0.72
Acacia greggii	0.71

Sciurus aberti (Abert's Squince)

Name	Corr
Berberis repens	0.87
Pinus flexilis	0.84
Pinus ponderosa	0.81
Pseudotsuga menziesii	0.80
Salix scouleriana	0.80
Quercus gambelii	0.80
Abies concolor	0.79
Picea engelmannii	0.76
Populus tremuloides	0.75
Acer negundo	0.73

Rapid comparison of habitats of similar species

We can compare related species to determine which plants they are most likely to be associated with. Do they come from similar communities or not?

For example:

- Physalis crassifolia and Physalis hederifolia
- Hibiscus denudatus and Hibiscus coulteri

Physalis crassifolia

Physalis hederifolia

Name	Corr	
Hyptis emoryi	0.94	
Olneya tesota	0.93	
Bebbia juncea	0.92	
Encelia farinosa	0.91	
Ambrosia ambrosioides	0.90	
Ambrosia dumosa	0.90	
Ferocactus cylindraceus	0.89	
Fouquieria splendens	0.88	
Parkinsonia microphylla	0.88	
Lycium berlandieri	0.86	

Name	Corr
Berberis haematocarpa	0.91
Juniperus arizonica	0.91
Eriogonum wrightii	0.90
Mimosa biuncifera	0.86
Canotia holacantha	0.82
Quercus turbinella	0.81
Rhus ovata	0.79
Sapindus saponaria	0.78
Yucca elata	0.77
Yucca baccata	0.74

Hibiscus denudatus

Hibiscus coulteri

Name	Corr
Encelia farinosa	0.91
Fouquieria splendens	0.91
Ambrosia dumosa	0.90
Ferocactus cylindraceus	0.88
Hyptis emoryi	0.86
Olneya tesota	0.85
Ambrosia deltoidea	0.85
Carnegiea gigantea	0.84
Parkinsonia microphylla	0.84
Cylindropuntia bigelovii	0.82

Name	Corr
Simmondsia chinensis	0.91
Calliandra eriophylla	0.89
Eriogonum fasciculatum	0.89
Dodonaea viscosa	0.84
Fouquieria splendens	0.84
Hyptis emoryi	0.80
Lycium berlandieri	0.79
Celtis pallida	0.78
Cylindropuntia bigelovii	0.78
Ambrosia ambrosioides	0.78

Conclusions

- CORRELATION appears useful for quantifying relationships between species
- Groups correspond well to biotic communities previously established by field studies
- Various analyses can all be done without further field work, just using existing databases.
- Animals, fungi and other organisms can be included in these analyses if there is coordinate data available.
- Concepts of Biotic Communities can be tested and or expanded with data on thousands of species in specimen databases.

Analogy

If two people spend a lot of time with the same people then you can conclude that they probably spend a lot of time with each other.

Maybe they belong to the same household, or work in the same place, or are in the same class at school.

One might be a shy less talkative person (a rare less known species)

And one might be an outgoing, talkative person that is everyone's friend (a common well known species)