

DRAFT REPORT

**HANGING GARDEN VEGETATION AND FLORA SURVEY,
SAN JUAN ARM, LAKE POWELL,
GLEN CANYON NATIONAL RECREATION AREA**

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INTRODUCTION

During the period July 26-31, 1991, hanging gardens were surveyed in and around Alcove Canyon, an unnamed canyon to the west (unofficially Pictograph Canyon), and between the two, on the north side in the San Juan arm of Lake Powell. Aims of the survey were to 1) locate populations of the endangered sedge Carex specuicola, 2) locate populations of the rare sawgrass Cladium californicum, 3) inventory the floras of selected, representative, hanging gardens, and 4) provide information on vegetation-structure of the surveyed gardens. In this report I detail the major results of this expedition. Methodology is documented, basic data for surveyed hanging gardens is listed, and analysis of the data is presented. Finally, I conclude with a discussion of the results and their significance, and suggest future work.

METHODS AND MATERIALS

Hanging gardens selected were predominantly of the "alcove" type (see Welsh 1989). As water seeps out of bedding planes, rock spalling and other forms of weathering eventually form an alcove of varying size in the canyon wall, with a vertical or sloping back wall, associated detritus slope, and a plunge pool. The back wall is usually wet from seepage. Each of these topographic units provides different habitats for plants. Generally, just downstream or down slope from the garden, a riparian zone is found, formed as the seep water becomes contained in a stream channel. For each topographic unit, the following acronyms are used:

BW=back wall,
DS=detritus slope,
PP=plunge pool,
RZ=riparian zone

Water flow rates at each garden were scored as:

- 1=early intermittent, dries out by late May or June, at about time spring flowering ceases and fruit develop is well under way,
- 2=late intermittent (permanent in wet years), dries out by mid to late summer (July-August),
- 3=permanent flow throughout year.

At each garden surveyed, a species list X applicable topographic unit matrix was prepared. Each species was rated using the following abundance scale, derived from Spence & Henderson (1991):

D=dominant (95%+ cover),
A=abundant (conspicuous, very high cover, 50-95%),
C=common (conspicuous, high cover, 10-49%),
U=uncommon (conspicuous, but low cover, 1-9%),

O=occasional (not conspicuous but can be found with effort, <1% cover),
 R=rare (trace only, essentially no cover, difficult to locate).

The cover estimates are absolute, based on areal extent of site, rather than relative percent of total vegetation cover. Timed tests originally done using this survey technique (Spence, pers. observations) showed that about 90-95% of the species present can be found and surveyed within a 1 hour period for a large garden. Species most likely to be missed are small, ephemeral taxa (eg., annuals) and sterile grasses and sedges that are likely to be confused with other species.

Floristic and vegetation data were analysed by principal components analysis, cluster analysis, and Monte Carlo simulation. The basic data matrix for ordination and cluster analysis consisted of the 25 topographic units (backwall, detritus slope, plunge pool) for the hanging gardens, and the spring, by 64 species. A variance-covariance analysis of untransformed data was performed with the PCORD program (McCune 1987). The cluster analysis used the unweighted pair-group mathematical algorithm, and Euclidean distance. For both the PCA and CA, the abundance scale was converted to a numerical scale as A=6, D=5, C=4, U=3, O=2, and R=1.

Monte Carlo simulations were done on the 25 site floras using the techniques detailed in Spence and Henderson (1991), Spence and Pocs (1989), and Rice and Belland (1982). Jaccard's coefficient of similarity was used to compute pairwise floristic associations. The 64 species were then pooled together, and species were randomly drawn to produce a flora for each site out of this pool, subject to the constraints that, 1) the number of random species corresponds to the observed number of species, and 2) the species are represented in the pool in proportion to their actual abundance among the sites (more widespread species are more likely to be picked). This process was repeated 20 times and 95% confidence intervals were constructed. Finally, the random pairwise comparison was tested against the analogous real comparison. If the real comparison was outside the 95% confidence intervals for the random comparison, the null hypothesis that it does not differ significantly from random was rejected.

Nomenclature follows Welsh et al. (1987).

RESULTS

Rare and T&E species

The navajo sedge, Carex specuicola, was not located during the course of this survey. At present, it appears to be restricted to hanging gardens south of the San Juan and Lake Powell. A survey of only 12 hanging gardens is unlikely to be representative of all gardens. It is possible that the sedge has specialized site requirements, perhaps related to water quality, microclimate, or associated species. Most of the gardens surveyed in this work were

either large wet alcove sites with high (100% or more) plant cover, or small dry seeps. Particularly in the larger gardens, competition may be a factor in preventing the navajo sedge from establishing. A search for smaller, wet, and rockier gardens with lower vegetation cover, may discover the sedge.

The sawgrass, Cladium californicum, is considered rare in Utah. Many sites, or potential sites, are currently drowned by Lake Powell. However, during this survey, the species was encountered several times, in hanging gardens as well as along riparian zones. One new population each in Alcove Canyon and "Pictograph" Canyon were discovered in riparian zones, while populations were found in "Cliff" and "Hardwood" gardens. Previously, the only local population known was at "Cladium" garden. Many more populations will probably be discovered as more canyons entering into Lake Powell are surveyed.

Floristics

The 64 species encountered in this survey are listed in the Appendix, with general geographic distribution at the North American level listed in Table 1. The unidentified Lactuca species was not classified as both introduced and native species occur in western North America. Seven Colorado Plateau endemics were encountered; Aquilegia micrantha, Carex curatorum, Cirsium rydbergii, Habenaria zothecina, Mimulus eastwoodiae, Primula specuicola, and Yucca toftiae, comprising 12% of flora. Most of the remainder of the flora consists of widespread North American or western North American boreal-temperate species. Relatively fewer species (15%) are southwestern in distribution. Three species with unusual distributions were encountered; Andropogon glomeratus (s. US temperate with extensions onto the Great Plains), Calamagrostis scopulorum (Rocky Mountain subalpine-alpine), and Sorghastrum nutans (Great Plains, s. US-subtropical). The Andropogon and Sorghastrum were placed in the North American group, while the Calamagrostis was placed in the western North American group. Bromus tectorum was the most common introduced species. The Sorghastrum, and Carex lanuginosa, are new and interesting additions to hanging garden floras.

Garden floras ranged from 10 to 39 species, with an average of 24.3. The most diverse was "Rattlesnake garden", with 39 species. This garden exhibited classic alcove features, and was the only garden surveyed that had a distinct plunge pool. For eleven gardens, a distinction could be made between the backwall and the detritus slope. Backwalls averaged 11.4 species per garden (range 5-15), while detritus slopes averaged 13.4 species (range 7-19). These are not significantly different at the 0.05% level by a t-test. The plunge pool had nine species, while the spring supported 14 species.

Jaccard's coefficients of similarity ranged from 0 (many comparisons) to 57.9% between the detritus slope and backwall of "Vista Garden". The results of Monte Carlo simulations of the floristic relationships are summarized in Table 2. Significant

positive associations occurred between backwalls (28% of comparisons), backwalls and detritus slopes (20% of comparisons), and between detritus slopes (9% of comparisons). The plunge pool of "Rattlesnake Garden" and the spring showed no significantly positive associations with the other sites. Interestingly, only 23% of comparisons within a garden were significantly positive, with most (69%) not significantly different from random. The detritus slope and backwall of "Cladium Garden" were significantly different.

There were fewer significantly negative compared with positive associations (Table 2). The spring and plunge pool were most distinct from backwalls, and less so with detritus slopes.

Vegetation and Ordination

The most abundant or important species using cover varied from garden to garden. The dominant species in many backwalls was Adiantum capillus-veneris, followed by Petrophytum caespitosum. In all, 12 species were dominant or shared dominance in the 11 investigated backwalls. Quercus gambelii and Calamagrostis scopulorum were the most common dominants on detritus slopes. Overall, 14 species dominated or shared dominance on 11 detritus slopes. Some species could assume dominance in both habitats; Cirsium rydbergii, Toxicodendron rydbergii, Calamagrostis scopulorum, Rhannus betulifolia, and Andropogon glomeratus. However, in no cases did a single species dominate both habitats in the same garden.

The ordination of the vegetation data for 24 sites, with the spring excluded, is shown in Figure 1 (an ordination, not presented, including the spring showed it to be quite distinct vegetationally from the hanging gardens). Amount of variance extracted on the first three axes was 16%, 15%, and 10%. The first axis separates sites by topography, with detritus slopes on the positive end, and backwalls towards the negative end. The second axis separates sites by flow rates, with wet sites (flow rate = 3) at the top (positive), to dry sites (flow rate = 1) at the bottom (negative). Species with high loadings (importance) on these axes are listed in Table 3. On the first axis, Quercus gambelii, Cercis occidentalis, and Artemisia ludoviciana had strong positive loadings (detritus slope end), while Adiantum capillus-veneris, Petrophytum caespitosum, and Primula specuicola had high negative loadings (backwall end). On the second axis, Aquilegia micrantha, Mimulus eastwoodiae, and Parthenocissus vitacea had high positive loadings (wet end), while Andropogon glomeratus, Castilleja linariifolia, and Yucca toftiae had high negative loadings (dry end).

The results of a cluster analysis (not shown) were generally similar to the ordination. Clusters comprised predominantly backwall or detritus slope sites, while smaller groupings within clusters usually grouped wet sites and dry sites.

Classification

The hanging gardens are dominated by a variety of species, making classification by floristics and dominance difficult. However, most can be grouped into three kinds of series, related to dominance by monocots, backwall specialists, and woody plants. The most important series species are; Calamagrostis scopulorum, Cladium californicum, Quercus gambelii, Cirsium rydbergii, Adiantum capillus-veneris, and Petrophytum caespitosum. The most prevalent and widespread series was Adiantum capillus-veneris, with associations related to forb species that varied from garden to garden. Other series include Quercus gambelii and Calamagrostis scopulorum. Higher level classification of forb-dominated gardens are currently possible only using Spence (1990), as the Brown, Lowe & Pase system (eg., Brown 1982) does not include forblands.

DISCUSSION

The hanging gardens discussed in this report represent a small, relatively uniform, fraction of all hanging gardens in Glen Canyon National Recreation Area. An expanded data set may reveal additional patterns of floristics and vegetation related to geographic differences. Furthermore, many additional species will probably be found when a survey of a larger set of hanging gardens is done. These considerations should be kept in mind as the results are discussed.

Floristically, large wet hanging gardens were the most species rich, while smaller drier gardens were relatively species poor. Differences in flora occurred between backwalls and detritus slopes in most gardens. A small suite of backwall specialists was usually present in wetter gardens that included Adiantum capillus-veneris, Primula specuicola, Aquilegia micrantha, Mimulus eastwoodiae, and Petrophytum caespitosum. Several are Colorado Plateau endemics. A more widespread survey of hanging garden species (cf. Welsh 1989) indicates that additional Plateau endemics are backwall specialists, eg., species of Aquilegia, Carex, Mimulus, Eriogonum, and Perityle. Detritus slopes tended to be more diverse, with a particularly large component of widespread boreal-temperate species. Regional endemics and backwall specialists were generally absent or rare on detritus slopes. The Monte Carlo simulations showed that some of the backwalls and detritus slopes were significantly different floristically, including two sites in one garden.

Ordination revealed non-random patterns of vegetation that could be related to topographic unit and flow rate. Detritus slopes and backwalls were shown to be vegetationally distinct by the ordination on the first axis, accounting for the largest amount of variation in the data. Flow rates accounted for the second largest set of variation, and separated wet sites from dry sites.

The estimate of flow rate used in this survey is very crude, and a more refined and quantitative scale should be adopted in future work. However, even with the crude scale used, important

points emerged. First is that vegetation patterns are related to flow rates, although this seems to be less important in this study than topographic unit. Second, the vegetation pattern depicted in the ordination suggests two interesting possible applications. If flow rates have recently (last 1-5 yrs?) declined or increased within a garden, this may be possible to predict from an ordination. This is because the vegetation at the garden may reflect past flow rates, and dynamic changes related to reduced or increased flow rates have either lagged behind or not occurred. The second possible application is in correcting estimated flow rates. The ordination, for example, places the detritus slope of "Cliff" garden with detritus slopes having flow rates of 3, although it is classified as a 2 in this study. This suggests that either flow rates have declined at this garden, or they were not classified correctly.

Overall, hanging gardens are fascinating ecological systems, essentially unique to the Colorado Plateau (Spence 1990). They are isolated from each other, controlled largely by physical features, especially water and topography, and exhibit various types of disturbance regimes (cf. Malanson 1980, 1982; Malanson & Kay 1980). They may be the best vegetation systems on the Plateau to monitor for climate change. There is an old (probably pre-Pleistocene) backwall association which is relatively uniform and widely distributed, dominated by the fern Adiantum capillus-veneris, a species with tropical-subtropical relationships, and including numerous local endemics biogeographically related to temperate eastern North American and Mexican floras. Detritus slopes are generally also present, and support a mixture of species with North American and circumpolar affinities. They are also more variable than the backwall flora, possibly because of greater disturbance regimes. The available literature also suggests variation related to geography, as hanging gardens from Canyonlands and Arches on the east, to Zion and Grand Canyon on the west and south, show substantial floristic differences (Allan 1977; Loope 1977; Brotherson et al. 1985; Welsh 1989)

Future work and recommendations

Much important work on hanging gardens can be done with the survey technique used in this study. Of prime importance at present is to survey and document the flora and vegetation of as many gardens as possible in GLCA, concentrating on different geographical regions, such as the San Juan arm, Escalante area, Canyonlands-Dark Canyon, etc. Data from Zion and Grand Canyon National Parks would also be useful for comparative purposes. The results of this survey can focus and define future work on monitoring and ecological research. In particular, the results of a widespread survey can be used to select gardens for long-term monitoring.

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Table 1. Summary of North American geographic distributions of the 60 species encountered in the 12 investigated hanging gardens. Note that Sorghastrum nutans is placed in group 2, although it may be introduced to the Colorado River basin.

<u>Distribution</u>	<u>Number</u>	<u>Percent of Total</u>
1. Colorado Plateau endemics	7	12
2. Widespread North American boreal-temperate	19	32
3. Widespread western North American temperate	22	36
4. Southwestern North American	9	15
5. Introduced	3	5
Total	60	100

Table 2. Summary of the Monte Carlo simulation of floristic associations between hanging garden topographic sites and the spring. The values are the number of comparisons significantly different (negative or positive) from random, expressed as a percentage of the total number of comparisons (N). See Methods and results for more details. BW = backwall, DS = detritus slope, PP = plunge pool, SP = spring.

<u>Comparison</u>	<u>N</u>	<u>Negative</u>	<u>Positive</u>	<u>Random</u>
BW - BW	65	0	28	85
BW - DS	66	5	20	75
DS - DS	65	6	9	72
BW - SP	11	18	0	82
DS - SP	11	9	0	91
BW - PP	11	18	0	82
DS - PP	11	9	0	91
PP - SP	1	0	0	100

Table 3. The most important species on the first two axes of the PCA ordination of the hanging garden sites. The five most important species (highest Pearson correlation with each axis) at each pole of each axis are listed, ranked from most important to least important. The first three letters of the genus and epithet are used.

Axis I		Axis II	
Positive (DS's)	Negative (BW's)	Positive (wet)	Negative (dry)
<u>Quegam</u>	<u>Petcae</u>	<u>Aqumic</u>	<u>Yuctof</u>
<u>Cerocc</u>	<u>Adicap</u>	<u>Minaes</u>	<u>Andglo</u>
<u>Artlud</u>	<u>Prispe</u>	<u>Parvit</u>	<u>Caslin</u>
<u>Glycan</u>	<u>Clacal</u>	<u>Adicap</u>	<u>Brotec</u>
<u>Equlae</u>	<u>Opuspp</u>	<u>Habzoc</u>	<u>Solspa</u>

APPENDIX: Site data

Species list (hanging gardens; not alphabetical). For each species, its general distribution is noted (1 = Colorado Plateau endemic, 2 = widespread North American boreal-temperate, 3 = widespread western North American temperate, 4 = southwestern North American, 5 = introduced).

<i>Cirsium rydbergii</i>	1
<i>Parthenocissus vitacea</i>	2
<i>Habenaria zothecina</i>	1
<i>Mimulus eastwoodiae</i>	1
<i>Smilacina stellata</i>	2
<i>Carex lanuginosa</i>	2
<i>C. curatorum</i>	1
<i>C. aurea</i>	2
<i>Juncus ensifolius</i>	2
<i>Elymus canadensis</i>	2
<i>Adiantum capillus-veneris</i>	2
<i>Salix amygdaloides</i>	2
<i>S. lutea</i>	3
<i>Petrophytum caespitosum</i>	3
<i>Cercis occidentalis</i>	4
<i>Artemisia ludoviciana</i>	2
<i>Briellia longifolia</i>	4
<i>Aquilegia naicrantha</i>	1
<i>Quercus gambelii</i>	3
<i>Epipactis giganteus</i>	3
<i>Aster chilensis</i>	3
<i>Rhamnus betulifolia</i>	4
<i>Panicum acuminatum</i>	2
<i>P. virgatum</i>	2
<i>Taraxacum officinale</i>	5
<i>Clematis ligusticifolia</i>	3
<i>Solidago sparsiflora</i>	3
<i>Castilleja linariifolia</i>	3
<i>Rhus aromatica</i>	2
<i>Stephanomeria tenuifolia</i>	3
<i>S. paucifolia</i>	4
<i>Celtis reticulata</i>	3
<i>Apocynum cannabinum</i>	2
<i>Equisetum laevigatum</i>	3
<i>Bromus tectorum</i>	5
<i>Primula specuicola</i>	1
<i>Toxicodendron rydbergii</i>	2
<i>Calamagrostis scopulorum</i>	3
<i>Amelanchier utahensis</i>	3
<i>Symphoricarpos longiflorus</i>	3
<i>Cladium californicum</i>	4
<i>Thelypodium integrifolium</i>	3
<i>Phragmites australis</i>	2

<i>Typha latifolia</i>	2
<i>Yucca toftiae</i>	1
<i>Tamarix ramosissima</i>	5
<i>Fraxinus anomala</i>	4
<i>Muhlenbergia curtifolia</i>	2
<i>Hymenoxys acaulis</i>	3
<i>Opuntia</i> sp. (<i>polyacantha</i> / <i>phaeacantha</i>)	3
<i>Schizychyrium scoparium</i>	2
<i>Oenothera elata</i>	3
<i>Aristida purpurea</i>	3
<i>Andropogon glomeratus</i>	2
<i>Baccharis salicina</i>	4
<i>Sorghastrum nutans</i>	2/5?
<i>Mentzelia albicaulis</i>	3
<i>Juniperus osteosperma</i>	3
<i>Dyssodia pentachaeta</i>	4
<i>Heterotheca villosa</i>	3

Garden 1: "Rattlesnake Garden", lower Pictograph Canyon, 2nd large alcove on west or left, facing up canyon from lake. Classic alcove features. Flow rate=3.

<u>Species</u>	<u>BW</u>	<u>DS</u>	<u>PP</u>	<u>RZ</u>
Parthenocissus vitacea	U	O	O	A
Habenaria zothecina	O	R	O	-
Minulus eastwoodiae	C	-	-	-
Smilacina stellata	-	U	U	R
Carex lanuginosa	-	O	-	-
C. curatorum	-	O	O	-
Juncus ensifolius	O	C	U	-
Elymus canadensis	O	U	-	-
Adiantum capillus-veneris	A	O	-	-
Salix amygdaloides	-	-	R	-
S. lutea	-	O	O	-
Petrophytum caespitosum	O	-	-	-
Cercis occidentalis	-	O	-	-
Artemisia ludoviciana	-	U	-	O
Brickellia longifolia	O	O	-	U
Aquilegia micrantha	U	O	-	-
Quercus gambelii	-	C	-	-
Epipactus gigantea	-	O	-	-
Cirsium rydbergii	-	U	-	U
Aster chilensis	O	O	-	-
Rhamnus betulifolia	-	R	-	-
Panicum acuminatum	-	-	C	U
Taraxacum officinale	R	-	O	R
Clematis ligusticifolia	R	-	-	-
Chenopodium sp. (large)	-	-	-	R
Carex hystericina	-	-	-	U
Castilleja linariifolia	-	-	-	U
Typha latifolia	-	-	-	U
Juncus arcticus	-	-	-	R
Erigeron utahensis	-	-	-	R
Equisetum laevigatum	-	-	-	U

Garden 2: "Parthenocissus Garden", part way up left fork of Pictograph Canyon. Flow rate=2. No PP; RZ in area where PP would normally be.

<u>Species</u>	<u>BW</u>	<u>DS</u>	<u>RZ</u>
Aquilegia micrantha	O	-	-
Cirsium rydbergii	U	C	-
Carex aurea	-	O	-
Rhamnus betulifolia	-	O	-
Smilacina stellata	-	R	O
Quercus gambelii	-	U	O
Solidago sparsiflora	-	R	-
Castilleja linariifolia	-	R	-
Adiantum capillus-veneris	U	-	-
Parthenocissus vitacea	-	C	O
Aster chilensis	-	R	R
Brickellia longifolia	R	O	-
Artemisia ludoviciana	-	U	-
Rhus aromatica	-	R	-
Stephanomeria tenuifolia	-	R	-
Mimulus eastwoodiae	U	-	-
Celtis reticulata	-	R	O
Habenaria zothecina	-	R	-
Apocynum cannabinum	-	R	U
Clematis ligusticifolia	-	O	-
Lactuca cf. serriola	-	R	-
Equisetum laevigatum	-	R	U
Elymus canadensis	-	R	O
Juncus arcticus	-	-	C
Solidago occidentalis	-	-	O
Populus fremontii	-	-	U
Carex curatorum	-	-	C

Garden 3: "Shady Garden", at end of right fork of Pictograph Canyon. No distinct PP, DS discontinuous, RZ starts at base of BW and DS. Flow rate = 3.

<u>Species</u>	<u>BW</u>	<u>DS</u>	<u>RZ</u>
<i>Cirsium rydbergii</i>	O	R	O
<i>Adiantum capillus-veneris</i>	C	-	-
<i>Cercis occidentalis</i>	R	-	-
<i>Parthenocissus vitacea</i>	O	O	-
<i>Aquilegia micrantha</i>	U	R	O
<i>Bromus tectorum</i>	-	O	-
<i>Panicum acuminatum</i>	-	O	O
<i>Primula specuicola</i>	U	O	-
<i>Brickellia longifolia</i>	O	U	R
<i>Petrophytum caespitosum</i>	O	-	-
<i>Quercus gambelii</i>	R	U	-
<i>Toxicodendron rydbergii</i>	-	A	U
<i>Equisetum laevigatum</i>	-	R	O
<i>Calamagrostis scopulorum</i>	R	-	-
<i>Mimulus eastwoodiae</i>	U	-	-
<i>Elymus canadensis</i>	-	-	O
<i>Apocynum cannabinum</i>	R	O	-
<i>Celtis reticulata</i>	-	O	-
<i>Clematis ligusticifolia</i>	-	-	O
<i>Erigeron utahensis</i>	-	R	R
<i>Solidago sparsiflora</i>	-	-	U
<i>Taraxacum officinale</i>	-	-	O
<i>Rhamnus betulifolia</i>	-	-	R
<i>Aster chilensis</i>	-	-	R

Garden 4: "Vista Garden", 1st alcove on west or left side of Pictograph Canyon, from lake. Flow rate=3. No distinct PP, rather bare rock platform that occasionally gets wet.

<u>Species</u>	<u>BW</u>	<u>DS</u>
<i>Cirsium rydbergii</i>	U	O
<i>Quercus gambelii</i>	U	C
<i>Calamagrostis scopulorum</i>	C	C
<i>Mimulus eastwoodiae</i>	U	-
<i>Toxicodendron rydbergii</i>	R	O
<i>Primula specuicola</i>	O	R
<i>Adiantum capillus-veneris</i>	U	-
<i>Habenaria zothecina</i>	R	R
<i>Rhamnus betulifolia</i>	U	C
<i>Carex aurea</i>	O	-
<i>Aquilegia micrantha</i>	R	O
<i>Parthenocissus vitacea</i>	R	O
<i>Solidago sparsiflora</i>	O	O
<i>Amelanchier utahensis</i>	O	-
<i>Clematis ligusticifolia</i>	-	O
<i>Erigeron cf. utahensis</i>	R	-
<i>Petrophytum caespitosum</i>	-	R
<i>Symphoricarpos longiflorus</i>	-	R
<i>Cercis occidentalis</i>	-	R

Garden 5. "Cliff H.G.". First garden downstream from Pictograph Canyon, on canyon wall, terraced, lacking alcove formation. Consists of a series of small backwalls and terraces, three obvious ones.

First Backwall-top
(dry but shaded; flow rate = 1)

<u>Species</u>	<u>BW</u>	<u>DS</u>
<i>Cirsium rydbergii</i>	-	0
<i>Cladium californicum</i>	-	C
<i>Mimulus eastwoodiae</i>	U	-
<i>Aquilegia micrantha</i>	U	-
<i>Primula specuicola</i>	U	0
<i>Solidago sparsiflora</i>	0	-
<i>Parthenocissus vitacea</i>	-	C
<i>Habenaria zothecina</i>	-	0

ppca 1
E/ro 2

Second Backwall-2/3 distance up slope
(exposed, wet; flow rate = 3)

<u>Species</u>	<u>BW</u>
<i>Typha latifolia</i>	U
<i>Phragmites australis</i>	U
<i>Rhamnus betulifolia</i>	A
<i>Cladium californicum</i>	C
<i>Cirsium rydbergii</i>	U

Third Backwall-lowest, 1/2 distance up slope
(shaded, wet, some alcove formation; flow rate = 3)

<u>Species</u>	<u>BW</u>	<u>DS</u>
<i>Cirsium rydbergii</i>	U	0
<i>Calamagrostis scopulorum</i>	-	0
<i>Carex aurea</i>	U	U
<i>Adiantum capillus-veneris</i>	U	-
<i>Aquilegia micrantha</i>	0	U
<i>Epipactus gigantea</i>	0	-
<i>Petrophytum caespitosum</i>	0	-
<i>Rhamnus betulifolia</i>	0	U
<i>Brickellia longifolia</i>	-	0
<i>Phragmites australis</i>	0	-
<i>Quercus gambelii</i>	-	A
<i>Thelypodium integrifolium</i>	R	-
<i>Toxicodendron rydbergii</i>	R	0

Garden 6: "Dune H.G." In large alcove between Alcove and Pictograph canyons, closer to Pictograph Canyon. Flow rate = 1/2. Has two backwalls, higher one is drier, some detritus slope development, but no distinct plunge pool.

<u>Species</u>	<u>BW</u>	<u>DS</u>
<i>Cercis occidentalis</i>	-	R
<i>Carex curatorum</i>	U	-
<i>Adiantum capillus-veneris</i>	O	U
<i>Primula specuicola</i>	O	-
<i>Cirsium rydbergii</i>	O	U
<i>Calamagrostis scopulorum</i>	O	-
<i>Salix lutea</i>	-	O
<i>Solidago sparsiflora</i>	R	O
<i>Yucca toftiae</i>	R	-
<i>Panicum acuminatum</i>	O	-
<i>Clematis ligusticifolia</i>	-	U
<i>Tamarix ramossissima</i>	-	R
<i>Rhus aromatica</i>	-	R
<i>Brickellia longifolia</i>	-	O
<i>Celtis reticulata</i>	-	O
<i>Rhamnus betulifolia</i>	-	U
<i>Petrophytum caespitosum</i>	U	-
<i>Fraxinus anomala</i>	O	O
<i>Castilleja linariifolia</i>	-	R
<i>Muhlenbergia curtifolia</i>	-	O
<i>Lactuca cf. serriola</i>	R	R
<i>Taraxacum officinale</i>	-	R
<i>Hymenoxys cf. acaulis</i>	-	R

Garden 7: "Crossbed H.G." In same alcove as Dune Garden, on east/northeast side. No plunge pool. Flow rate = 1.

<u>Species</u>	<u>BW</u>	<u>DS</u>
Calamagrostis scopulorum	O	O
Cirsium rydbergii	O	-
Adiantum capillus-veneris	U	-
Opuntia erinacea	R	-
Cladium californicum	O	-
Aster chilensis	O	-
Petrophytum caespitosum	C	-
Castilleja linariifolia	R	-
Primula specuicola	U	-
Schizachyrium scoparium	O	O
Lactuca cf. serriola	-	R
Oenothera elata/howardii	-	R
Cercis occidentalis	-	U
Aristida purpurea	-	O
Solidago sparsiflora	-	O
Hymenoxys cf. acaulis	-	R
Yucca toftiae	R	O
Fraxinus anomala	O	U

Garden 8: At upper end of Alcove Canyon, massive backwall, some detritus slope development, no plunge pool, dry. Flow rate = 1.

<u>Species</u>	<u>BW</u>	<u>DS</u>
<i>Celtis reticulata</i>	U	C
<i>Brickellia longifolia</i>	O	U
<i>Minulus eastwoodiae</i>	O	-
<i>Calamagrostis scopulorum</i>	U	-
<i>Cirsium rydbergii</i>	U	-
<i>Adiantum capillus-veneris</i>	C	-
<i>Cercis occidentalis</i>	-	O
<i>Petrrophytum caespitosum</i>	U	-
<i>Solidago sparsiflora</i>	O	-
<i>Epipactus gigantea</i>	O	-
<i>Primula specuicola</i>	O	-
<i>Stephanomeria tenuifolia</i>	R	-
<i>Quercus gambelii</i>	-	O
<i>Bromus tectorum</i>	-	O
<i>Lactuca cf. serriola</i>	-	R
<i>Carex curatorum</i>	-	R
<i>Stephanomeria pauciflora</i>	R	-

Garden 9: "Baby H.G." small side canyon on right looking upstream in Alcove Canyon, c. 1 km from water. Very small, dry, shaded backwall and small detritus slope, no plunge pool. Flow rate = 1.

Species

BW/DS

Panicum virgatum
 Epipactus gigantea
 Rhamnus betulifolia
 Calamagrostis scopulorum
 Panicum acuminatum
 Adiantum capillus-veneris
 Celtis reticulata
 Rhus aromatica
 Brikellia longifolia
 Solidago sparsiflora

O
 R
 C
 U
 O
 C
 O
 O
 R
 R

Garden 10: "Baby 2", short distance up side canyon from Baby 1. Somewhat larger, better backwall-detritus slope separation. Dry. Flow rate = 1.

<u>Species</u>	<u>BW</u>	<u>DS</u>
Petrrophytum caespitosum	C	-
Adiantum capillus-veneris	C	-
Castilleja linariifolia	R	O
Primula specuicola	O	-
Rhamnus betulifolia	R	-
Calamagrostis scopulorum	-	C
Solidago sparsiflora	-	O
Andropogon glomeratus	-	C
Panicum acuminatum	R	O
Aster chilensis	O	U
Yucca toftiae	-	O

Garden 11: "Hardwood H.G." Large, with two backwalls. Wettest part of backwall 2 (lower one) surveyed. Flow rate = 1.

Backwall-Detritus slope 1

<u>Species</u>	<u>BW</u>	<u>DS</u>
Baccharis salicina	C	-
Solidago sparsiflora	O	U
Cirsium rydbergii	-	O
Parthenocissus vitacea	U	-
Cercis occidentalis	-	C
Panicum acumination	O	O
Yucca toftiae	O	U
Elymus canadensis	-	U
Quercus gambelii	-	U
Calamagrostis scopulorum	R	O
Andropogon glomeratus	-	U
Adiantum capillus-veneris	U	-
Celtis reticulata	-	C
Clematis ligusticifolia	-	O
Castilleja linariifolia	-	O
Bromus tectorum	-	U
Primula specuicola	U	-
Petraphytum caespitosum	U	-
Rhus aromatica	O	-
Schizachyrium scoparium	O	-
Phragmites australis	R	-
Thelypodium integrifolium	-	R

Backwall 2 (minimal DS)

<u>Species</u>	<u>BW</u>
Solidago sparsiflora	U
Adiantum capillus-veneris	C
Cladium californicum	C
Calamagrostis scopulorum	C
Baccharis salicina	U
Castilleja linariifolia	R
Cirsium rydbergii	U
Petrophytum caespitosum	U
Muhlenbergia curtifolia	U
Quercus gambelii	O
Yucca toftiae	O

Garden 12: "Cladium H.G." On the cliff face between Alcove and Pictograph canyons, closer to Alcove Canyon. Sloping rock face with water seeping out at base of Navajo SS, distinction between backwall and detritus slope weak. South facing, exposed. Water flow = 2/3.

<u>Species</u>	<u>BW</u>	<u>DS</u>
Mentzelia albicaulis	-	R
Cladium californicum	U	C
Carex curatorum	O	-
Sorghastrum nutans	-	U
Calamagrostis scopulorum	U	-
Phragmites australis	-	U
Rhus aromatica	-	U
Castilleja linariifolia	R	O
Brickellia longifolia	-	O
Cirsium rydbergii	U	O
Yucca toftiae	R	O
Adiantum capillus-veneris	-	O
Andropogon glomeratus	U	U
Petrophytum caespitosum	U	-
Primula specuicola	U	-
Bromus tectorum	-	O
Juniperus osteosperma	-	O
Dyssodia pentachaeta	-	R
Epipactus gigantea	O	-
Stephanomeria tenuifolia	-	O
Heterotheca villosa	-	O
Tamarix ramosissima	(R	- base of cliff)
Baccharis salicina	(O	- at high water)
Silene antirrhina	(O	- level of 1983)
Juncus nodosus	(O	-

Seep 1: Large seep just below and down canyon from "Vista H.G.". Exposed, some rock faces wet, extensive detritus.

<u>Species</u>	<u>Abundance</u>
Phragmites australis	C
Solidago occidentalis	C
Quercus gambelii	C
Calamagrostis scopulorum	U
Brickellia longifolia	O
Thelypodium integrifolium	O
Clematis ligusticifolia	O
Elymus canadensis	U
Artemisia ludoviciana	O
Lepidium cf. montanum	R
Muhlenbergi curtifolia	O
Juncus arcticus	C
Parthenocissis vitacea	U
Toxicodendron rydbergii	C

Figure 1. A PCA ordination of the hanging garden stands in species space, without the spring. Each stand is either a detritus slope, plunge pool or backwall, except for number 18, which is a combined backwall/detritus slope stand. The first two axes are shown.

Site numbers for PCA stands.

- 1=Rattlesnake garden backwall
- 2=Rattlesnake garden detritus slope
- 3=Rattlesnake garden plunge pool
- 4=Parthenocissus garden backwall
- 5=Parthenocissus garden detritus slope
- 6=Shady garden backwall
- 7=Shady garden detritus slope
- 8=Vista garden backwall
- 9=Vista garden detritus slope
- 10=Cliff garden backwall (composite)
- 11=Cliff garden detritus slope (composite)
- 12=Dune garden backwall
- 13=Dune garden detritus slope
- 14=Crossbed garden backwall
- 15=Crossbed garden detritus slope
- 16=end of Alcove Canyon, no name selected; backwall
- 17=same; detritus slope
- 18=Baby 1 garden
- 19=Baby 2 garden backwall
- 20=Baby 2 garden detritus slope
- 21=Hardwood garden backwall
- 22=Hardwood garden detritus slope
- 23=Cladium garden backwall
- 24=Cladium garden detritus slope

UNTRANSFORMED PCA OF HANGING GARDENS, SAN JUAN ARM OF LAKE POWELL
SECOND
AXIS

B = Bor
D = Dri

