DISTRIBUTION OF HANGING GARDEN VEGETATION ASSOCIATIONS
ON THE COLORADO PLATEAU, USA

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ABSTRACT

Hanging gardens are island-like habitats dominated by mesophytic-hydrophytic plant communities, growing on seeps on the xeric canyon walls of the Colorado Plateau in the American West. We measured the abundance of species and physical microhabitat characteristics of 73 individual hanging gardens during the growing seasons of 1991–1993. Cluster analysis of a simplified Morisita community similarity index matrix produced four distinct clusters of herbaceous vegetation: Adiantum capillus-veneris, Aquilegia micrantha, Calamagrostis scopulorum, and Cirsium rydbergii. These associations are based on species abundance and are floristically described via summary tables showing dominance, constancy, and presence of hanging-garden endemic species. Univariate comparisons of species richness, hanging garden size, and dominance show that the A. capillus-veneris and A. micrantha associations tend to be smaller, less species rich, and have higher dominance values than the C. scopulorum and C. rydbergii associations. Two associations were dominated by species endemic to hanging gardens: Aquilegia micrantha and Cirsium rydbergii. These four hanging garden associations contrast with previous local vegetation surveys which place all hanging garden communities into one vegetation type despite the lack of a common dominant or constant species.

The lush plant growth of hanging gardens on canyon walls in the entrenched drainage system of the Colorado Plateau attracted the attention of early botanists and pioneers (Welsh & Toft 1981). Powell (1895), the first scientific explorer of the Colorado River canyon, noted the “oak glens,” ferns and mosses on moistened sandstone, and rich vegetation associated with seeps “in marked contrast to the general appearance of naked rock” within what is now Glen Canyon NRA (Fig. 1). Many subsequent visitors have noted the island-like boundary between hanging gardens and their xeric canyon-wall surroundings (Woodbury 1933; Malanson & Kay 1980; Welsh 1989). The microclimate of the larger hanging gardens often contrasts sharply with the surrounding high desert: water is abundant, soils are moist, and canyon walls offer periodic shade (Malanson 1980; Welsh & Toft 1981). Hanging gardens are also relatively small, mostly less than one hectare, further contributing to the island-like effect, visually similar to the inselberg (granitic and gneissic rock outcrop) communities found in North and South America, Africa, and Australia (Barthlott & Porembski 2000). However, in contrast to the much better studied inselberg systems (Groger & Barthlett 1996; Porembski et
Hanging gardens are moist vegetation islands rather than xeric vegetation islands (Szarzynski 2000) embedded within bedrock expanses. Hanging gardens are dominated by mesophytic and hydrophytic herbaceous vegetation (Malanson 1980; Welsh & Toft 1981; Welsh 1989) which develops at and downslope from ground-water seepage zones within the exposed aquifer along crossbedded sandstone canyon walls. Ground-water “sapping” erosion processes (Higgins 1984; Laitly & Malin 1985; Baker 1990; Dunne 1990; May et al. 1995) produce the physical hanging garden habitat: perennally wet rock walls and/or wet, subirrigated colluvial soils (May et al. 1995). They are often located in wet theater-headed valleys formed “by weakening or removal of basal support as a result of enhanced weathering and erosion” by water seepage (Laitly & Malin 1985, p. 203). These diffuse-discharge,
seepage erosion areas are the result of ground water moving through highly transmissive aquifers, down the dip planes to where impermeable layers within or below an aquifer intersect a canyon wall, as well as along deep fractures within the aquifer (Laity & Malin 1985; Dunne 1990; May et al. 1995), and are distinctly different from point-source erosion processes caused by discharge at springs (Higgins 1984). Ground-water sapping processes provide both the raw material for colluvial soil development and water for subirrigation of vegetation growing on that habitat.

Floristic work has elucidated the flora associated with hanging garden habitats (Eastwood, 1896; Clover & Jotter 1944; Harrison et al. 1964; Welsh & Moore 1968; Welsh 1986a, b; Shultz et al. 1987; Welsh 1989), including several species endemic to hanging gardens (Harrison et al. 1964; Welsh 1989; Fowler et al. 1995; Welsh et al. 2003). Microhabitat affinities for several hanging garden plant species have also been described (Welsh & Toft 1981; Welsh 1989).

Woodbury (1933), Welsh and Toft (1981), and May et al. (1995) have proposed hanging garden classification systems based on microhabitats and geomorphology. Woodbury (1933) briefly described hanging garden seral associes in Zion NP as part of a park-wide vegetation classification monograph. Malanson (1980, 1982) and Malanson and Kay (1980) measured frequency of species occurrence, species richness, and calculated similarity indices to investigate the effects of flooding frequency, dispersal distance, plant dispersal types, and physical habitat characteristics on species assemblages in 29 small hanging gardens in Zion NP. These studies did not measure species abundance or take a phytosociological approach. In this study, we measured canopy coverage for each vascular plant species on 73 hanging gardens in a regional study, classified them into herbaceous associations, and examined the regional distribution of those associations.

**STUDY AREA**

The study area was located on the Colorado Plateau in Utah and Colorado (Fig. 1), a major portion of the known geographic range of hanging gardens. Field work was conducted on hanging gardens at seven National Park Service units during the summers of 1991–1993: Arches NP, Canyonlands NP, Capitol Reef NP, Dinosaur NP, Glen Canyon NRA, Natural Bridges NM, and Zion NP (Fig. 1). We selected most of the larger, known hanging gardens in each park unit and many smaller ones that we were able to locate. Hanging gardens that were too small to use the vegetation sampling methods described below were excluded from this study.

**METHODS**

We defined hanging garden habitats as predominately herbaceous vegetation growing on permanently wet soil and wet rock surfaces, originating from seeps on canyon walls in sandstone aquifers (Malanson & Kay 1980). Hanging gardens were delineated from the surrounding bedrock and xeric soils by the presence of wet rock surfaces and/or wet soils (May et al. 1995). The hanging garden boundary with a riparian community, when present, was defined by where colluvial soils stop and alluvial soils begin (May et al. 1995).

Each hanging garden was visually separated into the following microhabitats: seepline, wet wall, ledge, and wet colluvial soil to stratify vegetation sampling. Seeplines are drier, linear microhabitats that develop at fractures in the sandstone or, more often, at horizontal impervious bedding planes on canyon walls and at the back of small alcoves. Wet walls included inverted, vertical, or sloping rock surfaces below seeps that moisten the sandstone surface or have sufficient discharge to produce thin sheet flows of water with occasional drip points. Ledge microhabitats are of sufficient horizontal width to support strips of hydrophytic vegetation in depressions with wet, saturated soil. Wet colluvial soil microhabitats are complex in shape and composed of wet, subirrigated colluvial soils located downslope of seepage zones, sometimes within and/or below a larger alcove created by groundwater sapping. Since these soils develop directly from the weathering of sandstone, they are obviously very sandy and may be virtually saturated near seeps.

We collected data on the following physical parameters: length of major axis, aspect, elevation, map location, and geologic formation. Hanging garden size was calculated from major axis length and the mean of ten equally spaced widths taken during vegetation sampling.
Vegetation

On each hanging garden, the herbaceous, vascular plant vegetation stratum was systematically sampled (Cochran 1977; Krebs 1989) using 20 × 50 cm quadrats and six cover classes to estimate canopy cover for each species (Daubenmire 1959) in each microhabitat. Woody plants less than two m tall were included in the herbaceous stratum canopy estimates; the few occurrences of isolated trees were not included. The major axis of each microhabitat was divided into ten equal segments. Widths were measured beginning with a random starting point along the initial segment and at subsequent equal-segment lengths. A random point was chosen along each width to determine placement of the lower left corner of the sampling frame (20 cm side). Edge quadrats were proportionally weighted to include only the portion within the hanging garden.

Total floristic composition (Daubenmire 1959, 1961), vascular plants only, was recorded during canopy cover sampling and during an additional visual search (approximately one hr) on each hanging garden. Voucher specimens for each species were collected. These were identified by B. E. Nelson, Herbarium Manager and R. L. Hartman, Curator of the Rocky Mountain Herbarium at the University of Wyoming and are deposited there and at the respective parks. Vascular plant nomenclature follows Flora of North America Editorial Committee (1993+) and Welsh et al. (2003) in that order of priority.

Floristics of each herbaceous association are described in summary stand tables by floristic criteria (Meuller-Dombois & Ellenberg 2002) and follow the definitions and analysis techniques of the U. S. National Vegetation Classification (ESA 2006). Diagnostic classes for this study were dominance determined by absolute canopy cover (Daubenmire 1959), constancy (frequency of occurrence)(Daubenmire 1952; Meuller-Dombois & Ellenberg 2002), and endemism.

Indices

Plant community diversity (heterogeneity) was measured as two separate components (Krebs 1989): species richness (McIntosh 1967) and dominance. Dominance in a community was determined by the proportion $d = \frac{N_{\text{Max}}}{N_T}$ (Berger & Parker 1970) where $N_{\text{Max}}$ = number of individuals in the most abundant population and $N_T$ = the total number of individuals in the community. Canopy coverage estimates were used as $\frac{N_{\text{Max}}}{N_T}$ since both are proportional measures of species community importance.

Classification of hanging garden vegetation was based on cluster analysis of simplified Morisita (Horn 1966) community similarity indices for 73 hanging gardens calculated from species-level canopy coverage estimates of existing vegetation. An exception is the genus Carex. Our canopy coverage estimates for six species in this genus were combined since consistent, vegetative separation of species was not possible. These indices were placed in a community similarity matrix for cluster analysis in SYSTAT 9 (SYSTAT 1999a) using the complete linkage method (farthest neighbor) on maximum Euclidean distances between indices.

Statistics

Statistical analyses were performed with SYSTAT 9 (1999a). Plant species richness, species dominance, and hanging garden size data were analyzed by General Linear Model ANOVA. Dominance and hanging garden size were log transformed (SYSTAT 1999b) to achieve normal distributions prior to ANOVA tests. Homogeneity of variances was checked post hoc and Tukey HSD tests were used for pairwise comparisons of ANOVA results to detect significant differences between vegetation associations.

The statistical association between geologic formation and the putative herbaceous associations was described using the Pearson Chi-square goodness-of-fit test to detect the presence of an association (Loether & McTavish 1976; Wilkinson et al. 1996), and a proportional reduction in error measure (PRE), Goodman-Kruskal’s lambda, to measure the strength of statistical association (Wilkinson et al. 1996). PRE statistics describe how much error is reduced in predicting the column variable when the row variable is known for association tables (Wilkinson et al. 1996).

RESULTS

Vegetation Classification

Species lists with abundance estimates for species are in Appendix I. Cluster analysis of the simplified
Morisita community similarity index (Krebs 1989) matrix classified the 73 hanging garden vascular plant communities into four associations plus one dissimilar cluster (Fig. 2): *Adiantum capillus-veneris*, *Aquilegia micrantha*, *Calamagrostis scopulorum*, and *Cirsium rydbergii* Herbaceous Associations. Euclidian distance classification thresholds (Fig. 2) ranged from 1.03 for separating the *Cirsium rydbergii* Herbaceous Association from the dissimilar group to 1.31 for separating the *C. rydbergii* and the *Adiantum capillus-veneris* Herbaceous Associations. The dissimilar cluster (n=11) had hanging garden communities with little similarity within the cluster (mean similarity index of 0.069) and had no plant species consistently in common.

The distribution of the four herbaceous associations across the seven geologic formations was different than expected by chance alone (p=0.0098), the lambda statistic indicating a 25% improvement in being able to predict the herbaceous association when the geologic formation is known (Table 1). The *A. micrantha* and *C. scopulorum* Herbaceous Associations were widespread on the Colorado Plateau (Table 1). Both were found in five parks and five sandstone geologic formations, differing in only one park and one geologic formation; the *C. scopulorum* Herbaceous Association was found on the Humbug formation omitted from Table 1. The *C. rydbergii* Herbaceous Association was found only in the central part of the Colorado Plateau: two parks and three formations (Table 1). The *A. capillus-veneris* Herbaceous Association was found on the same geologic formation as the *C. rydbergii* Herbaceous Association but was more widespread (Table 1). The *A. capillus-veneris* and *C. rydbergii* Herbaceous Associations were notably absent from the Cedar Mesa and Weber formations, which were found only in our Natural Bridges NM and Dinosaur NP study sites respectively. However, there were significant, positive statistical associations between geologic formations and herbaceous associations (Table 1). The strongest ones being between the *A. micrantha* Herbaceous Association and the Weber formation and between the *C. rydbergii* Herbaceous Association and the Navajo formation.

### *Adiantum capillus-veneris* Herbaceous Association

Floristics of the *Adiantum capillus-veneris* Herbaceous Association are defined in Table 2. The dominant species in this association was *Adiantum capillus-veneris* which covered from 32–93% of the herbaceous canopy in the 11 hanging gardens classified here (Fig. 2). Pairwise simplified Morisita community similarity indices ranged from 0.48 to 0.99. Both *A. capillus-veneris* and *Epipactis gigantea* had high constancy. *Adiantum capillus-veneris* was found in seepline and wet wall microhabitats, whereas *E. gigantea* was found in seepline microhabitats and on the upper portion of wet soil microhabitats next to vertical canyon walls with wetter seeplines. *Epipactis gigantea* and the Genus *Carex* also had high canopy cover on some hanging gardens. The vegetation was dominated by ferns, forbs, and graminoids (Table 2), but woody plants were occasionally present as isolated individuals or at the drier edges of the wet soil/rock habitats characteristic of hanging gardens.

Species diversity was relatively low in this association as shown by high dominance values, a measure of community evenness, as well as low species richness (Table 3). Dominance values were significantly higher than in *Calamagrostis scopulorum* and *Cirsium rydbergii* Herbaceous Associations (ANOVA F = 5.02, p = 0.0036; Tukey HSD p = 0.0167 and 0.044 respectively). Five species endemic to hanging gardens were found in this association (Table 2). The overall size of hanging gardens with this association was comparatively small (Table 3), significantly smaller than hanging gardens in the *Cirsium rydbergii* and *Calamagrostis scopulorum* Herbaceous Associations (see below) (ANOVA F = 7.21, p = 0.0003; Tukey HSD p = 0.0003 and 0.0266 respectively).

### *Aquilegia micrantha* Herbaceous Association

The *Aquilegia micrantha* Herbaceous Association was dominated by the hanging garden endemic *A. micrantha*, a constant species with an average canopy cover of 29% (Table 4). *Aquilegia micrantha* predominately grew on wet colluvial soil microhabits. *Calamagrostis scopulorum* was also a constant species in this herbaceous association, but with less than 5% average cover. Pairwise simplified Morisita community similarity indices ranged from 0.28 to 1.00 for this association. With the exception of small *Pinus edulis* plants, which occurred in trace amounts of cover on 47% of these hanging gardens, woody plants rarely occurred (Table 4).

In addition to *A. micrantha*, four other hanging garden endemic species were found on these sites, but
Table 1. Percentage of hanging garden vegetation associations found on each of five geologic formations (row percentages). Pearson Chi Square ($X^2 = 34.8798, p = 0.0098$) and Goodman-Kruskal’s lambda ($\lambda = 0.2564$ PRE) statistics indicate the existence and strength of statistical association respectively. Positive “+” and negative “−” indicate the statistical association between a geologic formation and a vegetation association. Cell Chi Square contributions are shown below cell percentages for each row followed by two letter park codes (shown in Fig. 2) to indicate geographic distribution. Observed geologic formations are Jurassic Entrada sandstone, Jurassic Navajo sandstone, Jurassic Navajo sandstone/Jurassic Kayenta formation contact zone, Permian Cedar Mesa sandstone, Pennsylvanian-Permian Weber sandstone. Vegetation associations are Adca, Adiantum capillus-veneris; Aqmi, Aquilegia micrantha; Casc, Calamagrostis scopulorum; Ciry, Cirsium rydbergii. N = 60, note that 2 geologic formations with only 1 hanging garden each were omitted from this table.

<table>
<thead>
<tr>
<th>Geologic Formation</th>
<th>Adca</th>
<th>Aqmi</th>
<th>Casc</th>
<th>Ciry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Entrada</strong></td>
<td>n = 11</td>
<td>n = 17</td>
<td>n = 19</td>
<td>n = 11</td>
</tr>
<tr>
<td>n = 7</td>
<td>29%</td>
<td>43%</td>
<td>0%</td>
<td>29%</td>
</tr>
<tr>
<td>0.4002</td>
<td>0.5211</td>
<td>2.4500</td>
<td>0.4002</td>
<td></td>
</tr>
<tr>
<td>AR</td>
<td>AR</td>
<td>AR</td>
<td>AR</td>
<td>AR</td>
</tr>
<tr>
<td><strong>Navajo</strong></td>
<td>n = 17</td>
<td>35% +</td>
<td>6% −</td>
<td>18% 41% +</td>
</tr>
<tr>
<td>n = 17</td>
<td>3.0243</td>
<td>1.4626</td>
<td>4.8386</td>
<td></td>
</tr>
<tr>
<td>2.6675</td>
<td>18%</td>
<td>53%</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>0.0044</td>
<td>0.6852</td>
<td>1.5634</td>
<td>0.4001</td>
<td></td>
</tr>
<tr>
<td>CR, GC, ZI</td>
<td>GC</td>
<td>GC, ZI</td>
<td>GC</td>
<td>GC</td>
</tr>
<tr>
<td><strong>Navajo/Kayenta</strong></td>
<td>n = 17</td>
<td>18%</td>
<td>18%</td>
<td>53%</td>
</tr>
<tr>
<td>n = 17</td>
<td>1.5634</td>
<td>1.4667</td>
<td>0.4001</td>
<td></td>
</tr>
<tr>
<td>0.0044</td>
<td>0.6852</td>
<td>1.5634</td>
<td>0.4001</td>
<td></td>
</tr>
<tr>
<td>GC, ZI</td>
<td>CL, GC</td>
<td>CL, ZI</td>
<td>GC</td>
<td>GC</td>
</tr>
<tr>
<td><strong>Cedar Mesa</strong></td>
<td>n = 8</td>
<td>0%</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>n = 8</td>
<td>1.3255</td>
<td>0.5143</td>
<td>1.4667</td>
<td></td>
</tr>
<tr>
<td>1.4667</td>
<td>0% 50%</td>
<td>50%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td><strong>Weber</strong></td>
<td>n = 9</td>
<td>0%</td>
<td>67% +</td>
<td>33%</td>
</tr>
<tr>
<td>n = 9</td>
<td>4.6676</td>
<td>0.0071</td>
<td>1.6500</td>
<td></td>
</tr>
<tr>
<td>1.6500</td>
<td>DI</td>
<td>DI</td>
<td>DI</td>
<td></td>
</tr>
</tbody>
</table>

at lower constancy (Table 4). This association was significantly less species rich than the C. scopulorum and C. rydbergii Herbaceous Associations (see below) (ANOVA $F = 3.79, p = 0.015$; Tukey HSD $p = 0.0248$ and 0.0372 respectively). Dominance values averaged 0.59, not significantly different than the other three associations (Table 3). Hanging gardens in this association were also significantly smaller in average size than hanging gardens classified in the C. rydbergii association (see below) (ANOVA $F = 7.21, p = 0.0003$; Tukey HSD $p = 0.0009$, Table 3).

**Calamagrostis scopulorum Herbaceous Association**

Floristics of the Calamagrostis scopulorum Herbaceous Association are defined in Table 5. As the dominant species, C. scopulorum had an average cover of 31% and a range of 13–66% (Table 5). Calamagrostis scopulorum grew in larger clumps on wet colluvial soil microhabitats and as smaller patches on seepline and wet wall microhabitats. Several Carex species also occurred in these hanging gardens (Table 5). The hanging garden endemic A. micrantha was moderately constant and ranged up to 11% total cover. Simplified Moristia community similarity indices ranged from 0.27 to 0.99 among the 23 hanging gardens classified into this association.

Species diversity in this association was relatively high as shown by high species richness and low dominance (Table 3). This association was significantly richer than the A. micrantha Herbaceous Association (ANOVA $F = 3.79, p = 0.0003$; Tukey HSD $p = 0.0248$), and its dominance values were significantly lower than the A. capillus-veneris Herbaceous Association (ANOVA $F = 5.02, p = 0.0036$; Tukey HSD $p = 0.0167$). Three hanging garden endemic taxa were found on the 23 hanging gardens classified in this association (Table 5). The C. scopulorum Herbaceous Association tended to contain large hanging gardens (Table 3), significantly larger than hanging gardens in the A. capillus-veneris Herbaceous Association (ANOVA $F = 7.21, p = 0.0003$; Tukey HSD $p = 0.027$).
Fig. 2. Cluster tree showing four hanging garden herbaceous vegetation associations and a dissimilar cluster based on cluster analysis of simplified Moristia community similarity indices. Names refer to 73 individual hanging garden plant communities. Two letter codes following hanging garden names refer to individual parks: AR = Arches (NP); CL = Canyonlands (NP); GC = Glen Canyon (NRA); ZI = Zion (NP); CR = Capitol Reef (NP); NB = Natural Bridges (NM); DI = Dinosaur (NP).
Table 2. Stand table for the *Adiantum capillus-veneris* Herbaceous Association showing canopy cover, diagnostic classes, and constancy for all species with a constancy ≥0.40 and/or species endemic to hanging gardens. Constant species are defined as constancy ≥0.60, and "t" is defined as less than 0.5% canopy cover. N = 11.

<table>
<thead>
<tr>
<th>Species</th>
<th>Diagnostic class</th>
<th>Constancy</th>
<th>Average % cover</th>
<th>Minimum % cover</th>
<th>Maximum % cover</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Adiantum capillus-veneris</em></td>
<td>dominant, constant</td>
<td>1.00</td>
<td>57</td>
<td>32</td>
<td>93</td>
</tr>
<tr>
<td><em>Epipactis gigantea</em></td>
<td>constant</td>
<td>0.82</td>
<td>2</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td><em>Aquilegia micrantha</em></td>
<td>endemic</td>
<td>0.27</td>
<td>1</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td><em>Cirsium rydbergii</em></td>
<td>endemic</td>
<td>0.36</td>
<td>2</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td><em>Mimulus eastwoodiae</em></td>
<td>endemic</td>
<td>0.55</td>
<td>t</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><em>Primula specuicola</em></td>
<td>endemic</td>
<td>0.27</td>
<td>t</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><em>Zigadenus vaginatus</em></td>
<td>endemic</td>
<td>0.09</td>
<td>t</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Carex sp.</td>
<td></td>
<td>0.45</td>
<td>3</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td><em>Petrophytum caespitosum</em></td>
<td></td>
<td>0.45</td>
<td>t</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 3. Mean values (± 1 SE) for hanging garden size, species richness, and dominance of four hanging garden herbaceous associations. Also shown are number of sites (N) and number of hanging garden endemic plants species found (HGE) in each association. Values followed by the same letter within each column do not differ at P<0.05 in Tukey’s HSD post hoc tests.

<table>
<thead>
<tr>
<th>Hanging garden vegetation association</th>
<th>Size m²</th>
<th>Species Richness</th>
<th>Dominance</th>
<th>N</th>
<th>HGE</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Adiantum capillus-veneris</em></td>
<td>68±20  a</td>
<td>14±2 ab</td>
<td>0.71±0.05 a</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td><em>Aquilegia micrantha</em></td>
<td>167±45 ab</td>
<td>12±1 a</td>
<td>0.59±0.06 ab</td>
<td>17</td>
<td>5</td>
</tr>
<tr>
<td><em>Calamagrostis scopulorum</em></td>
<td>314±80 bc</td>
<td>18±2 b</td>
<td>0.48±0.04 b</td>
<td>23</td>
<td>3</td>
</tr>
<tr>
<td><em>Cirsium rydbergii</em></td>
<td>587±168 c</td>
<td>18±2 b</td>
<td>0.41±0.03 b</td>
<td>11</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 4. Stand table for the *Aquilegia micrantha* Herbaceous Association showing canopy cover, diagnostic classes, and constancy for all species with a constancy ≥0.40 and/or species endemic to hanging gardens. Constant species are defined as constancy ≥0.60, and "t" is defined as less than 0.5% canopy cover. N = 17.

<table>
<thead>
<tr>
<th>Species</th>
<th>Diagnostic class</th>
<th>Constancy</th>
<th>Average % cover</th>
<th>Minimum % cover</th>
<th>Maximum % cover</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aquilegia micrantha</em></td>
<td>dominant, constant, endemic</td>
<td>1.00</td>
<td>29</td>
<td>9</td>
<td>54</td>
</tr>
<tr>
<td><em>Calamagrostis scopulorum</em></td>
<td>Constant</td>
<td>0.82</td>
<td>4</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td><em>Cirsium rydbergii</em></td>
<td>Endemic</td>
<td>0.24</td>
<td>1</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td><em>Mimulus eastwoodiae</em></td>
<td>Endemic</td>
<td>0.35</td>
<td>1</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td><em>Primula specuicola</em></td>
<td>Endemic</td>
<td>0.24</td>
<td>t</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><em>Zigadenus vaginatus</em></td>
<td>Endemic</td>
<td>0.35</td>
<td>2</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>Carex sp.</td>
<td></td>
<td>0.41</td>
<td>2</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td><em>Pinus edulis</em></td>
<td></td>
<td>0.47</td>
<td>t</td>
<td>0</td>
<td>t</td>
</tr>
</tbody>
</table>

Cirsium rydbergii Herbaceous Association

The hanging garden endemic *Cirsium rydbergii* dominated this association with an average of 23% canopy coverage (Table 6). These hanging gardens also had nine additional constant species (Table 6). Two of these were co-dominants, *A. capillus-veneris* and *Schyzachrium scoparium*, and three were endemic to hanging garden habitats: *A. micrantha*, *Mimulus eastwoodiae*, and *Primula specuicola*. One additional hanging garden endemic species was also found at low constancy in these hanging gardens: *Zigadenus vaginatus*. *Cirsium rydbergii* and *A. micrantha* were found throughout the wet colluvial soil microhabitat and *Z. vaginatus* was often
Table 5. Stand table for the Calamagrostis scopulorum Herbaceous Association showing canopy cover, diagnostic classes, and constancy for all species with a constancy ≥0.40 and/or species endemic to hanging gardens. Constant species are defined as constancy ≥0.60, and “t” is defined as less than 0.5% canopy cover. N = 23.

<table>
<thead>
<tr>
<th>Species</th>
<th>Diagnostic class</th>
<th>Constancy</th>
<th>Average % cover</th>
<th>Minimum % cover</th>
<th>Maximum % cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calamagrostis scopulorum</td>
<td>dominant</td>
<td>1.00</td>
<td>31</td>
<td>13</td>
<td>66</td>
</tr>
<tr>
<td>Carex sp.</td>
<td>constant</td>
<td>0.65</td>
<td>3</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Aquilegia micrantha</td>
<td>endemic</td>
<td>0.43</td>
<td>2</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Zigadenus vaginatus</td>
<td>endemic</td>
<td>0.22</td>
<td>t</td>
<td>0</td>
<td>t</td>
</tr>
<tr>
<td>Mimulus eastwoodiae</td>
<td>endemic</td>
<td>0.22</td>
<td>t</td>
<td>0</td>
<td>t</td>
</tr>
<tr>
<td>Adiantum capillus-veneris</td>
<td>constant</td>
<td>0.57</td>
<td>4</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Erythronium gigantea</td>
<td>constant</td>
<td>0.48</td>
<td>1</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Maianthemum stellatum</td>
<td>constant</td>
<td>0.57</td>
<td>3</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Toxicodendron rydbergii</td>
<td>constant</td>
<td>0.48</td>
<td>t</td>
<td>0</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 6. Stand table for the Cirsium rydbergii Herbaceous Association showing canopy cover, diagnostic classes, and constancy for all species with a constancy ≥0.40 and/or species endemic to hanging gardens. Constant species are defined as constancy ≥0.60, and “t” is defined as less than 0.5% canopy cover. N = 11.

<table>
<thead>
<tr>
<th>Species</th>
<th>Diagnostic class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cirsium rydbergii</td>
<td>dominant, constant, endemic</td>
</tr>
<tr>
<td>Adiantum capillus-veneris</td>
<td>co-dominant, constant</td>
</tr>
<tr>
<td>Schizachyrium scoparium</td>
<td>co-dominant, constant</td>
</tr>
<tr>
<td>Carex sp.</td>
<td>constant</td>
</tr>
<tr>
<td>Aquilegia micrantha</td>
<td>constant, endemic</td>
</tr>
<tr>
<td>Primula specuicola</td>
<td>constant, endemic</td>
</tr>
<tr>
<td>Mimulus eastwoodiae</td>
<td>constant, endemic</td>
</tr>
<tr>
<td>Calamagrostis scopulorum</td>
<td>constant</td>
</tr>
<tr>
<td>Petrophytum caespitosum</td>
<td>constant</td>
</tr>
<tr>
<td>Epipactis gigantea</td>
<td>constant</td>
</tr>
<tr>
<td>Zigadenus vaginatus</td>
<td>endemic</td>
</tr>
<tr>
<td>Castilleja linearifolia</td>
<td>constant</td>
</tr>
<tr>
<td>Dichanthelium acuminatum</td>
<td>constant</td>
</tr>
</tbody>
</table>

found in the upper portions of the wet colluvial soil microhabitat next to canyon walls. *Mimulus eastwoodiae* and *P. specuicola* were often attached directly to vertical or inverted, wet rock surfaces. Simplified Morisita community similarity indices ranged from 0.06 to 0.90 among the 11 hanging gardens in this association.

Species richness was relatively high (Table 3), significantly higher than in the *A. micrantha* Herbaceous Association (ANOVA F = 3.79, p = 0.015; Tukey HSD p = 0.0372). Dominance values were low (Table 3), significantly lower than in the *A. capillus-veneris* Herbaceous Association (ANOVA F = 5.02, p = 0.0036, Tukey HSD p = 0.0044). Similar to the *C. scopulorum* Herbaceous Association, this association occurred on large hanging gardens; the average size was significantly larger than in the *A. capillus-veneris* and *A. micrantha* Herbaceous Associations (ANOVA F = 7.21, p = 0.0003; Tukey HSD p = 0.0003 and 0.0009 respectively).

**DISCUSSION**

The *A. capillus-veneris* and *A. micrantha* Herbaceous Associations tend to grow on smaller hanging gardens that are less diverse; i.e., have low species richness and high dominance values (Table 3). The *A. capillus-veneris* Herbaceous Association is dominated by relatively dry seepline microhabitats and by rhizomatous
stands of *A. capillus-veneris* which grow on and near narrow seeplines formed in the Navajo sandstone. The *A. micrantha* association is dominated by *A. micrantha* which grows on the less wet colluvial soil microhabitats, especially on Cedar Mesa and Weber sandstone formations. Note that these two geologic formations and the Entrada formation were found in only one park each and thus also act as surrogates for geography. In contrast, the hanging gardens with *C. scopulorum* and *C. rydbergii* Herbaceous Associations tended to be larger and, by implication, wetter: i.e., large wet colluvial soil microhabitats. They also tend to be more diverse: i.e., more species rich and low species dominance (Table 3).

The dissimilar cluster (Fig. 2) may represent a collection of unique plant communities which are not part of any herbaceous association. Alternatively, with further sampling on the Colorado Plateau, we may find that some of the hanging gardens within this cluster do represent undiscovered herbaceous associations. Further research is needed.

Neither Tuhy and MacMahon (1988) nor Romme et al. (1993) attempted to classify the vegetation of individual hanging gardens but rather placed all hanging gardens into one vegetation type. We found no species that all hanging gardens had in common (much less a common dominant) which precludes a single hanging garden herbaceous association. The alliance name on NatureServe (2006), *Aquilegia micrantha* saturated hanging garden herbaceous vegetation, would obviously work for the *A. micrantha* Herbaceous Association but not for the remaining three associations since neither *A. micrantha* nor any other species was constant or dominant across all four associations described in this paper (Tables 2, 4, 5, 6). Four separate alliances would seem to be necessary in spite of a common distinct habitat.

NatureServe (2006) also lists two hanging garden herbaceous associations inside our study area: *A. micrantha* - *M. eastwoodiae* and *A. micrantha* - *C. scopulorum* Herbaceous Vegetation, each association being named for its dominant species. *Aquilegia micrantha* and *C. scopulorum* are shown as characteristic species for both associations, but no data are shown for canopy coverage or constancy. In addition, no publications are cited that have this type of data and the link to VegBank (2006) indicates that no plot-observations are available, precluding further comparison. Woodbury’s (1933) *fern-columbine* associes in Zion NP hanging gardens is habitat-based and seems to overlap the *A. capillus-veneris* and *C. scopulorum* Herbaceous Associations described in this paper.

Outside of Woodbury’s (1933) study in Zion NP, there are no previously published studies that describe hanging garden associations. Most inselberg studies also classify vegetation by habitat (e.g., Burbanck & Platt 1964), but we found one with a phytosociological focus. Sarthou and Villiers (1998) conducted a regional vegetation study on three inselbergs in French Giana using relevé quadrats and tabular analysis. In spite of different techniques, their results were comparable to our study. They found six vegetation associations versus our four, and they found two French Gianan inselberg endemics versus our five hanging garden endemics. More interestingly, their most widespread vegetation association (with three subassociations) was dominated by *Pepinietum geyskesii*, a French Gianan inselberg endemic. In our study, two vegetation associations were dominated by hanging garden endemics: the *A. micrantha* and the *C. rydbergii* Herbaceous Associations (Tables 4 & 6). Both studies illustrate the concept of insular vegetation on continental islands at a regional scale. Our study also looked at the regional distribution of these four herbaceous associations and found that each has a unique distribution on the Colorado Plateau (Table 1).

**APPENDIX 1**

Vascular plant species lists and species richness (R) for each hanging garden sampled. Canopy coverage estimates (0-100%) are shown to the right of the scientific name for species which fell within community sampling quadrats with T indicating less than 0.5%; no estimates were made for taxa not falling within sampling quadrats: ARCH = Arches NP, CANY = Canyonlands NP, CARE = Capitol Reef NP, DINO = Dinosaur NM, GLCA = Glen Canyon NRA, NABR = Natural Bridges NM, ZION = Zion NP.

<table>
<thead>
<tr>
<th>Anacardiaceae</th>
<th>Asteraceae</th>
<th>Euphorbiaceae</th>
<th>Cyperaceae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cirsium rydbergii 7</td>
<td><em>Pseudognaphalium microcephalum</em> T</td>
<td><em>Euphorbia brachycera</em> T</td>
<td><em>Carex aurea</em> 2</td>
</tr>
<tr>
<td>Toxicodendron rydbergii 7</td>
<td><em>Heterotheca villosa</em> var. minor T</td>
<td><em>Solidago velutina</em> subsp. sparsiflora</td>
<td></td>
</tr>
</tbody>
</table>
Fabiaceae
Dalea oligophylla 3

Fagaceae
Quercus turbinella T

Liliaceae
Zigadenus vaginatus T

Onagraceae
Oenothera longissima

Orchidaceae
Epipactis gigantea 2
Platanthera zothecina

Poaceae
Elymus canadensis T
Muhlenbergia andina 3
Dichanthelium acuminatum 1
Phragmites australis 2
Schizachyrium scoparium 1

Pteridaceae
Adiantum capillus-veneris 48

Primulaceae
Primula specuicola T

Ranunculaceae
Aquilegia micrantha 9

Rosaceae
Rosa sp.

Scrophulariaceae
Castilleja linanotilia
Mimulus eastwoodiae T

Asteraceae
Cirsium rydbergii 1
Heterotheca villosa var. minor 3

Cyperaceae
Carex aurea 4

Euphorbiaceae
Euphorbia brachycera T

Fabaceae
Dalea oligophylla 1

Liliaceae
Zigadenus vaginatus T

Orchidaceae
Epipactis gigantea 3

Poaceae
Dichanthelium acuminatum 7
Schizachyrium scoparium 32

Pteridaceae
Adiantum capillus-veneris 23

Primulaceae
Primula specuicola 2

Ranunculaceae
Aquilegia micrantha 14
Clematis ligusticifolia T

Santalaceae
Comandra umbellata var. pallida 3
Scrophulariaceae
Mimulus eastwoodiae T

Arch Bake-oven Wall HG
R = 15

Asteraceae
Cirsium rydbergii 1
Heterotheca villosa var. minor 3

Cyperaceae
Carex aurea 4

Euphorbiaceae
Euphorbia brachycera T

Fabaceae
Dalea oligophylla 1

Liliaceae
Zigadenus vaginatus T

Orchidaceae
Epipactis gigantea 3

Poaceae
Dichanthelium acuminatum 7
Schizachyrium scoparium 32

Pteridaceae
Adiantum capillus-veneris 23

Primulaceae
Primula specuicola 2

Ranunculaceae
Aquilegia micrantha 14
Clematis ligusticifolia T

Santalaceae
Comandra umbellata var. pallida 3

Scrophulariaceae
Mimulus eastwoodiae T

Arch Banded HG
R = 6

Pinaceae
Pinus edulis

Poaceae
Dichanthelium acuminatum

Pteridaceae
Adiantum capillus-veneris 6

Primulaceae
Primula specuicola

Ranunculaceae
Aquilegia micrantha 33

Scrophulariaceae
Mimulus eastwoodiae 11

Arch Winter Camp HG
R = 19

Anacardiaceae
Rhus aromatica var. simplicifolia T

Asteraceae
Cirsium rydbergii
Heterotheca villosa var. minor 16
Solidago velutina subsp. sparsiflora

Cyperaceae
Carex aurea 7

Euphorbiaceae
Euphorbia brachycera T

Liliaceae
Zigadenus vaginatus 19

Orchidaceae
Epipactis gigantea 5

Poaceae
Muhlenbergia thurberi 3
Dichanthelium acuminatum 1

Pteridaceae
Adiantum capillus-veneris 4

Primulaceae
Primula specuicola 2

Ranunculaceae
Aquilegia micrantha 38

Scrophulariaceae
Mimulus eastwoodiae 1

ARCH Dead Tree HG
R = 18

Apocynaceae
Apocynum cannabinum

Asteraceae
Cirsium rydbergii 16
Packera multiflora

Cyperaceae
Carex aurea 2

Liliaceae
Maianthemum stellatum
Zigadenus vaginatus

Orchidaceae
Epipactis gigantea

Primulaceae
Primula specuicola 2

Ranunculaceae
Aquilegia micrantha 38

Scrophulariaceae
Mimulus eastwoodiae 1

ARCH Scaly HG
R = 8

Anacardiaceae
Rhus aromatica var. simplicifolia T

Toxicodendron rydbergii 1

Asteraceae
Adiantum capillus-veneris 19
Pellaea breweri

Primulaceae
Primula specuicola 2

Ranunculaceae
Aquilegia micrantha 29

Santalaceae
Comandra umbellata var. pallida 2

Scrophulariaceae
Castilleja exilis
Mimulus eastwoodiae

ARCH Solitaire HG
R = 16

Anacardiaceae
Rhus aromatica var. simplicifolia T

Toxicodendron rydbergii 1

Asteraceae
Cirsium rydbergii 1
Heterotheca villosa var. minor 2

Solidago velutina subsp. sparsiflora 1

Cyperaceae
Carex aurea 7

Euphorbiaceae
Euphorbia brachycera T

Liliaceae
Zigadenus vaginatus 19

Orchidaceae
Epipactis gigantea 5

Poaceae
Muhlenbergia thurberi 3
Dichanthelium acuminatum 1

Pteridaceae
Adiantum capillus-veneris 11

Primulaceae
Primula specuicola 3

Ranunculaceae
Aquilegia micrantha 8

Santalaceae
Comandra umbellata var. pallida 1

Scrophulariaceae
Castilleja exilis T
Mimulus eastwoodiae 8

CANY Box HG
R = 17

Apocynaceae
Apocynum cannabinum

Asteraceae
Artemisia ludoviciana subsp. ludoviciana
Cirsium rydbergii 16
Packera multiflora

Cyperaceae
Carex aurea 2

Liliaceae
Maianthemum stellatum
Zigadenus vaginatus

Orchidaceae
Epipactis gigantea

Primulaceae
Primula specuicola 2

Ranunculaceae
Aquilegia micrantha 38

Scrophulariaceae
Mimulus eastwoodiae 1

Pinaceae
Pinus edulis
Poaceae
Calamagrostis scopulorum 66
Phragmites australis

Ranunculaceae
Aquilegia micrantha 10

Rhamnaceae
Rhamnus betulifolia
Rosaceae
Rosa sp.

Scrophulariaceae
Castilleja linariifolia

Mimulus eastwoodiae

CANY Northface HG R = 13

Asteraceae
Cirsium rydbergii 8

Betulaceae
Betula occidentalis

Cornaceae
Cornus sericea

Cyperaceae
Carex sp.

Fagaceae
Quercus gambeli

Liliaceae
Maianthemum stellatum

Orchidaceae
Platanthera zothecina

Poaceae
Calamagrostis scopulorum

Ranunculaceae
Aquilegia micrantha 54

Rosaceae
Amelanchier sp.
Rosa sp.

Scrophulariaceae
Mimulus eastwoodiae

CANY Raven HG R = 16

Anacardiaceae
Rhus aromatica var. simplicifolia

Toxicodendron rydbergii

Apocynaceae
Apocynum cannabinum T

Asteraceae
Cirsium arizonicum subsp. simplicifolium 8

Erigeron sparsiflorus 1

Pinaceae
Pinus edulis

Poaceae
Calamagrostis scopulorum 48

Ranunculaceae
Aquilegia micrantha 10

Rhamnaceae
Rhamnus betulifolia 3

Rosaceae
Holodiscus dumosus

Rosa sp.

Rubiaceae
Galium sp.

Scrophulariaceae
Castilleja linariifolia

Mimulus eastwoodiae

CANY Gate HG R = 12

Anacardiaceae
Toxicodendron rydbergii

Asteraceae
"Cirsium anisodon var. bipinnatum 2"

Cyperaceae
Carex aurea 9

Orchidaceae
Platanthera zothecina

Pinaceae
Pinus edulis

Poaceae
"Calamagrostis scopulorum 31"

Muhlenbergia thurberi

Piptatherum micranthum

Ranunculaceae
Aquilegia micrantha 37

Rosaceae
Amelanchier sp.

Cercocarpus sp.

Rosa sp.

CANY Rocky HG R = 7

Asteraceae
"Cirsium anisodon var. bipinnatum 8"

Erigeron sparsiflorus 1

Pinaceae
Pinus edulis

Poaceae
"Calamagrostis scopulorum 21"

Ranunculaceae
Aquilegia micrantha 6

Santalaceae
Comandra umbellata var. pallida 4

Scrophulariaceae
Mimulus eastwoodiae

CANY Tier HG R = 18

Agavaceae
Yucca sp. T

Anacardiaceae
Toxicodendron rydbergii 1

Apocynaceae
Apocynum cannabinum T

Asteraceae
"Cirsium calareum 1"

Cyperaceae
Carex aurea 9

Fagaceae
Quercus gambeli T

Liliaceae
"Maianthemum stellatum 4"

Orchidaceae
Epipactis gigantea 3

Platanthera zothecina T

Pinaceae
Pinus edulis

Poaceae
CALLAGrostis scopulorum 49

Polemoniaceae
"Gilia aggregata var. maculata 2"

Ranunculaceae
Aquilegia micrantha 11

Rhamnaceae
Rhamnus betulifolia

Rosaceae
Rosa sp. 2

Santalaceae
Comandra umbellata var. pallida T

Scrophulariaceae
Castilleja linariifolia 1

Mimulus eastwoodiae T

CARE Sidewall HG R = 12

Anacardiaceae
Toxicodendron rydbergii 19

Asteraceae
"Cirsium arizonicum var. bipinnatum 4"

Heterotheca villosa var. minor T

Santalaceae
Comandra umbellata var. pallida 4

Scrophulariaceae
Castilleja linariifolia 1

Mimulus eastwoodiae T

CARE Horseshoe HG R = 8

Asteraceae
Cirsium ownbeyi 2

Erigeron nematopyllus

Heterotheca villosa var. minor T

Cupressaceae
Juniperus osteosperma

Hydrangiaceae
Fendlerella utahensis

Liliaceae
Zigadenus vaginatus 14

Pinaceae
Pinus edulis

Poaceae
Calamagrostis scopulorum 19

Muhlenbergia thurberi

Piptatherum micranthum

Poa fendleriiana

Pteridaceae
Pellaea glabella subsp. simplex

Ranunculaceae
Aquilegia micrantha 1

Rosaceae
Amelanchier sp.

Petrophytum caespitosum

Rubiaceae
Galium sp.

Scrophulariaceae
Castilleja linariifolia
Fowler et al., Distribution of hanging gardens in the Colorado Plateau

**Poaceae**

- *Pseudotsuga menziesii* (Pinaceae)
- *Pinus edulis* (Pinaceae)
- *Zigadenus vaginatus* (Liliaceae)
- *Zigadenus vagnatus subsp. minor* (Liliaceae)
- *Taraxacum officinale* (Asteraceae)

**Asteraceae**

- *Erigeron nematophyllus* 6
- *Heterotheca villosa var. minor* 2
- *Packera multilobata* (Taraxacum officinale)
- *Capsifoliaceae*
- *Symphoricarpos*
- *Cupressus*

**Liliaceae**

- *Zigadenus vagnatus subsp. minor* 2
- *Xanthisma griffeliioides* (Taraxacum officinale)

**Berberidaceae**

- *Berberis repens*

**Boraginaceae**

- *Cryptantha*

**Cryptanthaceae**

- *Dodecatheon pulchellum*

**D сто ло и п о к ув**

- *Aquilegia micrantha* 3
- *Clematis luginotilica* 34
- *Asteraceae*

**Poaceae**

- *Carex aurea 2*
- *Euphorbia*
- *Euphorbia brasycera*

**Liliaceae**

- *Zigadenus vagnatus subsp. minor* 2
- *Xanthisma griffeliioides* (Taraxacum officinale)

**Scrophulariaceae**

- *Castilleja linearifolia*

**Primulaceae**

- *Dodecatheon pulchellum var. pulchellum*

**Ranunculaceae**

- *Aquilegia micrantha* 35
- *Clematis luginotilica* 34
- *Heterotheca villosa var. minor* 2

**D сто ло и п о к ув**

- *Aquilegia micrantha* 3
- *Clematis luginotilica* 34
- *Asteraceae*

**Poaceae**

- *Carex aurea 2*
- *Euphorbia*

**Liliaceae**

- *Zigadenus vagnatus subsp. minor* 2
- *Xanthisma griffeliioides* (Taraxacum officinale)

**Scrophulariaceae**

- *Castilleja linearifolia*

**Primulaceae**

- *Dodecatheon pulchellum var. pulchellum*
DINO Redrock HG R = 18
Asteraceae
Toxicodendron rydbergii
Artemisia ludoviciana subsp. ludoviciana 2
Heterotheca villosa var. minor 4
Taraxacum officinale 4
Brassicaceae
Lepidium latifolium 15
Cyperaceae
Carex aurea 5
Fabaceae
Mellotus albus
Mellotus officinalis
Liliaceae
Maianthemum stellatum
Orchidaceae
Platanthera zonolica 11
Poaceae
Agrostis stolonifera
Calamagrostis scopulorum 2
Muhlenbergia andina
Poa pratensis 2
Ranunculaceae
Aquilegia micrantha 18
Clematis ligusticifolia
Rosaceae
Petropitys caespitosum 7
Ulmaceae
Celtis reticulata 4
DINO Limestone HG R = 29
Apocynaceae
Apocynum cannabinum
Asclepiadaceae
Asclepias speciosa
Asteraceae
Artemisia ludoviciana subsp. ludoviciana 2
Ericameria nauseosa
Cirsium owneyi 15
Tragopogon dubius T
Brassicaceae
Lepidium montanum var. jonesii
Cyperaceae
Carex parryianna 2
Carex aquatilis var. aquatilis
Carex aurea
Equisetaceae
Equisetum laevigatum 1
Fabaceae
Mellotus officinalis T
Juncaceae
Juncus ensifolius var. montanus
Lamiaceae
Mentha arvensis 2
Lilaceae
Maianthemum stellatum T
Onagraceae
Epilobium sp.
Oenanthera caespitosa T
Poaceae
Calamagrostis scopulorum 28
Elymus trachycaulis 1
Glyceria striata T
Koeleria macrantha
Phagmites australis 8
Poa pratensis
Pseudoroegneria spicata
Polygonaceae
Erigeron corymbosum var. corymbosum
Ranunculaceae
Aquilegia micrantha 1
Clematis ligusticifolia 12
Rosaceae
Rosa woodsii 6
Violaceae
Viola sp.
DINO Ely HG R = 17
Asteraceae
Crepis runcinata var. glauca
Erigeron nematophyllum
Betulaceae
Betula occidentalis
Euphorbiaceae
Euphorbia brachycera T
Hydrangiaceae
Fendlerella utahensis
Loasaceae
Mentzelia sp. 3
Pinaceae
Pinus edulis
Poaceae
Calamagrostis scopulorum 4
Muhlenbergia thurberi 1
Achnatherum hymenoides 1
Pteridaceae
Pellaea glabella subsp. simplex 4
Primulaceae
Dodecatheon pulchellum var. pulchellum 1
Ranunculaceae
Aquilegia micrantha 13
Rosaceae
Cercocarpus intricatus
Petrophytum caespitosum 7
Santalaceae
Comandra umbellata var. pallida 2
Scrophulariaceae
Castilleja linarifolia
GLCA Camp HG R = 19
Apocynaceae
Apocynum cannabinum 3
Asteraceae
Artemisia ludoviciana subsp. mexicana
Brickellia longifolia var. longifolia T
Taraxacum officinale
Berberidaceae
Berberis repens
Betulaceae
Ostrya knowltonii
Cyperaceae
Carex aurea 10
Fabaceae
Cercis occidentalis var. orbiculata 3
Fagaceae
Quercus gambeli
Orchidaceae
Platanthera zonolica 1
Poaceae
Calamagrostis scopulorum 4
Polypogon interruptus
Polypogon viridis
Pteridaceae
Adiantum capillus-veneris 15
Ranunculaceae
Aquilegia micrantha 9
Clematis ligusticifolia
Rhamnaceae
Rhamnus betulifolia
Rosaceae
Rubus neomexicanus 3
Scrophulariaceae
Mirabilis longifolia 3
GLCA Channel HG R = 11
Anacardiaceae
Toxicodendron rydbergii T
Asteraceae
Cirsium rydbergii 1
Cyperaceae
Carex sp. T
Fagaceae
Quercus gambeli 2
Poaceae
Calamagrostis scopulorum 6
Pteridaceae
Adiantum capillus-veneris 7
Primulaceae
Primula specuicola 1
Ranunculaceae
Aquilegia micrantha 18
Rosaceae
Petropitys caespitosum 5
Scrophulariaceae
Mirabilis longifolia 1
Vitaceae
Parthenocissus vitacea 2
GLCA Corner HG R = 13
Agavaceae
Yucca sp. T
Anacardiaceae
Rhus aromatica var. simplicifolia
Asteraceae
Artemisia ludoviciana subsp. ludoviciana
Cirsium rydbergii 2
Cyperaceae
Carex aurea
Fagaceae
Quercus gambeli
Orchidaceae
Epipactis gigantea
Poaceae
Calamagrostis scopulorum 14
Pteridaceae
Adiantum capillus-veneris 54
Rosaceae
Petropitys caespitosum
Scrophulariaceae
Mirabilis longifolia 3
Ulmaceae
Celtis reticulata
Vitaceae
Parthenocissus vitacea 4
GLCA Crossbed HG R = 23
Agavaceae
Yucca sp. 1
Anacardiaceae
Rhus aromatica var. simplicifolia
Asteraceae
Brickellia longifolia var. longifolia 1
Cirsium rydbergii 11
Erigeron sparsifolius
Tetraneuris ivesiana
Gutierrezia sarothrae T
Solidago velutina subsp. sparsiflora 2
Cyperaceae
Carex curatorium 3
Loasaceae
Mentzelia cronquistii

Oleaceae
Fraxinus anomala

Orchidaceae
Epipactis gigantea

Poaceae
Andropogon glomeratus var. scabriglumis
Calamagrostis scopulorum 2
Dichanthelium acuminatum
Schizachyrium scoparium 26

Polygonaceae
Eriogonum corymbosum var. corymbosum T

Pteridaceae
Adiantum capillus-veneris

Primulaceae
Primula specuicola

Primulaceae
Primula specuicola 1

Rhamnaceae
Rhamnus betulifolia 9

Rosaeeae
Rhus aromatica var. simplicifolia

Asteraceae
Symphyotrichum chilense T
Cirsium rydbergii 9
Solidago velutina subsp. sparsiflora 2

Asteraceae
Cirsium sp. 2

Orchidaceae
Epipactis gigantea

Poaceae
Andropogon glomeratus var. scabriglumis 69
Dichanthelium acuminatum
Phragmites australis

Asteraceae
Cirsium sp. 13

Orchidaceae
Gilia aggregata var. maculata 2

Pteridaceae
Adiantum capillus-veneris 4

Primulaceae
Primula specuicola

Rosaeeae
Ramus betulifolia

Asteraceae
Brickellia longifolia var. longifolia

Orchidaceae
Epipactis gigantea 5

Poaceae
Muhlenbergia sp. T

Pteridaceae
Adiantum capillus-veneris 93

Ranunculaceae
Aquilegia micrantha

Rhamnaceae
Rhamnus betulifolia

Asteraceae
Baccharis emoryi 7
Cirsium rydbergii Erigeron sparsiflouis
Brassicaceae
Thelypodium integrifolium

Asteraceae
Carex aurea
Cladium californicum 6

Fagaceae
Cercis occidentalis var. orbiculata

Fagaceae
Quercus gambelii 3

Juncaceae
Juncus arcticus 13

Oleaceae
Forestiera pubescens 6

Orchidaceae
Epipactis gigantea

Poaceae
Calamagrostis scopulorum 3
Elymus canadensis T
Muhlenbergia andina
Dichanthelium acuminatum-T
Panicum virgatum 7
Phragmites australis
Schizachyrum scoparium T
Sphenopholis obtusata

Pteridaceae
Adiantum capillus-veneris 20

Primulaceae
Primula specuicola 1

Ranunculaceae
Aquilegia micrantha

Rosaceae
Ramus betulifolia

Asteraceae
Artemisia ludoviciana subsp. ludoviciana 4

Herrickia glauca var. glauca 4

Brickellia longifolia var. longiflora

Cirsium rydbergii 49

Solidago sp.
Sonchus asper

Juncaceae
Juncus arcticus 9

Liliaceae
Maianthemum stellatum 5

Orchidaceae
Epipactis gigantea T
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Calamagrostis scopulorum T
Elymus canadensis 3
Dichanthelium acuminatum 14
Pteridaceae
Adiantum capillus-veneris 1
Primulaceae
Primula speciucola T
Rosaceae
Poaceae
Pteridaceae
Adiantum capillus-veneris 2

GLCA Zephyr HG R = 17
Agavaceae
Yucca sp. 12
Anacardiaceae
Rhus aromatica var. simplificifolia 2
Asteraceae
Cirsium rydbergii 31
Cyperaceae
Carex curatorum 4
Fagaceae
Quercus gambelii
Orchidaceae
Epipactis gigantea T
Poaceae
Andropogon glomeratus var. scabrigrumus
Muhlenbergia sp. T
Schizachyrium scoparium 50
Primulaceae
Primula speciucola T
Pteridaceae
Adiantum capillus-veneris 2

GLCA Upper Three HG R = 16
Asclepiadaceae
Asclepias latifolia
Asteraceae
Solidago velutina subsp. sparsiflora
Cirsium rydbergii 40
Cyperaceae
Carex aurea 15
Fabaceae
Cercis occidentalis var. orbiculata
Fagaceae
Quercus gambelii 1
Orchidaceae
Epipactis gigantea 1
Poaceae
Calamagrostis scopulorum 13
Muhlenbergia sp. 1
Dichanthelium acuminatum
Schizachyrum scoparium 5

Pteridaceae
Adiantum capillus-veneris 1
Primulaceae
Primula speciucola T
Rosaceae
Petrophytum caespitosum
Scrophulariaceae
Castilleja linanifolia
Mimulus eastwoodiae T

GLCA Wrong HG R = 10
Anacardiaceae
Toxicodendron rydbergii 11
Apocynaceae
Apocynum cannabinum
Asteraceae
Artemisia ludoviciana subsp. mexicana T
Solidago velutina subsp. sparsiflora
Fagaceae
Quercus gambelii
Poaceae
Andropogon glomeratus var. scabrigrumus
Calamagrostis scopulorum 28
Dichanthelium acuminatum 2
Polemoniaceae
Gilia aggregata var. maculata
Pteridaceae
Adiantum capillus-veneris 30

GLCA Zephyr HG R = 17
Agavaceae
Yucca sp. 12
Anacardiaceae
Rhus aromatica var. simplificifolia 2
Asteraceae
Cirsium rydbergii 31
Cyperaceae
Carex curatorum 4
Fagaceae
Quercus gambelii
Orchidaceae
Epipactis gigantea T
Poaceae
Andropogon glomeratus var. scabrigrumus
Muhlenbergia sp. T
Schizachyrium scoparium 50
Primulaceae
Primula speciucola T
Pteridaceae
Adiantum capillus-veneris 2

Ranunculaceae
Aquilegia micrantha 2
Rhamnaceae
Rhamnus betulifolia 2
Rosaceae
Petrophytum caespitosum 2
Scrophulariaceae
Castilleja linanifolia 2
Ulmaeae
Cellis reticulata
Urticaceae
Panetaria pennsylvanica T

GLCA Zigy HG R = 30
Agavaceae
Yucca toftiae
Apocynaceae
Apocynum cannabinum
Asteraceae
Artemisia ludoviciana subsp. ludoviciana
Cirsium rydbergii 21
Coneza canadensis
Sonchus asper
Cyperaceae
3
Carex aurea
Carex curatorum
Eleocharis rostellata 12
Scirpus sp.
Fabaceae
Oxytropis sp.
Liliaceae
Zigadenus voginatus 13
Onagraceae
Oenothera longissima
Orchidaceae
Epipactis gigantea T
Poaceae
Andropogon glomeratus var. scabrigrumus
Muhlenbergia sp. T
Schizachyrium scoparium 50
Primulaceae
Primula speciucola T
Ranunculaceae
Aquilegia micrantha 1
Clematis ligusticifolia
Rosaceae
Petrophytum caespitosum
Rosa woodsii
Scrophulariaceae
Mimulus eastwoodiae

Typhaceae
Typha sp.
FABR Fir HG R = 11
Asteraceae
Cirsium undulatum 5
Cirsium sp.
Erigeron kachinensis 5
Heterotheca villosa var. minor T

Gentianaceae
Swertia radiata 2
Hydrophyllaceae
Phacelia sp.
Liliaceae
Zigadenus voginatus 13
Pinaceae
Abies bifolia
Poaceae
Calamagrostis scopulorum 29
Poa fendleriiana
Rosaceae
Amelanchier sp. 2
Holodiscus dumosus 2
Rubiaceae
Gallium multiflorum var. coloradoense

NABR Kachina HG R = 19
Apiraceae
Aletes mcdougalii subsp. breviradiatus 2
Asteraceae
Cirsium undulatum 5
Cirsium sp.
Erigeron kachinensis 5
Heterotheca villosa var. minor T

Celastraceae
Pachystima myrsinites T
Cyperaceae
Carex aurea T
Ephedraceae
Ephedra viridis 12
Gentianaceae
Swertia radiata T
Juncaceae
Juncus arcticus T
Equisetaceae
Equisetum laevigatum

Liliaceae
Maianthemum stellatum

Oleaceae
Fraxinus velutina

Orchidaceae
Epipactis gigantea

Poaceae
Agrostis exarata

Calamagrostis scopulorum

13

Muhlenbergia sp. 14

Poa pratensis 5

ZION Falling Water HG

F = 21

Aceraceae
Acer negundo var. violaceum

Anacardiaceae
Toxicodendron rydbergii

Araliaceae
Aralia racemosa ssp. bicornata

Asteraceae
Symphyotrichum lanceolatum var. hesperium 30

Brickellia longifolia var. longifolia

Cirsium neomexicanum

Berberidaceae
Berberis repens T

Brassicaceae
Erysimum capitatum

Caprifoliaceae
Symphoricarpos sp.

Celastraceae
Pachystima myrsinites

Hydrangeaceae
Jamesia americana var. zonis

Liliaceae
Maianthemum stellatum

Poaceae
Bromus ciliatus

Calamagrostis scopulorum

10

Maianthemum stellatum

T

ZION Fall HG R = 14

Araliaceae
Aralia racemosa subsp. bicornata

Asteraceae
Erigeron sions

Taraxacum officinale

Brassicaceae
Nasturtium officinale

Juncaceae
Juncus ensifolius var. montanus

Liliaceae
Maianthemum stellatum 6

Orchidaceae
Epipactis gigantea

Poaceae
Agrostis exarata

Pteridaceae
Adiantum capillus-veneris

Prunus virginiana

Rubieae
Galium trifidum

Saxifragaceae
Parnassia palustris var. montanensis

Scrophulariaceae
Mirulus cardinalis

ZION Lower Emerald HG

R = 12

Anacardiaceae
Toxicodendron rydbergii

Asteraceae
Herrickia glauca var. glauca 1

Cyperaceae
Carex aurea

Liliaceae
Maianthemum stellatum

Orchidaceae
Epipactis gigantea

Poaceae
Agrostis exarata 5

Calamagrostis scopulorum

33
Pteridaceae
Adiantum capillus-veneris 1
Primulaceae
Dodecatheon pulchellum var. zionense 25
Ranunculaceae
Aquilegia chrysantha T
Scrophulariaceae
Mimulus cardinalis
Vitaceae
Vitis arizonica

ZION Menu Falls HG R = 23
Aceraceae
Acer negundo var. negundo
Anacardiaceae
Toxicodendron rydbergii
Apocynaceae
Apocynum cannabinum
Asteraceae
Baccharis salicina
Cirsium arizonicum
Sonchus asper
Cyperaceae T
Carex aurea
Carex curtorum
Equisetaceae
Equisetum laevigatum
Fagaceae
Quercus turbinella
Liliaceae
Maianthemum stellatum
Oleaceae
Fraxinus velutina
Poaceae
Agrostis exarata
Bromus diandrus
Calamagrostis scopulorum 13
Polygono viridis
Muhlenbergia sp. 6
Pteridaceae
Adiantum capillus-veneris 16
Ranunculaceae
Aquilegia chrysantha 9
Aquilegia formosa var. forma
Clematis ligusticifolia
Rosaceae
Petrophytum caespitosum
Scrophulariaceae
Mimulus cardinalis T
Vitaceae
Vitis arizonica 3

ZION Pine Creek HG R = 6
Asteraceae
Herrickia glauca var. glauca 8
Solidago velutina subsp.
sparsiflora
Poaceae
Calamagrostis scopulorum
Poa fendlerianna
Pteridaceae
Adiantum capillus-veneris
Primulaceae
Dodecatheon pulchellum var. zionense 6

ZION Snail HG R = 13
Anacardiaceae
Toxicodendron rydbergii
Asteraceae
Herrickia glauca var. glauca
Liliaceae
Maianthemum stellatum T
Oleaceae
Fraxinus velutina
Orchidaceae
Epipactis gigantea
Poaceae
Bromus ciliatus
Calamagrostis scopulorum 15
Polypogon viridis
Pteridaceae
Adiantum capillus-veneris 32
Ranunculaceae
Aquilegia chrysantha 1
Rosaceae
Petrophytum caespitosum
Rubiacae
Galium aparine var. echinospermum
Scrophulariaceae
Mimulus cardinalis

ZION Trail’s End HG R = 13
Asteraceae
Cirsium arizonicum var. arizonicum
Sonchus arvensis
Sonchus asper
Berberidaceae
Berberis repens 1
Liliaceae
Maianthemum stellatum 3
Orchidaceae
Epipactis gigantea
Poaceae
Bromus tectorum
Calamagrostis scopulorum 20
Elymus canadensis 3
Muhlenbergia andina 1
Poa pratensis
Pteridaceae
Adiantum capillus-veneris
Primulaceae
Dodecatheon pulchellum var. zionense 20
Ranunculaceae
Aquilegia chrysantha T
Aquilegia formosa var. forma
Rosaceae
Petrophytum caespitosum
Saxifragaceae
Heuchera rubescens
Scrophulariaceae
Mimulus cardinalis
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