

# Level of Endemism in Hanging Gardens of the Colorado Plateau

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**Abstract.** Infrequent seeps and springs along xeric canyon walls of the Colorado Plateau support hydrophytic habitats called hanging gardens. We surveyed the level of endemism among vascular plant taxa of hanging gardens in three National Park Service units: Zion and Capitol Reef national parks and the Glen Canyon National Recreation Area. The number of hanging-garden endemics per hanging garden was significantly higher in the Glen Canyon National Recreation Area than in Zion National Park or in Capitol Reef National Park ( $F = 8.640$ ,  $P = 0.001$ ). This higher level of endemism was not because of larger hanging gardens or higher richness of vascular plant species per garden. Community importance of endemic plant taxa as measured by species canopy coverage has a range of 0–52%. The canopy coverage of hanging-garden endemics did not differ among the three parks ( $F = 1.740$ ,  $P = 0.189$ ).

**Key words:** Capitol Reef, Glen Canyon, species richness, vegetation community, Zion.

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Hanging gardens are small, hydrophytic, herbaceous plant communities (Malanson 1980; Welsh and Toft 1981; Tuhy and MacMahon 1988<sup>\*3</sup>; Welsh 1989; Heil et al. 1991\*) on canyon walls in the entrenched drainage system of the Colorado Plateau. The microclimate at larger hanging gardens contrasts sharply with the surrounding high desert—water is abundant, soils are moist, and canyon walls offer periodic shade. Several plant taxa that are endemic to hanging gardens have been found in Utah and Colorado (Loope 1977; Welsh and Toft 1981; Welsh 1989; Naumann 1990\*). We compared levels of endemism in vascular plant taxa among hanging gardens in Zion National Park (ZION), Glen Canyon National Recreation Area (GLCA), and Capitol Reef National Park (CARE).

## Methods

Hanging-garden vegetation was sampled for species richness and the species community importance in Zion National Park, Capitol Reef National Park, and Glen Canyon National Recreation Area during the summers of 1991 and 1992. We define a hanging-garden community as an area that is dominated by hydrophytic, herbaceous vegetation on canyon walls at perennial, broad-based seeps or springs that originate from a sandstone aquifer. Key physical parameters are permanently wet rock surfaces or subirrigated colluvial soils. Woody plants occasionally become established on drier islands and are often in the mesophytic ecotone around a hanging garden. The boundary with surrounding desert vegetation is where the more mesic-xeric vegetation begins. The boundary with the riparian community is placed where colluvial soils stop and alluvial soils begin. Colluvial soils develop on deposits that accumulated by gravitational downslope movement, whereas alluvial soils develop on water-transported deposits as in a floodplain (Brady 1974).

Vegetation was systematically sampled (Krebs 1989; Manly 1989\*) with 20- × 50-cm quadrat frames to estimate herbaceous canopy cover by species. The major axis of the hanging garden was divided into 10 equal segments. Beginning with a random start in the initial segment and systematically thereafter, widths were measured and a second random point chosen (Manly 1989\*) to determine placement of the lower left corner of the sampling frame. Edge

<sup>3</sup>Asterisk indicates unpublished material.

quadrats were proportionally weighted to include only the portion inside the hanging garden. Hanging-garden area was calculated from the width and major axis measurements. The Daubenmire method (1959) was used for visually estimating and analyzing the following canopy cover classes: 1 = 0–5%, 2 = 5–25%, 3 = 25–50%, 4 = 50–75%, 5 = 75–95%, 6 = 95–100%. Voucher specimens of each species were collected and deposited at the Rocky Mountain Herbarium of the University of Wyoming (Laramie). Nomenclature followed Welsh et al. (1993). Plant species distributions were taken from Weber (1987), Albee et al. (1988), Atwood et al. (1991), and Welsh et al. (1993). Colorado Plateau endemic taxa included species found in other habitats as well as on hanging gardens. Hanging-garden endemics are restricted to that habitat, or nearly so. Our data were analyzed with the least-squares ANOVA program MGLH in SYSTAT (1992), which adjusts mean square and probability for unbalanced designs. Hanging-garden area data were log transformed and canopy-coverage data were arcsine transformed before analysis (Zar 1974).

## Results

In 48 hanging gardens, we found 144 species, of which 11 were taxa endemic to the Colorado Plateau and 7 were taxa endemic to hanging gardens (Table 1). The level of plant endemism differed among the three parks (Tables 2, 3, and 4): the number of Colorado Plateau endemics per hanging garden was significantly higher in the Glen Canyon National Recreation Area than in Capitol Reef National Park (one-way ANOVA,  $F = 6.371$ ,  $P = 0.004$ ; Bonferroni post hoc test GLCA vs. CARE,  $P = 0.009$ ) and had a trend to be higher than in Zion National Park (Bonferroni post hoc test GLCA vs. ZION,  $P = 0.064$ ). When the focus of endemism was narrowed to the seven taxa endemic to hanging gardens (Table 1), the trend became significant. The Glen Canyon National Recreation Area is richer in hanging-garden endemics than Zion National Park or Capitol Reef National Park (one-way ANOVA,  $F = 8.640$ ,  $P = 0.001$ ; Bonferroni post hoc test, GLCA vs. CARE,  $P = 0.008$  and GLCA vs. ZION,  $P = 0.005$ ).

The community importance of endemic plant taxa was measured in 40 hanging-garden communities (Tables 2, 3, and 4). Thirty-five communities had endemic plant taxa that may make up as much as 52% of the canopy. In eight hanging gardens, canopy coverage of hanging-garden endemics was less than 5% (Tables 2, 3, and 4; Figure). The Horseshoe hanging garden, for example, had

**Table 1.** Endemic plant taxa found in hanging gardens where they make up small proportions (trace–0.05) of canopy coverage.

Endemic plant taxa <sup>a</sup>	Park <sup>b</sup>	Hanging garden
<i>Mimulus eastwoodiae</i> (HGE) <sup>a</sup>	CARE	Horseshoe
	GLCA	Pyro
	GLCA	Hardwood
<i>Primula specuicola</i> (HGE)	GLCA	Rattlesnake
	GLCA	Hardwood
	GLCA	Pyro
<i>Zigadenus vaginatus</i> (HGE)	GLCA	Fence
<i>Aquilegia micrantha</i> (HGE)	GLCA	Graffiti
	GLCA	Rattlesnake
<i>Cirsium rydbergii</i> (HGE)	GLCA	Pyro
	GLCA	Hardwood
<i>Habenaria zothecina</i> (CPE)	GLCA	Rattlesnake
<i>Jamesia americana zionis</i> (CPE)	ZION	Canyon Overlook I
	ZION	Falling Water
	ZION	Grotto
<i>Erigeron sionis</i> (CPE)	ZION	Canyon Overlook II
<i>Sphaeromeria ruthiae</i> (CPE)	ZION	Falling Water
<i>Carex haysii</i> (HGE)	ZION	Menu Falls
	ZION	Weeping Rock
<i>Dodecatheon pulchellum zionense</i> (HGE)	ZION	Weeping Rock

<sup>a</sup>HGE = Hanging garden endemic; CPE = Colorado Plateau endemic.

<sup>b</sup>CARE = Capitol Reef National Park; GLCA = Glen Canyon National Recreation Area; ZION = Zion National Park.

small clumps of the Eastwood monkeyflower, *Mimulus eastwoodiae* (Tables 1 and 4). The three parks showed no difference in canopy coverage for either Colorado Plateau endemic plant taxa (one-way ANOVA,  $F = 1.807$ ,  $P = 0.178$ ) or for hanging-garden endemic plant taxa (one-way ANOVA,  $F = 1.741$ ,  $P = 0.189$ ). Zion National Park and the Glen Canyon National Recreation Area have large populations of endemic plant taxa in some hanging gardens (Tables 2 and 3), and all three parks had hanging-garden communities with small populations of hanging-garden endemics (Table 1; Figure).

## Discussion

The higher level of endemism in the hanging gardens of Glen Canyon National Recreation Area was not an artifact of different patterns of species

**Table 2.** Number of endemic vascular plant taxa in hanging gardens of Zion National Park (ZION), Utah, by site.

Hanging garden	R <sup>a</sup>	HGE <sup>b</sup>	CPE <sup>c</sup>	Area(m <sup>2</sup> ) <sup>d</sup>	CC <sup>e</sup>
<b>ZION total</b>	95	2	5		
Upper Emerald	33	2	2	1,170	0.23
Kaye's	29	1	1	124	0.16
Weeping Rock	28	2	2	812	0.03
Grotto	28	1	2	628	0.24
Narrows Trail	26	1	1	383	0.22
Canyon Overlook II	26	0	1	70	T <sup>f</sup>
Menu Falls	23	1	1	190	T
Falling Water	21	0	2	420	T
Court Patriarchs	20	0	0	99	0
Fall	14	1	1	274	0.49
Canyon Overlook I	14	0	1	4	T
Hailstone	13	1	2	28	NA
Snail	13	0	0	61	0
Trail's End	13	1	1	226	0.12
Lower Emerald	12	1	1	131	0.29
Pine Creek	6	1	1	72	0.32

<sup>a</sup>Total species richness.

<sup>b</sup>Number of taxa endemic to hanging gardens.

<sup>c</sup>Number of taxa endemic to Colorado Plateau.

<sup>d</sup>Area of hanging garden.

<sup>e</sup>Sum of canopy coverage proportions for all hanging-garden endemic taxa.

<sup>f</sup>T < 0.005 of canopy coverage.

richness because the total vascular plant species richness per hanging garden was not significantly higher (one-way ANOVA,  $F = 6.940$ ,  $P = 0.002$ ; Bonferroni post hoc test GLCA vs. ZION,  $P = 0.118$ , GLCA vs. CARE,  $P = 0.053$ , CARE vs. ZION,  $P = 0.002$ ). Nor does Glen Canyon National Recreation Area's larger number of endemic taxa in hanging gardens seem to be related to hanging garden area. Hanging garden areas were significantly larger in Zion National Park and in the Glen Canyon National Recreation Area than in Capitol Reef National Park but were not significantly different from each other (one-way ANOVA,  $F = 10.889$ ,  $P = 0.000$ ; Bonferroni post hoc test, GLCA or ZION vs. CARE,  $P = 0.000$ , GLCA vs. ZION,  $P = 1.000$ ). The small hanging-garden area and low level of endemism in Capitol Reef National Park may have been because of the absence of an adequate sandstone aquifer (May et al. 1995).

The higher level of endemism in hanging gardens of the Glen Canyon National Recreation Area may have been due to stronger microclimatic isolation

**Table 3.** Number of endemic vascular plant taxa in hanging gardens of the Glen Canyon National Recreation Area (GLCA), Utah, by site.

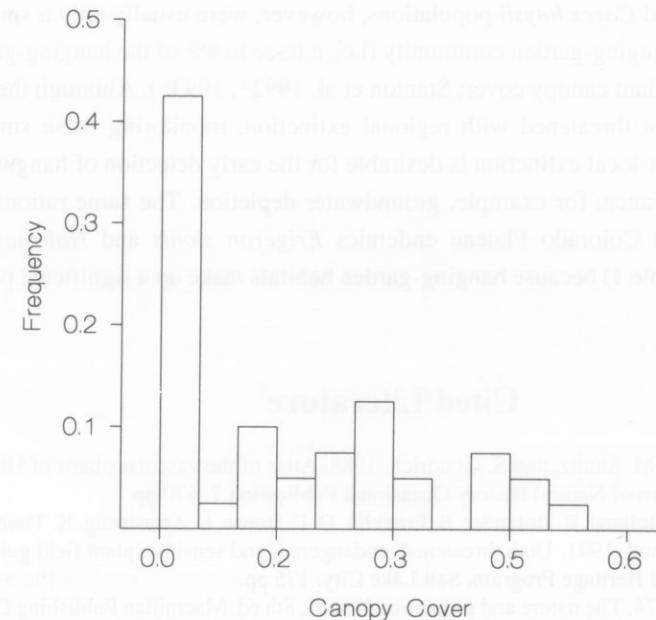
Hanging garden	R <sup>a</sup>	HGE <sup>b</sup>	CPE <sup>c</sup>	Area(m <sup>2</sup> ) <sup>d</sup>	CC <sup>e</sup>
<b>GLCA total</b>	82	5	6		
Zigy	30	5	5	1,215	0.43
Hardwood	29	3	3	1,177	0.01
Hook	27	4	4	351	0.52
Crossbed	22	2	2	115	0.18
Pyro	21	3	3	37	T <sup>f</sup>
Fence	21	2	2	344	T
Rattlesnake	20	3	4	836	0.04
Ice	18	4	5	893	0.43
Dune	18	2	2	173	0.12
Zephyr	16	3	3	81	0.29
Stone Basin	16	0	0	115	0
Camp	15	2	3	341	0.29
Pedestal	15	2	2	269	0.13
Upper Three	15	3	3	825	0.42
Lower Cow	14	1	1	86	0.15
Corner	13	2	2	249	0.27
Hawk	12	4	4	193	0.49
Channel	11	4	4	714	0.27
Swallow	11	4	5	52	0.13
Boondoggle	11	0	0	17	0
Wrong	11	0	0	35	0
Baby Too	10	1	1	38	NA
Baby	10	0	0	35	NA
Surprise	9	0	0	150	NA
Ivy	7	0	0	70	NA
Graffiti	7	1	1	44	T
Lower Three	6	2	2	162	0.28

<sup>a</sup>Total species richness.<sup>b</sup>Number of taxa endemic to hanging gardens.<sup>c</sup>Number of taxa endemic to Colorado Plateau.<sup>d</sup>Area of hanging garden.<sup>e</sup>Sum of canopy coverage proportions for all hanging-garden endemic taxa.<sup>f</sup>T < 0.005 of canopy coverage.

effects. The visual contrast between hanging garden vegetation and the surrounding xeric habitats was more abrupt in the Glen Canyon National Recreation Area with its predominance of slickrock and narrow riparian zones. More mesic habitats surrounded hanging gardens within Zion Canyon. Alternatively, the higher level of endemism in the Glen Canyon National Recreation Area may have been due to its more central geographic location between the Rocky

**Table 4.** Number of endemic vascular plant taxa in hanging gardens of Capitol Reef National Park (CARE), Utah.

Hanging garden	R <sup>a</sup>	HGE <sup>b</sup>	CPE <sup>c</sup>	Area (m <sup>2</sup> ) <sup>d</sup>	CC <sup>e</sup>
<b>CARE total</b>	22	1	1		
Sidewall	12	0	0	42	0
Beaver Dam	9	0	0	2	0
Horseshoe	8	1	1	25	T <sup>f</sup>
Fort	4	0	0	3	0
Meander	3	0	0	9	0

<sup>a</sup>Total species richness.<sup>b</sup>Number of taxa endemic to hanging gardens.<sup>c</sup>Number of taxa endemic to Colorado Plateau.<sup>d</sup>Area of hanging garden.<sup>e</sup>Sum of canopy coverage proportions for all hanging-garden endemic taxa.<sup>f</sup>T < 0.005 of canopy coverage.**Figure.** Community importance values of endemic plant taxa measured as the total amount of endemic taxa in the herbaceous canopy in each of 48 hanging gardens in Zion National Park, in the Glen Canyon National Recreation Area, and in Capitol Reef National Park during summers of 1991 and 1992.

Mountain and Great Basin floras. These hypotheses are testable and will be the subject of future analysis.

Some hanging gardens in Zion National Park and in the Glen Canyon National Recreation Area have large populations of endemic plant taxa (Tables 2 and 3; Figure). These are primarily large, dense patches of Rydberg's thistle, *Cirsium rydbergii*, in the Glen Canyon National Recreation Area and many smaller, scattered clumps of Zion shooting star, *Dodecatheon pulchellum zionense*, in Zion National Park.

Eleven hanging gardens had small proportions of endemic species in the canopy coverages (Tables 2, 3, and 4; Figure). The trace—5% class (Figure) may be used to identify hanging gardens with small endemic-species populations that are more susceptible to local extinction. Among the endemic taxa of hanging gardens (Table 1), *Cirsium rydbergii*, *Aquilegia micrantha*, *Zigdenus vaginatus*, and *Dodecatheon pulchellum zionense* are more abundant in other hanging gardens from Zion National Park and the Glen Canyon National Recreation Area (Stanton et al. 1992\*, 1993\*). *Mimulus eastwoodiae*, *Primula specuicola*, and *Carex haysii* populations, however, were usually only a small part of each hanging-garden community (i.e., a trace to 8% of the hanging-garden vascular plant canopy cover; Stanton et al. 1992\*, 1993\*). Although these species are not threatened with regional extinction, monitoring these small populations for local extinction is desirable for the early detection of hanging-garden disturbance; for example, groundwater depletion. The same rationale applies to the Colorado Plateau endemics *Erigeron sionis* and *Habenaria zothecina* (Table 1) because hanging-garden habitats make up a significant part of their range.

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