

Report on Three Hanging Gardens in the
Central Escalante Canyon System

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Abstract

Hanging gardens are unique oasis habitats in the otherwise semi-desert environment of the Colorado Plateau. They occur at seeps and springs which issue directly from vertical canyon walls, causing the vegetation to literally hang from the rock surface. Their species assemblies are distinct from the riparian and scrub habitats which dominate the region. This study examines three remote hanging gardens in the central Escalante River canyon system in south-central Utah.

Introduction

The Colorado Plateau is dominated geologically by massive horizontal layers of Mesozoic sandstone. The layers are incised by deep canyons cut by the Colorado River and its tributaries (Figure 1). Precipitation in the region is low, most of which runs directly off into one or another of the Colorado River tributaries. Any moisture which does not immediately run off or evaporate, may percolate into a layer of porous sandstone and migrate downward through the rock until reaching a less-permeable layer. Here the moisture flows laterally until it intersects a canyon. When this happens, seeps and springs issue directly from the canyon wall, providing moist, humid habitats surrounded by semi-arid desert. These unique and isolated habitats have long been called "hanging gardens" because the plants within them cling to the vertical rock faces, often festooning the canyon walls with luxuriant growth, in sharp contrast to their surrounding environment. Aesthetically, even a modest hanging garden is quite pleasing.

A few authors have briefly mentioned hanging gardens in the context of broader vegetative, floristic, and ecological studies on the Plateau. Alice Eastwood (1896) said of them "Here is a most strange vegetation, a boreal oasis in the midst of a Sonoran desert." Woodbury (1933) discusses succession in the gardens of Zion National Park. The tendency for species to stratify along the moisture gradient within gardens has been observed by Harrison et al. (1964) at Arches National Park (then Arches National Monument), and Welsh and Moore (1968) at Natural Bridges National Monument.

Hanging gardens contain several species unique to the garden habitat, such as the Scarlet Monkey Flower (*Mimulus cardinalis*) whose only known location in Utah is in Zion National Park (Welsh and Toft, 1981), and the Katchina Daisy (*Eriqeron kachinensis*), known only from certain seeps and gardens near Kachina Bridge in Natural Bridges National Monument (Welsh and Moore, 1968). Other species endemic to, or rarely found outside, the garden habitat, but found in many gardens on the Plateau, include the Eastwood Monkey Flower (*Mimulus eastwoodiae*), the Cave Columbine (*Aquilegia micrantha*), and the Death Camas (*Zigadenus vaginatus*).

While there are many thousands of hanging gardens occurring throughout the Colorado Plateau, a relative handful have been intensively studied. Vehicular travel is severely restricted by the region's topography, and hanging gardens, being within the canyons, are generally remote from the nearest trailhead. Some relatively accessible sites have been investigated (see Figure 1). Nebeker, Harper, Brotherson, and Welsh (1977) examined gardens in Arches and Canyonlands National Parks in the

north-central portion of the Plateau. While their data are not published and were not made available for this study, Malanson (1980) reports that they estimate over 25 percent of hanging garden species, when found on the Plateau at all, are found only within hanging gardens. They conclude that species composition in these gardens is a random function of those species which are capable of both dispersing to, and surviving within, the garden environment.

Malanson (1980, 1982), and Malanson and Kay (1980), conducted detailed analytical studies of several gardens in The Narrows of the Virgin River in Zion National Park, in extreme southwest Utah. Their studies indicated support for the Nebeker et al. random dispersal hypothesis, and note the influence which flooding has in the unique Zion Narrows environment.

Welsh and Toft (1981) surveyed Glen Canyon gardens, finding their species assemblies to be distinct both from that on the canyon rims above, as well as from the riparian habitat along the small or intermittent streams found in many canyon bottoms. They describe the gardens as "relictual refugia" because many of their species are characteristic of other geographic locations. Welsh and Wood (1976), and Wood and Welsh (1976) discuss the structure and productivity of a selected garden in Glen Canyon, finding productivity to be high. Unfortunately the waters of Lake Powell have now drowned the majority of Glen Canyon's gardens.

Welsh and Toft prepared a classification scheme for hanging gardens based on rock type and morphology, describing how the structural characteristics of the various geological formations influence the appearance of the gardens which form in them (Table

1). They note that the Wingate Sandstone "is apparently almost completely lacking in even modest garden development," citing one exception in Canyonlands National Park, which is "not strictly a hanging garden, [but] does support some characteristic hanging-garden plants." They attribute the lack of Wingate gardens to the general impermeability of the Kayenta formation, which overlays the Wingate, hence blocking the percolation of water into the Wingate and preventing the formation of aquifers which would feed any potential garden. It was that observation which prompted this study.

The Escalante River is the major northern tributary to the Colorado River in Glen Canyon (Figure 1). It is deeply entrenched throughout its length, cutting a canyon which ranges from 50 meters to nearly 500 meters deep through the Navajo, Kayenta, Wingate, and Chinle formations. The Escalante itself contains numerous side-canyons which in turn cut back from the river. In its central region, one group of these side canyons dissect a large block of Wingate known locally as Choprock Bench (Figures 2 and 3). Most of the Navajo and much of the Kayenta has been eroded from this bench, exposing the Wingate and its intricate aeolean crossbedding.

The Choprock Bench canyons discussed here are known as Chopslot (a tributary to Choprock Canyon proper), Neon, and Baker. Morphologically they are very similar, having formed along the major structural faults which run parallel through Choprock Bench in a southwest to northeast direction. The upper reaches of each canyon is a narrow, deeply incised slot. The slots range from less than a meter up to two or three meters wide at the

bottom, and from tens to over a hundred meters in depth from the rim, depending on local variations in the Wingate sandstone. Each slot runs through the Wingate for several kilometers, before coming to a pouroff where the slot opens out into the wide, lower portions of the canyons (Figures 4, 5, and 6). The pouroffs are dry waterfalls except immediately following heavy rains. Below each pouroff is a plungepool which collects and holds a few millitimeters at Baker, a half-meter at Chopslot, and from one to three meters depth below the unique, triple natural bridge at the "Halo Temple" in Neon Canyon.

Each canyon contains a hanging garden situated at the mouth of the slot, below their respective pouroffs. Each garden owes its existence to the slot above it. Rainfall here is sporadic, seldom averaging more than 8 or 10 inches per year, most of which falls as high-intensity, short-duration summer thunderstorms, and runs quickly off the nearly naked slickrock. No one spot can be guaranteed of receiving much rain in any given year, but by draining a sufficiently large area, the slot canyons can trap, and shelter from the sun, enough runoff to modestly charge the tiny aquifers which feed the gardens.

Methods

Choprocks Bench lies in a wilderness area within Glen Canyon National Recreation Area. With a collecting permit from the Park Service, I visited the Choprocks Bench gardens during July of 1987. Numbers of specimens were limited both as a condition of the permit, and by practical necessity. Species collected were limited to vascular plants found growing on the vertical

face-wall of the gardens, the "clinging" species of Welsh and Toft which both characterize and define a hanging garden. Standard sampling techniques employing quadrats for estimating foliar cover are impractical for most hanging gardens. One compromise is the modified line-point transect method described by Welsh and Wood (1976), similar to that Malanson used at Zion. However, it is awkward to implement alone when the "ground" is sloping towards the vertical, wet, slippery, and above one's head.

Accurate maps from which direct area measurements may be taken are produced from vertical aerial photography by rectifying the photographic image to account for the effect of relief displacement due to terrain variation. Basically, the procedure requires calculating separate photo scales for known reference points on the image, and eliminating the effects of relief mathematically by converting the photo points to an arbitrary datum-level ground coordinate system (typically the average elevation of the area photographed). Lengths and areas are then computed using similar triangles and the Pythagorean theorem to find actual ground coordinates. For details see Lillesand and Kiefer (1979), or Avery and Berlin (1985).

To derive cover values for this study, I photographed each hanging garden in panoramic sequence, using a carefully levelled tripod, while recording distances between selected checkpoints on the garden wall, and their distances from the camera. The resulting photographic panoramas were assembled and digitized. Area calculations for large clusters of vegetation readily discernible from the photographs were taken directly from the

digitized images; for solitary specimens not resolvable on the image, but known to exist from inspection, an average area-per-specimen value was calculated from the collections. The low numbers of species made practical actual counts of individual occurrences for the infrequent and rare specimens, and these values are inserted individually into the database.

Flow rates from gardens such as these are difficult or impossible to measure directly, being both sparse and highly variable from place to place within each garden. For many of the clustered patches of vegetation within them, surrounded by dry wall on all sides, every drop of available water is either transpired or evaporated. In other spots along the wall, actual flow is barely perceptible in a broad sheet oozing down the rock face, or as often hidden behind the banks of Maidenhair.

I derived three surrogate measures for flow and flow potential from the ratios of garden wall area to canyon drainage area, garden wet wall area to drainage area, and wet wall to total wall area.

Values for solar input are taken from direct observation on the days of collection, as modified by each site's unique aspect. The gardens are all shaded from the sun for most of the summer day. The Chopslot site faces north of northwest receiving direct sunlight only in the afternoon; earlier and later in the growing season, it would receive correspondingly less direct light. Baker garden faces more west of south, but is shielded from morning and afternoon sun by the high walls downcanyon from the pouroff. Neon's garden faces almost due south, and is recessed deep within an alcove formed below the mouth of the slot canyon, at its

pouroff. The garden wall proper actually received no direct sun on the days of collection; however, earlier and later in the year with the sun at a lower angle, the back wall gets the full brunt of the sun, correspondingly enhanced by the reflector-oven nature of the alcove. The values reported here are my best estimates based on recollections of previous trips during other times of the year, and on experience with similar site aspects elsewhere.

Results

Twenty species were counted in the three Choprock Bench gardens examined. Five grasses were identified only to the family level, and four plants occurring too infrequently to collect remained unidentified. Richness ranged from 1 to 14, frequency from 1 to 3, with only the nearly-ubiquitous Maidenhair fern occurring in all three gardens.

The boundary manipulation algorithm provided with the computerized mapping program used to digitize the garden panoramas proved unable to rectify the images to my satisfaction. While developing a more sophisticated program to do the rectifying in order to find actual coverage values, I have used two relative species cover values, percent of total wall area, and percent of wet wall area. These percentage values are not dependent on the image being rectified to a ground coordinate system.

Spatial relationships between the Choprock Bench gardens are summarized in Figures 7, 8, and 9, and Tables 2, 3, and 4. Comparisons of the Choprock Bench gardens with others on the Plateau are summarized in Tables 5 through 8. For Glen Canyon I

have included only those species from the Welsh and Wood study which they describe as belonging to the hanging garden proper. For both Arches and Natural Bridges, the species used are those described as having been collected specifically from hanging gardens. From all locales, only specimens identified to the species level have been included.

Discussion

Structurally the Choprock Bench gardens resemble others described in the literature, although soils are practically nonexistent, being restricted to small cracks and pockmarks in the wall. Moisture on the rock provides a site for algae, which in some places forms dense mats. Sphagnum species combine to provide a purchase place for vascular species. Ultimately the algae mat peels or sloughs from the wall, carrying its dependent vegetation with it. Interestingly, in the Choprock Bench gardens, the Maidenhair fern seems to require the presence of sphagnum; while there are numerous patches where sphagnum occurs by itself, in none of the gardens does Maidenhair grow without sphagnum for support.

The use of panoramac photographs and aerial photographic mapping techniques seems appropriate to the study of hanging gardens when more traditional sampling methods are impractical due to access problems. In placing the camera, equal distances to all points on the wall is desirable. A sturdy tripod is required, and care is needed to ensure that it is level in all directions. The 35mm format used here is the smallest practical, while larger format cameras would yeild correspondingly greater image

resolution. Digitizing the photographs by hand is no more tedious than other methods of calculating area coverage such as dot-density overlays, with the benefits of rapid manipulation once the boundaries are entered. When a suitable algorithm is completed for rectifying the photo coordinates to the ground (or wall) coordinate system, actual species cover information will be available from the database, in addition to percent cover relative to wall area.

The measures of similarity between the Choprock Bench gardens and others on the Colorado Plateau (Table 8), with perfect-to-very close matches for observed-expected values between many of the garden pairs, indicates support for the random-dispersal hypotheses of both Malanson at Zion, and his report of the Nebeker et al. findings at Canyonlands and Arches. With additional sampling data, more powerful statistical tests may yield deeper insights.

Acknowledgments

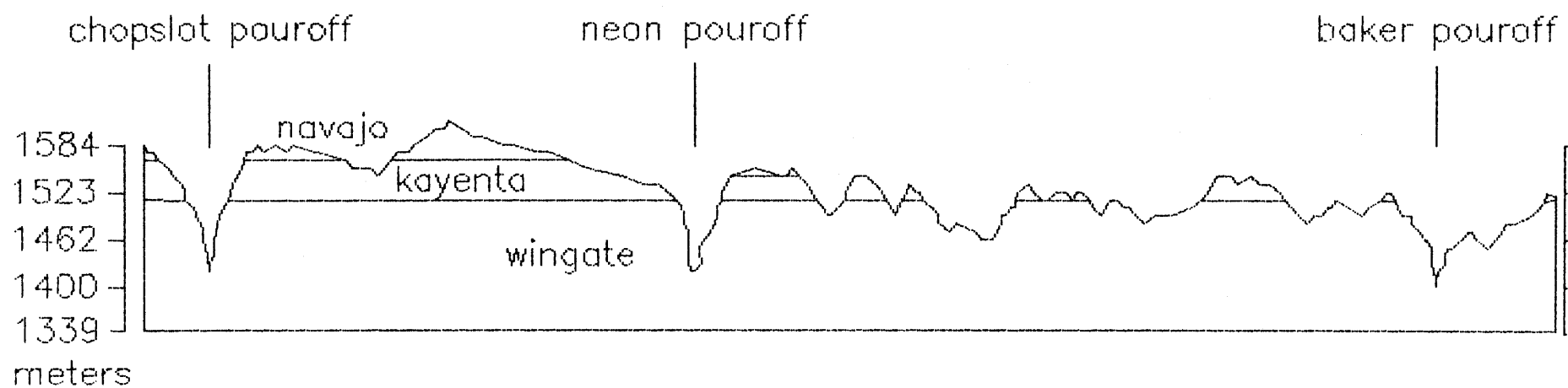
I wish to thank Dr. Thomas Veblen, Department of Geography, University of Colorado for agreeing to supervise this study; Dr. William Weber, University of Colorado Herbarium for species identification; and the National Park Service, Glen Canyon NRA for permission to collect specimens.

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Choprock Bench Geologic and Topographic Cross Section

Vertical Exageration 5 Times



0 .5 1
kilometer

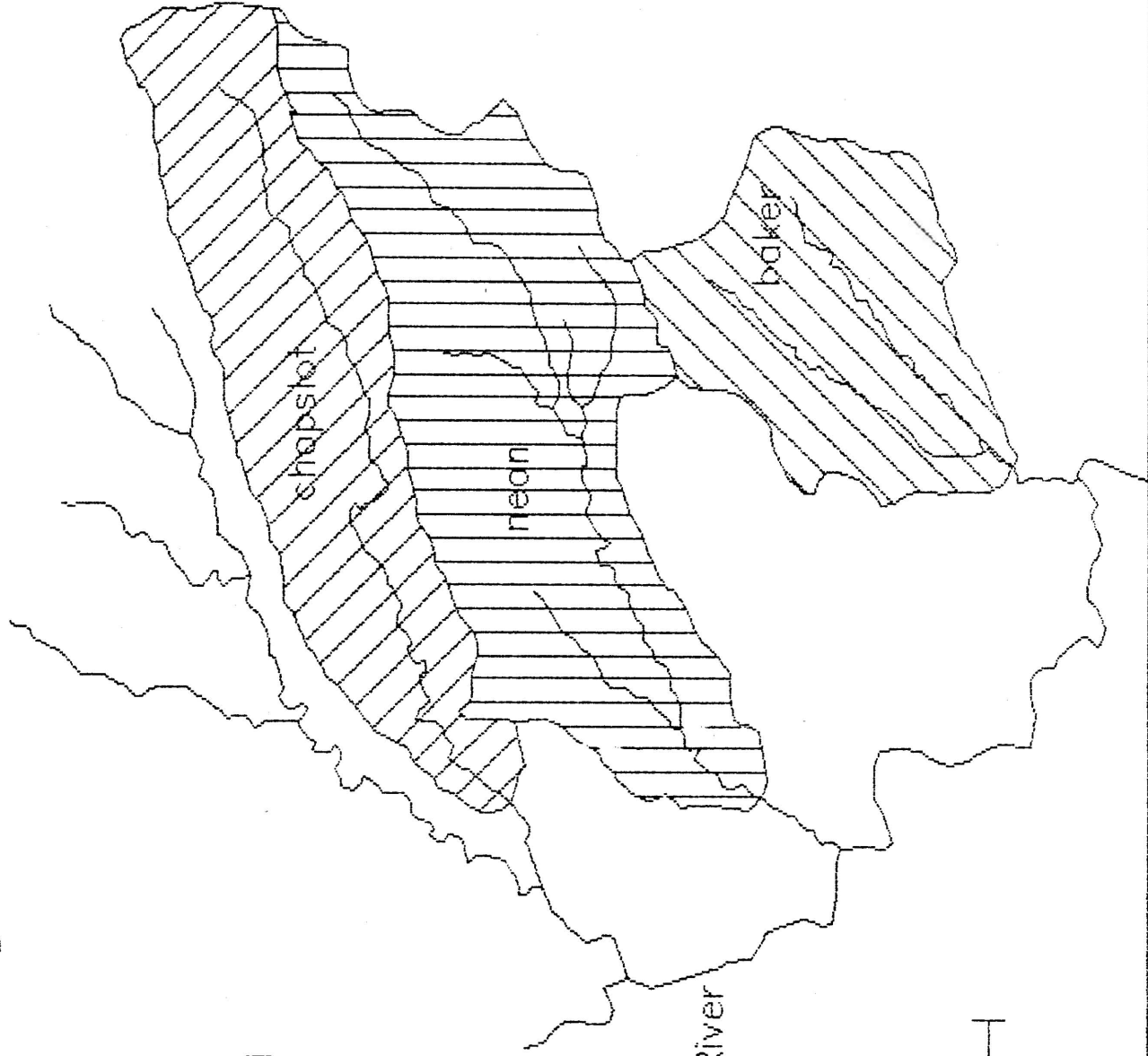
Choprock Bench Canyons

Drainage Areas Above the Pouroffs

 chopslot 10.49 km sq

 neon 13.78 km sq

 baker 7.45 km sq




scale 4 km

FIGURE 4.

CHOTSLLOT CANYON TOUR OFF

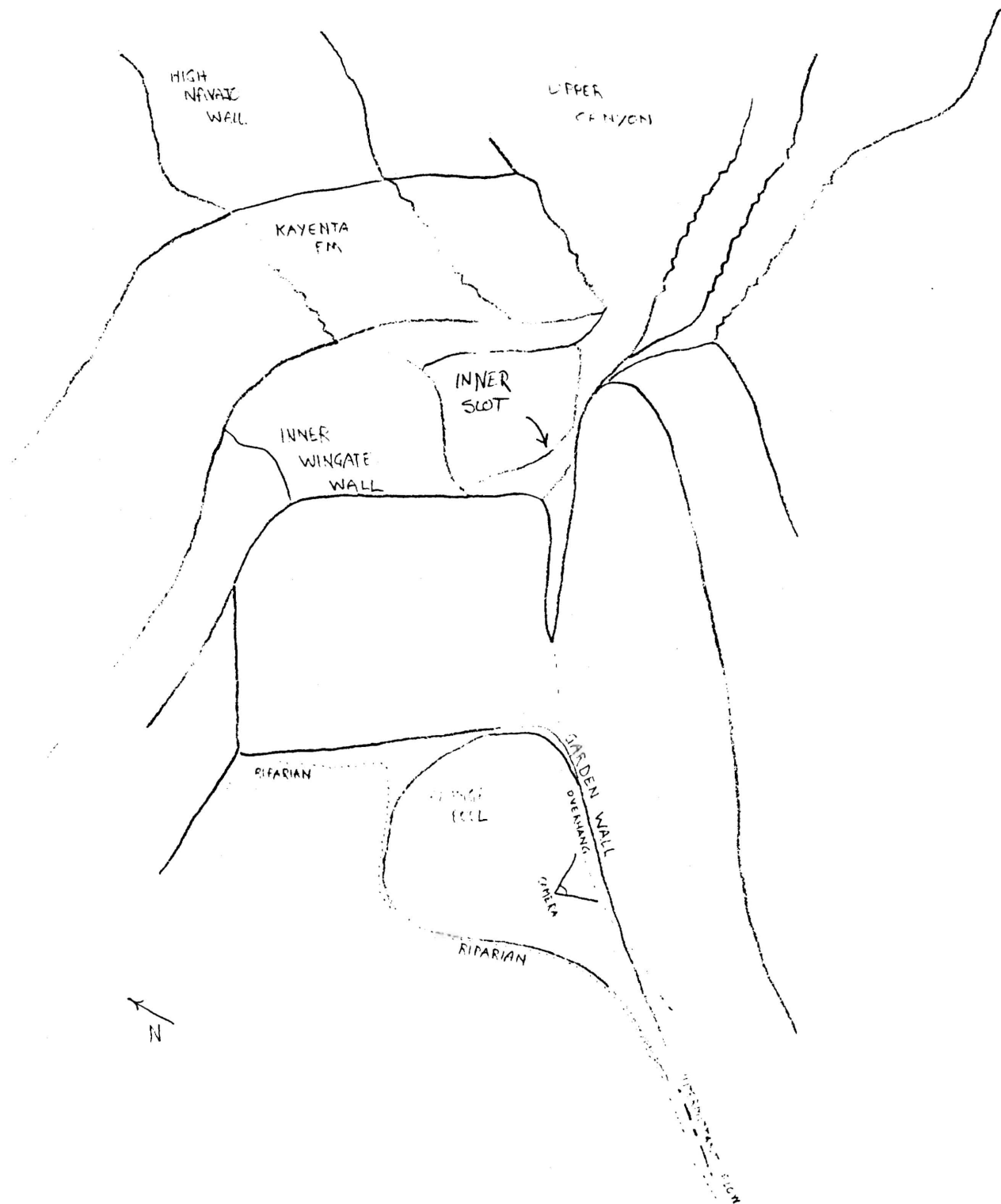


FIGURE 5.

NEON CANYON POUROFF

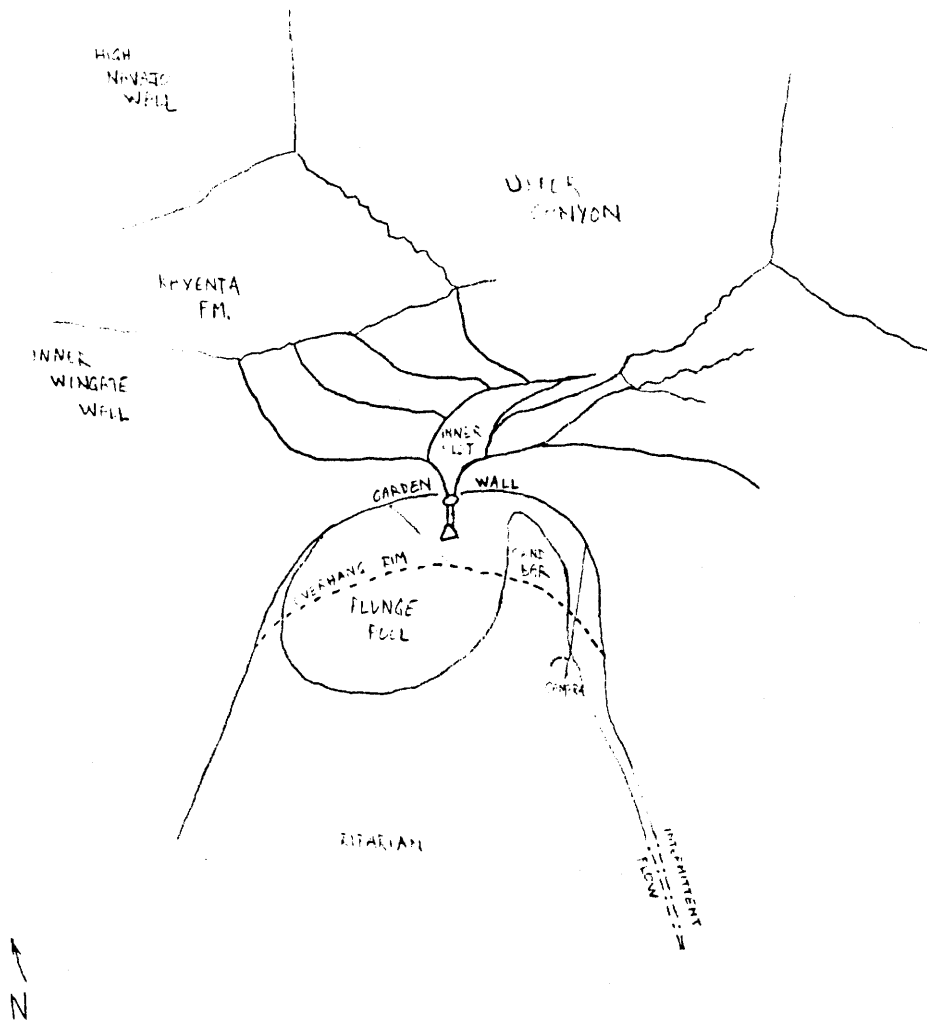
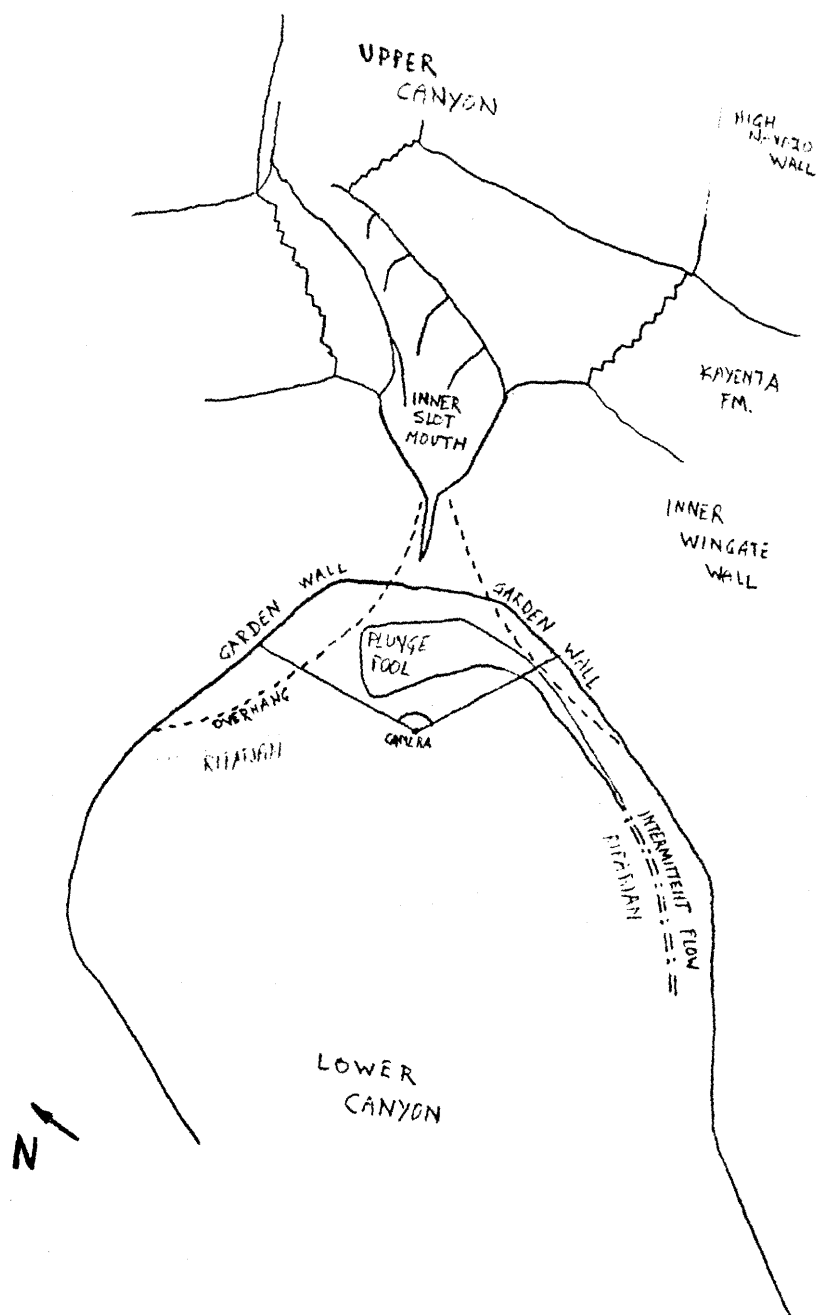


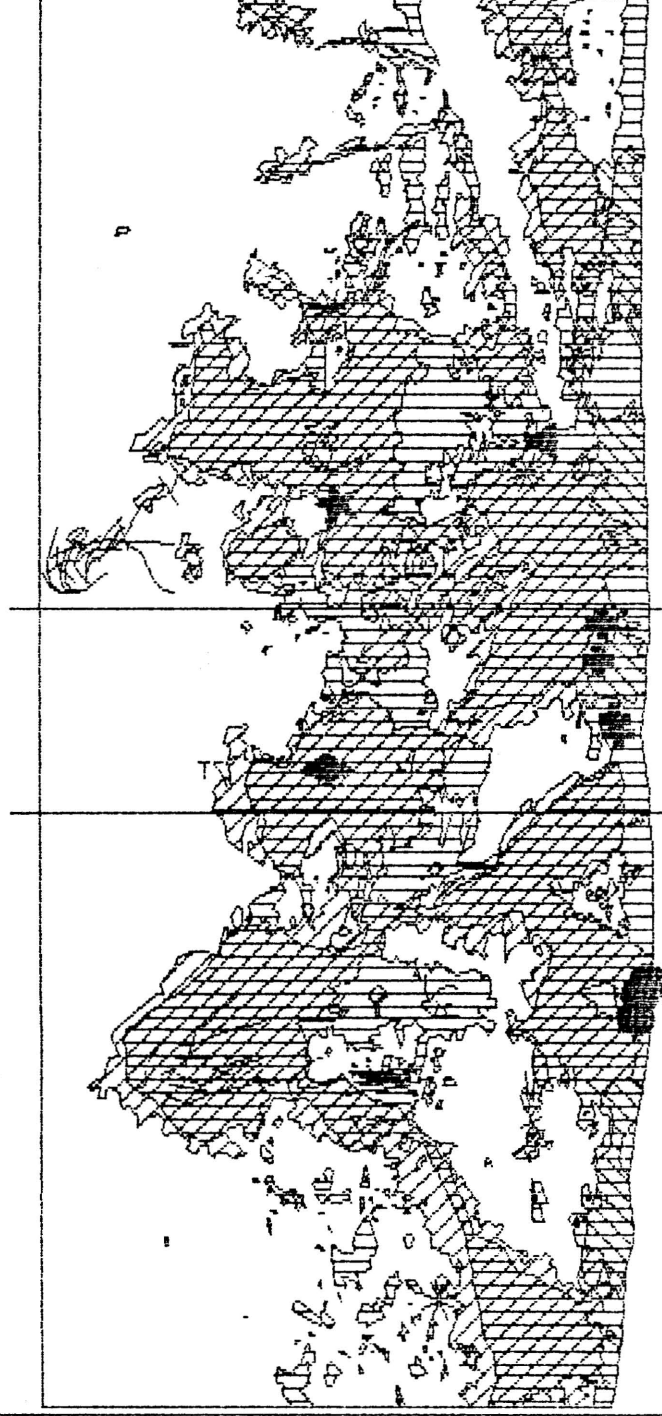
FIGURE 6, BAKER CANYON POUROFF



Chopslot Canyon Pouroff Hanging Garden

Legend

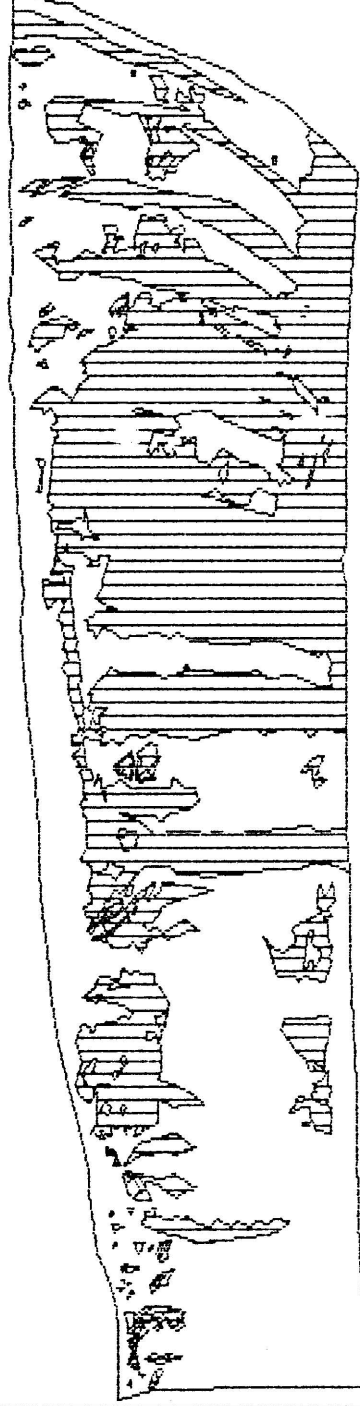
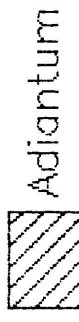
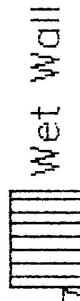
	Dry Wall
	Wet Wall
	Adiantum
	Polypogon
	Elymus
	Gramineae A
	Gramineae B
	Gramineae C
	Artemesia
	Taraxacum
	Mimulus
	Epipactus
	E. hornemannii
	E. ciliatum
	Unkn Flower
	Clematis



scale 1 meter

Neon Canyon Pouroff Hanging Garden

Legend

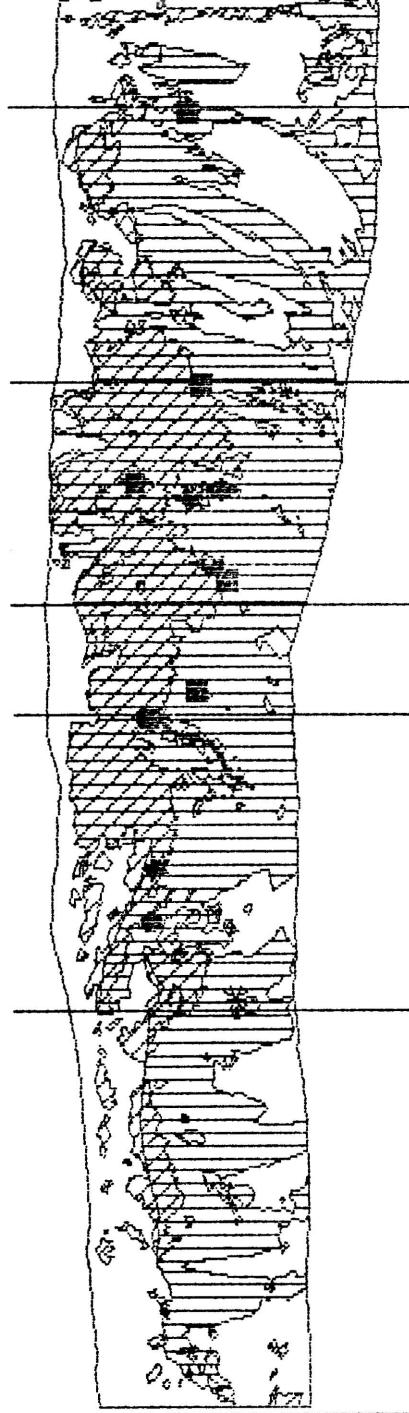


scale 1 meter

Baker Canyon Pouroff Hanging Garden

Legend

	Dry Wall		Gramineae A
	Wet Wall		Gramineae B
	Adiantum		Gramineae C
	Aquilegia		Unkn Forb 1
	Clematis		Unkn Forb 2
	Mimulus		Unkn Flower
	Taraxacum		



scale 1 meter

Table 1. Main Garden-Bearing Strata

<u>Geologic Age</u>	<u>Strata</u>	<u>Region</u>
Cretaceous	Wahweap	Kaiparowits
	Straight Cliffs	Kaiparowits
Jurassic	Entrada	Arches
		Kaiparowits
	Navajo	Lake Powell
		Bluff
		Canyonlands
Triassic	Navajo Kayenta Wingate	Lake Powell
		Lake Powell
		Escalante Canyons
Permian	White Rim	Canyonlands
	Cedar Mesa	Natural Bridges

After Welsh and Toft (1981), modified to reflect Wingate gardens.

Table 2. Choprock Gardens Species Composition and Relative Cover
by Percent of Garden Area and Wet Wall

Canyon -- Species	Chopslot		Neon		Baker	
	% Area	% Wet	% Area	% Wet	% Area	% Wet
Adiantum						
capillus-venerus	30.4015	80.2104	1.2900	2.9533	23.0198	37.598
Artemesia						
ludociciana	.1427	.3764	0	0	0	0
Aqueligia						
micrantha	0	0	0	0	.7064	1.1537
Clematis						
ligusticifilia	.2745	.7241	0	0	.0931	.1521
Elymus						
trachycaulus	.0679	.1792	0	0	0	0
Epilobium						
hornemannii	.0978	.2581	0	0	0	0
ciliatum	.0644	1.1543	0	0	0	0
Epipactus						
gigantea	.8085	2.1240	0	0	0	0
GRAMINEAE spp	.0890	1.5952	0	0	.0015	.0106
Mimulus						
eastwoodiae	.0090	.1613	0	0	.0150	.0245
Polypogon						
semiverticillatus	2.6529	5.5474	0	0	0	0
Taraxacum						
officinale	.3179	.8388	0	0	.0065	.0106
Unidentified 1	.0611	.1613	0	0	0	0
Unidentified 2	0	0	0	0	.0075	.0123
Unidentified 3	0	0	0	0	.0216	.0294
Unidentified 4	0	0	0	0	.0216	.0294

Table 3. Choprock Gardens Environmental Values

Canyon --	Chopslot	Neon	Baker
Drainage Area (km sq)	10.4900	13.7800	7.4500
Total Wall Area (m sq)	14.7200	20.1400	119.9490
Wet Wall Area (m sq)	5.5792	8.7970	73.4400
Wall Area : Drainage Area	1.4032	1.4615	16.1005
Wet Wall : Drainage Area	.5318	.6383	9.8577
Wet Wall : Wall Area (%)	37.9022	43.6792	61.2260
Solar Input, hours/day	3.0	5.0	4.0

Table 4. Choprock Bench Gardens Similarity Indices

Dice:		Chop	Neon	Baker
2C	Chop	-----	.1538	.4762
-----	Neon	.1538	-----	.2000
N1 + N2	Bakr	.4762	.2000	-----

Jaccard:		Chop	Neon	Baker
C	Chop	-----	.0833	.3125
-----	Neon	.0833	-----	.1111
N1+N2-C	Bakr	.3125	.1111	-----

Otsuka:		Chop	Neon	Baker
C	Chop	-----	.2887	.4811
-----	Neon	.2887	-----	.3333
sqrt(N1*N2)	Bakr	.4811	.3333	-----

	Dice	Jaccard	Otsuka
Chop-Neon	.1538	.0833	.2887
Chop-Baker	.4762	.3125	.4811
Neon-Baker	.2000	.1111	.3333

Table 5. Regional Hanging Garden Species Comparison
Page 1 of 2

Species	Zion	Glen	Chop	NatB	Arch	Freq
Abies concolor		X				1
Acer negundo		X				1
Adiantum capillus-veneris	X	X	X	X	X	5
Adiantum pedatum		X				1
Amaranthus graecizans		X				1
Amsonia eastwoodiana	X					1
Anaphalis margaritaceae		X				1
Andropogon hallii	X					1
Apocynum cannabinum		X	X			2
Aqueligia micrantha		X	X	X	X	4
Aralia racemosa		X				1
Aristida longiseta	X					1
Artemesia ludoviciana		X	X			2
Aster eatonii		X				1
Astragalus lentiginosus	X					1
Berberis repens		X				1
Brickellia grandiflora		X				1
Bromus ciliatus		X				1
Bromus rubens	X					1
Bromus tectorum	X					1
Calamagrostis scopulorum	X		X			2
Carex garberi	X				X	2
Carex specuicola				X		1
Castilleja linariaefolia	X				X	2
Cirsium arizonicum		X	X			2
Cirsium pulchellum				X		1
Cirsium rydbergii	X				X	2
Clematis ligusticifolia			X			1
Cystopteris fragilis		X				1
Descurania pinnata	X					1
Dodecatheon pulchellum	X	X				1
Dryopteris filix-mas		X				1
Elymus canadensis	X					1
Elymus trachycaulus			X			1
Epipactis gigantea	X	X	X	X	X	5
Epilobium hornemannii			X			1
Epilobium ciliatum			X			1
Equisetum hyemale		X				1
Equisetum laevigatum				X		1
Erigeron divergens	X				X	2
Erigeron kachinensis				X		1
Euphorbia robusta					X	1
Festuca octoflora	X					1
Fraxinus velutina		X				1
Galium aparine		X				1
Habenaria sparsiflora				X	X	2
Hedeoma drummondii					X	1
Heterotheca villiosa	X					1
Heuchera versicolor		X				1
Hilaria jamesii	X					1

(continued)

Table 5. Regional Hanging Garden Species Comparison
Page 2 of 2

Species	Zion	Glen	Chop	NatB	Arch	Freq
Juncus saximontanus				X		1
Lepidium montanum	X					1
Lobelia cardinalis	X	X				1
Mimulus cardinalis	X	X				1
Mimulus eastwoodiae			X	X		2
Mimulus guttatus		X				1
Muhlenbergia andina		X				1
Muhlenbergia curtifolia	X				X	1
Muhlenbergia mexicana		X				1
Nasturtium officinale	X					1
Oenothera longissima					X	1
Oryzopsis hymenoides	X					1
Pachystima myrsinites				X		1
Panicum lanuginosum	X					1
Panicum tennesseensis					X	1
Phragmites communis					X	1
Poa longiligula					X	1
Poa nevadensis		X				1
Polypogon semiverticillatus			X			1
Primula specuicola	X				X	2
Pteridium aquilinum					X	1
Rhus radicans		X				1
Rhus trilobata					X	1
Rubus leucodermis		X				1
Salix lutea					X	1
Sitanion hystrix	X					1
Smilacina stellata		X		X		2
Solidago altissima					X	1
Solidago sparsiflora	X					1
Sorghastrum nutans	X					1
Sphenopholis obtusata	X					1
Stephanomeria exigua	X					1
Stephanomeria pauciflora					X	1
Stipa comata	X					1
Taraxacum officinalis		X	X			2
Thalictrum fendleri	X					1
Thelypodium integrifolium					X	1
Toxicodendron radicans					X	1
Zygadenus elegans				X	X	2

89 species counted

Zion : Zion Narrows, Zion Nat. Park, Malanson, 1980, 48 spp

Glen : Three-Garden, Glen Canyon, Welsh and Wood, 1976, 29 spp

Chop : Choprock Bench, Escalante River, Green, 1988, 11 spp

NatB : Natural Bridges Nat'l Mon., Welsh and Moore, 1968, 12 spp

Arch : Arches Nat'l Park, Harrison, Welsh, and Moore, 1964, 24 spp

Table 6. Regional Hanging Garden Species Comparison
Species Present in Two or More Gardens

Species	Zion	Glen	Chop	NatB	Arch	Freq
<i>Adiantum capillus-veneris</i>	X	X	X	X	X	5
<i>Apocynum cannabinum</i>		X			X	2
<i>Aqueligia micrantha</i>		X	X	X	X	4
<i>Artemesia ludoviciana</i>		X	X			2
<i>Calamagrostis scopulorum</i>	X	X			X	3
<i>Carex garberi</i>	X				X	2
<i>Castilleja linariaefolia</i>	X				X	2
<i>Cirsium arizonicum</i>		X			X	2
<i>Cirsium rydbergii</i>	X				X	2
<i>Epipactis gigantea</i>	X	X	X	X	X	5
<i>Erigeron divergens</i>	X				X	2
<i>Habenaria sparsiflora</i>				X	X	2
<i>Mimulus eastwoodiae</i>			X	X		2
<i>Muhlenbergia curtifolia</i>	X				X	2
<i>Primula specuicola</i>	X				X	2
<i>Smilacina stellata</i>		X			X	2
<i>Taraxacum officinalis</i>		X	X			2
<i>Zygadenus elegans</i>				X	X	2

18 species counted

Zion : Zion Narrows, Zion Nat. Park, Malanson, 1980, 8 spp

Glen : Three-Garden, Glen Canyon, Welsh and Wood, 1976, 9 spp

Chop : Choprock Bench, Escalante River, Green, 1988, 6 spp

NatB : Natural Bridges Nat'l Mon., Welsh and Moore, 1968, 6 spp

Arch : Arches Nat'l Park, Harrison, Welsh, and Moore, 1964, 15 spp

Table 7. Colorado Plateau Hanging Gardens
 Similarity Indices
 Number of Common Species above the diagonals,
 Similarity Index below the diagonals

Dice:		Zion	Glen	Chop	NatB	Arch
	Zion	-----	3	1	3	8
2C	Glen	.3333	-----	4	4	6
-----	Chop	.1426	.5714	-----	2	3
N1 + N2	NatB	.4000	.5333	.3636	-----	5
	Arch	.6666	.5000	.3000	.4762	-----

Jaccard:		Zion	Glen	Chop	NatB	Arch
	Zion	-----	3	1	3	8
C	Glen	.0200	-----	4	4	6
-----	Chop	.0769	.4000	-----	2	3
N1+N2-C	NatB	.2500	.3636	.2222	-----	5
	Arch	.5000	.3333	.1765	.3125	-----

Otsuka:		Zion	Glen	Chop	NatB	Arch
	Zion	-----	3	1	3	8
C	Glen	.4472	-----	4	4	6
-----	Chop	.1361	.9428	-----	2	3
sqrt(N1*N2)	NatB	.0555	.5443	.3651	-----	5
	Arch	.6885	.5164	.3464	.5270	-----

Table 8. Colorado Plateau Hanging Gardens
Observed vs Expected Values
Assuming Equiprobable Species

	Zion	Glen	Chop	NatB	Arch	
# Spp	(30)	(35)	(11)	(12)	(28)	
Zion	-----	3	1	3	8	Observed numbers of common species in garden pairs are above diagonal
Glen	12	-----	4	4	6	
Chop	4	4	-----	2	3	
NatB	4	5	2	-----	5	
Arch	9	11	3	4	-----	

Below the diagonal is the expected number
of common species for each garden pair.

Chi-Squared Tests
Assuming Equiprobable Species

	Zion	Glen	Chop	NatB	Arch	
# Spp	(30)	(35)	(11)	(12)	(28)	
Zion	----	3	1	3	8	Observed numbers of common species in garden pairs are above diagonal
Glen	6.75	----	4	4	6	
Chop	2.25	0.00	----	2	3	
NatB	0.25	0.20	0.00	----	5	
Arch	1.33	2.27	0.00	0.25	----	

Below the diagonal is the Chi-Squared
value for each pair of gardens.

$$X^2 = \frac{\sum (O - E)^2}{E}$$

$$O = \text{Observed in common}, \quad E = \text{Expect in common} = \frac{\text{Spp in A} * \text{Spp in B}}{\text{Total HG Spp}}$$

Total Species Pool = 89