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ON THE DISTRIBUTION OF UTAH'S HANGING GARDENS

Stanley L. Welsh

ABSTRACT.—This is a summary monograph of the hanging gardens as they occur in the Colorado River and Virgin River portions of the Colorado Plateau in Utah. Discussed in this paper are the hanging gardens, their geography, geomorphology, aspects of distribution and diversity, and principal vascular and algal plant species. Animal trapping studies and plant productivity aspects are reviewed.

The sea of aridity that overlies southern Utah and vicinity is broken by seasonal influences and by the dendritic trenches of the Colorado River and its tributaries. The effects of the river are restricted to its banks and adjacent alluvial terraces; the riparian vegetation is generally both monotonous and predictable. Away from the riverbanks aridity is the general rule. However, here and there on the canyon walls are moist places clothed in green. They are well-watered islands in an ocean of drought (Figs. 1 and 2). It is with these patches of greenery that this paper is involved. They must be placed within their setting in order to understand the contrast of their mesophytic vegetation with the xeric communities that surround them.

The Colorado River system is entrenched into a great platform supported by a geological substructure more than a billion years old. Impressive as the inner gorges of this canyon are, the broader aspect of the system is evident to the east or south of the Wasatch Plateau in central Utah. The canyon of the Colorado at that point is more than a hundred miles wide, having yielded to the processes of erosion hundreds of cubic miles of alluvium. Despite its huge size, the canyon is of relatively recent origin, geologically speaking (Hintze 1972).

The geological strata are remarkably evident in this arid setting, where vegetative cover is thin and where rate of soil development is exceeded by processes of erosion. No great bodies of contemporary alluvium serve to obscure the underlying geology as in the Great Basin to the west. The Colorado River and its tributaries have excavated the alluvium almost as it has formed. The canyon is open to the south, and the products of erosion have been transported in the great river. Pediments of ancient erosional deposits persist for a while perched atop highlands between arms of modern drainages, but raw geological strata are exposed over huge areas of the basins of the Colorado.

Reason for the sparse protective layer of plants and for the limited soil development are related to the general aridity of the region. The dryness is a function of both low precipitation and high evaporation. Eubank (1979) records the following long-time precipitation means (in inches, followed by centimeters in parentheses) for the following stations: Hanksville 5.19 (13.18), Green River 6.06 (15.39), St. George 8.78 (22.3), Moab 8.82

1Life Science Museum and Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602.
Mean temperatures Fahrenheit (centigrade in parentheses) for those stations are: Zion National Park 61.2 (16.2), St. George 60.1 (15.6), Moab 55.0 (12.8), Hanksville 52.3 (11.3), Green River 52.5 (11.2), Blanding 49.4 (9.7), and Price 48.8 (9.3). Extreme temperatures are probably more important than means to the survival of plants. Summer temperatures greater than 100 degrees Fahrenheit (38 degrees centigrade) are common at all of the selected stations, and winter temperatures of below zero on that scale have been recorded at all stations.

My first experience with this grandly arid country occurred almost four decades ago when I visited Glen Canyon and the townsite of Hite. I was traveling as a student in a class led by Professor Bertrand F. Harrison. No measurable rain had fallen for more than a year at the pioneer community, along the Colorado River at the mouth of Trachyte Wash, that 17th of May 1950 when I visited there.
Despite the aridity, there had been sufficient unmeasured water to allow for germination of some seeds, and a few diminutive plants of red brome had each matured a solitary seed, replacing those from which they had germinated. And, plants of datura displayed their huge, sweetly scented white flowers, which contrasted with the red, barren background. Prince's plume grew against a backdrop of purple siltstone, the difference in hue both pleasing and startling.

Later on that same trip to the canyon country of the Colorado, we reached Natural Bridges National Monument, where we camped. The following day we explored Armstrong and White canyons, looked at the amazing bridges, and observed the small, vertical wet seeps, occupied by mesophytic plants. This was my first introduction to the peculiar vegetative assemblages known as hanging gardens. At the time their peculiarity was lost in the immense amount of information thrust upon a student in this remarkable land for the first time.

The hanging gardens result from coincidence of water in perched bedding planes within sandstone strata intersected by the dendritic drainages of the Colorado River system (Fig. 1). The kind of garden development, whether alcove, terrace, or window-blind (Welsh and Toft 1981), is determined by the nature of the geological formation and the presence or absence of joint systems. Complexity of the plant community within a hanging garden is a function of quantity and quality of water, developmental aspects, and accessibility of plant species to it.

Hanging gardens occur in sandstone formations and sandstone members of several formations ranging in age from Pennsylvanian to Cretaceous. Massive sandstones seem to be best suited for alcove development coincidental with garden formation, some better than others. The formations with greatest development are the Navajo and Entrada, both of them cross-bedded, massive formations composed of wind-blown sand and containing ancient pond bottoms that serve as impervious bedding planes. The Wingate Formation is of similar composition but lacks significant hanging gardens. More thinly bedded sandstone formations tend not to form alcove gardens similar to those of the Navajo or Entrada. Exceptions occur, however. Main formations bearing hanging gardens are listed in Table 1.

Less than massive, though not especially bedded strata such as the Kayenta at St. George, Springdale Sandstone at Zion, and the Bluff Sandstone at Bluff, are alcove formers. The base of the alcove is not in the sandstone formation, however. Instead, the base is on the impervious formation beneath the sandstone.

The Colorado River is entrenched into geological strata that are displayed over vast regions in flat or only somewhat inclined positions. The strata are those exposed in that more or less stable geological highlands east of the hingeline in Utah (Hintze 1972). The canyons dissected into those highlands display vast sandstone surfaces along their walls. The sands of formations suitable for hanging garden development were deposited mainly on land, as dunes with interdune valleys. The interdune valleys were often the sites of lakes, whose bottoms were made impervious by accumulations of dust and other fine particles. Thin layers of limestone are evident in many of the bedding planes. Turned to stone, the ancient lake and pond basins continue to exist within the strata. Water percolating through the porous rock encounters the ancient bedding planes, still impervious and capable of

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<tr>
<th>Geologic age</th>
<th>Strata</th>
<th>Region</th>
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<tr>
<td>Cretaceous</td>
<td>Wahweap</td>
<td>Kaiparowits</td>
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<tr>
<td></td>
<td>Straight Cliffs</td>
<td>Kaiparowits</td>
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<td>Jurassic</td>
<td>Morrison</td>
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<td>(Bluff Sst)</td>
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<td></td>
<td>Entrada (various members)</td>
<td>Arches</td>
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<td>Lake Powell</td>
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<td>Navajo Sandstone</td>
<td>Canyonlands</td>
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<tr>
<td>Triassic</td>
<td>Navajo Sandstone</td>
<td>Zion Canyon</td>
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<td></td>
<td>Kayenta</td>
<td>Zion Canyon</td>
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<td></td>
<td>Moenave (Springdale Sst)</td>
<td>Zion Canyon</td>
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<td>Permian</td>
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<td>Cedar Mesa</td>
<td>Natural Bridges</td>
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<tr>
<td>Pennsylvanian</td>
<td>Hermosa</td>
<td>Cataract Canyon</td>
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However, this table presents the geological strata and distributions of hanging gardens.
holding water. When filled to overflowing, these bedding planes carry the water downward to the next bedding plane beneath or to another impervious stratum at the base of the formation.

Joint systems within the rock act as passageways for water, which follows the vertical gradient of the crack downward until it encounters some obstacle to that flow. Where the joint systems are exposed along canyon walls, the water flows over the moist surfaces. Here gardens of the windowblind type are formed. Alcove gardens develop in massive sandstones with minimal jointing. Terrace gardens result when water at the base of a stratum encounters an obstacle to its movement, flows laterally to the margin of the formation along a canyon wall, and tumbles over the terracelike margin of that impervious layer.

Flow of water from the margin of the bedding plane varies in amount from that hardly sufficient to moisten the surface of the rock to substantial quantities that collect into streams below the gardens. Many of the canyons carved in sandstone in southern Utah feature crystal-clear streams that flow perennially.

Whatever the type of garden development (alcove, terrace, or windowblind), no wet surface exists for long prior to invasion of plant propagules (Malanson 1980). Spores and dust-sized seeds are carried to the moist sites by air currents that sweep the canyons. Sticking to the moist surface, the propagules germinate to form prothallia seedlings. Algae, ferns, and seed plants are involved in community development on the wet sites.

Hanging garden formation as a geomorphological process has been discussed by Welsh and Toft (1981). The gardens are positionally unique. They tend to occur at all exposures of the canyon walls, but whatever the direction of exposure, they are shaded for much to most of each day. Indeed, some of the gardens never receive direct sunlight. A hygrothermograph placed within the Step Garden alcove along Glen Canyon recorded smooth rounded curves of temperature and humidity, as if the instrument had been placed within a house. Temperatures are moderated by the shade of canyon walls and frequently by an enclosing margin of trees and other vegetation. Air movement is restricted in well-developed gardens also, but in some they are exposed directly to both intense light and winds. Thus, there is a diversity of gardens. They vary in size, aspect, exposure to the elements, water quantity and quality, number of bedding planes, and amount of light received.

Water quality, in some degree, controls the kinds of plants in hanging gardens. Quality of water is dictated by the nature of the formations through which the water passes. Most gardens are the products of water of drinkable quality. However, water in some formations is saline and leaves a crust of various salts upon drying. In others the water is laden with calcium, which results in tufa deposits in the gardens. Generally, however, water from the gardens is potable.

Hanging garden vegetation is frequently closely juxtaposed to that of riparian plant communities immediately down the drainage. Several common components of the riparian communities occur in the gardens, but there are a series of species that are unique to this peculiar vegetative type. The unique species are more than mere extensions of the riparian vegetation. Many taxa of the gardens are widely distributed plants of diverse habitats elsewhere; others are known only from this habitat. Some of the latter, the endemics, and the distributionally unique species have taxonomic relationships with species of wide distribution in North America (Welsh and Toft 1981). Nevertheless, the plants that occupy hanging gardens are opportunists. The habitats are available to plants from specific areas, and the plants of adjacent or contemporaneously disjunct floristic regions are those that now occur in the gardens.

Hanging garden algal floras in Utah have been studied by Clark (1972), Rushforth et al. (1976), and Johansen et al. (1983). Rushforth and Merkley (1988) have published a comprehensive list by habitat of the algae of Utah. Wet walls (i.e., hanging gardens) are included by Rushforth and Merkley (1988) as one of nine habitat categories. Lists of algal species of hanging gardens cited below in Tables 2 and 3 are abstracted from the paper by Rushforth and Merkley (1988).

The small number of species known currently only from wet walls or hanging gardens might be simply an artifact of collection. They could yet be found elsewhere in subsequent collections.
Hanging garden algae represent approximately 10.7% of the 1,900 species known from Utah. The greater proportion of the species (75%) are evidently generalists, being reported from two or more habitats besides hanging gardens. The 20 species reported from only a single habitat other than the wet walls are from lakes and reservoirs (15), not from rivers and streams, which would be more likely due to juxtaposition of the walls to those features. The others are from rivers and streams (2), thermal springs (2), and soils (1). These data might be indicative of the uniqueness of the wet wall habitat, or they might be an artifact of collection or merely an indication of commonality between species of wet walls.
and the great preponderance of species that occur in the lakes and reservoirs.

The current list of algae known only from wet walls in Utah and their geographic localities are given in Table 3.

Whether the apparent differences in distribution represent reality or merely lack of collection is not known. Certainly the differences noted are similar to those demonstrated conclusively for vascular plant species.

The Chrysophyta is the largest single group of algae in the hanging gardens. The 144 species comprise 70.5% of the known algal flora. The group is represented in the gardens in greater proportion than would be expected based on the ratio of diatoms to other algae in Utah, where only slightly more than 50% of the algal flora is composed of diatoms. Evidently the wet walls present excellent habitats for diatom species.

Johansen et al. (1983) note:

In most cases we have studied, the moist wall is inhabited primarily by mucilage secreting green and bluegreen algae. As such species become established an abundance of secondary species colonize the mucilage. These include green and bluegreen algae and numerous diatom species as well as occasional Euglenophyta and chrysophytes.

Despite the designation as opportunists, not all plants that grow within this community type should be regarded as hanging garden species. Only those whose distribution is exclusively (or almost so) within the garden (the endemics), whose range is almost entirely from them (the elevational or spatial junctures), or of unusual distribution should be so categorized.

Hanging gardens are typical of the canyons of the Colorado, which occupy two main portions of Utah. They are best formed along Glen Canyon and northward to the vicinity of Moab and Arches National Park along the Colorado and Green rivers (the Canyonlands), and along the Virgin River in southwestern Utah. The gardens of the two areas are of fundamentally different structure geomorphologically. Those from along the Virgin River are best developed on the jointed walls of Zion Canyon. Alcove types along the Virgin do occur, however, especially in the Springdale member of the Moenave in Zion Canyon and vicinity, and in the Kayenta on the Red Hill in St. George. In southeastern Utah the gardens are mostly of the alcove type within poorly jointed rocks or where the jointing is not controlling the water source. Terrace gardens are present along the steplike margins of bedded sandstones such as the Wahweap and Straight Cliffs formations in western Kane County. Alcoves sometimes form in the less than massive White Rim (Cutler), Bluff (Morrison), and members of the Entrada formations. The impervious layer associated with some garden formation is the immediately underlying stratum. The Kayenta is often the layer immediately below the Navajo Formation. It acts to halt the flow of water downward, and, where intersected by a canyon, the water tumbles down its margin in a cascading terrace garden. Above the Kayenta, huge alcoves sometimes are formed near the base of the Navajo proper (Fig. 15).

Several bedding planes are present in some alcoves (Fig. 11). Alcoves within the Navajo Sandstone are frequently more than 100 m in height. In some of them, water drips from superposed bedding planes separated by several meters of sandstone. Each of the bedding planes supports one or more of the species typical of hanging garden habitats.

The hanging garden habitat does not form a sharp boundary with the desertic vegetation externally. Some of the desertic species occur near or within the more mesic margins of the garden, and some of them are occasionally present in the gardens (e.g., species of yucca). Typically, the gardens give way gradually to plants that are more drought tolerant. Plants of intermediate moisture tolerance include a series of grass species, especially those common elsewhere in western North America on prairies and plains.

The classic alcove type of hanging garden in the Canyonlands of southeastern Utah consists of an overhanging back wall, a vaulted face wall, a detrital slope, and a plunge basin. The back and face walls support clinging plants of maidenhair fern (Adiantum capillus-veneris L.), cave primrose (Primula speculosa Rydb.), Eastwood monkey-flower (Mimulus eastwoodiae Rydb.), rock plant [Petroplytum caespitosum (Nutt.) Rydb.], and several other species. Some of these species occur also on the detrital slope, but the wet, sandy detritus supports the Garber phase of the golden sedge (Carex aurea Nutt.), small-flowered columbine (Aquilegia microsperma Eastw.), Jones reedgrass (Calamagrostis scopulorum Jones), helleborine orchid
Figure 3. Late winter view of Weeping Rock, Zion Canyon, Washington Co., Utah. Note the striated tufa deposit to the right of the main alcove. Cardinal monkey-flower and golden columbine are components of the vascular flora.

(Epipactis gigantea Doug. ex Hook.), alcove orchid (Habenaria zothecina Higgins & Welsh), bundle panic (Panicum acuminatum Swartz), Rydberg thistle (Cirsium rydbergii Petrak), alcove death camas [Zigadenus vagnalis (Rydb.) Macbr.], and several other species also. A fringing margin of western redbud (Cercis occidentalis Torr. ex Gray), netleaf hackberry (Celtis reticulata Torr.), and Gambel and Eastwood oaks (Quercus gambelii Nutt. and Q. x eastwoodiae Rydb.) often occurs outward from the foot slope where the plants tend to conceal the alcove base. Toward the drier margins of the garden are grasses typical of the prairies and plains of the western United States. Little bluestem [Schizachyrium scoparium (Michx.) Nash in Small] is a common component, occasionally growing with Indian grass (Sorghastrum nutans Nash in Small), switchgrass (Panicum virgatum L.), bushy bluestem [Andropogon glomeratus (Walter) B.S.P.], and big bluestem (Andropogon gerardii Vit.). The gardens tend to form a kind of microcosm of the prairies and deciduous summer forests more typical of portions of North America eastward from the Colorado Plateau.

Other species of the back and face wall of some of the alcoves are the alcove daisy (Erigeron zothecius Welsh) and alcove rock-daisy (Perityle specuicola Welsh & Neese).

Only the cave primrose, Eastwood monkey-flower, Rydberg thistle, small-flowered columbine, alcove orchid, alcove daisy, and alcove rock-daisy are endemic to the hanging gardens of the Colorado.

Both terrace and windowblind gardens exist along the canyons of the Colorado also. Their floristic composition is frequently similar to that noted above. However, unless there is at least some alcove development, the typical garden species are lacking or occur in reduced numbers.

Hanging gardens in Zion Canyon are often of the windowblind type, with a flat face wall and a vaulted, dry arch at the top (Figs. 3–5). Sometimes the wet wall is curving and without an apparent arch at the top. The joints are mostly evident as cracks that can be seen between the dry capstone arch and the smooth
face wall, but they are markedly apparent as vertical cracks in the rock faces of gardens such as those at Upper Emerald Pool. Alcove development does occur to some extent within the windowblind gardens (Fig. 6), and alcoves are present below the Springdale Sandstone member of the Moenave Formation (Fig. 7). There are no classic alcove gardens in Zion Canyon. Lack of classic alcoves can be attributed to the control of downward movement of water along the joint systems in the Navajo Sandstone, which is sometimes transitional into the bedded Kayenta Formation. Alcove development within the windowblind gardens is minimal, due in part to the peculiarity of climatic conditions within Zion Canyon. Narrow, deep, and shaded for much of each day, more so than the gardens of Canyonlands, the windowblind gardens of Zion Canyon have low winter temperatures that result in ice formation over the wet surfaces of the gardens. Moderating weather results in ice melt. Sheets of ice cascade from the cliff face, shearing plantlets clung precariously to the stone. The attachment fails prior to building up an accumulation of detritus and prior to creation of minor indentations in the rock surface. Alcove development is slowed.

Trees adjacent to the wet walls of Zion Canyon are etiolated as a result of shading through much of each day. The long, slender branches of many trees are unable to support the weight of the crown and break under the stress. Proportionally, the trees are too tall for the thickness of the trunks.

Even the alcove at Weeping Rock is not well developed (Figs. 3, 6). Ice forms on its flat upper surface also, during some winters at least. And, though water from its aquifer is abundant during late winter and spring (Fig. 6), the water flow diminishes during early summer, and the garden is often merely damp during late summer and autumn. Tufa deposits in the Weeping Rock garden provide microhabitats where plants are protected from erosion by ice. Tiny caverns and depressions beneath overhanging tufa accumulations
support miniature gardens. The tufa deposits also protect the alcoves from exfoliation, which is apparent in the north portion of Weeping Rock where tufa is absent.

Clinging plant species in the Zion Canyon gardens tend to be few in number (Malanson 1980, 1982, Malanson and Kay 1982). Fewer still are coincidental species with the hanging gardens of the Colorado. Jones reedgrass (Calamagrostis scopulorum Jones), Garber sedge (Carex aurea Nutt.), and maidenhair fern (Adiantum capillus-veneris L.) are present in gardens of both places. Northern maidenhair fern (A. pedatum L.) is present also in some gardens in Zion Canyon but is missing in all Colorado gardens except for a few near the head of the Escalante drainage. Mostly the representation within the Zion gardens is congeneric, not conspecific, with that of the Canyonlands. Columbine (Aquilegia) is present in both areas, but that of the Colorado is Aquilegia micrantha Eastw., while those of Zion Canyon are A. formosa Fisch. in DC. and A. chrysantha Gray and their hybrids. A peculiar phase (var. fosteri Welsh) of A. formosa simulates A. micrantha in being glandular overall, but the plant is obviously allied to A. formosa.

Red-flowered species of monkey-flower occur in gardens of both areas, but the species are different. That of the Canyonlands is Mimulus eastwoodiae Rydb., while that of Zion is M. cardinalis Dougl. ex Benth. (including M. verbenaceus Kearney & Peebles). Eastwood monkey-flower is evidently confined to the hanging garden habitats of the Colorado Plateau, while the cardinal monkey-flower is a disjunct garden plant only at the northern limits of its distribution in Zion Canyon. Otherwise the cardinal monkey-flower is a widespread species of moist sites of the Southwest. The two species likewise differ in flowering time. The plant of the Colorado gardens flowers from August to October or even to November in some years. The Zion plants have an initial flush of flowering in May and June, with fewer flowers produced thereafter into the summer months.

The cave primrose (Primula specuicola Rydb.) of the Canyonlands gardens has a conspecific representative in Zion, i.e., the beautiful, broad-leaved shooting-star, Dodecatheon...
pulchellum (Raf.) Merrill var. zionense (Eastw.) Welsh. While both the cave primrose and the Zion shooting-star begin growth and flower early, the cave primrose is the more precocious, flowering as early as late January in some years. The typical period of main flowering is March to May. The Zion shooting-star seldom flowers prior to early April, with greatest flowering occurring during May. The genus Primula per se is not known in Zion. The Zion variety of the pretty shooting-star extends into some minor gardens along the Colorado, especially in those of lower Last Chance Canyon east of Wahweap and in selected gardens as far north as the mouth of the Escalante along Glen Canyon.

Zion Canyon has other species unique to Utah hanging gardens. American spikenard, Aralia racemosa L. ssp. bicrenata (Woot. & Standl.) Welsh & Atwood, is perhaps the most peculiar of Zion hanging gardens species. It is typically present on margins and lower shelves below the great wet walls. Occasionally it clings, attached in crevices, to the walls of the grottos associated with the gardens, and seldom the plants grow on sandy benchlands and terraces in the Narrows portion of Zion Canyon, removed from the gardens altogether. The spikenard occasionally grows to a height of almost 2 m and has ternate-pinnate leaves to almost 1 m in width. The Zion daisy, Erigeron zionis Cronq., is an endemic of moist sites in Zion Canyon. Habitats of the Zion daisy vary in size from minute areas, wet only in springtime by water percolating shallowly in sandstone, to the largest of the hanging gardens in the canyon. Growth of this attractive small plant with white flowers and lobed leaves is aided by production of stolons that bind the plant closely to the moist, sandy surface.

Grasses typical of prairies and plains, such as occur within and on the fringes of gardens of the Colorado, seldom form such stands in Zion Canyon. Many of the same species occur in the vicinity, but in Zion they are typically riparian components.

Hanging gardens occur on the red sandstone cliffs immediately north of the business district of St. George, Utah. These gardens are exposed to direct sunlight through much of each day, except where the alcoves are sufficiently developed to provide shade in early morning and late afternoon. Maidenhair fern (Adiantum capillus-veneris L.) is a principal component of these gardens also, but the bright flowers of columbine, primrose, and shooting-star are missing. Instead, the blue flowers of Sisyrinchium demissum Greene grace these gardens. The thistle species, Cirsium virginensis Welsh, grows in them but is not confined to this habitat. Solidago spectabilis (D.C. Eaton) Gray, the Nevada goldenrod, is an opportunist in the St. George gardens. The gardens have served as dumping grounds for residents of the region and contain old refrigerators, tires, washing machines, and other refuse, a kind of permanent condemnation of the humanity of our time.

The examples discussed here give an indication of the importance of position and ecology in the determination of garden diversity and species composition. Not indicated is the variation from place to place within a major drainage system or from garden to adjacent garden at a given place.
**Virgin River Gardens**

Hanging gardens are present at St. George, in Zion Canyon along the North Fork of the Virgin River, and along Parunuweap, a canyon cut by the main fork of the Virgin. The largest and best developed are those of Zion Canyon, described above. The Parunuweap gardens are mainly associated with the base of the Springdale Sandstone, and they are generally small and lack the diversity of those in Zion Canyon. Eastward in Parunuweap the canyon is incised into the Navajo Sandstone, and gardens are larger and better vegetated.

The Virgin thistle (*Cirsium virgininensis* Welsh) was described from plants of the alcoves at the north margin of St. George. The species was first taken, evidently, by Charles Christopher Parry during his visit there in 1874 (Welsh 1988). Subsequently, the plant was collected by other botanists but remained unnamed until this decade (Welsh 1982). The thistle is evidently a riparian species, which reaches its northernmost distribution in these hanging gardens. The plant is known otherwise from moist habitats in adjacent Mohave County, Arizona, and Clark County, Nevada.

**Colorado River Canyons Gardens**

**Glen Canyon**

There is a land that was
That we who are can never see
For it is drowned
In crystal waters of a
Stone-bound inland sea—
Glen Canyon

SLW, Goldfield, Nevada, 2 April 1982

Moist spots on the canyon walls immediately downstream from Glen Canyon Dam support hanging garden species. These can be viewed by looking almost vertically into Glen Canyon from the visitor center of the recreation area. They are only an indication of the gardens to the east along Glen Canyon proper in Utah.

Glen Canyon was named by John Wesley Powell, who entered it on 29 July 1869 (Powell 1875). Powell (1875) states:

On the walls, and back many miles into the country, a number of monument-shaped buttes are observed. So we have here a curious ensemble of wonderful features—carved walls, royal arches, glens, alcove gulches, mounds, and monuments. From which of these shall we select a name? We decided to call it Glen Canyon.

On 3 August 1869, Powell (1875) gave the following description:

Sometimes the rock is overhanging; in other curves curious narrow glens are found. Through these we climb by a rough stairway, perhaps several hundred feet, to where a spring bursts out from under an overhanging cliff and where cottonwoods and willows stand, while along the curves of the brooklet oaks grow and other rich vegetation is seen, in marked contrast to the general appearance of naked rock. We call these Oak Glens.

Thus, Powell not only chose to name the canyon after the glens observed in its length, but he gave a general description of these unique botanical features. The oak glens are now known as hanging gardens.

Glen Canyon, which begins at the confluence of the Dirty Devil River and the Colorado, near the Hite Bridge, and terminates at Lee’s Ferry in Arizona, is readily visible into the following three main segments.

**Wahweap to Confluence of the San Juan**

Vegetation along the shores of Lake Powell from Wahweap eastward to Rock Creek and vicinity is composed mainly of species of shrubs, perched atop sands derived from the Navajo and Carmel formations. North of the lake the Entrada forms cliffs below the escarpments carved into the soft Tropic Shale member of the Mancos Shale. The Entrada changes appearance east from Wahweap; at Padre Bay it has become a candy-striped to red sandstone, instead of the chalky white, stained brown cliff former at Wahweap Bay.

Small hanging gardens of the terrace type are in Crosby Canyon, a minor tributary of Warm Creek. Other similar terrace gardens are present in Last Chance Canyon, which intersects bedded portions of the Entrada. A small garden at Nipple Spring on Nipple Bench, north of Big Water (formerly Glen Canyon City), includes maidenhair fern in a tiny, well-watered alcove in the Straight Cliffs formation. Excess water supports Fremont cottonwood and other riparian plants (Fig. 8). Water quality in these formations is generally saline, and white encrustations of salts are commonplace. Zion shooting-star is a component of the gardens, which support large stands of little bluestem. Eutoliated, sprawling plants of roundleaf buffalo berry (*Shepherdia rotundifolia* Parry) and skunkbush (*Rhus aromatica* Ait.) sometimes persist in minor alcoves in this formation. These gardens have not been studied in detail.
There are some small gardens in the red, pockmarked phase of the Entrada in the Rock Creek vicinity. Others in that formation were inundated by Lake Powell. The best developed of the hanging gardens remaining in this sector of Glen Canyon are to the east of Dangling Rope, where the Navajo Formation reappears at the water’s edge. Possibly the best examples are those in Driftwood Canyon, whose backdrop to the north is the great gray, water-stained cyclorama of cliffs below the summit of Fifty-Mile Mountain. On the east side of Driftwood Canyon, around the first meander bend north of its mouth, are the remains of a small but unique plant assemblage known as Step Garden. For the sake of reference the hanging gardens studied previously by this author have been given binomials, not unlike those used scientifically for plants.

Step Garden received its name from the historic steps, now beneath the lake, carved by optimistic early prospectors in search of gold in ancient terrace gravels perched high above the present inner gorge. Though small, Step Garden is almost unique among hanging gardens in Glen Canyon in supporting a stand of saw-grass [Cladium californicum (Wats.) O’Neil in Tidestr. & Kittel]. This saw-grass, a close relative of the warm temperate and subtropical C. mariscus R. Br. with which it is sometimes united as a variety, grows here in huge clumps. The accumulated bases beneath the current seasons of growth are now more than 2 m thick. A sample of leaf bases from near the bottom of the accumulation was radiocarbon dated at more than 400 years in age. The saw-grass is unusual in Utah, reaching its northern limits here. The species grows also along Furnace Creek in Death Valley, California. In the broad sense of C. mariscus, the species is known from California, Nevada, Arizona, Mexico, Central America, eastern North America, and the Old World (Munz 1970). In Step Garden the saw-grass occurs with western redbud, another species of broad distribution to the south and west of Glen Canyon.
The alcove at Step Garden is very small, only about 3–5 m in height. It has an overhanging upper ledge, whose underside is clothed with maidenhair fern and Eastwood monkey-flower. The face wall has more maidenhair fern, rock plant, and helleborine orchid. A small plunge basin, scoured by water that pours over the cliff margin from a drainage above, is filled with cool water that seeps from the sandstone of the alcove. The alcove was formed from interaction of plants and the wet surface at the margin of a small bedding plane almost at the base of the Navajo Sandstone. Such alcoves are a dominant feature of this portion of Glen Canyon, and it is suggested that all alcoves along the canyon, whether now vegetated or not, are the result of previous hanging garden and wet bedding plane interaction.

There is a developmental sequence in hanging garden and alcove development from a simple wet wall or wet spot on a wall, to a simple alcove without a plunge basin, to a classic alcove with a plunge basin (Welsh and Toft 1981). A final category of alcoves is that designated as decadent, those in which the alcove has become too deep and the roof has collapsed, sealing the moisture of the bedding plane or those in which the bedding plane has dried.

Step Garden is a small classic alcove, sheltered in front from the searing heat of the sun and from wind action by a cluster of redbud and the growth of saw-grass. The plunge basin at Step Garden is sheltered behind the wall of redbud. In some gardens the plunge basin is unvegetated, the falling water from seasonal storms or from melting snow scouring the basin into bedrock. However, in some classic gardens the plunge basin is in accumulated sandy detritus from both the falling water and exfoliation of the alcove. In those situations the plunge basin will be surrounded by mesophytes such as seep willow (Baccharis spp.), bushy bluestem, alcove death canas, and various sedges.

Pot sherds adjacent to Step Garden and other gardens with plunge basins suggest their importance as sources of water for prehistoric peoples. Pipelines and water cisterns of contemporary civilization are prominent features of hanging gardens in St. George and in Zion National Park.

Water in the gardens is utilized by animals of many kinds (Welsh, Wood, and Raines 1975). Birds drink the water and roost and nest in the vegetation. And, since the water supply of the gardens is more or less independent of the climatic regime of the region, plant growth in them is independent of current annual rainfall. There is vegetation in abundance each year (Welsh and Wood 1975). Because of the productivity of the gardens, several species of small desert mammals survive in them during periods of less than adequate rainfall in the sea of aridity abounding beyond the gardens proper. Woodrats and deer mice especially live in the gardens during periods of climatic stress and move outward from them during seasons of adequate moisture and concurrent vegetative growth in the surrounding desertic lands (see discussion under Three Garden below).

Canyon tree frogs (Hyla arenicolor Cope) and red-spotted toads (Bufo punctatus Baird & Girard) congregate in the plunge basins of the gardens and in canyons with permanent streams (Toft 1972). They begin to call as evening falls, often accompanied by the dying calls of a canyon wren, with its lilting song that begins high and falls gradually prior to ceasing. In spring and early summer croaking of the frogs and toads rises to an amazing cacaphony soon after nightfall, often magnified by the vaulted arch of a hanging garden alcove.

Eastward from Driftwood Canyon, on the south side of the lake, is Forbidding Canyon, which contains Rainbow Bridge, sculpted from Navajo Sandstone and perched on shelfrock of Kayenta Formation, an impervious sandstone. A stream channel bearing perennial water is entrenched into the Kayenta at Rainbow Bridge. The Kayenta supported several small hanging gardens prior to flooding by Lake Powell. Plants of Toft yucca occur on sand adjacent to the bridge, and western redbud grows here and there against the cliffs, watered by runoff from the slickrock.

Not far west from the confluence with the San Juan Arm, Hidden Passage Canyon enters Glen Canyon from the west. Its walls are vertical and the canyon is short, ending abruptly in a boxed end. Along the canyon, at the base of vertical cliffs atop rounded sandstone slopes that drop to the water, are a
couple of clumps of saw-grass, a portion of what existed prior to the high water of Lake Powell.

Across the lake from the mouth of Hidden Passage is Music Temple Canyon, or what is left of it. The canyon mouth plunged for more than 100 feet into a huge alcove or grotto, elongated oval in form. The walls were clothed in part with patches of maidenhair fern and monkey-flower. It was in this grotto that Powell (1875) and his party encamped. Powell noted:

On entering, we find a little grove of box-elder and cottonwood trees, and turning to the right, we find ourselves in a vast chamber, carved out of the rock. At the upper end there is a clear, deep pool of water, bordered with verdure. Standing by the side of this, we can see the grove at the entrance. The chamber is more than 200 feet high, 500 feet long, and 200 feet wide. Through the ceiling, and on through the rocks for a thousand feet above, there is a narrow, winding skylight. . . . It was doubtless made for an academy of music by its storm-born architect; so we name it Music Temple.

To the north of Music Temple Canyon, across Lake Powell, is Reflection Canyon, certainly one of the most photogenic tributaries of Glen Canyon. Interlocking canyon spurs now plunge into the placid waters of the lake, giving reflections that deceive the mind—air passes into water without perception of the difference in state of matter. Some of the meander bends contain remnants of hanging gardens. One such garden, named Reflection (Fig. 9), had an alcove more than 60 m in height and breadth. A plunge basin more than 15 m across served as home for a family of beavers. Alcove death camas, bearded blue-stem, and seep willow grew around the plunge basin and on the foot slope of this enormous garden. The wet wall of this and of most other gardens was covered by a mat of green and blue-green algae, often with globes of Nostoc staring eyelike from the glistening algal mat (Clark 1972, Rushforth et al. 1976). Now the lower portion of the garden is flooded, including the plunge basin, a part of Lake Powell. The beaver have moved up canyon in pursuit of cottonwood trees, their main source of food.
San Juan Confluence to Bullfrog

North of the confluence of Glen Canyon with the San Juan, on the east side of the lake, is an area designated as Gardens Cove. Several small hanging gardens existed in this area, and a large one, designated as Three Garden, is present at the north end (Fig. 10). Three Garden was named for its three superposed alcoves, each with hanging garden development. It was a classic set. The lowermost garden had a plunge basin, a lower shelf, a gently angled foot slope, a rounded, arching face wall, and an overhanging back wall, with all of the plant components noted previously. It became the type with which all other gardens were compared by me in later studies. The basal two-thirds of the lower garden is now drowned, but Middle and Upper gardens persist. The two upper gardens can be reached by judicious scrambling up slickrock. Middle Garden is dryish, with a pothole arch in its back wall. Upper Garden (Fig. 11) is huge, with a scoured shelf where a plunge basin might develop. Down the drainage toward the lip of the overhanging margin of Middle Garden are a series of swirl holes carved into the stone, one of which became the pothole arch.
At Three Garden we undertook investigations of small mammal populations (Welsh and Toft 1972, Welsh, Wood, and Raines 1975) and studied the use of the gardens by rodents especially. Three groups of rodents were found in or near the garden habitats. They are the cricetids, heteromyids, and sciurids. Cricetid rodents include the native rats [Neotoma cinerea (Ord) and N. mexicana (Baird)] and deer mice [Peromyscus boylei (Baird) and P. crinitus (Merriam)]; the heteromyids are the kangaroo rats [Dipodomys ordii (Woodhouse)] and pocket mice [Perognathus apache (Merriam) and P. intermedia (Merriam)]; and the sciurids are the antelope ground squirrel [Ammospermophilus leucurus (Merriam)] and chipmunk [Eutamias quadrivittatus (Say)].

The cricetid and heteromyid rodents are nocturnal animals who forage at night and sleep in burrows during the daytime. The sciurids are diurnal. The trapping design was primarily for the nocturnal animals. Traps were opened and baited in early evening, and the traps were checked and the animals released prior to sunrise. Inclusion of the sciurids in the traps at all represented chance occurrences of late afternoon or early evening visitation.

Three principal habitats occurred in the vicinity of the gardens, i.e., the gardens proper (HG), the immediately adjacent talus (TDS) slopes dominated by sparse cover of shrubs and grasses, and a semidesert shrub (SDS) on the more gently sloping, sandy ground away from the garden and talus slopes. The hanging garden habitat was tested in the summer of 1972 (Welsh and Toft 1972) to determine species presence and potential of movement from garden to garden in the superposed set. Animals moved from Middle to Lower Garden during the three-night test trapping. In 1973 and 1974 a larger trapping design was imposed on the HG, TDS, and SDS communities. Results of those studies indicated that there was a partitioning of habitat by species of the three rodent groups. Heteromyids avoided the gardens altogether (except for Perognathus intermedius, which lives almost exclusively in the adjacent TDS habitat). Sciurids visited the gardens probably for food and occasionally for water, even
Welsh and Wood (1975) conducted productivity, cover, and composition studies on the plant community within lower Three Garden. Productivity of the gardens was high during both 1973 and 1974, even though 1974 was a dry year and productivity of the SDS community declined considerably during that year.

Similar studies of animal communities and plant productivity should be conducted in other hanging garden sites in both the Colorado and Virgin basins.

To the west, across Lake Powell from Three Garden, is Double Garden whose hanging garden vegetation is aligned along a bedding plane near the base of the Navajo Sandstone (Fig. 12).

North of Hole-in-the-Rock, where the San Juan pioneers labored so diligently, on the east side of Glen Canyon, a canyon named Ribbon enters through sentinellike monoliths of Navajo Sandstone. Immediately within the mouth of the canyon, on the south side, is a huge, perpetually shaded alcove, bearing the monument-sized Ribbon Garden (Figs. 2, 13). Within the huge alcove is a smaller one, facing westerly. Both gardens support plant
species unusual in the Utah flora. It was here that we first discovered the New Mexico raspberry (*Rubus neomexicanus* Gray), a plant with leaves more like a currant or gooseberry and with pure white, roselike flowers to 4 cm wide. The species is known in Utah only in hanging gardens along Glen and Cataract canyons, where shaded for most of each day.

Growing with the raspberry is the Knowlton ironwood (*Ostrya knowltonii* Cov.), another rarity within the Utah flora. The small trees flower early in springtime, with stamineate catkins borne pendulous from buds near branch ends. Pistillate catkins appear later, finally evident from the hoplike, inflated, papery bracts. The species is known in Utah only from along Glen Canyon and its tributaries, from the Needles section of Canyonlands National Park, and from along the Colorado River near Moab.

The small alcove on the east side of Ribbon Garden is almost perpetually in shade, and the foot slope is overgrown with a dense carpet of Rydberg thistle (*Cirsium rydbergii* Petrak), another plant confined to or near hanging gardens in the canyons of the Colorado.
The basal cluster of leaves can be up to 1 m across, much larger than any other native Utah thistle, but the flower heads are small, seldom more than 20 mm in length.

Ribbons Canyon is only a few thousand feet in length, ending abruptly in boxed ends. There are numerous alcoves along its margin, some with well-developed plunge basins. Those on the south side of the canyon support the New Mexico raspberry; those on the north do not. Water from the gardens forms a stream that flows into the lake. Reduced evaporation results in maximum stream flow at night; some of the streams and portions of hanging gardens dry completely each day in summer.

East of the mouth of Escalante Canyon, on shelfrock of Kayenta Sandstone rising gently from the water's edge on the north side of the canyon, are the Escalante gardens. There are eight alcoves carved into the base of the Navajo Formation, some of them with plunge basins. They contain the usual hanging garden species for Glen Canyon. Additionally, one of them is the type locality for the alcoye daisy, *Erigeron zothecina* Welsh. Tall spires of the Toft yucca (*Yucca toftiae* Welsh) stand sentinel-like along the shelfrock associated with the gardens.

**Bullfrog to Hite**

Near the lake end in Moki Canyon, in the first meander bend east of Halls Crossing, there is a large hanging garden along the south side of the canyon. The approach is through drowned Fremont cottonwood trees. The alcove is classic with a plunge basin, but the foot slope is brush clad, with poison ivy (*Toxicodendron rydbergii* Small) as a principal component. Poison ivy exists in many hanging gardens, but nowhere as abundantly as in this garden.

Knowles Canyon has the remnants of magnificent hanging gardens on the south side. Possibly they had plunge basins in the past, but now the lake receives the water from pour points and from the gardens. New Mexico raspberry is included in the vegetation. Garden development in alcoves on the north side is not as great, but the gardens there support an abundance of grass, with little bluestem and Jones reedgrass being common.

On the east side of the lake at Good Hope Bay there are springs surrounded by a peculiar phase of Gambel oak. The spring sites are not situated on exposed sandstone walls, but rather arise on the Chinle Formation, with water possibly developed from joint systems in the Wingate Sandstone to the east. The oak there has acorns much larger than the species elsewhere in Utah. It is called *Quercus gambelii* Nutt. var. *bonina* Welsh, the Good Hope oak. Possibly this phase of Gambel oak has been derived through hybridization and back-crossing between *Q. gambelii* and *Q. havardii* Rydb., the shinnery oak. Potentially it could exist in hanging gardens in this portion of Glen Canyon, but further exploration is necessary.

Ticaboo Canyon enters Good Hope Bay from the west. Water flows perennially down the canyon bottom for a short distance, and there is minor hanging garden development near its juncture with the lake. Here along the stream is the northernmost known locality for bushy bluestem and for the scarlet lobelia or cardinal flower (*Lobelia cardinalis* L.). The cardinal flower is known from hanging gardens in the vicinity of Gardens Cove near the San Juan confluence, and in moist situations in Zion Canyon also. Prior to the existence of Lake Powell, a peculiar species of aster was taken at Ticaboo. *Aster spinosus* Bent., the Mexican devilweed, was known from a garden in the mouth of Llewellyn Gulch, which was flooded during the high water of 1983. Otherwise the species exists as a plant of sandy and gravelly flood plains and bars north to near the confluence of the Colorado and Green rivers.

**Escalante Canyon—Waterpocket Fold**

Escalante Canyon was formed by entrenchment of Escalante Creek in the synclinal flexure west of the Waterpocket Fold anticline, whose east side is steeply dipping and whose west side falls more gradually to the Escalante. Two canyons near the south end of the fold drain into Glen Canyon proper. They are Bowns Canyon and Long Canyon. Bowns Canyon is of interest because of the numerous small alcoves, most of them with at least some hanging garden development. It is in this canyon that evidences of prehistoric animals, including mammoths, have been discovered amidst evidences of vegetation now confined to higher elevation, cooler portions of the state. The entrance to Long Canyon is blocked by a huge nickpoint, occupied by a moderately developed hanging garden. A
route to the west will lead into the canyon, which requires additional investigation.

There are several canyons that drain west from the crest of the fold into Escalante Canyon. Explorer Canyon had a perennial stream and some garden development, but the most interesting of the Waterpocket canyons is that named Cow. Indeed, it is perhaps the most intriguing of all canyons that drain water to Lake Powell. Cow Canyon is deeply entrenched through the Navajo Sandstone into the Kayenta Formation. The slope of the canyon bottom approximates that of the dipping west slope of the Waterpocket Fold. Alcoves line the canyon walls, with one or more in each meander bend. Typically the alcoves are perched atop the Kayenta platform. The gardens often are classic alcoves with developed plunge basins, but the species complement varies with each garden—there are no two gardens alike. The canyon has two main branches, and the left-hand branch forks again near its apex. Each of the forks is terminated by box ends that form hanging gardens of huge vertical relief. The left fork terminates in paired, owl-face-like alcoves filled with greenery (Fig. 14). The right fork terminates in an alcove of great height, possibly as much as 120 m.

One alcove west of the forks of the left-hand fork of Cow Canyon is occupied by Knowlton ironwood almost to the exclusion of other woody vegetation. Other of the alcoves studied lacked this plant. Evidences of past occupation by Indians are also present. Alcoves where the bedding planes had dried support small stone structures where grain and other items derived from primitive agriculture could be stored. Dwellings are also present.

White Canyon

White Canyon drains from the west margin of Elk Ridge and enters Glen Canyon south of the Hite Marina. The canyon proper is entrenched through the Permian Cedar Mesa Formation, which consists of water-deposited sands alternating with fine-textured materials. The sands are sometimes massive, and the fine materials serve to halt the flow of percolating water. Small alcove gardens, mainly lacking plunge basins, are present in this formation. Some of the exposed aquifers are linear, extending as strips along the exposed sandstone margin, only a few decimeters to a few meters in width. Maidenhair fern grows in these wet sites along with small-flowered columbine and the Kachina daisy (Erigeron kachinensis Welsh & Moore). Gardens occur here and there along much of the length of the canyon, but possibly the best of them occur within Natural Bridges National Monument, in both White and Armstrong canyons. The alcove death camas was initially collected by P. A. Rydberg and A. O. Garrett in 1911, probably from the wet spot in the canyon immediately south of Owachomo Natural Bridge. The Kachina daisy was taken from gardens on the east side of the Kachina Meander in 1963 by Welsh and Moore (1964). This plant was at first thought to be endemic to the gardens, but more recent collections show it to occur on sandy sites in ponderosa pine forests in the Abaj o Mountains. It is known from hanging gardens in Dark Canyon and from along the Delores River in Colorado also.

Fig. 14. Cow Canyon Garden, at the end of the Left Fork of Cow Canyon, Waterpocket Fold, Kane Co., Utah. Principal vegetation on the foot slope of the upper garden is Rydberg thistle. This is one of many alcove gardens at the base of the Navajo Formation in Cow Canyon.
Cataract Canyon

At the Hite Marina a buff sandstone, the Cedar Mesa Formation, is intersected by Lake Powell. This very old sandstone is a portion of the Cutler Group of formations. Slickrock margins of the lower portion of Cataract Canyon are in this formation. The slickrock supports scattered specimens of Utah juniper, narrowleaf yucca, blackbrush, and many other shrubs and grasses. The lower end of Cataract Canyon is marked by cliffs, with shelves supporting desert shrubs such as single-leaf ash (Fraxinus anomala Torr. ex Wats.). Redbud grows along the shelfrock also, with the vicinity of Dark Canyon marking its northern limits. Just north of Dark Canyon, on the east side of Cataract, is a poorly developed hanging garden. The garden faces north and is stained by carbonaceous black water stripes. The foot of the garden supports some of the typical garden species noted earlier. This garden is the southernmost known locality for the alcove rock-daisy, Perityle specuicola Welsh & Neece. It is a peculiar, rushlike member of the sunflower family with slender, drooping branches and small heads of cream disk flowers. The plant is known otherwise from gardens in the vicinity of Moab.

There is another poorly developed hanging garden on the south side of the first bend west of the Gypsum Canyon reentry, east of Clearwater Canyon. The garden, named Ron's Garden, is peculiar in that it is formed in limestone and has a large central pillar of tufa (similar to the tufa deposits along the trail to Zion Narrows), derived from calcium carbonate in water that has percolated through the Hermosa Formation. Besides several of the usual hanging garden plants—such as maidenhair fern, cave primrose, and the small-flowered columbine—the New Mexico raspberry is present. This is the northernmost location known for the raspberry.

San Juan Arm

At the juncture of the San Juan with Glen Canyon, the Navajo Formation rises above lake level. The canyon of the San Juan Arm of Lake Powell is entrenched in a series of meander bends, each different from the others and each with hanging gardens. On the west side of the first meander bend, almost straight through the rock less than 1 km from Three Garden, is a huge alcove, dry in its tremendous upper portion but wet along the terraced base formed from the Kayenta Sandstone. A cottonwood tree grows on the shelfrock, and a terraced type of hanging garden exists. Rydberg thistle, redbud, maidenhair fern, and alcove death camas are components of the vegetation. This is Death Camas Garden (Fig. 15). It is an excellent example of an alcove with upper bedding planes either dried or buried with detritus, but with the impervious Kayenta being wet from water percolating to its surface and flowing down its margin.

Death Camas Garden demonstrates the difference in species composition of closely spaced garden assemblages. It contains the alcove death camas, which did not occur in Three Garden, but was present in other gardens almost due west of Three Garden across Glen Canyon. The death camas occurred also in Reflection Garden. Other species show similar peculiarities of distribution.

A small canyon enters the San Juan at the north end of the first meander curve. Several hanging gardens are present in its box end and margins, in alcoves perched atop the Kayenta high above the lake surface. Most of these gardens lack plunge basins, the water having scoured the rock surface smooth and in some instances having worn swirl holes in the stone.

Nasja Canyon enters from the south in the beginning of the second meander bend. Its entry is blocked by a nickpoint in stone, whose alcove contains remnants of a depauperate hanging garden clad with small-flowered columbine, cave primrose, and a few other plant species.

Eastward along the lake, Wilson Creek enters across from Trail Canyon. The mouth of Wilson Creek is also blocked by a nickpoint, which is sometimes above and sometimes below lake level. Perennial water flows from Wilson Creek. Above the nickpoint grows a stand of saw-grass, a third known locality, if it still survives following the high lake level of 1984 and 1985. Along the stream grow cottonwood, seep willow, willow, and the beautifully plumed satintail grass (Imperata brevifolia Vasey), which is currently known from only this location in Utah.

Wilson Creek is evidently that described by Platte D. Lyman of the Hole-in-the-Rock expedition (Miller 1959). Lyman and party
followed it down to the San Juan River. The canyon was described as having a small stream and lush vegetation. Deep water-filled holes occurred here and there, and Lyman indicated that they caught several mud turtles as large as a man's hand. These have not been found in recent times, but an occasional turtle shell has been recorded for Glen Canyon. Doubtlessly, Lyman's observation of 1 December 1879 is correct.

The Great Bend of the San Juan is marked in its outer margin by huge alcoves with hanging gardens. The alcoves are some distance from the lake. Limited investigations yielded no new distributional information from these gardens.

Bluff

Pioneer plant taxonomist Alice Eastwood (1896) took plants from the moist garden-clad alcoves near Bluff, Utah, in the 1890s. She was probably the first botanist of consequence to visit and describe the unique hanging garden habitat. She (1896) stated that the habitat "is a boreal oasis in the midst of a Sonoran desert." Gregory (1938), in speaking of the canyons of the San Juan and of Butler Wash, noted that "the spring line at the base of the bare Bluff sandstone is marked by a bank of green vegetation formed by plant species that seem out of place in the present scheme of distribution." The types of *Mimulus eastwoodiae* Rydb., *Primula specuicola* Rydb., and *Cirsium rydbergii* Petrak (*C. lactucinum* Rydb.) were collected by Rydberg and Garrett during 1911 (Rydberg 1912, 1917, Petrak 1917). *Aquilegia micrantha* Eastw. was taken from the gardens by Alfred Wetherill in 1894 (Eastwood 1896).

The Bluff Sandstone has been variously regarded, either as a member of the Entrada, a separate formation, or, more recently, as a basal member of the Morrison Formation. The stratum is not especially thick, and alcoves worn in its margin rest on the Wanakah Formation (previously regarded as Summerville).
The gardens are readily accessible in Cottonwood Canyon north of Bluff, or along the strike of the formation east or west of that canyon. The cliffs of the Bluff Sandstone are less imposing to the eastward, and the gardens are accessible at ground level. Indeed, some of the easternmost gardens are grazed by sheep and goats, who drink the water draining from them and that which accumulates in the plunge basins following storms.

The cave primrose is most impressive when in full flower, and coincidence of flowering in some years with the Easter season has led to the local common name of Easter flower. The gardens and their flowers are easily seen from the main highway through Cottonwood Canyon.

Moab and Vicinity

Examination of the plant collection in the herbarium of Brigham Young University in 1960 demonstrated the existence of *Ostrya knowltonii* Cov., represented by several sheets of a single collection taken many years earlier by Walter P. Cottam, pioneer plant ecologist at the University of Utah and prior to that professor of botany at Brigham Young University. The locality for the plant was simply "Moab." In a later discussion with Dr. Cottam I asked him from where the plant had been taken, and he replied: "I won't tell you! It is so much fun when you find it for yourself!" The collection came from a hanging garden near Moab, and I later rediscovered it there.

There are distinctive classic alcove gardens west of Moab at The Portals, east of the Colorado River bridge north of Moab, and in the reentry canyons along the Colorado River. Negro Bill Canyon has several gardens ranging in size from a few meters square to huge classic alcoves with plunge basins. The reentry canyon west of Negro Bill has a darkly shaded alcove and plunge basin at its boxed end. The garden is accessible only by considerable effort of clawing one’s way through a thick growth of oak and scrambling over rock falls. Cave primrose, maidenhair fern, alcove death camas, and other species characterize these gardens. The alcove rock-daisy and alcove bog-orchid were named and typified on plants taken from alcoves in the first meander bend east of the Colorado River bridge. The gardens nearest the road are heavily impacted by humans, and they have not survived as they were when first visited by botanists following the turn of this century. Several introduced tree species have escaped and grow within or immediately in front of the gardens. Catalpa, Siberian elm, and tamarix are now growing in them. Refuse from campers and hikers clogs some of the gardens.

The Delicate Arch section of Arches National Park displays many hanging gardens. A fault line north of the trail head to that arch trends generally east-west and the Entrada Formation has an offset of some meters. The wall of that offset is marked by alcoves that continue along the strike of the formation west to Fresh Water Canyon. The trail to Delicate Arch is on the downthrown side of the fault, and the gardens are readily visible along it. Dead Tree Garden is the larger of those displayed (Figs. 16, 17, 18). It is approachable up a slickrock drainage. There is an upper alcove with a low, horizontal back wall and darkly shaded face wall. A dead juniper occupies a place on the lip of this upper alcove. Maidenhair fern and Eastwood monkey-flower grow on the back wall. The lower alcove is not so deeply cut. Its slightly indented and curved wet wall is occupied by cave primrose, magnificent in early springtime when in full flower. Alcove death camas grows along the base of the face wall and sometimes clings to the surface of the wall itself. Plants of Garber sedge and helleborine orchid hug the wall base at the back of the detrital slope. The dryish margin is clothed with little bluestem.

Island in the Sky portion of Canyonlands National Park is margined by cliffs of Wingate Sandstone. Only rarely do alcoves form in the Wingate, possibly because the capstone Kayenta is so impermeable. Exceptions to hanging garden formation in the Wingate occur at the head of Trail Canyon off the north side of the island, where a huge alcove is present in the Wingate and a small saline seep hints at a garden there in the past, and at Naturalists Cove south of the first switchback of the Schafer trail. There behind a grove of Douglas-fir and Rocky Mountain maple is a small garden supporting Fendler barberry (*Berberis fendleri* Gray), cave primrose, and Jones reedgrass. The elevation is about 1,770 m. Fendler barberry is known also from a dryish garden below The Neck.

The White Rim formation is encountered along the edge of the Green River west of
Island in the Sky, north of Anderson Bottoms. It is best displayed downriver from Anderson Bottoms, where the formation gradually rises above the river as a prominent marginal feature. The gardens occur along its strike, with alcoves developed to the underlying impervious Cutler. The gardens have not been explored but are known to support cave primrose. More work is indicated. A poorly developed garden at Anderson Bottoms was tentatively explored as a water source by a private owner prior to establishment of the Canyonlands as a national park.

**Hanging Garden Species**

Hanging garden species show diverse affinities as was outlined by Welsh and Toft (1981). Some are boreal plants, whose phenology still reflects their northern habitat regimen. Others are southwestern in their relationships, and still others have affinities with plants to the south. The following list is not meant to be exhaustive of all species that occur in the gardens. Especially listed are the plants that regularly occupy wet walls in the alcove, terrace, and windowblind gardens.

**Adiantum capillus-veneris** L. Maidenhair fern

This plant grows in practically all hanging gardens. It occurs in the salt-encrusted gardens in the Kayenta Formation in St. George, in the gardens of Zion, and in practically all of the gardens in the Colorado drainage. Elsewhere the species is widespread. In North America it occurs from British Columbia east to South Dakota, Missouri, Florida, and Texas. It grows in much of Europe, often on calcareous tufa. The species is also present in the subtropics of both hemispheres. It fits the requirements for a hanging garden species both in being disjunct and in being the most consistent of the hanging garden wall plants.

**Adiantum pedatum** L. Northern maidenhair fern

Northern maidenhair fern is disjunct in the hanging gardens of Zion Canyon mainly, but it occurs in some gardens in the head of the Escalante drainage of the Colorado Plateau.
Its distribution even in those areas is spotty. It grows usually beneath boulders where it is consistently more shaded than the habitats occupied by A. capillus-veneris. In Utah this species is not always a hanging garden plant. It grows in mesic sites in the Wasatch Mountains. The species occurs from Alaska to the Atlantic and south to California, Oklahoma, and Georgia. It is also known from Asia.

Aquilegia chrysantha Gray Golden columbine

Golden columbine is restricted to the Zion Canyon gardens in Utah. The first flowers are very large and attractive, with spurs 4–7 cm long. It hybridizes with A. formosa (see below) in the gardens, and the hybrids are conspicuous and recognizable by their telltale reddish sepals and spurs. The species is known from Arizona, New Mexico, Colorado, and Mexico.

Aquilegia formosa Fisch. in DC. Western columbine

Zion Canyon materials of A. formosa are of two types. Plants of only moderately mesic crevices at 1,678 to 2,288 m elevation are glandular overall and belong to the var. fosteri Welsh. Seeds cascade into the canyons where some plants of that type occur in the hanging
gardens. There they coexist with formosa plants that are glandular only in the inflorescence and with A. chrysantha. The formosa type of plants that lack glandular foliage is thought to represent hybrids between var. fosteri and A. chrysantha. Their lack of glandularity on the foliage, flowers that average larger, and more mesic habitat requirements (than var. fosteri) suggest such an origin. Plants of the formosa type are known from gardens only in Zion. Elsewhere in Utah A. formosa grows in seeps and along streams. The species is known from Alaska and Yukon south to Baja California, Nevada, and Montana.

Aquilegia micrantha Eastw. Alcove columbine

Alcove columbine is an endemic of hanging gardens of the canyons of the Colorado. It occurs in most of the gardens of that area. The small, white to cream-colored (less commonly pinkish to pale blue) flowers and overall glandularity are diagnostic for the species. Alcove columbine is not known from the Virgin River drainage. The species is known only from the Colorado Plateau of Arizona, Colorado, and Utah.

Aralia racemosa L. American spikenard

This plant forms clumps that reach a height of more than 2 m and have leaves to almost 1 m wide. The umbels of small white flowers are conspicuous in early summer and are followed by rounded clusters of fruits. The plants occur primarily on the floors of grottos, where they are shaded almost constantly. Occasional plants do occur on the garden walls and in the riparian communities, especially in the Narrows. The plant is known in Utah only from Zion Canyon. The phase of the species occurring in Utah is ssp. bicornata (Woot. & Standl.) Welsh & Atwood. The species occurs from southeastern Canada and northeastern U.S. southward to Arizona and New Mexico.

Calamagrostis scopulorum Jones Jones reedgrass

This species was named and described on the basis of plant specimens taken from Zion Canyon by Marcus E. Jones in 1894. The species is elevationally disjunct in the hanging gardens of Utah. Its principal distribution otherwise is in boreal and alpine sites. The species occurs from Montana to Arizona and New Mexico. It is the main grass in the gardens in Zion Canyon and is often a main component of gardens along the canyons of the Colorado in eastern Utah.

Carex aurea Nutt. Garber sedge; Golden sedge

The common sedge of hanging gardens in both Zion and Glen canyons vicinities differs in mainly intangible features from that typical of the species as it occurs in montane and alpine sites. It has been referred to as C. garberi Fern. It is usually a larger plant and has greenish rather than golden fruits of its alpine counterpart. However, it seems best to regard it as little more than an ecotype of the more broadly ranging C. aurea. The species is present in most of the Colorado gardens and some in Zion. It is widely distributed in North America and has been considered by some authors as a portion of the C. bicolor All. circumboreal complex.

Carex curvata Stacey Canyonlands sedge

This primocarex is easily recognized by its solitary, unisexual spikes borne on separate
This plant reached its northern distribution in hanging gardens along Glen Canyon. It was collected historically at the mouth of Kane Creek, now under several hundred feet of water held back by Glen Canyon Dam. Subsequent collections were taken at Step Garden in Driftwood Canyon, Cladium Garden in Hidden Passage Canyon, and Wilson Creek along the San Juan Arm. The high water of 1983 and 1984 lapped at the margin of the great clump of this species at Step Garden and apparently drowned a portion of the plants at the mouth of Wilson Creek. Cladium Garden has long since been inundated. A second small patch of saw-grass is present at the foot of one of the vertical walls in Hidden Passage Canyon, however. The plant is precariously situated in the flora of the region. Elsewhere it is known from along Furnace Creek in Death Valley, California, and when considered as a portion of the broadly distributed C. mariscus, its distribution is across much of the southern U.S. and southward.

**Dodecatheon pulchellum** (Raf.) Merrill Pretty shooting-star

The Zion Canyon phase [var. zionense (Eastw.) Welsh] of the shooting-star is also known from hanging gardens in Little Valley tributary of Last Chance Creek, north of Lake Powell, in the Escalante drainage, and along Lake Powell as far north as the confluence of the Escalante. Nowhere does it grow so profusely as in the shaded gardens of Zion Canyon. The species occurs in much of Utah and is widely distributed in western North America and disjunctly in the eastern U.S.

**Epipactis gigantea** Doug. ex Hook. Helleborine

This plant is mainly palustrine in its distribution, occurring around seeps and springs and along streams in much of western North America from the Canadian provinces southward. It is a common component of the alcove hanging gardens in southeastern Utah. The purplish to greenish purple or purple-brown flowers are displayed on plants that are usual at the juncture of detrital slopes and adjacent face walls in many gardens. It grows there with Garber sedge, bundle panic, and other garden species. The plant is not especially noted as a garden species in Zion Canyon, however. It is in the canyon but occupies marshy sites in The Narrows, where garden
development is not especially prominent. A single clump of the plant is present in a dryish garden associated with maidenhair fern along the trail to Refrigerator Canyon in Zion Canyon.

Erigeron kachensis Welsh & Moore  Kachina daisy

This pretty dwarf daisy produces stolons that allow it to grow on wet walls and moist sand in hanging gardens in Natural Bridges National Monument and Dark Canyon, Utah, and along the Dolores River in Colorado. The plants also occur as mere mesophytes in other plant communities besides hanging gardens at higher elevations in the Abajo Mountains. It is a Colorado Plateau endemic.

Erigeron sionis Cronq.  Zion daisy

The Zion daisy is a stoloniferous mesophyte. The stolons tend to bind the plant in colonies on moist sandstone. The nature of the stone in Zion Canyon allows water to percolate in shallow stone lenses, only to come to the surface along minor defiles. Some of the moist lenses are hand-sized and still support this daisy. The plants are provided with water for some time following snow melt in springtime or following rains at any season. Hanging gardens also serve as habitat for this plant, which is especially common along minor terrace margins and on rock faces in the grotto floors. Occasionally the plants grow along drainages below the gardens, and rarely the plants are found growing well on apparently dry sand. The plant is endemic to Zion Canyon.

Erigeron zothecinus Welsh  Alcove daisy

Alcove daisy is known only from a suite of hanging gardens (the North Escalante Gardens) on the north side of Glen Canyon immediately east of the confluence of the Escalante Canyon. It is confined to the wet walls and foot slopes of small gardens near the base of the Navajo Sandstone or top of the Kayenta Formation. The eight main alcoves in the Navajo to the north apparently do not support this plant.

Habenaria zothecina Higgins & Welsh  Alcove bog-orchid

Long thought to be a phase of H. sparsiflora Wats., this species with long-spurred flowers was named from the hanging gardens of the first meander bend east of the Colorado bridge north of Moab, Grand County, Utah. The species occurs in hanging gardens from Arch Canyon, west of Comb Reef, north to Arches National Park. It is endemic to the hanging gardens.

Lobelia cardinalis L.  Scarlet lobelia

This third of a triumvirate of plants with scarlet or brilliant red flowers is less likely to occur within the garden flora than adjacent to it. The species is rather common on the wet walls of Zion Canyon, however. The other two, Mimulus cardinalis Dougl. ex Benth. and Mimulus eastwoodiae Rydb., are characteristic of the gardens proper, even though they also occur on the downslope portions of the garden and less commonly along the drainages below them also. Those downslope and down drainage localities are the common sites occupied by scarlet lobelia in the Colorado canyons gardens especially. The species is present in Zion Canyon and along Glen Canyon as far north as the mouth of Ticaboo Canyon. It is widely distributed in the eastern United States, Mexico, and Central America.

Mimulus cardinalis Dougl. ex Benth.  Cardinal monkey-flower

This plant with brightly colored, large flowers reaches the northern limits of its distribution in the hanging gardens of Zion Canyon. Its entire distribution otherwise is in New Mexico, Arizona, Nevada, California, Oregon, and Mexico (including Baja California). Utah materials have sometimes been treated as a separate species, M. verbenaceus Kearney & Peebles, but the ranges, when treated separately, overlap and the characters used as diagnostic fail individually and in tandem. The plants are common in the gardens of Zion where they occur both as wall and floor plants in the grotto and windowblind gardens.

Mimulus eastwoodiae Rydb.  Eastwood monkey-flower

Back and face walls are the common sites of placement for this species in the alcove gardens of the canyons of the Colorado. The species is in most of the gardens where it shares the walls with cave primrose. It is a smaller plant in all respects than is the cardinal monkey-flower. Flowers are borne in late summer and autumn in this species. Its counterpart in Zion Canyon is mainly a spring-flowering plant, but flowering continues through the summer. The species is endemic to the hanging gardens.
Panicum acuminatum Swartz  Bundle panic
Gardens of the Colorado canyons typically support this plant, growing intermixed with Garber sedge on the detrital slopes of alcoves. It is less common in Zion Canyon. This is a Dianthus panicum, which has broad basal leaves. Flowers of two types are produced, open pollinated flowers at the summit of the plant and flowers that remain in the enclosing sheath that are self-pollinated. The species has passed under several names. It is a widespread plant in the U.S., portions of Canada, and Mexico.

Perityle specuicola Welsh & Neese  Alcove rock-daisy
Type locality for this species is the alcove immediately adjacent to the highway on the first meander bend east of the Colorado River bridge north of Moab. The plant grows there, hanging from crevices in the back wall of the alcove. It simulates Stephanomeria tenuifolia (Torr.) Hall with which it grows in both habit and position. The plants also grow in the hanging garden on the west side of the same meander bend, but there on the dry edge of the garden the plants stand erect. A second population is known from a small garden in Cataract Canyon north of its confluence with Dark Canyon. The plant is not otherwise known.

Petrophytum caespitosum (Nutt.) Rydb.  Rock spirea
Rock spirea grows in hanging gardens both in Zion and along the canyons of the Colorado. It does well in some of the alcove gardens where the substrate is wet, even growing associated with the algal mat on the walls, but is common in gardens that are dry. In Zion Canyon it is mainly a plant of garden margins. Often the plants occur as mats conforming to the contour of the surface, but sometimes the plant swings away from the wall and hangs pendentulous from the overhanging back of alcove gardens. Spikes of creamy flowers are borne in late summer and autumn. The species grows elsewhere on limestone and igneous outcrops, typically at middle elevations, from Washington to South Dakota and south to California, Arizona, New Mexico, and Texas.

Primula specuicola Rydb.  Cave primrose; Easter flower
The cave primrose was evidently first collected by Alice Eastwood in 1895 in the alcove gardens at Bluff, Utah. She mistakenly identified the plants with an Old World member of the genus but recognized the unique nature of the gardens and the misplaced distributions. The species might be regarded as the botanical motif of Canyonlands hanging gardens, but that role is shared practically always with Eastwood monkey-flower and small-flowered columbine. The flowers vary in color from pink (the usual color) to lavender, maroon, and white. Rarely the inflorescences are superposed as in some cultivated species, and rarely too the flowers are double. The plant is a hanging garden endemic.

Smilacina stellata (L.) Desf.  Solomonseal
Widespread in much of North America from the subarctic southward, this species is a common mesophyte. It grows in moist sites throughout Utah, not surprisingly in hanging gardens. The hanging gardens are elevationally placed below the general distribution of the species, and thus the species seems to be a somewhat regular occupant. Solomonseal occurs in gardens in Zion and Glen canyons, mainly on the foot slope or downward along the drainages.

Solidago sparsiflora Gray  Alcove goldenrod
Gardens of the Canyonlands region of eastern Utah are practically always partially clothed with alcove goldenrod. It is a plant of face walls and detrital slopes. Stream courses below hanging gardens and sometimes the gardens themselves also support specimens of S. canadensis L. Intermediates are known between these species, and some garden plants are difficult to assign to one or the other of them. The plant is less often a component of Zion Canyon gardens. Nevada goldenrod, S. spectabilis (D.C. Eaton) Gray, grows in the hanging gardens in St. George. Elsewhere it is a palustrine or riparian species. Alcove goldenrod is a common species, especially at elevations far above that typical for hanging gardens, in the western U.S., from Wyoming and South Dakota south to Arizona and Nevada.

Zigadenus vaginatus (Rydb.) Maehr.  Sheathed death camas
This death camas occurs sporadically in the hanging gardens of the canyons of the Colorado. Pool Garden in Reflection Canyon, Double Gardens on the west side of Glen Canyon, Three Garden, and Death Camas
Garden in the first meander bend of the San Juan east of the confluence with Glen Canyon were essentially aligned and distant directly not more than 3–4 km. Sheathed death camas was in Pool Garden, Double Garden, and Death Camas Garden, but not in Three Garden. This hit-and-miss distribution was characteristic of the large alcove gardens along Glen and San Juan arms. The plants occur in hanging gardens north to Arches and in seeps evidently north to Dinosaur National Monument. Relationships of this species lie to the south with Z. *volcanicus* Benth. of Central America. The type of *Anticlea vaginata* Rydb. (Rydberg 1912) was taken at Natural Bridges National Monument, probably in the seep beneath Owachomo Bridge.

**LITERATURE CITED**


