A PRELIMINARY SURVEY OF HANGING GARDENS AND RELATED VEGETATION ALONG THE COLORADO RIVER, GRAND CANYON NATIONAL PARK

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21 December 1993

INTRODUCTION

This report documents the results of a preliminary survey of hanging garden and related seep vegetation along the Colorado River corridor, from river mile 32 downstream. Included is data on floristics, vegetation, and physical characteristics of 10 sites along the corridor, from Vasey's Paradise (31.7) to Lava Falls (179.2), collected between October 31 and November 14, 1993. This is a preliminary account, and is intended primarily to explore issues related to future work on seep and garden vegetation in the Grand Canyon region. A more detailed report on the hanging gardens of Glen Canyon National Recreation Area is in preparation, and will include a review of the literature, methodology, and hypotheses of hanging garden origins and ecology (Spence 1994).

METHODS AND SITES

Sites were selected based primarily on ease of access from the river. Time constraints on the trip did not permit an extensive search of side canyons, and did not allow for very much time per site. The sites include Vasey's Paradise (31.7R), Triple Alcoves No. 2 (46.5R), Kanab Creek (143.5R-the first two gardens encountered upstream), 147.7R seep, Matkatamiba Canyon (148L-the first two gardens encountered upstream), Fern Glen Canyon (168R-the two obvious gardens encountered before the waterfall), Mohawk Canyon (171.5L-the first major seep on stream left ca. 1 km up from mouth), and Lava Falls spring (179.3L).

At each site, the following data were recorded: species presence and abundance, site aspect, water flow rate, presence of travertine or tufa, geomorphological habitats present, size of herbaceous component of garden, minimum and maximum distance above potential flooding in vertical meters, surrounding vegetation, bedrock geology, and exposure.

The herbaceous and shrub component of the vegetation at hanging gardens and seeps was surveyed. Trees and tall shrubs were recorded as present, but were only scored for abundance if they occurred as scattered individuals within a predominantly herbaceous or shrubby matrix. A six point scale was

used to assign abundance values to each species at the site. For most sites the abundances were based on all of the vegetation, but for large sites 100 m^2 plots were sampled. In this report only Vasey's Paradise and Lava Spring were sampled in this manner. The six point scale is a modified Daubenmire scale:

6 (dominant) = 95% or more cover at site, clearly the dominant species,

5 (abundant) = 50-95% cover, most abundant species at site,

4 (common) = 10-50% cover, easily seen and moderate cover,

3 (uncommon) = 1-10% cover, easily seen but relatively low cover,

2 (occasional) = <1% cover, easily found but very low cover,

1 (rare) = <<1% cover, difficult to find and very low cover, generally only 1-2 small individuals (note that a single individual of a woody species which is conspicuous would be scored as a 2)

This scale is semi-quantitative as no attempt is made to obtain more precise cover estimates. On average about 10-15 minutes was spent at each site. Preliminary tests of this technique in a variety of hanging garden and riparian vegetation suggested that about 80-100% of the species that actually occurred in the vegetation would be observed over this length of time (Spence 1991).

Water flow rate was scored using a four point scale:

1 = ephemeral seep, usually surface-dry by late spring (June), with flow starting in winter as aquifer is recharged,

2 = intermittent, surface-dry by late summer or fall, somewhat heavier flow than in 1,

3 = permanent, year-round surface flow, although the quantity can vary seasonally and generally with some drop in middle or late summer and fall,

4 = permanent, heavy year-round flow, not much seasonal variation.

This scale is at best a very crude attempt to quantify flow rates, and is based largely on my personal experience over many seasons in a variety of

gardens. Intermediate values can be obtained (eg., 1.5, 2.5) if these are thought to reflect flow rates.

Exposure is an attempt to determine the amount of sunlight that could potentially reach the site during the growing season. A lack of time and proper instruments prevents a more precise measure of amount of sun.

1 = exposed to at least 8 hrs/day during height of growing season, canyon width/depth ratio > 3:1

2 = similar to 1 but one aspect partially blocked by cliffs, 5-8 hrs/day, canyon W/D 2-3:1,

3 = site partially shaded by cliffs, generally only morning or afternoon exposure to sun, ca. 3-5 hrs/day, canyon W/D 1-2:1,

4 = narrow deep canyon that provides extensive shading from sun, 1-3 hrs/day, canyon W/D <1:1,

5 = alcove or other deeply shaded site, <1 hr/day at height of growing season, often site recieves only reflected light year round.

As in the water flow scale, intermediate values (eg., 2.5, 4.5) can be assigned to sites.

Habitats available for plants include plunge pools below alcove gardens, vertical or sloping backwalls, soil-covered ledges, and detritus slopes. In general, there is a sharp distinction between backwalls, detritus slopes, and plunge pools, while soil-ledges generally are intermediate between backwalls and detritus slopes. In this survey, only two habitats were commonly encountered, the backwall, and soil covered ledges.

Data were analysed with the SYSTAT 5.0 program. Cluster analysis was performed on the data with Ward' flexible sorting algorithm and Euclidean distance. Nomenclature follows Phillips et al. (1987), except for Dicanthelium acuminatum (=D. lanuginsoum).

RESULTS

Floristics and Vegetation

The species X site matrix is presented in Table 1, while physical characteristics are listed in Table 2. Lava Falls spring is not included in

the analyses for three reasons; it is strongly influenced by the Colorado River and is partly riparian in nature, is disturbed, and supports a variety of introduced species.

Overall, 47 native and two introduced species (Melilotus sp. and Nasturtium officinale) occurred at the nine sites. A species accumulation curve (Figure 1) shows that after Vasey's Paradise and Triple Alcoves No. 2, relatively few additional species were added. A regression based on the seven data points (sites 3-9) where the curve flattens in Figure 1 resulted in the following equation:

Number of native species = 29.9 + 1.9*number of sites

with an adjusted r^2 of 0.98. This suggests that a survey of 20 gardens would result in 68 native species, 30 gardens in 87 species, etc.

The most widespread and important native species were Adiantum capillus-veneris, Mimulus cardinalis, Muhlenbergia asperifolia, Imperata brevifolia, Cladium californicum, Andropogon glomeratus, Flaveria macdougallii, Muhlenbergia thurberi, and Brickellia longifolia. Acacia greggii, Epipactus gigantea, and Lobelia cardinalis were widespread but unimportant in terms of cover. Four species, Vitis arizonica, Petrophytum caespitosum, Aster glaucodes, and Toxicodendron rydbergii, were rare, but quantitatively important when found. Neither introduced species was quantitatively important or widespread.

Principal components analysis ordination (not shown) and cluster analysis (Figure 2) indicated that the most distinct sites were the Triple alcoves garden and Vasey's Paradise. Matkat I and 147.7R were the most similar sites. Overall, the vegetation groupings did not correspond with most environmental variables. Sites 2,4,5 and 3,6,9 formed two groups, and all but site 3 were characterized by extensive travertine.

Environment-Vegetation

No correlation was noted between size of garden and species richness (r^2=0.3%, p=0.894). If only species restricted to the site and not found in adjacent riparian and seep vegetation were included (see Table 2), the

correlation with size was 0. Overall, species richness was not strongly correlated with any site variable. The strongest correlation was between full species richness and exposure (r^2=0.246, p=0.099), and was negative. More exposed sites tended to have more species than more protected sites.

A significant correlation was found between flow rate and garden size (measured as the extent of herbaceous and shrub vegetation). Sites with heavier flows were significantly more likely to support more extensive herbaceous vegetation than drier sites (r^2=0.743, p=0.0017).

Classification of sites into geomorphic-structural categories proved difficult. Although Welsh and Toft (1981) classified gardens as alcove, window blind, or terrace types, these are very idealized. Many sites, both along the Colorado River, as well as elsewhere on the Colorado Plateau, cannot be easily classified by this system. Elsewhere (Spence 1994) I have discussed the geomorphic classification of gardens in more detail.

The Triple Alcove gardens are most similar to the Welsh and Toft alcove type. These gardens occur in large alcoves, but differ from the classic type in that they are not undercut. Ecologically this is important as the vegetation is exposed to much more sunlight than vegetation in the typical undercut alcove garden that would form in, eg., Navajo Sandstone. This presumably is a result of the lithology and weathering characteristics of the Redwall Limestone.

Several sites (Kanab Creek, 147.7R seep, and the Fern Glen sites) were simple backwalls, with water seeping out along bedding planes at right angles to the face. In most cases, some detritus had collected at the base of the wall. The sites in Matkatamiba Canyon were intermediate between this type, and terrace gardens. They had a seepy backwall of limited extent, with the water flowing over one or more horizontal ledges with accumulated detritus and soil. The site in Mohawk Canyon could be classified as a terrace garden, with water emerging from the hillside of the canyon and flowing down over a series of ledges covered with vegetation.

Vasey's Paradise was difficult to classify, as it was the largest and

most complex site. It consisted of a large backwall and waterfall, with a stream flowing down the wall, over several ledges, and through the accumulated detritus at the base of the wall. The lower edge of the detritus slope was sharply trimmed by Colorado River flows. This was the only site investigated that had a well developed woodland, formed of Celtis reticulata, Rhamnus betulifolia, Toxicodendron rydbergii, Cercis occidentalis, Salix exigua, and S. goodingii.

DISCUSSION

Many of the species that characterize the gardens along the Colorado River through Marble and Grand canyons are either rare, or not found, upriver. These include the local endemic Flaveria macdougallii, as well as species like Haplopappus salicifolius, Imperata brevifolia, Nolina microcarpa, and Cladium californicum. Another suite of species is more widespread along the river. Characteristic species in this group include Andropogon glomeratus and Primula specuicola. A third group occurs through the Grand Canyon, and in the Virgin River drainage in Zion National Park, but not Glen Canyon, eg., Mimulus cardinalis, Vitis arizonica, and Aquilegia chrysantha. Finally, a fourth group consisting of widespread species is found, including Adiantum capillus-veneris, Lobelia cardinalis, Petrophytum caespitosum, and Dicanthelium acuminatum.

Floristically, the gardens surveyed in this report were as species rich as, but very distinct from, those in Glen Canyon (Spence 1994), as well as those in Zion National Park (Malanson 1980; Welsh 1989). Environmental factors that may explain these differences include elevation and bedrock geology. All seven sites in the Grand Canyon occurred below 800 m. They are much warmer than gardens in Glen Canyon, most of which are found at about 1150-1500 m, and freeze in winter. A hot desert floristic element is present, represented in the gardens by, eg., Cladium californicum and Acacia greggii. Geologically, the Redwall and Muav limestones are the most important aquifers through the Grand Canyon. Most gardens on the Colorado Plateau are found in sandstones, such as the Navajo, Entrada, and Cedar Mesa formations. Hence,

differences in water chemistry and site geomorphology might explain some of the floristic differences.

Another interesting feature of the gardens surveyed in this report is that most lacked adventive species. By comparison, hanging gardens in Glen Canyon often support a substantial adventive component, characterized by species like Agrostis semiverticillata, Bromus tectorum, Lactuca serriola, Sonchus asper, and Tamarix ramosissima (Spence 1994).

More work will be needed to better understand the hanging gardens of Marble and Grand canyons. This survey was very preliminary, and only examined a small fraction of possible gardens. Many additional species will be discovered with a more intensive survey. Any future surveys should include higher elevations (3,500-5,000') in side canyons, as they might display differences in flora and structure from lower elevation sites.

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TABLES

Table 1. Vegetation data for ten sites; 1=Vasey's Paradise, 2=Triple Alcoves II, 3=Kanab Creek I, 4=147.7R seep, 5=Matkat I, 6=Matkat II, 7=Fern Glen I, 8=Fern Glen II, 9=Mohawk Canyon I, and 10=Lava Falls L seep.

	Site									
Species (native)	1	2	3	4	5	6	7	8	9	10
Mimulus cardinalis	5	-	3	2	3	2	2	3	2	4
Imperata brevifolia	-	-	2	1	-	3	-	-	4	-
Vitis arizonica	-	-	4	-	-	4	-	-	-	-
Cladium californicum	-	3	-	5	4	-	-	-	-	5
Andropogon glomeratus	-	-	1	1	-	4	-	-	3	4
Muhlenbergia asperifolia	-	2	-	-	-	-	4	2	3	3
Adiantum capillus-veneris	4	2	4	3	4	3	3	5	3	2
Epipactus gigantea	-	2	-	-	2	1	-	2	2	1
Acacia greggii	-	-	1	-	1	1	3	1	-	-
Lobelia cardinalis	1	1	2	-	2	1	2	-	2	-
Agave utahensis	-	-	-	-	-	-	2	-	-	-
Dicanthelium acuminatum	-	-	-	-	-	-	2	-	-	-
Rhamnus betulifolia	-	-	-	1	2	-	2	-	1	-
Brickellia longifolia	3	1	-	-	-	2	3	3	-	-
Flaveria macdougallii	-	-	-	3	-	4	-	4	4	-
Muhlenbergia thurberi	-	2	2	2	2	2	-	-	-	-
Cercis occidentalis	-	-	-	1	-	-	-	-	-	-
Petrophytum caespitosum	-	3	-	4	-	-	-	-	-	-
Aquilegia chrysantha	1	-	-	-	1	-	-	-	2	-
Nolina microcarpa	-	-	2	-	2	-	-	-	2	-
Haplopappus salicifolius	-	-	-	-	1	2	-	-	-	-
Thelypodium wrightii	-	-	-	-	-	-	-	-	2	2
Solidago sparsiflora	2	3	3	-	-	-	-	-	-	-
Aster glaucodes	-	-	4	-	-	-	-	-	-	-
Typha domingensis	-	-	1	-	-	-	-	-	-	-
Maurandya antirrhiniflora	-	-	1	-	-	-	-	-	-	-
Apocynum cannabinum	-	-	1	-	-	-	-	-	-	-
Toxicodendron rydbergii	4	-	-	-	-	-	-	-	-	-
Salix goodingii	1	-	-	-	-	-	-	-	-	-
S. exigua	1	-	-	-	-	-	-	-	-	-
Polydonum coccineum	2	-	-	-	-	-	-	-	-	-
Euthamia occidentalis	2	-	-	-	-	-	-	-	-	-
Celtis reticulata	2	-	-	-	-	-	-	-	-	-
Elymus canadensis	2	-	-	-	-	-	-	-	-	-
Schizachyrium scoparium	-	3	-	-	-	-	-	-	-	-
Euphorbia aaron-rossii	-	1	-	-	-	-	-	-	-	-
Baccharis sergiloides	-	3	-	-	-	-	-	-	-	-
Primula specuicola	-	2	-	-	-	-	-	-	-	-
Carex specuicola	-	2	-	-	-	-	-	-	-	-
Calamagrostis scopulorum	-	3	-	-	-	-	-	-	-	-
Yucca baccata	-	1	-	-	-	-	-	-	-	-
Tessaria sericea	-	-	-	-	-	-	-	-	-	2
Aster subulatus	-	-	-	-	-	-	-	-	-	1
Phragmites australis	-	-	-	-	-	-	-	-	-	2
Baccharis sarothroides	-	-	-	-	-	-	-	-	-	2
Carex cf. aurea	2	-	-	-	-	-	-	-	-	-
Muhlenbergia sp.	-	-	-	-	-	-	-	4	-	-
Vicia species	-	-	-	-	-	2	-	-	-	-
Equisetum X ferrissii	3	-	-	-	-	-	-	-	2	-
Solidago cf. altissima	-	-	-	-	-	-	-	-	1	-

Table 1 (continued)

unknown Asparagus-like plant (total=51)	-	-	-	-	-	-	1	-	-	-
Species (introduced)										
Onopordum acanthium	-	-	-	-	-	-	-	-	-	3
Tamarix ramosissima	-	-	-	-	-	-	-	-	-	2
Agrostis semiverticillata	-	-	-	-	-	-	-	-	-	2
Melilotus sp	-	-	-	-	-	-	-	-	1	-
Nasturtium officinale (total=5)	4	-	-	-	-	-	-	-	-	-

Table 2. Physical characteristics for ten sites; 1=Vasey's Paradise, 2=Triple Alcoves II, 3=Kanab Creek I, 4=147.7R seep, 5=Matkat I, 6=Matkat II, 7=Fern Glen I, 8=Fern Glen II, 9=Mohawk Canyon I, and 10=Lava Falls L seep.

	Site									
Characteristic	1	2	3	4	5	6	7	8	9	10
Flow Rate	4.0	2.0	2.5	3.0	2.5	2.0	2.0	3.0	2.0	4.0
Aspect (true N)	050	155	330	220	040	050	130	110	045	280
Size (m^2)	800	100	20	200	25	50	20	200	80	500
D above flood (m)	1-20	>100	0-3	10-30	3-5	4-8	2-4	0-10	2-8	0-3
Travertine/Tufa	-	+	-	+	+	+	-	-	+	+
Ledge-soil slope	+	+	+	-	+	+	+	+	+	+
Backwall	+	+	+	+	-	+	-	+	-	+
Exposure	3.0	1.5	4.0	3.0	4.5	4.5	4.5	4.5	2.0	2.5
No. native spp.	14	16	15	10	12	13	10	8	14	11
No. introduced spp.	1	0	0	0	0	0	0	0	1	3
Associated woodland	+	-	-	+	-	-	-	-	-	-
No. spp. in adjacent riparian zone	0	9	8	4	4	6	5	4	8	10
Bedrock Geology	RL	RL	ML	ML	ML	ML	ML	ML	ML	ML[1]
Site isolated from other riparian/seep	no	yes	no	no	no	no	yes	yes	no	no

[1]RL=Redwall Limestone; ML=Muav Limestone

FIGURES

Figure 1. Species accumulation curve, starting with Vasey's Paradise (1) and ending with Mohawk Canyon I (9). The sites are numbered as in Tables 1-2 and Figure 2.

Figure 2. Dendrogram of nine sites, clustered with the Ward's flexible sorting algorithm. The measure of association used was Euclidean distance.

SPECIES ACCUMULATION CURVE

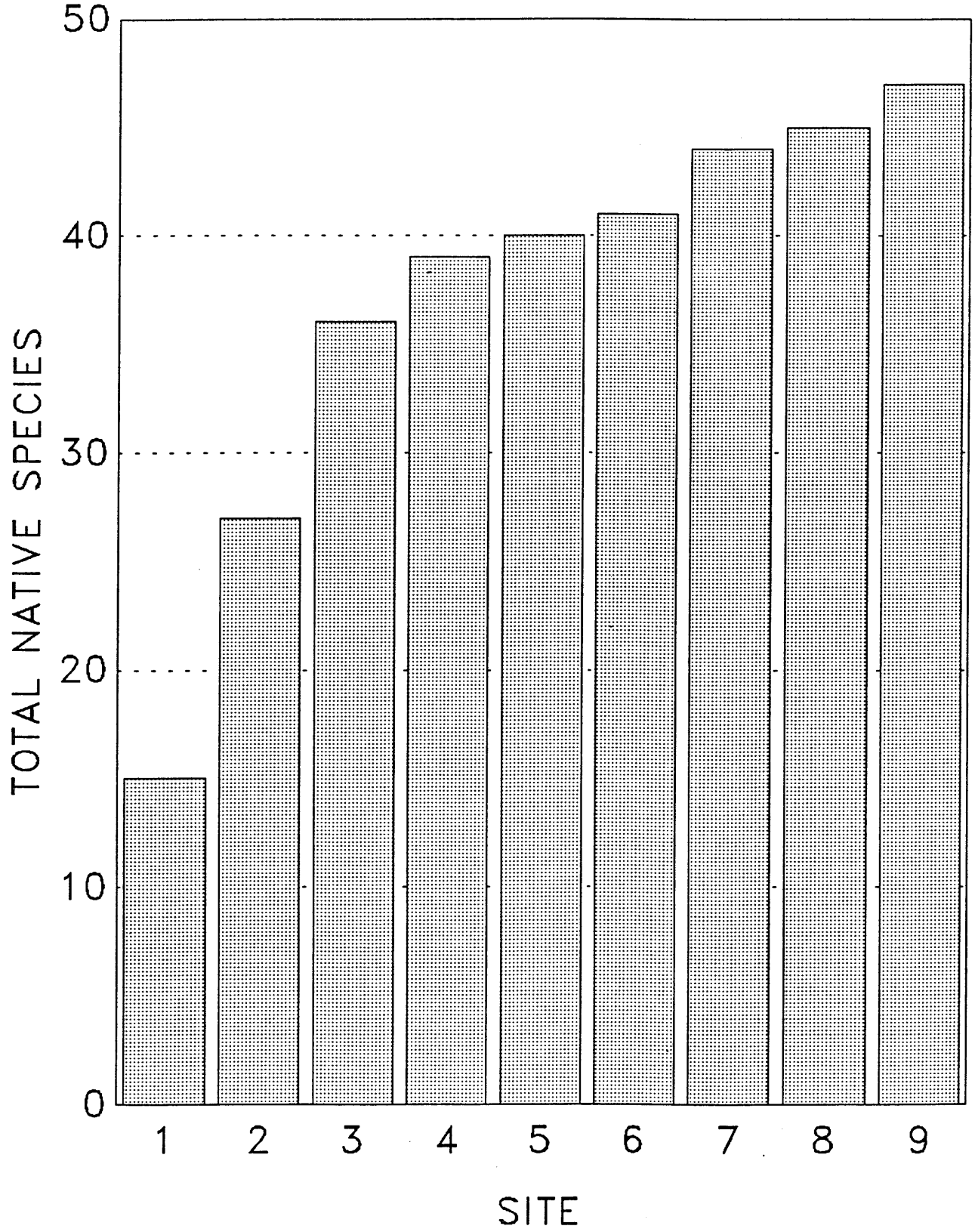
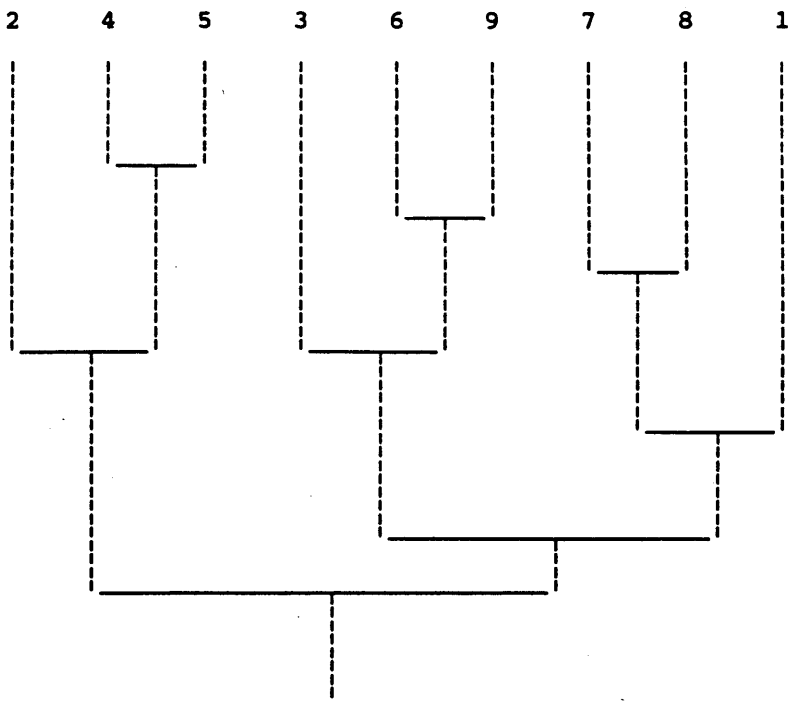


FIGURE 2



Sites

1=Vasey's Paradise
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