FINAL REPORT

A SURVEY AND CLASSIFICATION OF THE RIPARIAN VEGETATION IN SIDE CANYONS AROUND LAKE POWELL GLEN CANYON NATIONAL RECREATION AREA

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A SURVEY AND CLASSIFICATION OF THE RIPARIAN VEGETATION IN SIDE CANYONS AROUND LAKE POWELL, GLEN CANYON NATIONAL RECREATION AREA

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1. INTRODUCTION

A diversity of wetland plant communities occur on the Colorado Plateau. For convenience, these can be grouped into six main kinds: marshland, riparian, hanging garden-spring, strand, lake, and tinaja (waterpocket). These categories are summarized in Table 1 (tables begin on p. 46) with principal plant and environmental characteristics. All wetland communities (in the general sense) can be defined as vegetation composed at least partly of obligate phreatophytes (or water-loving plants) growing in sites, where either the water table is at or near the ground surface, or which are periodically flooded. Phreatophytes are species which require abundant available water during the growing season, generally by exploiting a ground water table, or which otherwise lack features (morphological or physiological) that could prevent or reduce water loss. The classification presented in Table 1 is intended primarily as a heuristic tool rather than an exact classification. Some kinds of vegetation are not well described by this system (bogs, lacustrine, some springs, algal and charophyte vegetation), and some sites will be transitional between these categories, eg., strand-riparian, or marshland-lake. Furthermore, obligate riparian species or phreatophytes are not always easily characterized, as they occupy one end of a continuum of water use, with the opposite end comprising arid-adapted species.

This report presents the results of the first phase of a three year NRPP-funded ecological survey of the riparian vegetation within Glen Canyon National Recreation Area (NRA). The 1992 survey concentrated on riparian (streamside) communities in selected side canyons of Lake Powell. Three main types of riparian zones occur in Glen Canyon NRA; ephemeral, intermittent, and permanent (Driscoll et al. 1984). Ephemeral zones are characterized by a deep water table which lies well below the streambed, with water only present during precipitation events.

Intermittent zones have some surface water, seasonally or permanently in some stretches, derived via groundwater discharge. Permanent zones support year round flows. This study concentrated on intermittent and permanent riparian zones, because ephemeral drainages usually lack riparian vegetation. Because of variable combinations of disturbance, topography, substrate and channel type, animal activity, and available plant species, riparian vegetation in these canyons is complex. Survey work concentrated primarily on vegetation occurring within the channels or on the fluvial terraces of streams. Some marshland vegetation occurred, however, within the matrix of predominantly riparian vegetation. This vegetation was included within the survey. All vegetation surveyed and reported in this study, except for one plot in Lake Canyon (see Appendix 4), occurred above the highest water level reached by Lake Powell in the period 1980-1986 (ca. 3700 feet), when it was at full pool.

Data is presented on riparian plant species distribution, life form, cover, sociability, and reproduction from general floristic surveys as well as quantitative descriptions of 80 plots. The primary goals were to, 1) produce a classification of the riparian vegetation around Lake Powell, and 2) present a detailed description of the resulting vegetation types. Derived from the basic data is a preliminary classification of non-hanging garden riparian vegetation, with analyses of species richness, evenness, diversity, and preliminary comparisons between the vegetation and environmental features. Finally, the riparian zones of those canyons investigated are ranked by criteria of water resources, biodiversity, disturbance, and communities present.

The report is organized into a brief literature review of riparian research in the region, site selection, data collection, analysis and interpretation methods, results, discussion, and recommendations. Appendices include a full plant species list, glossary of statistical and mathematical methods, and canyon descriptions and visitation schedule.

2. LITERATURE REVIEW

Riparian vegetation in the American southwest is less well known than adjacent upland desert vegetation (Brown 1982). The most detailed study in the region is that of Szaro (1989, 1990) on riparian vegetation of Arizona and New Mexico. Padgett et al. (1989) provide a classification and description of high elevation riparian communities of southern Utah. Other important regional studies include those of Baker (1989a,b, 1990) in western Colorado, Webb and Brotherson (1988) in southwestern Utah, Harper et al. (1992) in Zion National Park, and Romme (1992) in Capitol Reef National Park.

Most research on the vegetation along the Colorado River in the area now within the boundaries of Glen Canyon NRA deals with upland desert communities (Schultz et al. 1987; Tuhy and MacMahon 1988; West 1988; Spence 1990). Very little published work is available on wetlands. Perhaps the best known communities are the hanging gardens (Welsh and Toft 1981; Welsh 1984, 1989; Stanton et al. 1992; Spence and Henderson 1992). Riparian vegetation along the Colorado River and its tributaries was first studied by Clover and Jotter (1944) and Woodbury et al. (1959). Irvine (1976) and Irvine and West (1979) described the ecology of the principal woody species along the Escalante River. Waring (1992) studied the developing shoreline communities around Lake Powell itself. Agenbroad et al. (1990) examined the paleoecology and dynamics of fluvial deposits in Bowns Canyon. Other work on riparian vegetation in the area include Camp (1978) and Tuhy and MacMahon (1988). Spence (1991) surveyed several hanging gardens and adjacent riparian zones in the Great Bend part of the San Juan arm of Lake Powell. Spence and Henderson (1992) provide a detailed analysis of vegetation and floristic patterns in tinaja vegetation in the southern Waterpocket Fold in Capitol Reef National Park adjacent to Glen Canyon NRA.

Tuhy and MacMahon (1988) classified the wetland vegetation of Glen Canyon NRA and surrounding areas into six communities, hanging gardens, perennial riparian, ephemeral washes, and three "pseudoriparian" shrub types, Sarcobatus vermiculatus, Artemisia tridentata, and Atriplex canescens. The last two are generally not conisdered riparian because the dominant species are not riparian obligates. Ephemeral washes is principally a geomorphic-topographic type, and satisfactory classification of the vegetation of this type has not yet been achieved (cf. Romme 1992; see below in results).

3. METHODS

A. Canyon selection

A preliminary inspection of aerial photos, in conjunction with discussions with C. Wood (Res. Manag., Glen Canyon NRA.) and information on stream flows and surface water (Lively-Schall and Foust 1988), was used to select study canyons. Primary selection criteria included, 1) the canyon was entirely or largely within Glen Canyon NRA, 2) the canyon was relatively undisturbed by livestock and human-related activities, and 3) the canyon supported riparian vegetation. Excluded were canyons with mostly bare or poorly vegetated stream channels largely lacking in riparian vegetation. The principal sites selected are listed in Table 2. Many of these could not be visited during the 1992 field season due to lack of time or transportation, but will be included in the second or third years of the study. Sites visited included (uplake and clockwise from dam) Cow Canyon, Bowns Canyon, Long Canyon, lower Hall's Creek, upper Miller's Creek, Two Mile Canyon, Clearwater Canyon, Ribbon Canyon, lower Wilson's Creek, and Alcove Canyon. Canyons with some human or livestock-related disturbances that were visited included Last Chance Creek, Lake Canyon, and Slickrock Canyon. In addition, springs on the southeast shore of Good Hope Bay were surveyed.

B. Field survey techniques

During the canyon surveys, species found in the riparian zones were recorded when encountered. In general, only species considered riparian obligates, or species characteristic of the riparian zone, were noted. Critical or difficult specimens were collected for later identification. In representative homogeneous patches of riparian vegetation temporary plots were placed for quantitative description. The plots were 100 m^2 in extent and circular wherever possible (radius = 5.65 m). In some cases dimensions varied, such as where riparian zones were narrow. In these cases plot dimensions were more elongate (rectangular) in shape, but retained the 100 m^2 size. The plot size was chosen because it is common in description of herbaceous and woody vegetation. Useful summaries of field techniques can be found in Shimwell (1971) and Mueller-Dombois and Ellenberg (1974).

Physical data recorded for each plot included date, location, observer, aspect, elevation, amount of litter, soil (or other substrate) and rock, topographic position, flood terrace position, signs of disturbance (biotic, physical), and presence of surface water. The flood level was defined by a five point scale; 1 = current stream channel (0 m), 2 = stream channel margins or lowest obvious terrace (<1 m), 3 = intermediate terrace (dry), flooded yearly (1-2 m), 4 = high terrace (dry), not flooded every year but old flood sign present (2-3 m), 5 = highest terrace (dry), not flooded or only in extreme 100-500 year event (>3 m), 6 = alcove or hillside seep, not flood prone. Flood position are only approximate guidelines, because flood intensity is highly variable within and between canyons, and is related to features such as size of drainage basin, channel and streambed properties, vegetation, and stream gradient.

Within each plot species presence, height, abundance, sociability, and reproductive status, was noted (Table 3). In general, sampling lasted ca. 15-20 minutes per plot. This time interval was chosen as a compromise between completeness of plot description and number of plots surveyed. In preliminary tests using this technique, about 80-90% of the species present within test plots were located. Species likely to be overlooked include small annuals, or species that are morphologically similar when sterile. This was a problem primarily in spring and early summer, when critical genera like Baccharis, Juncus, Carex, Solidago, and many grasses, were not in flower.

Species abundance, defined as canopy cover (amount of ground covered by foliage as projected vertically), was recorded visually with a modified Daubenmire scale (Table 3). The scale intervals were chosen to reduce observer bias and increase repeatability of the measure. Height was estimated visually to the nearest meter over one meter, and the nearest decimeter under one meter. Heights were not exact, especially above ca. 5 meters. The time spent to measure height using a more detailed technique, or by use of an intrument, would have been prohibitive. For woody species, average lowest and highest heights were noted. Sociability was recorded using a modified Braun-Blanquet scale (Table 3), unless the species was too rare locally to determine sociability. Presence of flowers or fruits, from the current or previous years, was noted.

C. Data analysis

Only a brief description of the methods are presented below. Complete details on mathematical and statistical methods are presented in Appendix 1 (p. 67).

Classification of plot vegetation data was done using objective multivariate techniques. Recent work (Baker 1989a; Padgett et al. 1989; Szaro 1989) has demonstrated the value of multivariate analysis in the interpretation of complex matrices (species X plots) of riparian data. The most common mathematical classification techniques come under the general name of cluster analysis. Two basic methods of clustering data can be used, hierarchical or nonhierarchical clustering. There are reasons for using heirarchical techniques, primarily because hierarchy is a desirable property of a classification (cf. Spence 1992a). Sequential, agglomerative, hierarchical, non-overlapping clustering of vegetation plots using Euclidean distance as the measure of association and Ward's flexible linkage as the clustering algorithm, were used to produce a preliminary clustering of the riparian vegetation. The specifics and reasons for this are presented in Appendix 1. The basic data matrix comprised 80 plots by 140 species. For each species by plot occurrence, a value was assigned using the 6-point abundance scale, or given a 0 if the species did not occur in the plot in question (Table 3).

Seven measures were selected to describe and compare groups (=vegetation types) resulting from the cluster analysis. Measures of species richness, diversity and evenness were computed for each plot, and then averaged for each vegetation type. Richness was defined as the number of species found in the plot. Diversity was defined as the Shannon index, while evenness was the Shannon index divided by the log of species richness. Specific details are noted in Appendix 1. Prevalent and modal species were extracted from each vegetation type by the method of Curtis (1959). Prevalent species are characteristic species that attain high frequencies in a particular vegetation type, while modal species are those that reach maximal regional abundance in a particular vegetation type. The index of homogeneity was used to indicate how similar plots within a vegetation type are to each other. The index of distinctivness determines how distinct each vegetation type is from other types. The procedures for determining these paramaters are noted in Appendix 1.

4. RESULTS

A. Floristics

A total of 206 species are listed in Appendix 2 (p. 70). These comprise all riparian species seen or reported from canyons around Lake Powell, and all species found in the vegetation plots. Problems of identification were encountered with certain groups, principally grasses, Juncus, Baccharis, and Solidago. These are noted in the appendix. Species nomenclature follows Spence (1992b).

Table 4 presents a summary of life forms for the three groups, entire flora (N = 206 species), obligate riparian flora (N = 121), and introduced flora (N = 22). Perennial forbs, perennial graminoids, and shrubs were most common overall. The obligate riparian flora contained relatively more grasses and trees than the total flora, and included all ferns, fern allies, and lianas. The introduced flora included mostly herbaceous species, and many annuals, especially in grasses. Elaeagnus angustifolia and Tamarix ramosissima were the only introduced woody species.

Of the 206 species, 140 occurred in one or more vegetation plots. The most widespread species was Equisetum hyemale (39 plots), which is ubiquitous throughout the riparian zones of Glen Canyon NRA. Interestingly, this species is rare in hanging gardens (Spence, unpublished data). Other native species which occurred in 10 or more plots, in order, were Juncus arcticus (35 plots), Baccharis (including B. salicina and B. emoryi) (34), Elymus canadensis (29), Populus fremontii (27), Artemisia ludoviciana (24), Solidago (including S.

canadensis and S. occidentalis) (23), Salix exigua (19), Castilleja linariifolia (17), Phragmites australis (17), Oxytenia acerosa (17), Salix goodingii (16), Chrysothamnus viscidiflorus (14), Muhlenbergia asperifolia (14), Oenothera longissima (13), Panicum virgatum (13), Clematis ligusticifolia (12), Quercus gambelii (12), Brickellia longifolia (11), Ipomopsis aggregata (10), and Rhamnus betulifolia (10). Most of these are riparian obligates. The most widespread introduced species were Bromus tectorum (20 plots), Tamarix ramosissima (20), and Melilotus alba (10). Of the 140 species encountered in the plots, 44% occurred only in one or two. Obligate riparian species accounted for 47% of the species from the 80 plots, and 59% of the total flora.

B. Vegetation communities

During the 1992 field season, 79 plots were surveyed in 13 canyons and Good Hope Bay (Table 2). A seep plot surveyed in 1991 in an unamed canyon (unofficially called Garden) west of Alcove Canyon was also included (data from Spence 1991). Appendix 2 lists the 140 species found in these 80 plots.

The results of a cluster analysis on the basic data matrix (140 species X 80 plots) is presented in Figure 1. The selected cut off level produced six groups (rectangles), 1) a mixed group of predominantly herbaceous plots, 2) riparian scrub plots, 3) Populus fremontii woodland, 4) tinajas, and 5-6) two mixed groups of herbaceous and woody plots. The three mixed groups (1,5,6) were analysed separately in a second cluster analysis, which produced 11 groups (Figure 2), 1) a mixed group of herbaceous sites on low terraces or stream channels characterized by low cover, 2) Eleocharis palustris seeps, 3) regenerating P. fremontii woodland, 4) mixed Oxytenia acerosa-grass plots, 5) Phragmites australis seeps, 6) high elevation Pseudotsuga menziesii-Acer glabrum forest, 7) mixed deciduous woodland, 8) mixed herbaceous plots dominated by

Equisetum hyemale, 9) Betula occidentalis scrub, 10) mixed Solidago-Equisetum hyemale plots, and 11) a species rich spring in "Garden" Canyon dominated by Phragmites australis (labeled RZ4).

The final classification of vegetation types is presented in Table 5. Types are grouped into three categories, forest and woodland, shrub, and marshland (herbaceous), derived from the Brown-Lowe-Pase system (Spence 1992a). Most of the 17 resulting types were derived directly from the cluster analyses. Some types were recognized based on only one or a few plots that were extracted from other groups. These types were tentatively recognized because of relatively distinct vegetation physiognomy or floristics. A few plots were reassigned to groups with which they shared important species. For example, some plots with sapling or adult Populus fremontii were grouped with herbaceous plots lacking trees because of strong similarities in herbaceous vegetation. The presence of trees was considered a more important feature for classification purposes. Of the 80 plots, nine remained unclassified (reasons in results). Appendix 3 is a key to the vegetation types.

Most of the vegetation types recognized are probably equivalent with the series level in the U.S. Forest Service system. Within each of the larger or more complex types several "phases" based on floristics can be distinguished, probably equivalent to Forest Service community or habitat types, or floristic associations in the sense of Baker (1989a) and Szaro (1989). The term adopted in this study is vegetation type, so as not to imply exact correspondence with series, community and habitat types, or floristic associations.

Below, data on floristics, structure and site environment are presented for each type. A summary of chief vegetation and site features are provided in tables for all types comprising three or more plots. Each type was assigned to a biome in the Brown-Lowe-Pase system, as modified by Spence (1992a). Finally, comparisons are made with other regional classifications, particularly those on the Colorado Plateau.

1. Populus fremontii woodland (Table 6; plots = BOC2, COW12, COW15, GHB1, HAC1, HAC2, HAC7, LOC1, LOC2, LOC5, LOC6, LWC1, LWC2, RIC1, RIC2, SLC2, TMC2, TMC4; acronyms in Table 2).

Stands of Populus fremontii were rare along the Colorado River through Glen Canyon (Woodbury et al. 1959), but common in some side canyons. Continuous gallery forests of P. fremontii are rare within Glen Canyon NRA, with the best examples occurring along portions of the upper Escalante River downstream from its confluence with Calf Creek, and in upper Long Canyon. Most examples of this type occurred as isolated stands of old trees on high terraces (4-5) well above stream channels. In a few cases, younger stands consisting predominantly of saplings and seedlings were found on wet substrates in streambeds and lower terraces. Occasionally, cottonwoods occurred within the riparian scrub type, generally as saplings. The type was represented in all canyons investigated.

The most common prevalent species included P. fremontii, Baccharis salicina, Artemisia ludoviciana, Salix goodingii, Tamarix ramosissima, and Elymus canadensis. A large number of modal species occurred, many of which were upland desert species that were only common in this type, generally on the higher terraces. Structurally, the vegetation was variable, with some stands having a tall shrub layer, and others a low shrub layer. A herbaceous layer was generally present. A liana layer was occasionally present, represented by Clematis ligusticifolia. Richness, diversity and evenness were generally intermediate compared to other types, and lower than for relict woodlands.

Two types could be delineated within the P. fremontii type. One occurred mostly on high terraces, and was characterized by large cottonwood individuals (to 30 m) with Chrysothamnus viscidiflorus, C. nauseosus, and Artemisia dracunculus forming a low (1-2 m) understory. Cottonwood saplings and seedlings were absent in this subtype. The second type occurred on lower terraces and occasionally in streambeds where flooding was absent. The understory was dominated by a mixture of obligate riparian tall shrubs or low trees, including Baccharis salicina, Salix goodingii, and Tamarix ramosissima. Two further groups within this second subtype exist, with a species rich group characterized by Salix goodingii and Elymus canadensis and large cottonwood individuals, and the second by a significant amount of Tamarix with predominantly saplings or small individuals of cottonwood. These differences may be related to flooding and past livestock activity. Interestingly, Salix exigua was rare in all subtypes.

Populus fremontii woodlands were most similar vegetationally to the Baccharis-Salix riparian scrub type. In sites where flood activity is low or has ceased, the scrub type may be successional to cottonwood woodland. Cottonwood riparian woodlands are widespread in the western U.S., and well studied. Understory vegetation varies greatly from study to study, however. Romme (1992) described a P. fremontii - Chrysothamnus nauseosus community on river terraces which is similar to Glen Canyon NRA type. Szaro (1989) described a P. fremontii-Salix goodingii association which is similar to the Salix goodingii subtype in this study.

One important question that needs to be investigated is why regeneration is absent on higher terraces. Past livestock activity may have eliminated recruitment, but this does not explain why regeneration was often occuring on lower sites in grazed areas. Depth to the water table and flood activity may control recruitment in this species. P. fremontii requires a relatively high water table to establish, but is sensitive to flooding (Asplund and Gooch 1988). The older stands perched on high terraces (P. fremontii-C. viscidiflorus) may be relictual from the period prior to arroyo cutting (ca. 1880-1910), which isolated terraces and lowered water tables throughout the region (cf. Webb et al. 1991).

P. fremontii woodlands are classified in the Brown-Lowe-Pase Colorado Plateau warm-temperate riparian deciduous biome.

2. Relict mixed deciduous woodland (Table 7; plots = COW1, COW5, COW6, COW11, COW17, LOC3, CLW1).

This type is perhaps the most interesting and unusual riparian community recognized. Relict mixed deciduous woodland harbors more relict (cf. Spence 1992c) and rare species than any other type considered in this study. These woodlands were probably more widespread during the Pleistocene, when conditions were wetter and cooler in the region. With the warming and drying trend of the Holocene, they would have become gradually restricted to shaded wet sites. Many species presumably became locally extinct as conditions became unfavorable, particularly in sites that lacked permanent water.

Stands occurred in shaded watered alcoves and stream terraces well above the canyon bottoms and stream channels, and were often associated with springs. The sites were generally stable, with little disturbance, other than occasional tree falls, slope failure, rock fall, and deer browsing. Distribution of plots included Clearwater, Cow, and Long canyons. Other examples were seen in Alcove, Bowns, "Garden", and Ribbon canyons, and Hall's Creek. Two plots, COW11 and CLW1, were discussed in Spence (1992c).

Usually four layers were evident in the vegetation. A low tree or tall shrub stratum up to 7-8 m (rarely 10 m) dominated. In some stands a tall, emergent layer (20-25 m) formed by Populus fremontii occurred. A dense low shrub and herbaceous layer, mostly under 1 m, was characteristic of wet sites. Lianas of Clematis and Parthenocissus were common, often festooning individuals in the low tree stratum.

Defining species included Rhamnus betulifolia, Acer negundo, Quercus gambelii, and Parthenocissus vitacea. All these were prevalent and modal species (Table 7). Other prevalent woody species included Populus fremontii, Celtis reticulata, Salix exigua, and Ostrya knowltonii. The only prevalent herbaceous species was Smilacina stellata. Many rare species were unique to these woodlands, including Carex curatorum, Calamagrostis scopulorum, Galium triflorum, Rhus glabra, and Sambucus careulea. These explain the high value for ID, 80.5%, indicating that this type is very distinctive. IH was relatively low, indicating some site to site variation. Much of this may result from two factors, inclusion of the Clearwater Canyon plot, which differs in being dominated by Ostrya knowtonii and lacking Parthenocissus, and a relatively high beta diversity in the herbaceous layer. In this latter respect relict woodlands are similar to hanging gardens, which also show high beta diversity. More sampling of this type, and correlations with environment, might provide clues for the high beta diversity. Although species richness was not particularly high, relict woodlands were the richest type in woody species, with 17. If plots sampled in 1991 are included (Spence 1991), several additional woody species can be added to this type. Diversity and evenness values were also high.

Relict woodlands are often associated with hanging gardens in alcoves. The woody vegetation on many wet detritus slopes adjacent to gardens belonged to this type. Drier detritus slopes lacked the rich woody and herbaceous layers, and lianas, and supported predominantly Quercus gambelii. There were many similarities in the herbaceous layer of this type and hanging gardens, although strict garden specialists were generally rare or absent. An inspection of stand data from Spence (1991) showed that several detritus slope stands in hanging gardens in both Alcove and "Garden" canyons belonged to this type.

This vegetation type is placed under the Colorado Plateau warm-temperate riparian deciduous woodland biome in the Brown-Lowe-Pase classification. Romme (1992) described a hophornbeam - box-elder - oak woodland type from southern Capitol Reef NP, in the narrows of Hall's Creek, which is similar to the Glen Canyon NRA type. It may be restricted to the Colorado Plateau along the Colorado River. Woodbury et al. (1959) reported mixed deciduous woodland in areas now drowned by Lake Powell. At least one woody species they reported, chokecherry, Prunus virginiana, has not been collected since.

3. Relict Pseudotsuga menziesii-Acer glabrum forest (Table 8; plots = UMC2, UMC3, UMC4).

This type comprised three plots in the stand of Psuedotsuga menziesii at the head of Miller's Creek. It is considered a riparian type because of the presence of a stream in the grove. The site is in a north facing alcove at a relatively high elevation of 1760 m. Diversity, evenness and richness were low in this type. Prevalent species included P. menziesii (also modal), Acer glabrum (also modal), Smilacina stellata, Ostrya knowltonii, Habenaria zothecina, and Mahonia repens. Structurally, the vegetation consisted of a tall closed canopy (20-30 m) of P. menziesii, a low tree canopy (3-7 m) of Acer glabrum and Ostrya knowltonii, and a sparse herbaceous layer. Shade was very dense under the tree canopy.

This type is not closely related to other riparian communities in Glen Canyon NRA. It is a relictual montane stand that represents a type of riparian woodland that was probably more widespread during the Pleistocene in the region

(Spence 1992c). This hypothesis is supported by fossils of P. menziesii and A. glabrum which have been recovered together from alcove sites in the Forty Mile-Willow drainage, dated at ca. 12,000 BP (Agenbroad et al. 1990). Padgett et al. (1989) describe conifer-dominated riparian communities from higher elevations in which P. menziesii occurs. None of their described community types are similar to the stand in Miller's Creek. In the Forest Service terminology this stand would be classified as a P. menziesii series, P. menziesii-Acer glabrum community type. It is classified in the Brown-Lowe-Pase system as a Colorado Plateau cold-temperate evergreen riparian forest.

4. Salix-Baccharis scrub (Table 9; plots = COW16, GHB3, HAC5, HAC6, HAC8, LCC4, LCC5, RIC3, RIC6, RIC7).

Salix-Baccharis scrub is one of the most widespread vegetation types along intermittent and permanent streams in Glen Canyon NRA. Before the construction of Glen Canyon Dam a mixed riparian scrub comprising Baccharis, Salix, and Tamarix was found along the banks of the Colorado River. The type generally occupies low terraces (2-3) just above stream beds. Where flood activity is rare, the scrub species, principally the clonal Salix exigua, invade the stream bed itself. In most canyons investigated, the riparian scrub zone was not continuous, and in some was often poorly developed. It was generally rare or absent where bedrock was common, and best developed on sandy alluvial terraces.

The two most characteristic species were Salix exigua and Baccharis salicina (some may be B. emoryi, see Appendix 2). The willow was the more common of the two at most sites. Individuals of these species averaged 3 m in height, although occasionally they reached 6 m. Generally, a low herbaceous layer of Equisetum hyemale and Juncus arcticus occurred. Tamarix ramosissima was a common associate, although it rarely dominated. Saplings of Populus fremontii were occasionally present.

This type could be divided into two groups, related to terrace position. On higher infrequently flooded terraces Baccharis dominated, although S. exigua remained common. On lower sites that are probably flooded every year, S. exigua dominated, with Baccharis relatively uncommon. Juncus arcticus and Equisetum hyemale were abundant in this second group, and generally absent from the higher terraces. Tamarix was scattered throughout both groups.

Species richness and diversity were low. However, a variety of herbaceous species occurred unpredictably in low abundances, and produced some floristic diversity from site to site (IH=54.4%).

Although widespread, this riparian scrub type has not been adequately described on the Colorado Plateau. Salix exigua is especially widespread, and vegetation dominated by this species has been described in Arizona, New Mexico, and Utah (Padgett et al. 1989; Szaro 1989). Other studies discussing this type include Loope (1977) and Irvine and West (1979).

5. Relict Betula-Solidago scrub (Table 10; plots = COW3, COW7, COW8).

An unusual variant of riparian scrub occurs at the upper end of the south fork of Cow Canyon. On intermediate terraces along the permanent stream a scrub dominated by Betula occidentalis exists. Other prevalent species included Solidago occidentalis, a variety of other forb and shrub species, and Rhamnus betulifolia. Sites were shaded for much of the day. Both Salix exigua and the rare S. lutea occurred in low amounts.

Several montane relicts have been found along this stretch of Cow Canyon, including Mahonia repens, Sambucus caerulea, and Viola cf. nephrophylla. Relict mixed deciduous woodlands and hanging gardens are common, and harbor many unusual species. This scrub type is considered relict because Betula occidentalis is found typically at much higher elevations in this area, generally along montane streams above 2000 m. However, the type is not very distinctive (ID = 15.7%), and in the absence of the Betula the sites would be classified in the Salix-Baccharis scrub type. Interestingly, Padgett et al. (1989) have described high elevation B. occidentalis community types that share several species with the Cow Canyon sites, including Salix lutea, S. exigua, Smilacina stellata, and Equisetum hyemale. Scrub with Betula has been reported from Betatakin Canyon in Navajo National Monument (Brotherson et al. 1985).

6. Tessaria scrub (plots = LCC1).

This type is based on a single terrace plot in Last Chance Creek. Arrowweed, Tessaria sericea, dominated the site, along with scattered Fallugia paradoxa, Baccharis salicina, and Tamarix ramosissima. A low, sparse forb and subshrub layer with Bromus tectorum and Gutierrezia microcephala occurred. Arrowweed occurs throughout Glen Canyon NRA in riparian zones, but is usually rare. This type is described primarily because Tessaria is one of the principal riparian scrub species along the Colorado River from Glen Canyon Dam downstream. The reason for its failure to dominate or at least occur more commonly in most canyons around Lake Powell is not known.

7. Low elevation mixed shrub (plots = TMC1).

This shrub type is based on a single plot in upper Two Mile Canyon. A variety of shrub species occurs, with Fallugia paradoxa and Chrysothamnus nauseosus most common. Psoralidium lanceolatum and Lepidium montanum were common forbs. The site is along an ephemeral streambed, and is probably characteristic of many ephemeral streams in Glen Canyon NRA. Tuhy and MacMahon (1988) briefly mention this type, and point out that beta diversity is very high. Romme (1992) describes similar types (dry and mesic canyon bottom communities) from Capitol

Reef National Park.

8. Salix-Panicum scrub (Table 11; plots = HAC4a, HAC4b, HAC4c).

Tinajas are large waterpockets that occur in slickrock along incipient drainages that channel precipitation. They differ from other waterpockets by having more or less permanent water and supporting dense riparian vegetation (Spence and Henderson 1992). Rock pools along main ephemeral drainages may be vegetationally similar, but destructive flash floods are probably more frequent than in sites on slickrock. The best develped tinajas are found on Navajo sandstone, and are especially common along the Waterpocket Fold. Disturbance is high, and flood events probably damage vegetation on a regular basis, and may even scour out tinajas, at least occasionally. Size varies from a few square meters to about 100 square meters. Only three tinajas were sampled during 1992, all in the Waterpocket Fold west of lower Hall's Creek.

Prevalent species included Salix goodingii, Artemisia ludoviciana, Panicum oligosanthes, Schizachyrium scoparium, and Juncus tenuis. Tinajas generally exhibit high beta diversity, and the three surveyed sites differed floristically in several respects from those found further north (Spence and Henderson 1992). However, S. goodingii is almost always present in larger and deeper tinajas. A constant, defining, herbaceous species is Panicum oligosanthes, which is widespread in tinajas along the Waterpocket Fold. Spence and Henderson (1992) found with a larger sample of tinajas that vegetation patterns were related to pool depth and protection (shading) from the sun.

Tinaja vegetation was fairly distinctive (ID = 68.0%), and exhibited high richness, diversity, and homogeneity. Tinajas are interesting communities that deserve more attention and study than recieved to date. Other than Romme (1992) and Spence and Henderson (1992), no studies of tinaja vegetation are known from the Colorado Plateau.

9. Toxicodendron scrub (plots = ACL3, HAC3).

Two plots were dominated by the physiognomically highly distinctive poison ivy, Toxicodendron rydbergii. Although poison ivy is a shrub, its broad leaves and generally low stature suggests it may be ecologically similar to perennial dicot forbs. The two sites were hard to characterize, as one (HAC3) was in a deeply shaded stream level alcove in a small side canyon of Hall's Creek, and the second (ALC3) was in an exposed site on an intermediate terrace along the stream in Alcove Canyon. Other sites dominated by poison ivy occur in Glen Canyon NRA, hence this type is tentatively recognized. Most sites were, like HAC3, found in protected shaded alcoves, often associated with hanging gardens and springs.

Diversity, richness, and evenness were all relatively low. Toxicodendron was the only species common to both sites. Other sites investigated suggested that Acer negundo and Equisetum hyemale would become prevalent species with more plots. Sites were generally well watered, but apparently not flood prone. No other studies have described a Toxicodendron type from the Colorado Plateau.

10. High elevation mixed shrub (plots = UMC1).

An intermittent rocky stream channel extended downslope from the P. menziesii tree stand in upper Miller's Creek which was characterized by a mixture of deciduous shrubs, including Amelanchier utahensis, Chrysothamnus linifolius, Holodiscus dumosus, Ostrya knowltonii, Quercus gambelii, Rhus aromatica, and Sheperdia rotundifolia. This type of vegetation is found at moderate elevations (1600-2000 m) at the bases of cliffs, in defiles, and dry (laregely ephemeral) rocky shaded stream channels. It is common in such sites along the Waterpocket Fold through Capitol Reef National Park (Spence, personal observations), although without Ostrya knowltonii, which extends no further north than Hall's Creek

Narrows. This type is probably rare within Glen Canyon NRA, as few parts of the park reach the necessary elevations. It is classified as Colorado Plateau cold-temperate submontane riparian scrub in the Brown-Lowe-Pase system.

11. Equisetum-Solidago marshland (Table 12; plots = ALC2, ALC4, ALC5, ALC6, ALC7, BOC1, RIC5, SLC1).

This type was found in broader stretches of several canyons, where stream meandering and deep alluvium occurred. It was best developed on low flood plains, and was often associated with beaver dams. The type was most common in Alcove, Bowns, and Slickrock canyons, where it formed extensive stretches along stream channels.

All sites consisted of a mixture of *Equisetum hyemale*, *Solidago* (mostly *S. canadensis*), and *Juncus arcticus*. Of these, the *Equisetum* was generally the most common. Other prevalent species included *Muhlenbergia asperifolia*, *Bromus tectorum*, and *Elymus canadensis*. The only prevalent woody species was *Baccharis salicina*, which was often found in small numbers as saplings or young individuals. Two phases could be distinguished, one consisting of dense stands of *E. hyemale* with abundant *Juncus arcticus*, and the other with abundant *Solidago* and *J. arcticus*, and less *E. hyemale*. One site was dominated by *Aster glaucodes*, although the prevalent species were also present.

Species richness, diversity and evenness were all low. There was relatively little site to site variation (IH = 61.7%), and the type was moderately distinctive (ID = 68.7%). Structurally, the vegetation consisted of a relatively dense monolayer of *Equisetum* and forbs, generally less than 2 m tall. There was strong seasonal change in this type. In early season, the forbs, especially *Solidago*, were just starting growth, and *Equisetum* was most conspicuous. By late summer the *Solidago* had reached maturity and was flowering, and often was the most conspicuous component.

This mixed graminoid-forb type is unusual in several respects. Although classified under marshland because of the presence of Equisetum, Juncus, and Muhlenbergia, it is similar physiognomically to upland forbland communities. It also occurs on sites that should generally support riparian scrub rather than herbaceous vegetation. There are several possible explanations for why this type occurs where it does. Deep alluvium, as in Bowns Canyon, was often present, and some aspect of soil chemistry, water holding properties, or alluvial-stream dynamics could explain its presence. Sites may be flooded by meltwater in spring long enough to prevent the establishment of woody species. Also, tall herbaceous vegetation is more prone to damage by flood activity, especially strong floods that could uproot individuals and completely remove the plant cover. Several of the best developed stands were associated with beaver dams and other barriers. Such barriers would increase the likelihood of standing water in early season, or alternatively may prevent damage by dissapating destructive floods. If standing water and a high water table is the principal controlling factor, barriers would be expected to occur downstream from Equisetum-Solidago stands, but if reduction of damaging floods is the primary factor, barriers should be found upstream of stands. Future work, mapping stands in relation to alluvium, stream characteristics, and barriers, will be necessary to test these hypotheses.

The Equisetum-Solidago marshland type has not been previously reported from the Colorado Plateau. It is classified as a Colorado Plateau warm-temperate marshland in the Brown-Lowe-Pase classification.

12. Oxytenia-Panicum marshland (Table 13; plots = ALC8, ALC9, COW9).

This type comprised sites along stream channels without extensive flooding and dominated by copperweed, Oxytenia acerosa, and several grasses, particularly

Panicum virgatum and Muhlenbergia asperifolia. Soils were shallow, and bedrock often showed at the surface. Carbonate deposits on the surface occurred at all sites, suggesting that the controlling factor might be the presence of basic carbonates and salts.

Oxytenia acerosa was the only modal species. Species richness, diversity and evenness were low, and the ID was only 14.3%. In many respects this type was very similar to the Equisetum-Solidago type, differing only in the abundance of the three most common species. Both the Muhlenbergia and Panicum were found in the Equisetum-Solidago type, although copperweed was not present. The Oxytenia-grass type was only found commonly in Alcove Canyon, although scattered patches occurred in several other canyons, particularly in Cow Canyon. Its distribution elsewhere in Glen Canyon NRA is not known. No other studies in the region have documented this type.

13. Typha marshland (plots = LCC2).

Where beaver ponds, or quiet pools along permanent streams occur, patches of Typha domingensis and T. latifolia are found. Most are small, often occurring only as a narrow fringe around the water. However, in some cases they can become quite extensive, occupying up to a hectare or more. Only one plot, in Last Chance Creek, was surveyed, but similar patches exist in most canyons with permanent water.

Sites were generally in the lowest part of stream channels, and were typically saturated most of the year, with standing water often present. A dense tall (to 3 m) stand of Typha was typical, with forbs and other monocots scattered among the cattails. The existence and distribution of most sites may be related to beaver activities. Another important factor is an absence of destructive flooding, resulting from barriers created by beaver dams. In some cases, Typha marshes can also become quite extensive in the well watered upper portions of canyons where flooding does not occur, such as in Cow, "Garden", or Bowns canyons. They are also common in some canyons below the high water level of Lake Powell, such as in Lake Canyon and lower Hall's Creek.

More work is required before this type can be characterized. Although Typha wetlands are widespread throughout western North America, they are relatively uncommon on the Colorado Plateau. No other published work has been done on these wetlands on the plateau.

14. Phragmites marshland (Table 14; plots = GHB2, RIC11, TMC3, "GAC"1=RZ4).

Reedgrass, Phragmites australis, is a vigorous clonal species, and often forms almost pure stands, varying from a few square meters up to almost a hectare in some areas. It seems to favor a high but subsurface and reliable water table, although it will tolerate some inundation. Floods probably control the species' presence along stream channels, as clones often suffer high mortality during heavy flooding (cf. Stevens and Waring 1985). This type occurred in two settings, seeps on canyon slopes well above stream channels, and stream channels in the upper ends of well watered canyons where flood activity was minimal. Of the four sites surveyed, three were on hillsides associated with seeps, and the fourth was in a stream channel. This type occurs in all canyons investigated, and is one of the more widespread types in Glen Canyon NRA.

Prevalent species, in addition to reedgrass, included Solidago occidentalis, Juncus arcticus, Elymus canadensis, and Chrysothamnus viscidiflorus. Only reedgrass was modal. Diversity, richness, and especially evenness, were all low. The type was not very distinct (ID = 25.0%) or homogeneous (IH = 47.1%). A variety of species occurred unpredictably in low abundances in reedgrass stands.

Although widespread on the Colorado Plateau, Phragmites vegetation has not bee described or classified elsewhere. This may be a result of scale, as most examples are relatively small compared to other kinds of vegetation. This type is classified as a Colorado Plateau warm-temperate marshland.

15. Eleocharis-Lobelia marshland (Table 15; plots = BOC3, LCC3, LOC4).

This type is rare within Glen Canyon NRA. It occurred on open slopes or small side drainages around seeps with permanent above-ground flows. Sites were not flood prone, and appeared to be stable. Eleocharis palustris (some may have been the related E. rostellata) dominated, forming a dense sward. A variety of other graminoid species in Carex and Juncus often occurred. In late summer Lobelia cardinalis became conspicuous. Richness was often high, and the type was relatively distinct (ID=56.1%).

Prevalent species included E. palustris, Phragmites australis, Baccharis salicina, L. cardinalis, Soliodago sparsiflora, Panicum acuminatum, and Oenothera longisissima. Structurally, the vegetation consisted of a low dense sward of monocots with scattered emergent forbs, Phragmites, and rarely shrubs. Some forb species are characteristic of hanging gardens, such as Cirsium rydbergii and S. sparsiflora.

Eleocharis communities generally occur at higher elevations in southern Utah. Padgett et al. (1989) describe a E. palustris community type from central and southeastern Utah at elevations from 2200-3000 m, which is, however, floristically very different from the Glen Canyon NRA type. The Eleocharis-Lobelia type is classified as a Colorado Plateau warm-temperate marshland.

16. Elymus elongatus marshland (plots = COW13, COW18).

Western wheatgrass is abundant in some stretches of Cow Canyon's main and northern forks, where it forms dense stands on intermediate terraces (2-3) along the stream. The species was probably introduced when cattle grazed the canyon. Two sites were surveyed in the main fork of the canyon.

Species richness and diversity were relatively high, but evenness was low, with E. elongatus dominating. A variety of other grasses and forbs occurred, and rare individuals of Baccharis salicina and Populus fremontii. It is not known if the sites will remain dominated by western wheatgrass. They may be successional to Salix-Baccharis scrub. Western wheatgrass was not seen in any other canyons surveyed.

17. Cladium californicum marshland (plots = ALC10).

Sawgrass, Cladium californicum, is a rare species found in Utah only along the Colorado and San Juan rivers in Glen Canyon NRA. Most populations have apparently been drowned by Lake Powell. Several stands of sawgrass were discovered in 1991 in Alcove and "Garden" canyons (Spence 1991). Some occurred in hanging gardens, but at least two were found along stream channels. This type is recognized despite its rarity because of its unusual composition and regional importance. The species is more common along the Colorado River through Grand Canyon NP.

Physiognomically, this type consisted of dense stands of sawgrass mixed with some Typha, Carex, Juncus, Scirpus and forbs. The investigated site (ALC10) was drier than other sites where sawgrass occurs, and may not be typical. It occurred along the margin of the stream in Alcove Canyon, in an area with shallow soils, exposed slickrock, and carbonates at the surface. Patches of the Oxytenia-grass type occurred in the vicinity. Other sites away from hanging gardens tended to be associated with smaller wet side drainages downstream from hanging gardens. No other descriptive work is known on this type from the Colorado Plateau.

18. Unclassified sites (plots = ALC1, GHB2, COW2, COW10, COW14, LWC3, RIC4, RIC8,

RIC9, RIC10).

Several plots remained unclassified by the above classification. Three different kinds of vegetation remained in this group. Two plots consisted of Quercus gambelii scrub (GHB2, LWC3), a widespread "pseudoriparian" type that occurs in most canyons around Lake Powell. One plot (RIC10), which occurred in a stream channel bedrock basin, was dominated by Salix goodingii. A riparian S. goodingii type was not erected because the species generally occurs with P. fremontii, or in tinajas, and is rarely dominant or found alone in pure stands along streams. The majority of unclassified plots consisted of a mixture of herbaceous and woody species (especially Brickellia longifolia), occupying low sites, particularly current stream channels and sites which have frequent floods. They had little in common other than low cover and topographic-terrace position. These intermittent and ephemeral floodplains and flood channels are common in Glen Canyon NRA, but will be difficult to classify by floristics because of high beta diversity.

C. Species ecology

Average abundance per terrace-topographic position was calculated for all species that occurred in 16 or more plots (Table 16). For each species, the sample size per unit is listed, and highest abundance highlighted. In cases where a plot was intermediate between two levels (eg., 2-3), it was considered to include both levels. Hence sample sizes added up to more than 80 and were higher than the number of plots a species occurred in for most species.

Most species reached peak abundance in unit 6 (alcoves and sites protected from flooding). This trend was particularly evident with woody species, except for Salix exigua which was most common on low terraces (2-3). Herbaceous species like Elymus canadensis and Equisetum hymale tended to be most abundant on lower sites closer to stream beds. No species reached peak abundance in the lowest unit (1), current stream beds.

Diversity, evenness, and richness all showed weak, nonsignificant ($p>0.05$) declines with decreasing flood intensity, as determined by terrace position. The most diverse communities tended to be in stream channels or low terraces, while the least diverse tended to be on higher terraces. Protected alcoves generally showed high diversity because of the relict mixed deciduous woodland type. There was a great deal of variability in the data, related to factors like vegetation type, canyon, and actual flood activity.

Table 17 summarizes data on sociability and reproduction for prevalent species in the four best represented types. Sociability was averaged for each species across all the plots it occurred in within a type, while reproduction was the per cent of plots a species occurred in where evidence of flowering and/or fruiting was seen. Reproduction was not determined for P. fremontii, an early flowerer (April), as evidence of reproduction was often gone by July and August.

Most species tended to be slightly clumped in dispersion within plots, especially among tree species. The major exception was Equisetum hyemale, which displayed relatively more uniform dispersions in three of the four types. There was a tendency for species to be more uniformly dispersed in types where they were modal or most abundant, eg., Equisetum and Juncus in the Equisetum-Solidago type, Salix exigua and Baccharis salicina in the Salix-Baccharis type.

Sexual reproduction was somewhat erratic, but generally high for most species. Exceptions included the mostly clonal Salix exigua, dioecious Distichlis spicata, and a variety of species in the relict mixed deciduous woodland type.

D. Canyon rankings

The canyons surveyed during 1992 were ranked according to various criteria, including presence of unusual and rare species, numbers of vegetation types, disturbance, water resources, and suitability for continued NRPP ecosystem research (Table 18).

Water flows were permanent in Good Hope Bay, Bowns Canyon, lower Wilson's Creek, and parts of Cow, Long, and Slickrock canyons. Most canyons supported some flows in some stretches (intermittent), but Last Chance Creek and Two Mile Canyon were predominantly dry.

Although many canyons were grazed prior to Lake Powell, only three (Last Chance Creek, Lake Canyon, and Long Canyon) are currently affected. In Long Canyon two horses were seen in September 1992. They have caused extensive damage in most of the riparian zone and benches in the canyon. Beaver activity was seen in several canyons.

Cow Canyon had the richest flora and the largest number of unusual or relict species (cf. Spence 1992c). Lower Long Canyon was not investigated, but had numerous hanging gardens and seeps which might harbor interesting species. Hanging gardens were most diverse in "Garden", Ribbon, and Cow canyons. The most distinctive gardens were found in Last Chance Creek. The bird fauna was richest in Alcove, Cow, Long and lower Wilson's Creek (cf. Spence 1992d). Good habitat for frogs and toads was seen in Bowns, Cow, and Ribbon canyons, and especially lower Wilson's Creek. Leopard frogs were seen in all these canyons.

Suitability for vegetation research was based on the diversity and extent of riparian vegetation types in each canyon, and complexity of landforms. Although Alcove Canyon was highly diverse, its small size limits the development of some vegetation, particularly Populus fremontii and riparian scrub types. Last Chance Creek is ranked high because it is a classic ephemeral to intermittent stream with well developed riparian scrub showing zonation related to flood intensities. Overall, the upper ends of Bowns, Cow, and Long canyons supported the most diverse and extensive riparian communities and complex topography. Lower Wilson's Creek supported the best example of P. fremontii woodland seen in the 1992 survey. Apparently, this site has never been grazed by livestock (Tuhy and MacMahon 1988; Spence, personal observations).

Suitability for hydrology studies was based on stream flows, with permanent zones ranked highest. Geomorphology denotes the complexity and extent of landforms, particularly alluvial deposits, beaver dams, and floodplains. Finally, those canyons with extensive alluvium, and well developed patches of relict mixed deciduous woodland, were ranked highest for paleoecology studies. Some work has already been done in Bowns and Cow canyons (Agenbroad et al. 1990). In addition to these two, some alluvial deposits and well developed relict woodland was noted in "Garden" and Ribbon canyons. Lake Canyon was not investigated, but has high potential for paleoecology work, based on the deep alluvial and lacustrine sediments in the canyon. However, relict woodland was not seen in this canyon. Suitability for vegetation research is low in this canyon because of current heavy livestock grazing. The presence of potentially deep and stable alluvium and soils around springs in Good Hope Bay suggests some potential for paleoecological studies.

These canyons do not necessarily represent the best sites for research in Glen Canyon NRA. Several canyons in the Escalante drianage, including Coyote, Choprock, Fortymile-Willow, and Scorpion, need to be investigated as well, particularly for vegetation studies. Preliminary paleoecology work in Fortymile-Willow has already yielded spectacular results (Agenbroad et al. 1990).

5. DISCUSSION

Virtually nothing was known about the riparian vegetation along the

Colorado River through Glen Canyon prior to construction of the dam. Woodbury et al. (1959) reported that mixed riparian scrub, with Baccharis, Salix, and Tamarix, was the most widespread riparian type along the river. In side canyons and at their mouths patches of Populus fremontii and mixed deciduous woodland were found. Other than brief floristic surveys in the 1980's by Welsh (1984) and Tuhy and MacMahon (1988), the vegetation of many of the side canyons around Lake Powell has never been studied.

Many of the canyons investigated in 1992 were probably inaccessible prior to the lake ("hanging" canyons), due to the presence of pour offs, now flooded, in their channels. This is especially likely with canyons such as Alcove, "Garden", Bowns, Ribbon, and Slickrock. The presence of Lake Powell has had profound implications for riparian vegetation in many of these originally inacessable canyons, as many have been colonized in the last 20-30 years, probably for the first time, by beaver.

Because many canyons in Glen Canyon NRA have not yet been surveyed, the classification presented in this report should be considered very preliminary. Some types represented by many plots, such as P. fremontii woodland, are likely to be retained, but some types poorly represented in the data set may require extensive modification and reclassification with additional work. Also, additional types may be discovered as more canyons are surveyed. These vegetation types are best considered idealized "types", or "nodes", around which vegetational variation occurs. Vegetation similar to an idealized plot, based on prevalent and modal species, probably does not exist. Rather, these idealized types are class contructs that comprise a variety of similar vegetation which share one or more of a set of diagnostic or defining species.

Several of the types that were recognized have not been reported elsewhere in the region. These include the Toxicodendron scrub, Equisetum-Solidago marshland, Oxytenia-Panicum marshland, and Cladium marshland. All of these are best represented in the well watered, "hanging" canyons, including Alcove, "Garden", Bowns, Slickrock, and Ribbon. Many are rare, often represented in only one or a few canyons, and are small in extent. Other vegetation types have been previously described, and are widespread in the region. Many of these types occur throughout Glen Canyon NRA where permanent or intermittent riparian zones are found. These include the P. fremontii woodland, Salix-Baccharis scrub, Phragmites marshland, Typha marshland, and relict mixed deciduous woodland. Others, such as Pseudotsuga-Acer forest, Eleocharis marshland, or relict Betula scrub, are more common at higher elevations, and are represented in Glen Canyon NRA as restricted relict patches which have suffered extensive extinction and modification compared to typical higher elevation stands.

Correlations between vegetation and site physical variables were evident for several types. Perhaps the single most important variable was topographic position (terrace, alcove, stream channel, etc.), which integrates a variety of factors, including water table depth, flood intensity and frequency, microclimate, and substrate characteristics. Most regional riparian vegetation studies have indicated that flooding is the most important single variable influencing vegetation patterns. Topographic, especially terrace, position, is not always a good indicator of flood frequency and intensity, however. Stream barriers and canyon length and width can strongly influence flood activity. Beaver dams in particular can reduce downstream flooding, although their presence can also increase the intensity of a flood if dam failure occurs. Flood activity can be minimal in canyons lacking the necessary length and width to capture and funnel extensive runoff.

Relict mixed deciduous woodland and stands of older P. fremontii tended to occur in alcoves or high terraces where flood activity was minimal. Scrub types were often on medium-height terraces where some flooding occurred, but probably not every year. Marshland types were generally found either in low sites with a high water table, or where springs emerged at the surface, and in both cases where flood activity was minimal.

Other features that could be related to vegetation included substrate type and texture, canyon aspect, and soil chemistry. For example, the east-west orientation of Cow Canyon may have been partly responsible for the presence of numerous relict species, the relict Betula-Solidago scrub, and well developed relict mixed deciduous woodland. The presence of Oxytenia acerosa and Distichlis spicata was often correlated with surface crusts of salts.

It may be possible to predict the type of vegetation a site will support by a set of physical-environmental factors. A simple predictive model can be developed in the form of

$$\text{vegetation type} = \text{function}(A, B, C, D, E, F, G)$$

where:

A = topographic position (alcove, terrace, channel, etc)

B = terrace height (if A = terrace)

C = depth to water table

D = substrate type and texture (slickrock, sand, organic soil, etc.)

E = soil chemistry (salts)

F = site or canyon aspect (stream bearing)

G = recent flood activity

Testing of this model could provide clues to the repeatability of vegetation patterns and responses to the selected environmental factors. Failure to predict the vegetation type a site should support could lead to the development of alternative hypotheses, based on competition, other forms of disturbance, or chance colonization or survival events. Such a model, in conjunction with stand data, could also be useful in determining flood frequency along riparian zones.

Correlations of species richness, diversity and evenness with environmental features like elevation, flood activity, and stream bearing, are often weak in riparian vegetation (Baker 1989a,b; Szaro 1990). Most studies, however, have noted a positive relationship between species diversity and flooding, with high diversity in sites that are frequently flooded. In this study, weak correlations were found between all three species variables and terrace-topographic position. There was a tendency, in particular, for diversity to be higher in stream beds and low terraces compared with protected sites such as alcoves. The same trends, although weaker, were found for evenness and richness. These trends are supported in part by general theoretical considerations on the relationships among diversity, competition, and environment (eg., Huston 1979; White 1979). Where disturbance is minimal competition should be more intense, leading in particular to lowered evenness (dominance by one or a few species). However, species diversity and richness should be lower in highly disturbed sites compared to sites where disturbance is less frequent or intense. This was not the case in this study, nor in other regional riparian studies (Baker 1989a; Szaro 1990).

The riparian vegetation in many canyons was distinctly patchy, a feature that other southwestern studies have noted (cf. Szaro 1990). The upper ends of canyons with perennial flows, including those in Alcove, Bowns, Cow, and Ribbon, were especially distinctive in this respect. These upper canyons consisted of mosaics of relict woodland, P. fremontii stands, Typha and Phragmites patches, Toxicodendron scrub, and Salix-Baccharis scrub. C. Wood (personal communication) suggests that the complex and patchy nature of the riparian vegetation in these upper canyon settings results from a lack of disturbance, especially by flooding, and by the abundant available water. The lack of disturbance would lead to competitive interactions and sorting out of species and vegetation patches along subtle but stable environmental gradients. Support for this hypothesis includes the lower overall values of evenness, diversity and richness in protected sites, and the presence of numerous relict species that have been able to persist in the absence of disturbance. Many of these relicts rarely reproduce sexually, and would be expected to be especially vulnerable to high levels of disturbance.

A subsidiary hypothesis to explain the patchiness and overall lack of predictability of vegetation in these upper canyon sites can be developed based on flood frequency and chance survival. Past flood activity may have controlled the distribution of many species in parts of these riparian zones. However, as flooding is highly variable in time and space, differential survival of individuals or clones of particular species would have occurred. With subsequent cessation or reduction of flooding, survivors may have been at a competitive advantage compared to species dispersing into the site by seed. This may have led to site tenacity, ie., a species that survived a flood event would be more likely to reoccupy and dominate the site than a species dispersing into it. Strongly clonal, rapidly growing herbaceous species, such as *Phragmites* and *Typha*, in particular, would be expected to produce mosaics of different patches related to postflood clonal survival, with site tenacity (competitive ability) controlled by differences in water tables and substrate. This hypothesis may explain the mosaic of different vegetation patches in the channels of many of these upper canyon zones. Collection of field data on the ability to survive flooding and experiments on the growth rates of selected species could provide tests of this hypothesis.

A variety of other hypotheses were considered and developed during the course of field work. The principal ones are listed in Table 19. In addition to future work testing these hypotheses, more survey work and vegetation description should be done to provide clearer results on the relationships between environment and species richness, diversity and evenness. Finally, the riparian vegetation examined in this report is placed in context in the overall classification of wetlands vegetation in Glen Canyon NRA in Table 20. This table highlights those types of wetland vegetation that have been studied to date, and those which remain unstudied.

6. RECOMMENDATIONS

Canyon selection

Among canyons surveyed during 1992, several stand out as being most important, by virtue of well developed riparian vegetation. These are Alcove, Bowns, Cow, Long and Ribbon canyons, and lower Hall's and Wilson's creeks. Of these, only Alcove and lower Wilson's appear to have been never grazed, apparently supporting pristine riparian communities. However, the vegetation in Alcove Canyon appears to have changed dramatically at some point in the recent past (see report on this canyon in Appendix 4). This leaves only lower Wilson's Creek as being both undisturbed and lacking any obvious sign of recent vegetation change. Among the other five, Long Canyon is currently affected by horses, Hall's Creek was grazed up to 1986, and Bowns, Cow and Ribbon have not been grazed since the 1960's. Beaver are found in all except possibly Long Canyon.

Bowns, Cow and Long canyons are all centered on the east side of the Escalante River and west of the lower Waterpocket Fold. They are similar geologically, but differ substantially in geomorphology and water flows. The upper ends of Bowns and Cow canyons support perennial streams, while the situation in Long Canyon is reversed, with perennial flows only in the lower part, and none in the upper end. This upper end of Long Canyon is unusual because it supports the only P. fremontii gallery forest seen in the 1992 survey other than lower Wilson's Creek. Extensive alluvial deposits occur in Bowns Canyon, while more limited deposits are found in upper Cow and Long canyons. Cow Canyon is very long, and access to perennial stream stretches and associated vegetation is more difficult than similar sites in Bowns Canyon. Of these three, Bowns Canyon is probably the best candidate for NRPP work on riparian vegetation structure, woody species dynamics, and hydrology. It also has an excellent paleoecological record, and good habitat for amphibians. The bird fauna was not surveyed, but is probably similar to that in Long Canyon. The one drawback to Bowns is that its patches of relict mixed deciduous woodland are less extensive than in Cow or Long canyons.

Hall's Creek, although recovering from past grazing, and supporting a wide diversity of vegetation, is excluded because of the additional factor of grazing. Ribbon Canyon supports good stands of relict mixed deciduous woodland, but has little P. fremontii woodland and only intermittent and poorly developed riparian scrub.

Because of questions concerning resources, available personnel, and the amount of funding available for ecosystem work during 1993-5, the suggested canyons are ranked from highest potential to lowest potential. This way, a cut off level can be applied anywhere along this ranking:

1. lower Wilson's Creek
2. Bowns Canyon

3-4. Canyons to be selected from among Fourtymile-Willow, Scorpion, etc.

5. Cow Canyon

6. Ribbon Canyon

7. Alcove Canyon

Among canyons not visited during the 1992 survey, several in the Escalante River drainage have good potential for riparian ecosystems research. Of these, Coyote Canyon is a heavily used recreational area. Other similar canyons on the west side of the river include the Fourtymile-Willow, Scorpion, Fools, and Davis drainages. All are visited by recreationists to some extent but not as much as Coyote Gulch. At least one of these should be considered as a principal site for future work. Inspection of maps suggests that either upper Fools Canyon or parts of Scorpion Gulch show particular promise.

2. Future work

A variety of work on the riparian vegetation in the side canyons of Lake Powell can be intitiated or continued into 1993 and beyond. This work can be grouped into two kinds; additional survey work, and detailed site work.

The classification produced in this study should be considered a hypothesis that requires testing. This can be done through surveys of more plots. Surveys of all vegetation types should be continued, but especially important are those, like _Typha_ and _Phragmites_ marshland or _Toxicodendron_ scrub, that are represented by only a few plots in the current data base. In addition, survey work in canyons not studied in 1992 (see Table 2) should be completed before the riparian vegetation classification is finalized. The habitats and distribution of important taxa where identification problems occurred, especially between _Baccharis emoryi_-_B. salicina_, and _Solidago canadensis_-_S. occidentalis_, needs to be explored, as these species pairs may differ substantially in ecology. Finally, photographic documentation of a variety of sites for each finalized vegetation type should be prepared.

One goal of the 1992 survey work was to select sites for detailed work on ecosystem attributes of riparian vegetation, to include woody species stand structure and dynamics, flood regimes and vegetation composition, and topographic and geomorphological control on the distribution of vegetation and species. Possible approaches and topics are listed below as a preliminary guide to future work. Detailed work on permanent plots in selected canyons could include the following:

1. The stand structure, regeneration, dynamics, and environment of the relict mixed deciduous woodland.

2. Dynamics and composition of woody riparian scrub, concentrating on Baccharis, Populus fremontii, Salix exigua, S. goodingii, and Tamarix ramosissima, in relation to flood activity and terrace position.

3. Structure and regeneration in older stands of P. fremontii woodland, and relationships to flood activity and topography.

4. The relationship between canyon/channel geomorphology, beaver dams, flooding, and distribution and composition of marshland types, concentrating on the Equisetum-Solidago, Phragmites, and Typha types.

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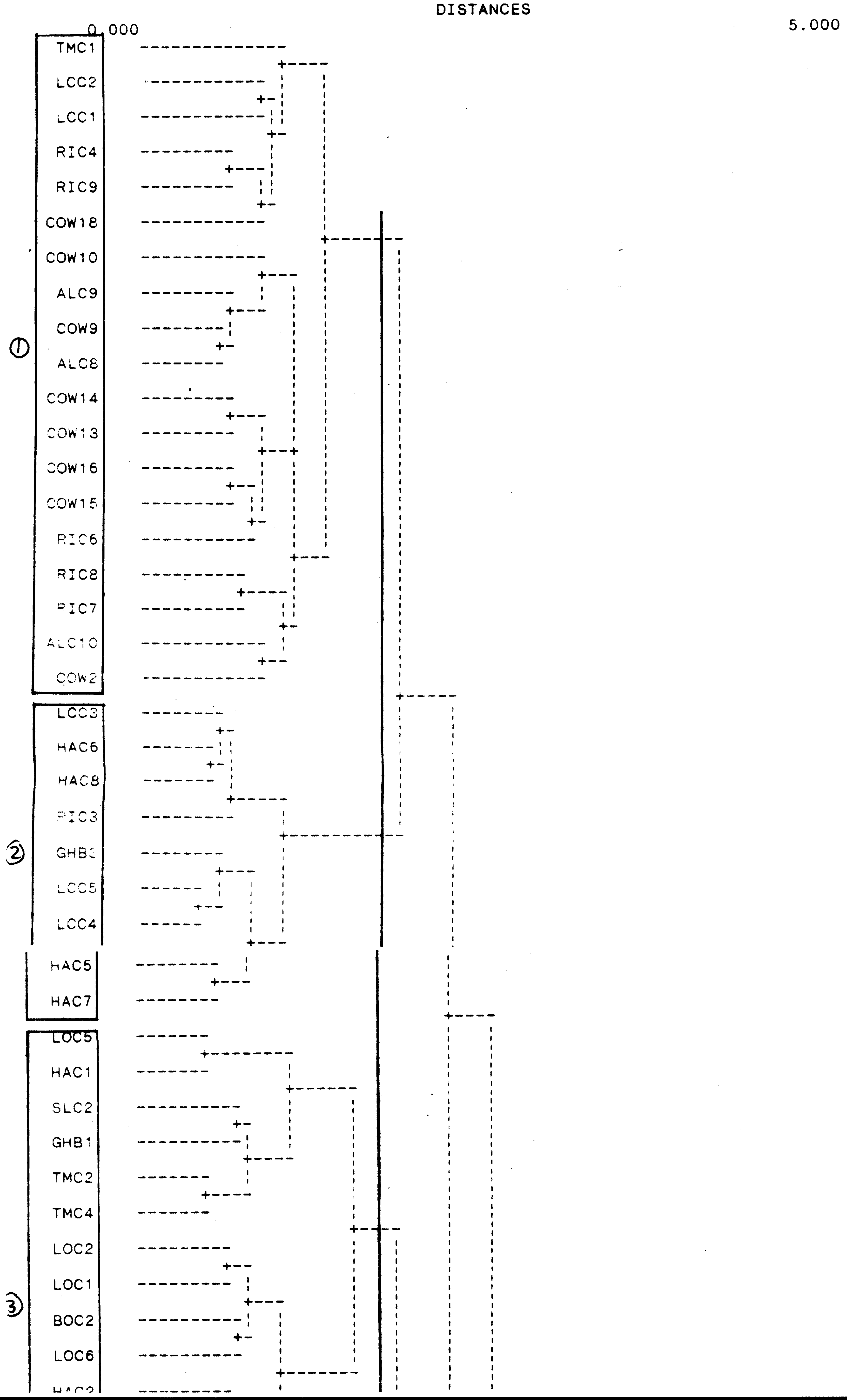
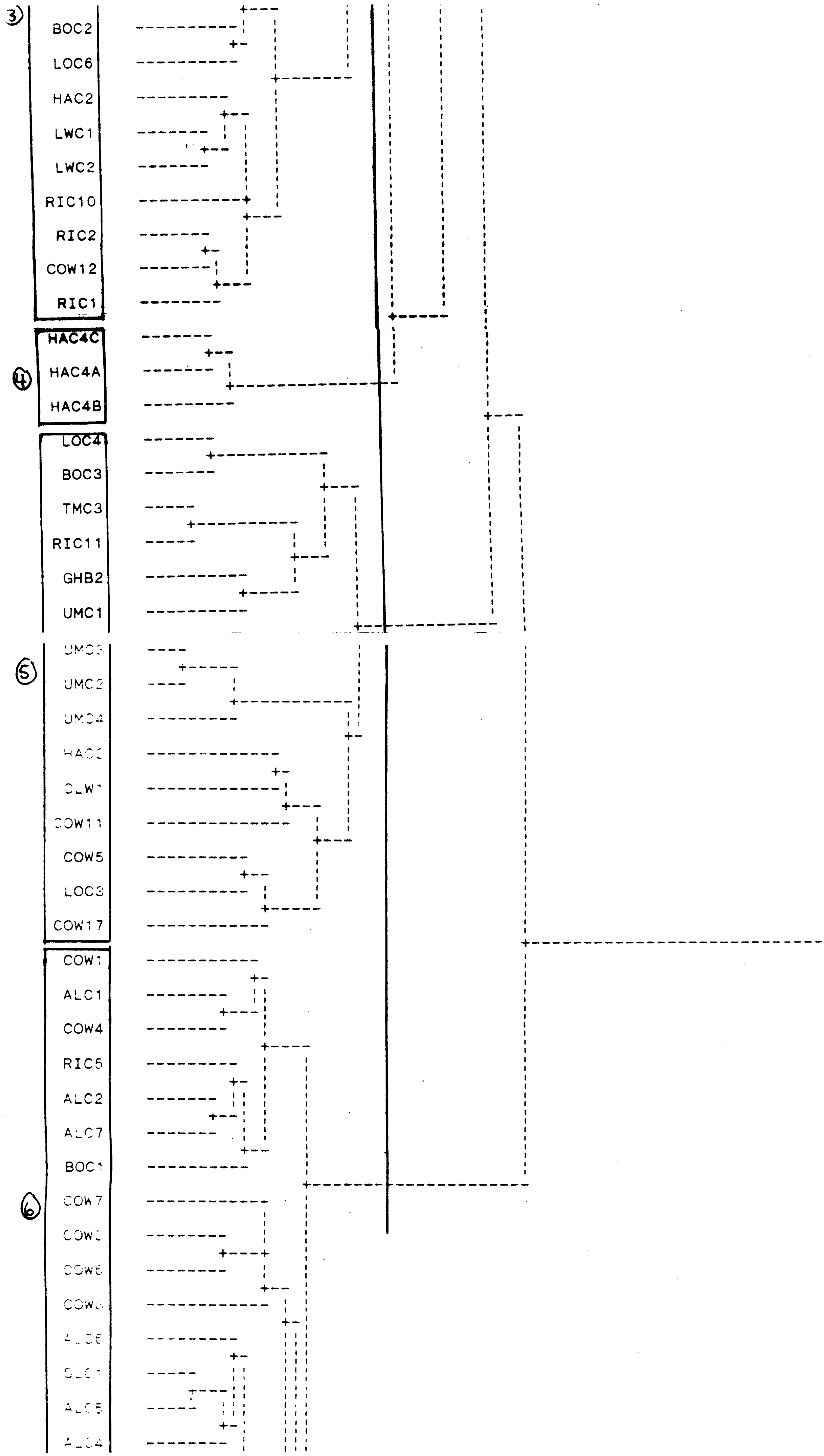
TREE DIAGRAM

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TMC3
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UMC1
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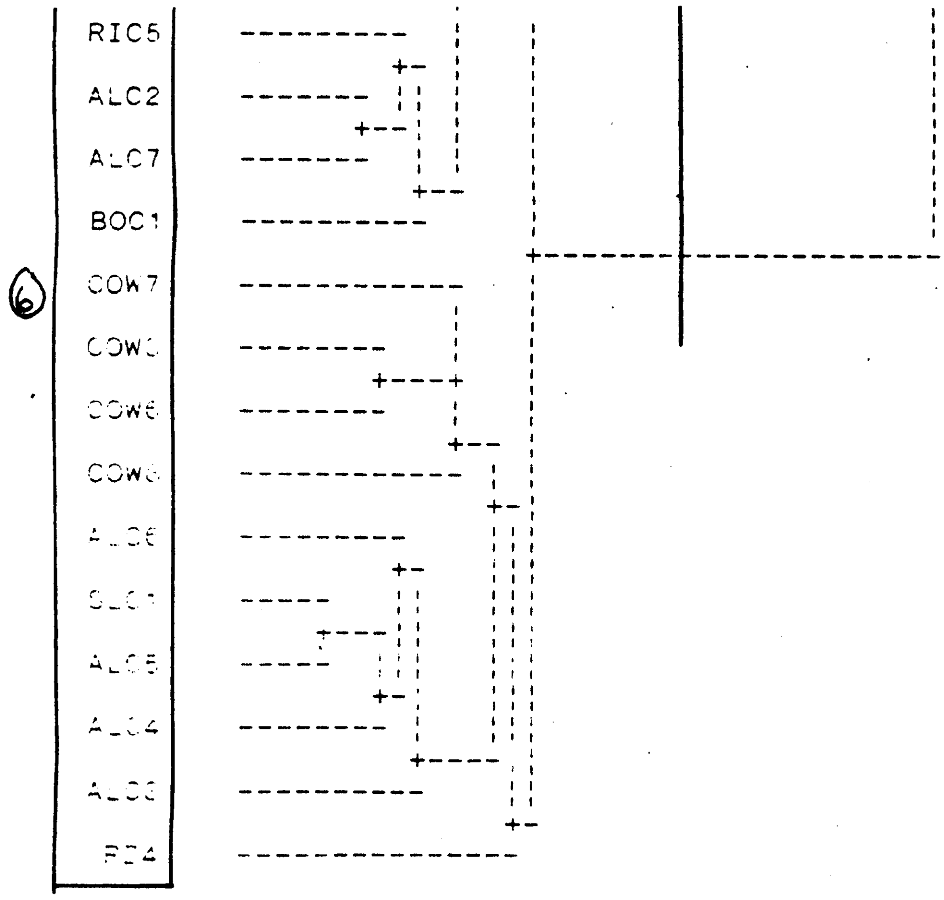

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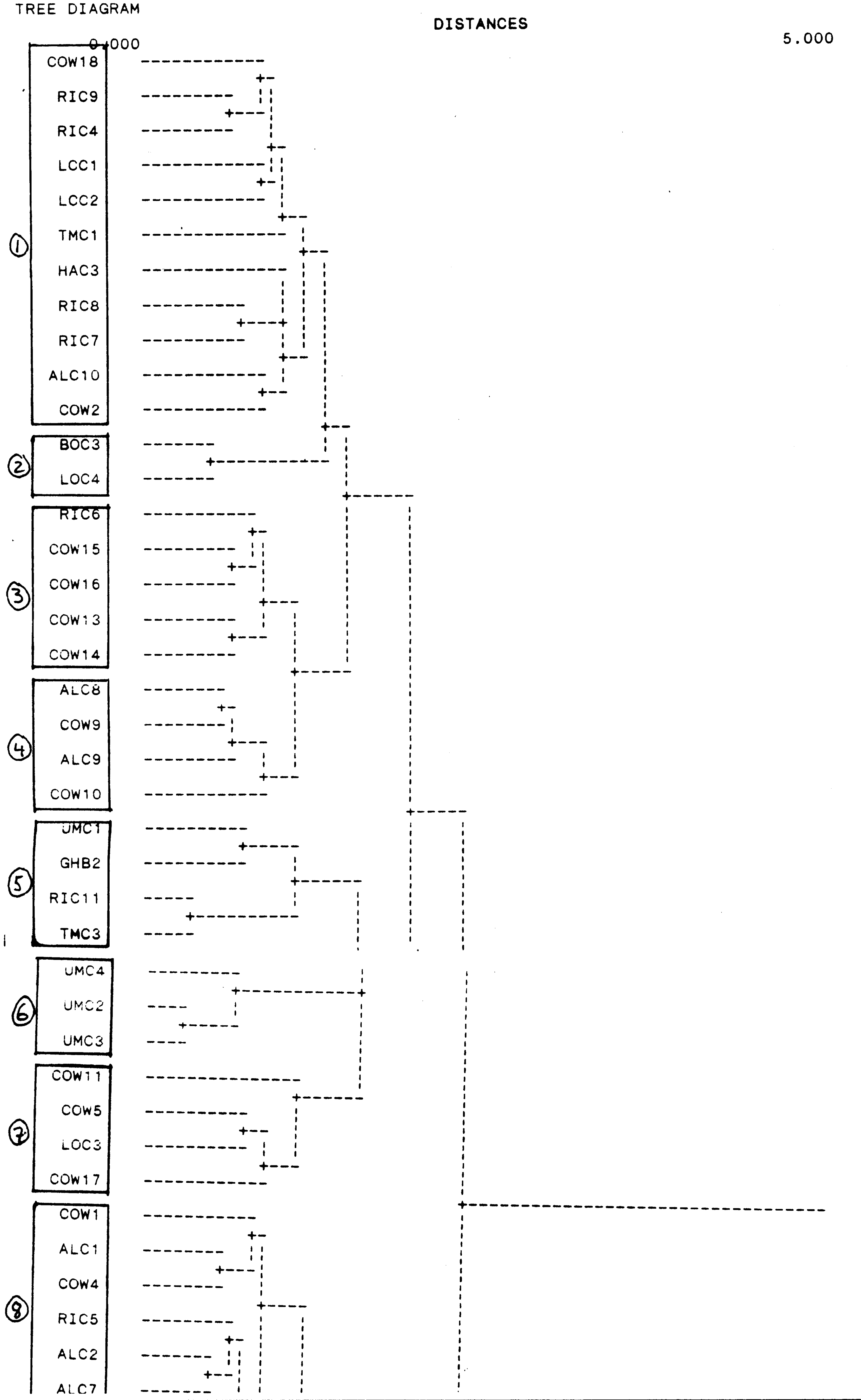
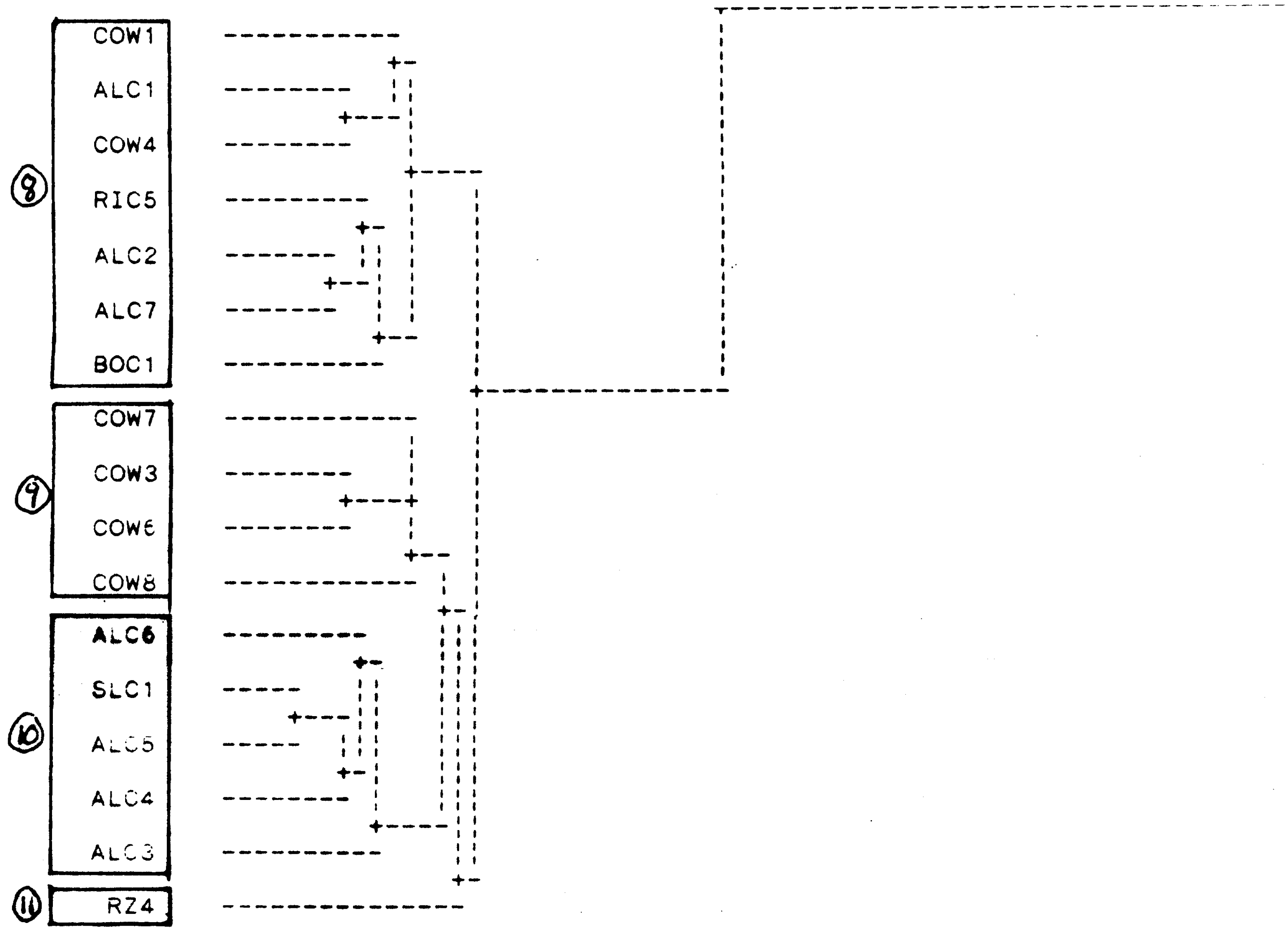
TREE DIAGRAM

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8. TABLES

Table 1. A brief and subjective topographic-vegetation classification of wetland vegetation with reference to the Colorado Plateau below 2000 m. Genera characteristic of sites on the plateau are included.

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1. MARSHLAND: permanently saturated flat low lying sites with high water table or periodic surface water and organic rich soils dominated by herbaceous monocots. Disturbance low. Characteristic genera: Carex, Equisetum, Juncus, Scirpus, Typha.

2. RIPARIAN: seasonally to permanently saturated stream and river margins with high water table, soils variable, sometimes absent, vegetation variable, often woody. Disturbance high. Characteristic genera: Baccharis, Equisetum, Juncus, Populus, Salix, Tamarix.

3. HANGING GARDEN-SPRING: permanently to seasonally saturated sites perched above low lying water table, spring-fed, with little soil development, usually in alcoves, vegetation predominantly herbaceous. Disturbance variable, low to high. Characteristic genera: Adiantum, Calamagrostis, Carex, Eleocharis, Mimulus, Phragmites, Primula.

4. STRAND: permanently to seasonally saturated recent deposits (eg., sand bars) or rock surfaces along rivers and fluctuating lakeshores, no soil development, water table high, periodically flooded, vegetation very sparse and open, woody and herbaceous. Disturbance high. Characteristic genera: Cyperus, Echinochloa, Elymus, Tamarix.

5. LAKE: still or slowly moving water, generally organic soil present, vegetation herbaceous, often floating on water surface. Disturbance low. Characteristic genera: Potamogeton, Zannichellia.

6. TINAJA: permanently to mostly seasonally saturated, periodically flooded pools eroded in bedrock, organic soil often present in basin, vegetation woody and herbaceous. Disturbance high. Characteristic genera: Juncus, Panicum, Phragmites, Salix.

Table 2. Selected study sites for riparian survey and ecosystem NRPP project. The dates visited are listed in parentheses. N is the number of surveyed plots in each canyon.

Sites visited during 1992	Code	N	Other selected sites not visited
Last Chance Creek (7/10)	LCC	5	Harris Wash
Cow Canyon (7/28-31)	COW	18	Lone Rock Canyon
Bowns Canyon (8/19)	BOC	3	Willow/Fortymile Creek
Long Canyon (9/2-4)	LOC	6	Coyote Gulch
lower Hall's Creek (6/18-19)	HAC	10	Scorpion Gulch
upper Miller's Creek (6/17, 9/23-25)	UMC	4	Choprock Canyon
Two Mile Canyon (4/22)	TMC	4	Trachyte Creek
Clearwater Canyon (8/13-14)	CLW	1	lower Dark Canyon
Good Hope Bay (4/23)	GHB	3	Slickhorn Canyon?
Lake Canyon (4/23)	LAK	1	Davis Gulch
Slickrock Canyon (8/20)	SLC	2	Four Mile Canyon
Ribbon Canyon (6/8-9)	RIC	11	Knowles Canyon
lower Wilson's Creek (5/26-27)	LWC	3	Iceberg Canyon
Alcove Canyon (5/28)	ALC	10	

Sites visited in 1991

"Garden" Canyon (GAC, 1 plot)

Table 3. Notation and definitions used in recording of plot vegetation data.

1. GROWTH FORM: Tr=tree; Sh=shrub/subshrub; Pf=perennial forb; Pg=perennial graminoid; BP=biennial-short lived perennial forb; Li=liana; Fr=fern/fern ally; Cr=cryptogam; Af=annual-biennial forb; Ag=annual-biennial graminoid.

2. ABUNDANCE: 6-D=dominant (95-100% canopy cover); 5-A=abundant (50-95% canopy cover); 4-C=common (10-50% canopy cover); 3-U=uncommon (1-10% canopy cover); 2-O=occasional (<1% canopy cover but easily found); 1-R=rare (<<1% canopy cover, difficult to find or a single individual present).

3. HEIGHT: x-y=lowest and highest average height of species in meters; 0<1=less than 1 m in height; if x=0, indicates species is regenerating at site (seedlings or vegetative growth present); if x only then a single individual present. A 0 indicates ground-hugging species less than 10 cm tall. All values rounded to nearest whole number.

4. REPRODUCTION: s=sexual reproduction occurring in current year or seen for previous year (sporangia, flowers and/or fruits present); v=extensive vegetative suckering; x=no sign of sexual reproduction.

5. SOCIABILITY: 1=individuals evenly and uniformly distributed in plot; 2=individuals distribution not discernable from random; 3=individuals tend towards clumping or patchy distribution in plot; 4=individuals exhibit extreme clumping or patchy distribution in plot; X=too rare to determine.

Table 4. Life form spectra for three groupings of the riparian flora; total, obligate riparian, and introduced.

	Life Form								
	Tr	Sh	Pf	Pg	BP	Af	Ag	Li	Fr
Total (N=206)	12	36	61	57	6	17	9	3	5
Obligate riparian (N=121)	9	16	30	43	2	6	7	3	5
Introduced (N=22)	1	1	4	6	0	6	4	0	0

Tr = tree
Sh = shrub or subshrub
Pf = perennial forb
Pg = perennial graminoid
BP = bienniel-short lived perennial forb
Af = annual forb
Ag = annual graminoid
Li = linana or vine
Fr = fern or fern ally

Table 5. A classification of riparian, seep, and tinaja vegetation based on 80 plots, informally grouped into three major physiognomic groups. N = number of plots, S = average species richness, H = Shannon diversity index, E = evenness index, IH = index of homogeneity, and ID = index of distinctiveness.

	N	S	H	E	IH	ID
A. FOREST AND WOODLAND						
1. Populus fremontii woodland	18	10.6	0.952	0.939	45.7	73.0
2. relict mixed deciduous woodland	7	11.4	1.023	0.972	52.2	80.5
3. relict Pseudotsuga menziesii-Acer glabrum forest	3	6.3	0.733	0.944	78.0	57.1
B. SCRUB						
4. Salix-Baccharis scrub	10	9.0	0.899	0.953	54.4	48.0
5. relict Betula-Solidago scrub	3	13.3	1.084	0.970	50.3	15.7
6. Tessaria scrub	1	13.0	1.082	0.971	-	-
7. low elevation mixed shrub	1	13.0	1.072	0.962	-	-
8. Salix-Panicum tinaja	3	11.7	1.027	0.955	73.7	68.0
9. Toxicodendron scrub	2	8.5	0.863	0.947	56.3	33.3
10. high elevation mixed shrub	1	10.0	0.975	0.975	-	-
C. MARSHLAND						
11. Equisetum-Solidago marshland	8	7.6	0.825	0.949	61.7	68.7
12. Oxytenia-Panicum marshland	3	10.0	0.946	0.957	72.6	14.3
13. Typha marshland	1	6.0	0.706	0.907	-	-
14. Phragmites marshland	4	8.5	0.810	0.890	47.1	25.0
15. Eleocharis-Lobelia marshland	3	10.3	0.986	0.949	53.7	56.1
16. Elymus elongatus marshland	2	12.0	1.011	0.957	58.3	20.0
17. Cladium californicum marshland	1	13.0	1.012	0.908	-	-
[18. unclassified plots	9]					

Table 6. Summary of the chief features of the Populus fremontii woodland vegetation type.

Number of plots	18
Total species	63
S	10.6
H	0.952
E	0.939
IH	45.7%
ID	73.0%
Average species sociability	2.5
Average flood position	3.3
Number of modal species	18
Number of unique species	6
Recent livestock sign (% of plots)	44%

Brown-Lowe-Pase assignment: Colorado Plateau warm-temperate deciduous riparian woodland

Prevalent species (*=modal species also)
1. Populus fremontii*
2. Baccharis salicina
3. Artemisia ludoviciana
4. Tamarix ramosissima*
5. Elymus canadensis
6. Salix goodingii
7. Castilleja linariifolia
8. Equisetum hyemale
9. Chrysothamnus viscidiflorus*
10. Bromus tectorum

Table 7. Summary of the chief features of the relict mixed deciduous woodland vegetation type.

Number of plots	7
Total species	45
S	11.4
H	1.023
E	0.972
IH	52.2%
ID	80.5%
Average species sociability	2.6
Average flood position	5.1
Number of modal species	20
Number of unique species	9
Recent livestock sign (% of plots)	14%

Brown-Lowe-Pase assignment: Colorado Plateau warm-temperate deciduous riparian woodland

<u>Prevalent species</u> (*=modal species also)
1. Rhamnus betulifolia*
2. Acer negundo*
3. Quercus gambelii*
4. Equisetum hyemale
5. Parthenocissus vitacea*
6. Smilacina stellata*
7. Salix exigua
8. Ostrya knowltonii*
9. Populus fremontii
10. Celtis reticulata*
11. Brickellia longifolia

Table 8. Summary of the chief features of the relict Pseudotsuga menziesii-Acer glabrum riparian forest type.

Number of plots	3
Total species	10
S	6.3
H	0.733
E	0.944
IH	78.0%
ID	57.1%
Average species sociability	2.2
Average flood position	6.0
Number of modal species	2
Number of unique species	3
Recent livestock sign (% of plots)	0%

Brown-Lowe-Pase assignment: Colorado Plateau cold-temperate evergreen riparian forest

Prevalent species (*=modal species also)
1. Pseudotsuga menziesii*
2. Acer glabrum*
3. Smilacina stellata
4. Ostrya knowltonii
5. Habenaria zothecina*
6. Mahonia repens

Table 9. Summary of the chief features of the Salix-Baccharis scrub type.

Number of plots	10
Total species	37
S	9.0
H	0.899
E	0.953
IH	54.4%
ID	48.0%
Average species sociability	2.3
Average flood position	2.2
Number of modal species	4
Number of unique species	0
Recent livestock sign (% of plots)	50%

Brown-Lowe-Pase assignment: Colorado Plateau warm-temperate riparian scrub

Prevalent species (*=modal species also)
1. Salix exigua*
2. Baccharis salicina*
3. Juncus arcticus
4. Equisetum hyemale
5. Tamarix ramosissima
6. Elymus canadensis
7. Oxytenia acerosa
8. Melilotus alba
9. Chrysothamnus viscidiflorus

Table 10. Summary of the chief features of the relict Betula-Solidago scrub type.

Number of plots	3
Total species	28
S	13.3
H	1.084
E	0.970
IH	50.3%
ID	15.7%
Average species sociability	2.4
Average flood position	3.2
Number of modal species	1
Number of unique species	0
Recent livestock sign (% of plots)	0%

Brown-Lowe-Pase assignment: Colorado Plateau warm-temperate riparian scrub

Prevalent species (*=modal species also)

1. Betula occidentalis*
2. Solidago occidentalis
3. Juncus arcticus
4. Chrysothamnus nauseosus
5. Elymus canadensis
6. Equisetum hyemale
7. Rhamnus betulifolia
8. Clematis ligusticifolia
9. Artemisia ludoviciana

Table 11. Summary of the chief features of the Salix-Panicum tinaja scrub type.

Number of plots	3
Total species	20
S	11.7
H	1.027
E	0.955
IH	73.7%
ID	68.0%
Average species sociability	-
Average flood position	-
Number of modal species	6
Number of unique species	2
Recent livestock sign (% of plots)	0%

Brown-Lowe-Pase assignment: Colorado Plateau warm-temperate riparian scrub

Prevalent species (*=modal species also)
1. Salix goodingii*
2. Artemisia ludoviciana*
3. Panicum oligosanthes*
4. Schizachyrium scoparium*
5. Juncus tenuis*
6. Rhus aromatica
7. Heterotheca villosa
8. Erigeron bellidiastrum*
9. Elymus canadensis
10. Celtis reticulata
11. Phragmites australis

Table 12. Summary of the chief features of the Equisetum-Solidago marshland type.

Number of plots	8
Total species	27
S	7.6
H	0.825
E	0.949
IH	61.7%
ID	68.7%
Average species sociability	2.2
Average flood position	2.4
Number of modal species	4
Number of unique species	0
Recent livestock sign (% of plots)	0%

Brown-Lowe-Pase assignment: Colorado Plateau warm-temperate riparian forbland

Prevalent species (*=modal species also)
1. Equisetum hyemale*
2. Solidago canadensis/S. occidentalis*
3. Juncus arcticus*
4. Baccharis salicina
5. Muhlenbergia asperifolia*
6. Bromus tectorum
7. Elymus canadensis

Table 13. Summary of the chief features of the Oxytenia-Panicum marshland type.

Number of plots	3
Total species	18
S	10.0
H	0.946
E	0.957
IH	72.6%
ID	14.3%
Average species sociability	2.4
Average flood position	3.0
Number of modal species	1
Number of unique species	1
Recent livestock sign (% of plots)	0%

Brown-Lowe-Pase assignment: Colorado Plateau warm-temperate marshland

Prevalent species (*=modal species also)
1. Oxytenia acerosa*
2. Panicum virgatum
3. Muhlenbergia asperifolia
4. Juncus arcticus
5. Solidago canadensis/S. occidentalis
6. Bromus tectorum
7. Equisetum hyemale
8. Elymus canadensis
9. Chrysothamnus viscidiflorus
10. Agrostis stolonifera

Table 14. Summary of the chief features of the <u>Phragmites</u> marshland type.

Number of plots	4
Total species	26
S	8.5
H	0.890
E	0.810
IH	47.1%
ID	25.0%
Average species sociability	2.2
Average flood position	6.0
Number of modal species	1
Number of unique species	1
Recent livestock sign (% of plots)	0%

Brown-Lowe-Pase assignment: Colorado Plateau warm-temperate marshland

<u>Prevalent species</u> (*=modal species also)

1. Phragmites australis*
2. Solidago occidentalis
3. Juncus arcticus
4. Elymus canadensis
5. Chrysothamnus viscidiflorus
6. Bromus tectorum
7. Quercus gambelii
8. Toxicodendron rydbergii

Table 15. Summary of the chief features of the *Eleocharis palustris*-*Lobelia cardinalis* marshland type.

Number of plots	3
Total species	24
S	10.3
H	0.986
E	0.949
IH	53.7%
ID	56.1%
Average species sociability	2.5
Average flood position	6.0
Number of modal species	5
Number of unique species	1
Recent livestock sign (% of plots)	33%

Brown-Lowe-Pase assignment: Colorado Plateau warm-temperate marshland

Prevalent species (*=modal species also)
1. Eleocharis palustris*
2. Phragmities australis
3. Baccharis salicina
4. Lobelia cardinalis*
5. Solidago sparsiflora*
6. Panicum acuminatum
7. Oenothera longisissima

Table 16. Summary of flood-terrace position for selected species, across all riparian vegetation types. The number under each flood-terrace topographic position for each species is its average abundance rating, with the sample size listed in parentheses. The peak abundance for each species is highlighted. Number of plots adds to more than 80 as those intermediate between two terrace positions were assigned to both.

Species	6	5	4	3	2	1
Artemisia ludoviciana	**2.8**(5)	2.5(4)	2.0(2)	1.5(6)	1.9(7)	2.0(6)
Baccharis salicina	**3.3**(4)	2.8(4)	3.0(2)	3.0(9)	2.3(14)	2.1(9)
Bromus tectorum	2.5(2)	2.0(6)	2.5(2)	2.0(7)	2.4(5)	1.3(3)
Castilleja linariifolia	-	1.0(1)	**2.0(1)**	1.8(5)	1.9(8)	1.9(8)
Elymus canadensis	0.8(3)	1.5(2)	2.0(1)	2.1(9)	**2.3**(13)	2.1(9)
Equisetum hyemale	2.3(3)	2.3(3)	2.0(1)	2.5(12)	**3.0**(17)	2.5(9)
Juncus arcticus	**4.0**(1)	2.0(1)	3.0(2)	2.9(10)	2.8(20)	2.9(11)
Oxytenia acerosa	2.0(1)	**4.0**(2)	2.5(2)	2.9(9)	2.7(3)	2.0(3)
Phragmites australis	**4.5**(4)	2.0(1)	-	1.3(4)	2.5(2)	2.7(3)
Populus fremontii	**4.3**(3)	4.2(6)	-	3.3(7)	3.3(7)	3.0(9)
Quercus gambelii	**4.3**(6)	3.0(1)	2.0(2)	1.3(3)	2.0(2)	-
Rhamnus betulifolia	**3.5**(4)	2.5(2)	2.3(3)	1.8(4)	1.5(4)	-
Salix exigua	3.0(2)	2.5(2)	2.5(2)	**3.3**(3)	3.2(6)	2.5(4)
S. goodingii	**4.3**(3)	3.0(1)	-	2.3(4)	2.8(6)	3.4(5)
Solidago sp.	2.5(2)	2.7(3)	**3.5**(2)	3.0(11)	2.8(12)	3.0(2)
Tamarix ramosissima	2.0(1)	**2.3**(3)	2.0(1)	1.8(6)	1.9(8)	1.9(8)
Number of plots	17	10	7	22	25	20

Table 17. Summary of sociability (average) and reproduction (per cent of plots species is flowering/fruiting in) for prevalent species in the four principle vegetation types (1 = P. fremontii woodland, 2 = Salix-Baccharis scrub, 3 = relict mixed deciduous woodland, 4 = Equisetum-Solidago marshland).

	1		2		3		4	
	Soc	Rep	Soc	Rep	Soc	Rep	Soc	Rep
Equisetum hyemale	1.6	67	1.8	100	2.0	100	1.5	88
Baccharis salicina	2.4	100	2.3	89	-	-	3.3	75
Elymus canadensis	2.3	75	2.3	75	-	-	2.5	100
Juncus arcticus	2.8	80	2.2	100	-	-	1.5	100
Artemisia ludoviciana	2.0	100	-	-	-	-	-	-
Bromus tectorum	2.0	100	-	-	-	-	2.0	100
Tamarix ramosissima	2.8	83	3.0	100	-	-	-	-
Populus fremontii	2.4	?	-	-	4.0	?	-	-
Castilleja linariifolia	2.6	57	-	-	-	-	-	-
Salix goodingii	2.8	63	-	-	-	-	-	-
S. exigua	-	-	1.8	33	3.0	33	-	-
Chrysothamnus viscidiflorus	-	-	2.8	75	-	-	-	-
Distichlis spicata	-	-	2.0	0	-	-	-	-
Melilotus alba	-	-	2.0	100	-	-	-	-
Oxytenia acerosa	-	-	3.0	75	-	-	-	-
Acer negundo	-	-	-	-	3.0	40	-	-
Brickellia longifolia	-	-	-	-	2.0	0	-	-
Celtis reticulata	-	-	-	-	3.0	100	-	-
Ostrya knowltonii	-	-	-	-	2.5	100	-	-
Parthenocissus vitacea	-	-	-	-	2.0	50	-	-
Quercus gambelii	-	-	-	-	2.8	40	-	-
Rhamnus betulifolia	-	-	-	-	2.7	71	-	-
Smilacina stellata	-	-	-	-	2.0	0	-	-
Muhlenbergia asperifolia	-	-	-	-	-	-	2.8	100
Solidago sp.	-	-	-	-	-	-	2.1	86

Table 18. Rankings for eleven canyons and Good Hope Bay in nine variables, and suitability for future research in four areas. Riparian vegetation is the number of different types represented in each canyon.

Variable	ALC	BOC	COW	CLW	GHB	LOC	LCC	GAC	RIC	SLC	TMC	LWC
Water flows	2	3	2/3	2	3	2/3	1/2	2	2	2/3	1/2	3[1]
Present livestock	-	-	-	-	-	+	+	-	-	-	-	-
Past livestock	-	+	+	-	-	+	+	-	+	+	+	-
Beaver	+	+	+	-	-	-	-	+	+	+	-	+
Rare plant species	1	3	10	4	1	0?	1	1	5	0	0	2
Riparian vegetation	9	8	8	4	3	5	3	9	7	5	5	3
Hanging gardens	2	2	3	1	0	2	2	3	3	2	1	1[2]
Birds	3	2	3	1	1	3	1	2	2	2	1	3[2]
Herps	2	3	3	1	1	2	1	2	3	1	1	3[2]
Research												
Vegetation	2	3	3	1	2	3	3	2	2	2	1	3[3]
Hydrology	2	3	2	1	1	2	1	2	2	2	1	3[3]
Geomorphology	1	3	2	1	1	2	3	1	1	2	2	2[3]
Paleoecology	1	3	3	1	2	1	1	2	2	1	1	1[3]

[1] 1=predominantly ephemeral, 2=predominantly intermittent, some surface flows but not continuous, 3=permanent flows
[2] 1=poorly developed or low diversity, 2=moderately well developed or diverse, 3=extremely well developed or diverse
[3] 1=not particularly good, 2=some potential for subject area work, 3=excellent choice for study

Table 19. Selected hypotheses derived from the 1992 field season and analysis of plot data, stated in the form of null hypotheses.

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1. H_0: old Populus fremontii stands on high terraces are relictual from a period of prior arroyo cutting (ca. 1880-1930).

2. H_0: establishment of principal woody riparian species (Baccharis, Populus, Salix) is related to flood activity, water table depth, and ability to withstand flooding.

3. H_0: along natural riparian zones, the competitive abilities among woody species is Baccharis>Salix exigua>Tamarix-Populus.

4. H_0: the flood sensitivity of woody species is (least sensitive to most sensitive) Salix exigua>Populus (juveniles)>Tamarix>Baccharis>Populus (adults).

5. H_0: extreme patchiness in riparian and wetland vegetation is related to reduced flood intensity and differential competitive abilities of post-flood survivors (Wood hypothesis).

6. H_0: the current stand structures of mixed deciduous woodlands is dynamic, related to minor disturbance events like tree fall or soil slumping, rather than comprising stable mixes.

7. H_0: the distribution and maintenance of Equisetum-Solidago marshland results from high water tables and spring ponding from downstream barriers like beaver dams. A corollary hypothesis is $H2_o$: flood activity is low where this vegetation type occurs.

8. H_0: beaver dams are important controlling factors in the occurrence of marshland vegetation types.

9. H_0: relict species lack specialized reproductive features such as outcrossing or specialized pollinators; rather they persist by wind or generalized insect pollination, autogamy, or vegetative means.

10. H_0: the occurrence of major vegetation types can be predicted by particular combinations of water, topography, substrate features, and flood activity.

Table 20. Principal types and distributions of wetland communities of Glen Canyon NRA, organized by the formations of Brown, Lowe and Pase (Spence 1992a). Those formations or communities that have been studied are underscored.

A. FOREST AND WOODLAND

1. Side canyons of Lake Powell, including riparian, spring, seep and hanging garden (common).
2. Principal rivers, including Cataract Canyon, Escalante, Dirty Devil, Colorado River below dam, Paria River (rare).

B. SCRUB

1. Permanent-intermittent zones in side canyons around Lake Powell (common).
2. Permanent zones along major rivers, including Cataract Canyon, Dirty Devil River, Escalante River, Colorado River below dam, Paria River (common).
3. Tinajas (rare).
4. Ephemeral riparian scrub (common).

C. MARSHLAND (INCLUDING FORBLAND COMMUNITIES)

1. Hanging gardens (common).
2. Tinajas (rare).
3. Colorado River below dam (rare).
4. Lake Powell and side canyons below high water (common).
5. Lake Powell side canyons above high water (rare).

D. STRAND

1. Lake Powell shoreline (common).
2. River strands, including Cataract Canyon, Dirty Devil and Escalante rivers, Colorado River below dam, and Paria River (common).
3. Ephemeral and intermittent stream channel strands (common).

E. AQUATIC

1. Stream pools, beaver dams, plunge pools of hanging gardens (rare).

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9. FIGURES

Figure 1. The dendrogram of 80 sites using Euclidean distance and Ward's flexible sorting algorithm.

Figure 2. The dendrogram of predominantly herbaceous and miscellaneous sites, using Euclidean distance and Ward's flexible sorting algorithm.

10. APPENDICES

Appendix 1. The mathematical and statistical methods used in the report are presented and discussed below. Cluster analysis was done using the SYSTAT package, version 5.02. All other computations were done by hand. Because the raw data matrix (80X140) was larger than the cluster analysis routine in SYSTAT could handle, the data were first subjected to a Euclidean distance analysis in the correlation routine. The smaller symmetric association (distance) matrix that was produced by this was then used for the cluster analysis.

1. Cluster analysis

Good discussions of cluster analysis as a classification tool are found in Sneath and Sokal (1973), Grieg-Smith (1983), Manly (1986), and Digby and Kempton (1987). For construction of the dendrograms of vegetation plots, several linkage methods were tried, including single, average (UPGMA), complete, and Ward's. The last method produced the most interpretable results, and appeared to provide a balance between the chaining inherant in single linkage, and the many small clusters often produced by complete linkage (Sneath and Sokal 1973). In all cases, Ward's method also produced tighter and more interpretable clusters than average linkage.

Euclidean distance was chosen as the association measure, as it has many desirable geometrical properties (Sneath and Sokal 1973), and is also commonly used in ecological work. Euclidean distance is computed between two plots i and j as:

$$d_{ij} = \sum_{k=1}^{S} (x_{ik} - x_{jk})^2$$

where k is any species common to one or both plots i and j, x is the abundance of the kth species in plots i and j, and S is the number of species found in the plots i and j.

2. Species diversity and evenness

Species richness (S) is the number of species present within a plot. Species diversity was computed using the Shannon information index:

$$H' = \sum_{i=1}^{S}(p_i \log_{10} p_i)$$

where S is the number of species, and p is the proportion of the total abundance contributed by the ith species. Diversity measures the overall complexity, or amount of "information" (unpredictability), in a set of data, with higher values reflecting more diverse sites.

Species evenness (Pielou's J) is:

$$E = H'/\log_{10}S$$

and measures the evenness of the distribution of abundances among the states (species). Vegetation dominated by a single species, with many rare species, would be very uneven, while vegetation in which all species were more or less equally abundant would be very even. E varies between 0 (very uneven) and 1.0 (very even).

3. Prevalent and modal species

Prevalent and modal species are defined by Curtis (1959). Prevalent species are those that reach highest frequency (percentage of plots) in a defined vegetation type. Modal species are those that reach maximum abundance in a vegetation type in a region, such as Glen Canyon NRA. Species can be both modal and prevalent, or one or the other.

4. Community indices of homogeneity and distinctivness

Both measures are from Curtis (1959), and require at least two plots to calculate, although more provide a better estimate. The index of homogeneity points out how similar all the plots within a vegetation type are to each other, and is calculated as:

$$IH = \frac{\text{sum \% frequency of prevalent species}}{\text{sum \% frequency of all species}}$$

Values range from 0% (least homogeneous) to 100% (most homogeneous). The index of distinctiveness determines how distinctive vegetationally a type is from all other types, and is calculated as:

$$ID = \frac{\text{sum \% frequency modal species}}{\text{sum \% frequency prevalent species}}$$

and can vary from 0% (least distinctive) to 100% (most distinctive). A variety of other ways of calculating distinctiveness and homogeneity are available as well. For example, average Euclidean distances could be calculated for each type, both within as a measure of homogeneity, and between as a measure of distinctiveness. However, the number of computations to do this would be extremely large. An alternative method using species presence-absence includes probability indices (Spence 1991; Spence and Henderson 1992).

Appendix 2. A list of species found in riparian and wetland vegetation, based on the 1992 field season, and information in Welsh (1984) and Tuhy and MacMahon (1988). All obligate riparian species (noted with an asterisk*) seen or reported are included, but only those non-riparian species which occurred within the 80 plots are included. The four letter acronym used in recording data and as the species name in the SYSTAT data files is listed. Distribution in eleven principal canyons are noted (+ present), along with hanging gardens (HG). Life forms (LF) can be found in Table 3. N is the number of plots the species was found in.

Species	LF	N	TARHLCCBLLU MLIACOLOOWM CCCCCWWCCCC	H G
Acer glabrum* (ACGL)	Tr	3	----------+	-
Acer negundo* (ACNE)	Tr	6	-+-+-+++--+	+
Adiantum capillus-veneris* (ADCA)	Fr	1	-++++++++++	+
Agrostis exarata*	Pg	0	-----------	+
A. stolonifera* (AGST)	Pg	7	++++++++++-	+
Ambrosia acanthicarpa (AMAC)	Af	5	---+++--+--	-
Amelanchier utahensis (AMUT)	Sh	7	+-+--++---+	-
Andropogon glomeratus (ANGL)	Pg	0	+++-++--++-	+
Apocynum cannabinum* (APCA)	Pf	8	--+++++-++-	+
Aquilegia micrantha* (AQMI)	Pf	1	--++++++-+-	+
Artemisia filifolia (ARFI)	Sh	2	+--++------	-
A. dracunculus (ARDR)	Pf	2	-----+-----	+
A. ludoviciana (ARLU)	Pf	24	+++++++++++	+
Asclepias latifolia	Pf	0	-----+-----	+
Aster chilensis* (ASCH)	Pf	2	-++--+-++--	+
A. glaucodes* (ASGL)	Pf	5	-++--+-+-+-	+
A. hesperius*	Pf	0	-----+-----	-
A. spinosus*	Pf	0	---------+-	-
Atriplex canescens (ATCA)	Sh	1	+--+++-----	-
Baccharis glutinosa*	Sh	0	---+-------	-
B. emoryi*	Sh	?	--+--+---+-	+
B. salicina* (BASA)	Sh	34	++++++-+++-	+
Betula occidentalis* (BEOC)	Sh	5	-----+-----	-
Bothriochloa laguroides	Pg	0	-------+-+-	-
Brickellia longifolia (BRLO)	Sh	11	++++++++++-	+
Bromus rubens	Ag	0	---+-------	-
B. tectorum (BRTE)	Ag	20	++++++++++-	+
Calamagrostis scopulorum* (CASC)	Pg	2	-+++++--+++	+
Carex aurea* (CAAU)	Pg	5	--+++++++--	+
C. curatorum* (CACU)	Pg	1	-++--++++--	+
C. hystricina* (CAHY)	Pg	6	-+-+-+++---	-
C. lanuginosa*	Pg	0	-----+-----	+

Species	LF	N	TARHLCCBLLU MLIACOLOOWM CCCCCWWCCCC	H G
C. parryana*	Pg	0	-----------	-
C. rossii (CARO)	Pg	1	------+---+	-
C. vesicaria*	Pg	0	-----------	-
Castilleja linariifolia (CALI)	Pf	17	++++-++++++	+
Centaurium calycosum	Af	0	-------+-+-	-
Cercis occidentalis* (CEOC)	Tr	2	++-------+-	+
Celtis reticulata* (CERE)	Tr	4	-+++-+++++-	+
Chenopodium sp.	Af	0	-----------	+
Chrysothamnus linifolius (CHLI)	Sh	3	---+--+-+-+	-
C. nauseosus (CHNA)	Sh	7	++++++++++-	-
C. viscidiflorus (CHVI)	Sh	14	++++++++++-	-
Cirsium arizonicum (CIAR)	Pf	2	+--+++++-++	+
C. rydbergii* (CIRY)	Pf	2	-+++-+-++--	+
Cladium californicum* (CLCA)	Pg	1	-+---------	+
Clematis ligusticifolia* (CLLI)	Li	12	++++++++++-	+
Comandra umbellatum	Pf	0	+---+-+----	+
Conyza canadensis (COCA)	Af	3	-----+++++-	+
Cortaderia sp.* (CORT)	Pg	1	-----+-----	-
Cryptantha sp. (CRY1)	Pf	1	----------+	-
Cynodon dactyloides*	Pg	0	-----------	-
Cyperus acuminatus*	Pg	0	-----------	-
Cystopteris fragilis*	Fr	0	-----+----+	+
Datura meteloides (DAME)	Pf	1	+--++---++-	-
Dalea oligophylla (DAOL)	Pf	5	--++---+---	-
Descurainia pinnata (DEPI)	Af	2	--+------+-	-
Distichlis spicata* (DISP)	Pg	6	+--++------	-
Dodecatheon pulchellum*	Pf	0	----+------	+
Echinochloa crus-galli*	Ag	0	---+-+-----	-
Elaeagnus angustifolia*	Tr	0	---+----+--	-
Eleocharis palustris* (ELPA)	Pg	4	--+-+--++--	+
E. rostellata*	Pg	0	--+------+-	-
Elymus canadensis* (ELCA)	Pg	29	++++-+++++-	+
E. elongatus* (ELE1)	Pg	4	-----+-----	-
E. elymoides (ELE2)	Pg	1	-+------+++	-
E. repens* (ELRE)	Pg	1	-----------	+
E. cf. trachycaulis (ELY1)	Pg	3	-----++-++-	-
Epilobium ciliatum* (EPCI)	Pf	2	---+-+-----	+
Epipactus gigantea* (EPGI)	Pf	3	-++++++-+--	+
Equisetum arvense* (EQAR)	Fr	1	---++------	-
E. hyemale* (EQHY)	Fr	39	++++++++++-	+
E. laevigatum* (EQLA)	Fr	1	--++-+-----	+
Erigeron bellidiastrum (ERBE)	Pf	2	--+--------	-
E. kachinensis*	Pf	0	------+----	+
E. utahensis (ERUT)	Pf	4	-+++-++++-+	+
Eriogonum corymbosum	Sh	0	+---------+	+
Euphorbia parryi (EUPA)	Pg	1	-----+--+--	-
Fallugia paradoxa (FAPA)	Sh	2	+---++-----	-
Fimbristylis spadicea*	Af	0	-----------	-

Species	LF	N	TARHLCCBLLU MLIACOLOOWM CCCCCWWCCCC	H G
Forestiera pubescens	Sh	0	------+----	+
Frasera paniculata	Af	0	-----+-+---	-
Fraxinus anomala (FRAN)	Sh	1	++-++++-+--	+
Galium multiflorum*	Sh	0	--+--------	+
G. triflorum* (GATR)	Pf	1	-----+-----	-
Gnaphalium chilense (GNCH)	Af	1	-----+---+-	+
Gutierrezia sarothrae	Sh	0	-----------	+
G. microcephala (GUMI)	Sh	6	--++++-+++-	-
Habenaria zothecina* (HAZO)	Pf	3	--++-+----+	+
Hedeoma drummondii	Pf	0	------+----	+
Heterotheca villosa (HEVI)	Pf	6	+-++++++-+-	+
Holodiscus dumosus (HODU)	Sh	1	----------+	+
Hutchinsia procumbens*	Af	0	-----------	+
Hymenopappus filifolius (HYFI)	Pf	2	++-++-+-+--	-
Hymenoxys acaulis	Pf	0	++---------	+
Ipomopsis (Gilia) aggregata (IPAG)	BP	10	++++++-++++	+
Juncus arcticus* (JUAR)	Pg	35	++++++++++-	+
J. articulatus*	Pg	0	-----------	-
J. bufonius*	Ag	0	--+--------	-
J. ensifolius* (JUEN)	Pg	2	---+++++++-	+
J. longistylis* (JULO)	Pg	1	---+-+-++--	-
J. nodosus*	Pg	0	-----------	+
J. tenuis* (JUTE)	Pg	3	--++-+--+--	-
J. torreyi* (JUTO)	Pg	2	-+++-++++--	-
Lactuca serriola	Af	0	--+--------	+
Lathyrus cf. brachycalyx	Pf	0	------+----	-
Lepidium montanum (LEMO)	Pf	4	++-+++--++-	-
Lobelia cardinalis* (LOCA)	Pf	3	---+-+-++--	+
Machaeranthera canescens (MACA)	BP	3	---+-+--++-	-
Mahonia fremontii (MAFR)	Sh	1	------+-+--	+
M. repens (MARE)	Sh	2	-----+---+-	+
Melilotus alba* (MEAL)	Af	10	++-+++-+++-	-
Mentzelia cronquistii	Pf	0	-----------	+
Mentzelia multiflora	Pf	0	--+--------	+
Mimulus eastwoodiae*	Pf	0	-+++-+---++	+
Mirabilis multiflora (MIMU)	Pf	1	-+---------	-
Muhlenbergia andina* (MUAN)	Pg	4	-++++------	+
M. asperifolia* (MUAS)	Pg	14	++++-+++++-	-
M. thurberi* (MUTH)	Pg	1	+++-+++++--	+
Oenothera longissima* (OELO)	BP	13	--++++++++-	+
Opuntia sp. (OPUN)	Pf	3	+--+++---+-	+
Ostrya knowltonii* (OSKN)	Tr	5	--++-++---+	+
Oxytenia acerosa* (OXAC)	Pf	17	++-++++-+--	+
Panicum acuminatum* (PAAC)	Pg	6	-+++-+++++-	+
P. capillare*	Ag	0	-----------	-
P. obtusum*	Pg	0	---+-+-----	-
P. oligosanthes* (PAOL)	Pg	3	---+-------	-
P. virgatum* (PVIR)	Pg	13	-+++-+-+-+-	+

Species	LF	N	TARHLCCBLLU MLIACOLOOWM CCCCCWWCCCC	H G
Parietaria pennsylvanica*	Af	0	--+--------	+
Parthenocissus vitacea* (PVIT)	Li	9	-+-+-+-++--	+
Penstemon eatonii (PEEA)	Pf	1	++-+-++----	-
P. rostriflorus (PERO)	Pf	1	------+----	-
Perityle specuicola	Pf	0	------+----	+
Petrophytum caespitosum*	Sh	0	-+++++++++-	+
Phragmites australis* (PHAU)	Pg	17	++++++++++-	+
Phacelia crenulata	Af	1	-----------	-
Pinus edulis	Tr	1	----------+	+
Plantago lanceolata*	Pf	0	-----------	-
P. major*	Pf	0	---------+-	-
P. patagonica	Af	0	--------+--	-
Poa annua*	Ag	0	---------+-	-
P. fendleriana	Pg	2	+----++--++	+
Poa sp.	Pg	1	------+----	-
Polypogon monspeliensis*	Ag	o	++++++++++-	+
P. semiverticillata*	Pg	0	--++-++-++-	+
Populus fremontii*	Tr	27	++++++++++-	-
Portulaca oleracea	Pf	0	--------+--	-
Potomageton nodosus*	Pf	0	-------+---	-
Primula specuicola*	Pf	0	-+++-+++++-	+
Psoralidium lanceolatum	Pf	2	+--+--+----	-
Pseudotsuga menziesii	Tr	3	----------+	+
Purshia mexicana	Sh	1	+-----+----	-
Quercus gambelii	Tr	12	++++++-++++	+
Ranunculus cymbalaria*	Pf	0	-----------	-
Rhamnus betulifolia*	Tr	10	-+++++-++++	+
Rhus aromatica	Sh	9	+++++++++++	+
R. glabra*	Sh	1	-----+-----	+
Rosa woodsii*	Sh	3	--++-+--+-+	+
Rubus neomexicanus*	Sh	0	--+---+----	+
Salsola iberica	Af	1	+++++------	-
Sambucus caerulea*	Sh	1	-----+-----	-
Salix exigua*	Sh	19	++++++++++-	+
S. goodingii*	Tr	16	-+++-+++++-	+
S. lutea*	Sh	2	-+---+---+-	+
Sarcobatus vermiculatus*	Sh	0	+----------	-
Sarcostemma cynanchoides*	Li	0	---+-------	-
Schizachyrium scoparium	Pg	5	-+++-++++--	+
Scirpus acutus*	Pg	0	-----+-----	-
S. maritimus*	Pg	0	-----------	-
S. pungens*	Pg	2	----++-----	-
S. validus*	Pg	0	-----+-----	-
Sheperdia rotundifolia	Sh	3	+---+++-+-+	+
Silene antirrhina	Af	0	---+----+--	+
Smiliacina stellata*	Pf	8	--+-++----+	+
Sonchus asper*	Af	5	-+++-+---+-	+
Solidago canadensis*	Pf	?	-++--+++++-	-

Species	LF	N	TARHLCCBLLU MLIACOLOOWM CCCCCWWCCCC	HG
S. occidentalis*	Pf	23	-+++-+-+++-	+
S. sparsiflora*	Pf	7	-++++++++-+	+
Sorghastrum nutans*	Pg	4	--+-++-+++-	+
Sphenopholis obtusata*	Ag	0	-----------	+
Spartina gracilis*	Pg	0	---+-+-----	-
Sporobolus cryptandrus	Pg	4	+-++++--+--	-
S. giganteus	Pg	2	---+-------	-
Stipa comata	Pg	5	++---------	-
S. hymenoides	Pg	8	+-++++--+--	-
S. speciosa	Pg	1	+-+--+---+-	+
Stanleya pinnata	Pf	1	--+-+----+-	-
Stephanomeria tenuifolia	Pf	1	-++-+-++-+-	+
Symphoricarpos longiflorus	Sh	2	------+--++	+
Taraxacum officinale*	Pf	0	--+--+-+---	+
Tamarix ramosissima*	Sh	20	++++++++++-	+
Tessaria sericea*	Sh	1	----+--+---	-
Thelypodiopsis divaricata	Af	0	+----------	-
Thelypodium integrifolium*	Af	4	-+++++-++--	+
Toxicodendron rydbergii*	Sh	6	-+-+-+-++-+	+
Tradescantia occidentalis*	Pf	2	-----+-----	-
Tragopogon dubius*	Af	0	-----+-----	-
Typha domingensis*	Pg	6	-+++++-+++-	-
T. latifolia*	Pg	5	--++++-----	-
Viola cf. nephrophylla*	Pf	0	-----+-----	-
Xanthium strumarium*	Af	8	--++-++-++-	-
Xylorhiza tortifolia	Pf	1	+----+-----	-
Yucca cf. angustissima	Pf	2	--++-+---+-	-
Y. toftiae	Pf	0	-++--+-+-+-	+
Zanichellia palustris*	Pf	0	--+--+-----	-
Zigadenus vaginatus*	Pf	0	--+--+-----	+

NOTES

Baccharis: most is probably B. salicina, which is the most common species from ca. the Escalante area north. However, some is likely to be B. emoryi, which differs only in characters of the flowers and fruits. In early season (prior to ca. July), the two cannot be distinguished. They are probably ecologically similar.

Eleocharis: most is probably E. palustris, but some may have been E. rostellata. The two species can only be distinguished when in flower or fruit.

Opuntia: the species is either O. phaeacantha or O. polyacantha.

Solidago: in early season species are hard to tell apart, but most is probably S. canadensis. Some S. occidentalis was also seen, most commonly associated with seeps, springs, protected wet sites, and hanging gardens. S. canadensis was abundant on low site flood plains, where it occurred with Equisetum hyemale.

Appendix 3. Key to the riparian vegetation types in Glen Canyon NRA. The abundance terms used are those found in Table 3. Several additional types are included in the key based on Tuhy and MacMahon (1988) and my own observations.

1. Woody species (shrubs and/or trees) common to dominant 2
1. Woody species absent or rare, never dominant 15

2. Pseudotsuga menziesii present relict P. menziesii-A. glabrum forest
2. P. menziesii absent 3

3. Trees at least 6 m tall or more, either Populus fremontii, Quercus gambelii, Rhamnus betulifolia, or Celtis reticulata present and common 4
3. Trees of above species rare or absent, sites dominated by either Salix, Baccharis, or Tamarix species generally less than 6 m in height, or by low shrubs 5

4. Populus fremontii dominant, other tree species generally absent except Salix goodingii, understory generally open, or composed of Chrysothamnus or Baccharis and Salix shrubs P. fremontii woodland
4. Mixed dense woodland comprising Quercus, Rhamnus, and Celtis present, P. fremontii occasionally present as emergent, understory often lush and herbaceous relict mixed deciduous woodland
5. Tall scrub along permanent or intermittent stream channels, composed of Baccharis, Salix, Tessaria, or Tamarix 6
5. Above species absent, low woody shrubs or Quercus gambelii 10

6. Sites in waterpockets or tinajas in slickrock in ephemeral, incipient drainages, Salix goodingii present Salix-Panicum tinaja
6. Sites along riparian zones, Salix goodingii absent, or present with Baccharis, Tessaria, Tamarix, or other Salix species 7

7. Tessaria sericea present and dominant Tessaria scrub
7. T. sericea absent or rare, not dominant 8

8. Betula occidentalis present, common, dense herbaceous layer with Solidago present relict Betula-Solidago scrub
8. B. occidentalis absent, herbaceous layer generally sparse, Baccharis, Salix exigua, or Tamarix present and dominant 9

9. Tamarix dominant, other species rare Tamarix scrub
9. Baccharis and Salix dominant, Tamarix present but uncommon Salix-Baccharis scrub

10. Toxicodendron rydbergii present and common to dominant, in wet protected sites Toxicodendron scrub
10. Toxicodendron absent, sites usually ephemeral channels 11

11. Sites on fluvial terraces or bottomlands at middle or higher elevations, either Artemisia, Atriplex, or Sarcobatus present and dominant 12

11. Sites in rocky streambeds or above species absent or uncommon, at low to high elevations 14

12. Sarcobatus vermiculatus present, common to dominant, Distichlis spicata usually present, carbonates or salts often at surface, usually on low terraces or channel bottoms Sarcobatus vermiculatus shrubland
12. S. vermiculatus absent or rare, sites usually on well developed or sandy soils on obvious terraces 13

13. Artemisia tridentata common to dominant, on deep loamy soils, Chrysothamnus species absent or rare Artemisia tridentata shrub
13. Atriplex canescens common to dominant, on sandy soils, Chrysothamnus species often present Atriplex canescens shrub

14. Holodiscus dumosus, Symphoricarpos longiflorus, and Ostrya knowltonii present with many other shrubs high elevation mixed shrub
14. Holodiscus and Ostrya absent, Symphoricarpos absent or rare, sites dominated by a mix of Amelanchier, Chrysothamnus, Fallugia, Purshia, or Rhus species low elevation mixed shrub

15. Forbs of Solidago and Equisetum common to dominant, Juncus arcticus often common but not dominant Equisetum-Solidago marshland
15. Monocot graminoids (Typha, Phragmites, Juncus, Eleocharis) dominant, forbs generally scarce, or if common then Oxytenia 16

16. Oxytenia present and common, grasses (Panicum virgatum and Muhlenbergia asperifolia) present, carbonates often present on soil surface Oxytenia-Panicum forbland
16. Oxytenia absent or rare, obligate riparian species of Juncus, Scirpus, Typha, Phragmites, Elymus or Cladium present and common 17

17. Typha dominant, surface water generally present, sites mostly in stream channels or associated with beaver dams Typha marsh
17. Typha absent, or if present not dominant, surface water present or absent, sites often above stream channels on hillsides, or on terraces 18

18. Cladium californicum present and common to dominant, often with Typha species Cladium californicum marshland
18. Cladium absent or rare 19

19. Elymus elongatus present and common to dominant, usually on drier terraces Elymus elongatus marshland
19. E. elongatus absent or rare, sites often wet and on hillsides 20

20. Phragmites dominant, surface water generally absent, Eleocharis absent or rare Phragmites marshland
20. Eleocharis common to dominant, Lobelia cardinalis and Phragmites often present but not common, surface water generally present Eleocharis marshland

Appendix 4 : canyon descriptions

CLEARWATER CANYON (4-21; 8-13/14)

Water flow: short stretches intermittent, but predominantly ephemeral.

Channel types: mostly slickrock or mixed rocky-sandy.

Geological strata: Cedar Mesa formation.

Main riparian vegetation types: limited development of 1,2,4,7.

The Clearwater Canyon drainage was visited April 21 by Charles Wood and John Spence. The canyon is entrenched into the Cedar Mesa formation, which forms sheer cliffs. Approaches from both the west and east sides were tried. In all cases, vertical drops in excess of 50 m were encountered, preventing entry into the canyon. Examination of vegetation in the canyon bottom indicated the presence of some riparian vegetation. A return trip was made on August 13-14 by helicopter by John Spence, Bill Sloan, and Bill Wolverton. The selected landing site was directly downstream of the prominent branch in the middle part of the canyon.

The riparian zone is not well developed in Clearwater Canyon for two reasons, flows are largely intermittent (near seeps), or ephemeral, and much of the stream channel is slickrock or blocked by large boulders. Common species included P. fremontii, S. goodingii, and especially Ostrya knowltonii, which was the most common tree in the middle part of the canyon. Several small hanging gardens were surveyed, and a patch of Ostrya woodland. The trip by helicopter in August was significant primarily in the discovery of three C2 species, Erigeron kachinensis (new to Glen Canyon NRA), Ostrya knowltonii, and Rubus neomexicanus, and the C1 species Perityle specuicola.

A short distance (ca. 500 m) up both main forks are impassable pour offs which prevented access into their upper parts. However, Bill Wolverton, on August 14, stated that he found a way into Clearwater Canyon by the central channel, trending north-south, from where the road crosses the streambed. This becomes the western fork of the canyon. He did not apparently reach the pour off that stopped the team the previous day, so it is not known yet if other pour offs occur in the west fork between where these two locations. The east fork is apparently impassable except by a long rappel. It was too narrow for safe helicopter access.

TWO MILE CANYON (4-22)

Water flow: some intermittent stretches, but predominantly ephemeral.

Channel types: all types represented.

Geological strata: Chinle, Moenkopi and Wingate formations.

Main riparian vegetation types: 1,4,12,14.

This canyon was visited on April 22 by Charles Wood and John Spence using a boat from Lake Powell. Bedrock in Two Mile Canyon is primarily Chinle, with the lower part at the top of the Moenkopi formation. The canyon consists of a series of steps, with flat stretches separated by short steep drops. Extensive Wingate debris blocks stretches of the canyon, particularly at the drops.

The composition of the vegetation varied depending on topography. Open riparian woodland dominated by *Cercis occidentalis* and *Populus tremuloides* occurred in the steep sections, where water seeps out at the faces of the exposed Chinle layers. Two Mile was the only canyon visited during 1992 where *Cercis* was found in the riparian zone. This species is usually associated with hanging gardens in alcoves. The flat stretches were primarily dry, and dominated by non-riparian shrub species, including *Fallugia paradoxa*, *Chrysothamnus nauseosus*, and *Fraxinus anomala*. During the survey, the canyon was divided into two principal topographic sections based on the flat and steep sections. Vegetation was generally similar within a topographic type throughout the canyon.

Approximately 3-4 km up canyon is a major drop in the Chinle, filled with

Wingate debris. Seeps emerged from the Chinle face, and supported an extensive patch of riparian woodland dominated by P. fremontii. Patches of Phragmites australis were also seen. Downstream of this drop were short stretches of riparian scrub and patches of Oxytenia acerosa. Much of the stream channel in the lower part of the canyon was formed in slickrock.

GOOD HOPE BAY (4/23)

Water flow: permanent.

Channel types: mostly in alluvium.

Geological strata: Kayenta formation.

Main riparian vegetation types: 1,4.

Isolated springs around Good Hope Bay support patches of Fremont cottonwood vegetation. One of these was investigated by Charles Wood and John Spence and surveyed. According to Welsh et al. (1987), the Quercus gambelii in these patches is an endemic variety known as Q. g. var. bonina Welsh, distinguished by its larger acorns (27-35 mm vs. 8-18 mm).

The spring emerged in a gully on a steep hillside composed of talus and alluvium, disappeared, then remained largely subsurface until the base of the hill, where the water re-emerged and formed a surface flow for 200-300 m. Three types could be distinguished; 1) Populus fremontii woodland, 2) Quercus gambelii thicket, and 3) Baccharis-Salix scrub. Types 1 and 2 were on the hillside, with Populus in the gully and Quercus on the adjacent slopes. Type 3 started at the base of the hill where water appears, and gradually merged downstream into Lake Powell high water Tamarix-dominated vegetation. Deep soils and eolian deposits appear to exist around these stands.

LAKE CANYON (4/23)

Water flow: perennial.

Channel types: predominantly soil and sand.

Geological strata: Navajo and Kayenta formations.

Main riparian vegetation types: 1,4,13,14.

This canyon was visited by John Spence and Charles Wood using boat access from Lake Powell. Extensive flats dominated by rushes and cattails occur below high water level in Lake Canyon. Above high water level the riparian vegetation was badly disturbed by livestock and beaver activity. Notes were taken on dominant species in this section, but detailed surveys were not conducted. It was felt at the time that more detailed survey work of the wetland flats below high water was warranted. Two common yellowthroats were observed in a dense patch of cattails in this stretch, and Woodhouse's toads were abundant in the wetlands.

These wetlands are inundated yearly by Lake Powell during summer high water levels. Extensive regeneration apparently occurs from rhizomes as water level drops. Typha in particular seems to be least affected, as it is abundant throughout the wetlands. Some dispersal into and establishment of P. fremontii and S. exigua on inundated ground was noted. A sequence of successional stages on various terraces of different hieghts and ages were evident along the stream flowing through the wetland complex. Lower terraces near the lake supported smaller (younger?) indiviudals of wetland species, which become gradually larger upstream. Differences in floristic composition between the terraces was also noted. Correlation of lake levels, heights of terraces, and vegetation composition could provide valuable data on regeneration and dynamics of these wetland communities.

A sample plot on older deposits was surveyed, and the data are reported below.

Shrub layer (1-3 m)

Populus fremontii	0

Salix exigua	O
Tamarix ramosissima	O
Herbaceous layer (0-2 m)	
Typha latifolia	A
Bulboschoenus (Scirpus) maritimus	C
Juncus arcticus	C
J. torreyi	U
Melilotus alba	C
Ranunculus cymbalaria	O
Scirpus pungens	O
Xanthium strumarium	O

A short species list compliled for these wetlands included:

Trees and shrubs
- Populus fremontii
- Salix exigua
- Tamarix ramosissima

Forbs
- Epilobium ciliatum
- Gnaphalium chilense
- Melilotus alba
- Polygonum persicaria
- Ranunculus acris? (not collected)
- R. cymbalaria
- Trifolium sp.
- Veronica anagallis-aquatica
- Xanthium strumarium

Graminoids
- Agrostis stolonifera
- Bulboschoenus (Scirpus) maritimus
- Cynodon dactylon
- Eleocharis palustris
- Juncus arcticus
- Juncus torreyi
- Phragmites australis
- Scirpus pungens
- Typha latifolia

Lianas
- Clematis ligusticifolia

An extensive open woodland of large Populus fremontii (up to 30 m) occurs above high water level in Lake Canyon. The shrubby understory consisted primarily of Baccharis salicina, Chrysothamnus nauseosus, Salix exigua, S. goodingii (often forming trees), and Tamarix ramosissima. Beaver activity had extensively modified this woodland. In particular, Salix goodingii had been preferentially attacked, with many large individuals fallen over. Much of the shrub layer along this stretch was dead or dying from beaver activities. There was little herbaceous understory, and abundant livestock sign was noted. Several beaver ponds were found, starting at high water level. Many older ponds in the upper part of the canyon were filled in with sediment derived from the extensive lake deposits, as well as possible erosional inputs from livestock activity.

LOWER WILSON'S CREEK (May 26-27)

Water flow: perennial.

Channel types: predominantly soil and sand.

Geological strata: Kayenta and Wingate formations.

Riparian vegetation types: 1,4,13,14.

Lower Wilson's Creek is in a shallow canyon cut into the upper part of the Wingate Formation. The area, surveyed by John Spence on May 26-27, consisted of a stretch of about 1 km, from a sheer cliff and waterfall at the lower end, near the Lake Powell high water mark, to a small cliff at the upper end. This entire stretch is densely vegetated by a stand of *P. fremontii*-*Salix goodingii* woodland along a perennial stream. American dippers were seen along this stream during the May visit. It is not known if they breed in the canyon. A rich bird fauna was observed, and three permenent bird census plots were established and censused. Amphibian life was abundant, with leopard frogs, Woodhouse's toads, and red-spotted toads seen. The canyon also contains good habitat for canyon treefrogs and spadefoot taods, but these taxa were not observed or heard during the visit. Previous work by Tuhy and MacMahon (1988) and Welsh (1984) had located two rare species, *Imperata brevifolia* and *Cladium californicum*. Neither was seen during the May visit, and *Cladium* was not at the location reported in 1988 by Tuhy and MacMahon (however, a patch of *Scirpus* was seen at the spot they had indicated).

Another interesting find was Aster spinosus. This was the only canyon where spiny aster was seen during the 1992 survey work.

This canyon is ranked first among canyons for more intensive ecosystem work for a variety of reasons. No sign of cattle was seen in the lower part, and there is a good chance that this stretch has never been grazed, although cattle could get into the area by a route at the upper end on the west side, where a dense patch of Quercus gambelii occurs on steep talus. Wilson's Creek is perennial, making it a good candidate for hydrology work. In May extensive signs of flooding was observed along the stream, with Typha knocked down in a swath in the streambed and to either side. The P. fremontii vegetation is probably the best representative of this type seen around Lake Powell. Finally, the canyon appears to get few visitors, although it is easily accessible by foot (ca. 10 minutes) from a boat.

ALCOVE CANYON (May 28)

Water flow: intermittent to ephemeral.

Channel types: all types represented.

Geological strata: Navajo and Kayenta sandstones.

Riparian vegetation types: 1,2,4,9,11,12,12,14,17.

This canyon was visited by boat on May 28 by John Spence. The vegetation in Alcove Canyon was among the most complex seen during the 1992 survey. Almost all major types were observed. Hanging gardens also exist, although they are not as well developed as those in "Garden" Canyon. The canyon lacks a perennial flow, however, and is considerably drier than "Garden" Canyon and lower Wilson's Creek. The upper end of the canyon is relatively dry, and much of the water comes from seeps in alcoves on the sides of the canyon. The only unusual rare species seen during survey work was Cladium califnornicum, a small stand of which was found ca. 1 km upcanyon from the 1992 water line, and just above the Lake Powell high water mark. No sign of livestock was seen, although deer were observed.

Throughout the riparian zone of the canyon are numerous old large logs, presumably of P. fremontii. The age of these logs is not known. Many of them had diameters of 1 m or more. There appears to have been a major dieback of this species in the canyon. Possible reasons include a decrease in water flow, disease, or beaver activity. Of the three, the last seems most likely as beaver sign was seen in the canyon, and as, a priori, there seemed to be adequate water in the canyon to sustain cottonwoods. This canyon may have been inacessible to beaver prior to the formation of Lake Powell. It is possible that the canyon supported an extensive cottonwood gallery forest that has been destroyed by beaver activity in the last 20-25 years.

RIBBON CANYON (June 8-9)

Water flow: intermittent and perennial.

Channel types: all types represented.

Geological strata: Navajo and Kayenta sandstones.

Riparian vegetation types: 1,2,4,11,12,13,14.

Ribbon Canyon was visited by John Spence on June 8-9 by boat from Lake Powell. The canyon is best known for its hanging gardens, which are probably the largest and best developed in the park. These gardens harbor many rare species, including Habenaria zothecina, Ostrya knowtonii, Rosa woodsii, Rubus neomexicanus, and Zigadenus zothecinus. Another distinctive feature are numerous small patches of relict mixed deciduous woodland. The riparian zone is best developed in the two forks of the canyon, especially in the northern fork. Relatively little P. fremontii woodland was seen, but well developed riparian scrub and marshland types occurred in the two forks. Deer are common in this canyon.

<u>**HALL'S CREEK**</u> (June 18-19)

<u>Water flow:</u> permanent in main creek and many side canyons.

<u>Channel types:</u> mostly sandy-alluvial.

<u>Geological strata:</u> complex, Morrison to Navajo formations.

<u>Riparian vegetation types:</u> 1,2,4,6,8,9,13,14.

This canyon was visited by John Spence on June 17-20.

<u>**UPPER MILLER'S CREEK**</u> (June 17; September 23-25)

<u>Water flow:</u> permanent in tree grove, ephemeral elsewhere.

<u>Channel types:</u> deep soil and slickrock.

<u>Geological strata:</u> Navajo, Kayenta, and Wingate formations.

<u>Riparian vegetation types:</u> 3,5,10.

<u>**LAST CHANCE CREEK**</u> (July 10)

<u>Water flow:</u> short stretches of intermittent flow, but mostly ephemeral.

<u>Channel types:</u> predominantly sandy and gravel-cobble, some slickrock.

<u>Geological strata:</u> Entrada sandstone.

<u>Riparian vegetation types:</u> 1,4,6,7,13.

On July 10 John Spence investigated the short stretch of canyon from the road crossing the creek bed down to Lake Powell high water level, a distance of ca. 4 km. The canyon is shallowly incised into Entrada sandstone, although the cliffs become tall near the end. Entrada sandstone forms ledges, and water often seeps out of the cracks and joints associated with the ledges, forming hanging gardens.

<u>**COW CANYON**</u> (July 28-31)

<u>Water flow:</u> perennial in main and south forks, upper end of north fork, intermittent in most of north fork.

Channel types: all types represented.

Geological strata: mostly Navajo and Kayenta formations, top of Wingate.

Riparian vegetation types: 1,2,4,5,11,12,13,14,16.

BOWNS CANYON (August 19)

Water flow: perennial.

Channel types: alluvial, slickrock.

Geological strata: Navajo and Kayenta formations.

Riparian vegetation types: 1,2,4,11,12,13,14,15.

SLICKROCK CANYON (August 20)

Water flow: permanent in lower, intermittent in upper part.

Channel types: sandy-alluvial and slickrock.

Geological strata: Navajo and Kayenta formations.

Riparian vegetation types: 1,2?,4,11,13,14.

Slickrock Canyon is short (ca. 3 km), with a large alcove at its upper end supporting a large complex hanging garden. Seeps on the side of the canyon provide enough water to produce a perennial stream in the lower part of the canyon. Well developed stands of P. fremontii woodland on high terraces are common, and dense riparian scrub occurs along the stream. In parts of the streambed where lateral cutting has produced a small floodplain, extensive marshland of Solidago canadensis is found. Slickrock Canyon contains the best example of the Equisetum-Solidago marshland type seen during the 1992 survey. Some patches of depauperate relict deciduous woodland were seen but not investigated.

Slickrock Canyon is not conisdered a high priority for further research because of disturbance by humans, as it is heavily visited by recreationists. A well developed hiking trail exists in most of the canyon, and frequent sign of humans was seen throughout the canyon.

LONG CANYON (September 2-4)

Water flow: intermittent to ephemeral in upper, permanent in lower part.

Channel types: alluvial, rocky, slickrock.

Geological strata: Navajo and Kayenta formations.

Riparian vegetation types: 1,2,4,7,13,14,15.

"GARDEN" CANYON (July 26-31, 1991)

Water flow: mostly ephemeral with intermittent stretches at upper ends.

Channel types: predominantly slickrock, some alluvial in upper part.

Geological strata: Navajo and Kayenta formations.

Riparian vegetation types: 2,4,7,9,12,13,14,17.

This canyon, west of Alcove Canyon in the Big Bend of the San Juan arm, does not have a name. It was visited during July 1991 by John Spence and Rick Harris during hanging garden survey work (Spence 1991). The unofficial name "Pictograph" Canyon was used during this survey. However, the name "Garden" is more appropriate as the canyon has extensive well developed hanging gardens. Alcoves with hanging gardens and patches of relict mixed deciduous woodland were seen predominantly on the western side of the canyon. A prominent fork occurs in the canyon, with the western fork supporting relatively well developed wetland and riparian vegetation at its upper end. A patch of *Cladium californicum* marshland occurs near the junction. "Garden" Canyon lacks extensive *P. fremontii* woodlands, although individual trees were seen. Beaver sign was common in the upper ends of the wetter fork, and as in Alcove Canyon beaver activity may have considerably reduced the abundance of this species in the canyon.