THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON RIPARIAN VEGETATION ALONG THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK, ARIZONA:

DRAFT 1992 ANNUAL REPORT

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THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON RIPARIAN VEGETATION IN THE COLORADO RIVER DOWNSTREAM FROM GLEN CANYON DAM, ARIZONA: 1992 DRAFT ANNUAL REPORT

ABSTRACT

This report evaluates the effects of interim flows from Glen Canyon Dam on riparian vegetation in the Colorado River corridor in Grand Canyon National Park. The interim flows criteria were designed to protect fluvial ecosystem resources as the Bureau of Reclamation Environmental Impact Statement is prepared. Thus, a report of no change in resource conditions signifies that the purposes for which interim flows were established are being achieved.

We used comparably collected data from the Glen Canyon Environmental Studies Phase II program to monitor the effects of discharge regimes on marsh and other riparian vegetation under the Bureau of Reclamation's interim flows from Glen Canyon Dam. This information is important because riparian vegetation provides essential food and habitat for the diverse riparian fauna of the Colorado River corridor, and is affected by sand bar stability.

We observed several effects of interim flows on the riparian vegetation in this system in 1992.

1) Interim flows appear to be inducing a slight downslope shift in fluvial marsh vegetation, and minor vegetational compositional changes on marsh transects. Marsh habitats are rare and play a disproportionately large role in ecosystem production and support several critical vertebrate species. For these reasons, fluvial marshes require continued monitoring during the interim flows period.

2) We noticed rapid aggradation of silts in return current channel mouths. The rate of in-filling appears to so rapid that these return current channels may soon be eliminated as a geomorphic setting.

3) Plant water potential studies support the view that <u>Salix exigua</u> is an appropriate indicator of fluvial marsh moisture stress resulting from interim flows. Our preliminary analyses suggest that plant moisture stress and growth rates are negatively correlated in <u>Salix exigua</u> across the elevational gradient in which fluvial marshes exist.

4) Although not a result of interim flows, the status of significant non-native riparian populations (e.g. <u>Saccharum ravennae</u>) has changed rapidly in response to changes in flow regimes, and requires prompt control efforts and monitoring.

From the data analyzed thus far, the initial year of interim flows appears to have had few negative impacts on riparian vegetation in the Colorado River corridor downstream from Glen Canyon Dam. Vegetation changes in 1992 may have been obscured by higher-than-normal growing season precipitation, and we anticipate stronger, more apparent responses under more normal weather conditions in 1993.

The interim flows criteria were designed to limit negative effects of dam operations during the GCD/EIS process, and those objectives generally appear to have been achieved in 1992.

INTRODUCTION

PROBLEM STATEMENT

Riparian vegetation is structurally adjusted and evolutionarily adapted to the flooding frequency of the river system in which it occurs (Odum 1981, Nilsson 1985, Stevens 1989); however, impoundment alters the frequency, magnitude, duration and seasonal timing of flooding disturbance. Discharge from Glen Canyon Dam affects riparian vegetation along the Colorado River downstream in Glen Canyon National Recreation Area and in Grand Canyon National Park (Carothers et al. 1979, Stevens and Waring 1988, Stevens 1989, Stevens and Ayers 1993). These effects include altered establishment and developmental trajectory of marsh and other shoreline plant communities by influencing erosion of alluvial sediment deposits, seed dispersal and seedling establishment, water relations of streamside plants, and the population dynamics of exotic plant species.

Riparian vegetation is widely recognized for its biodiversity and its relative bioproductivity. In the Southwest, riparian habitat comprises less than 0.05 percent of the landscape but supports more than 50 percent of the species in that landscape (Simcox and Zube 1985, Stevens in prep.). In Grand Canyon National Park, at least 5,000 species of plants and animals rely on desert riparian habitats. For this reason, Grand Canyon National Park established maintenance of riparian vegetation in the Colorado River corridor as a primary management objective.

On 1 August, 1991, the Secretary of the Interior mandated interim flows criteria, a program of reduced maximum flows and reduced fluctuation from Glen Canyon Dam. These interim flows were designed to mitigate impacts of dam operations on downstream riverine resources, until a Record of Decision is reached for the Glen Canyon Dam Environmental Impact Statement process. Interim flows consist of low-, medium-, and high-volume months, with low flows during the spring and late fall, moderate flows in June, September and November, and high flows during mid-summer and mid-winter. Interim flows have a minimum flow of 141.5 m^3/s (5,000 cfs), a maximum discharge of 566 m^3/s (20,000 cfs), a reduced range of daily fluctuation, and reduced up-ramping and down-ramping rates. Interim flow criteria were designed to limit sediment loss, thereby allowing riparian ecosystem processes to proceed unaffected by dam operations and in accord with the National Park Service management objectives until the Record of Decision. Thus, finding little change in resource states signifies that the purposes for which interim flows were established are being achieved.

We are monitoring the effects of interim flows on riparian vegetation composition and structure using comparably collected data from the Glen Canyon Environmental Studies Phase II program (Patten 1990). This study provides data on interim flows effects on the rate and trajectory of the riparian plant community development, fluvial/terrestrial ecosystem interactions, population changes in exotic plant species, and the risk status of endemic species.

OBJECTIVES

The objectives of this study are to determine whether interim flows are limiting the impacts of Glen Canyon Dam operations on riparian vegetation resources in the Grand Canyon.

1. Monitor the effects of interim flows from Glen Canyon Dam on the distribution, extent and development of fluvial marshes along the Colorado River from Glen Canyon Dam to Diamond Creek, AZ.

2. Monitor the effects of interim flows from Glen Canyon Dam on the distribution and development of other new high water zone plant assemblages between Glen Canyon Dam and Diamond Creek, Arizona.

3. Prepare monitoring data for inclusion into the GCES/NPS GIS database.

METHODS AND RESULTS

GENERAL LOGISTICS

We conducted three research river trips in 1992, one each in August, September and October-November, in accord with our proposed schedule. Staffing and equipment costs on these trips were borne by this project, and logistics were provided by O.A.R.S., Inc. and by personal contributions of equipment. Trips consisted of 12 to 22 staff, and hiring protocol for field and laboratory assistants conformed to that required by NAU Human Resources Department. We received the assistance of numerous volunteers, supported through the Volunteer In Park Program at Grand Canyon National Park.

Enclosed with this report is an administrative summary of expenditures on this project. This project was initiated later than anticipated, but we were able to accomplish the prescribed research and monitoring on schedule.

STUDY SITE SELECTION

Riparian vegetation research in GCES Phase II focused on variation in riparian vegetation associated with different geomorphic settings (Stevens and Ayers 1993). Twenty study areas were selected and established in Grand Canyon under that research program (Fig. 1). Each study area contains 5 m x 10 m permanent quadrats in the following geomorphic environments: marsh, beach (sand bar platform), channel margin and debris fan habitats, as well the old high water zone and desert zone (Fig. 2). In addition to these study areas, we examined 1988, 1990, 1991 and 1992 aerial still- and video photography of fluvial and springs marshes, and monitored experiments on marsh succession at several additional sites (Table 1).

OBJECTIVE 1: MONITOR THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON THE DISTRIBUTION AND DEVELOPMENT OF FLUVIAL MARSHES ALONG THE COLORADO RIVER BETWEEN LEES FERRY AND DIAMOND CREEK, ARIZONA.

Study Design

We used four approaches in 1992 to evaluate changes in marsh vegetation under interim flows in the Colorado River corridor in Grand Canyon National Park between Lees Ferry and Diamond Creek.

1) Remote sensing/aerial photogrammetry allowed us to document gross-scale changes in the extent of marsh habitats.

2) Monitoring of pre-established belt transects in marshes provided data on within-habitat processes, including changes in species composition and sediment deposit erosion or aggradation.

3) Measurement of plant water potential and stem growth of <u>Salix exigua</u> growing along a moisture/elevational gradient showed the effects of interim flows on a species closely associated with fluvial marshes.

4) Lastly, microscale marsh succession dynamics were monitored to determine patch dynamics changes at three interim flows stages. Analyses of these data are presently underway, but methods and some preliminary results are reported below for each sampling technique.

General Observations

Under interim flows, macrophyte vegetation is rapidly colonizing newly stabilized, low elevation portions of the Colorado River corridor. At nearly every site we examined, the "new dry" zone between the 566 m^3/s and 890 m^3/s stages, sustained a surprising amount of primary colonization by emergent herb, macrophyte and clonal perennial vegetation. This vegetation encroachment was documented through the GCES 225 m^3/s test flow in October, and data are presented below. The spring precipitation in 1992 was unusually great an may have obscured interim flows effects in what is normally the hottest, driest season. In the fall of 1992 we noticed die-back of Salix exigua ramets attributable to desiccation on the ca. 1,100 m^2/s stage terraces at the Mile 43L and 51.5L marshes, and premature chlorosis of this species on high terraces at Mile 194L marsh.

1) Remote Sensing

To assess areal and developmental rate changes in fluvial marsh patches, we examined serial video- and still image aerial photographic mapping at 20 new high water zone (NHWZ) marshes and four old high water zone (OHWZ) spring marshes (Table 2) using Map and Image Processing System (MIPS). The NHWZ marshes were distributed throughout the river corridor, and were selected on the basis of distribution within geomorphic reaches established by Schmidt and Graf (1990). The four OHWZ marshes constituted a set of control sites against which to determine changes in wetland vegetation not induced by dam operations.

Aerial photograph sets included: 28 May, 1988 (still photography, variable flow); 4-5 June, 1990 (still photography, constant 141.5 m^3/s); July 28-29, 1991 (video, constant 141.5 m^3/s); and 10-11 October, 1992 (still photography, constant 141.5 m^3/s). Several of the study marshes were under study by Stevens in 1984-1986, and some field observational data are included in this analysis for 1986. The 1991 video imagery was collected immediately prior to implementation of interim flows on 1 August, 1991, and therefore provides a good control for this analysis.

Relative marsh area was determined by mapping from photographs at approximately 1:4800 scale, scanning the images into MIPS and digitizing marsh area in relation to two repeatedly identifiable points on the photographs. Video images were digitized directly off the MIPS screen (Table 2). Marsh development rate (MDR) was standardized by arbitrarily assigning a distance of 100 map units to the two fixed points located on each photograph, and mean relative MDR (%MDR) in each year was by comparing the increase in relative marsh area (MRA) for the duration of growing season time (8 months/year) since the previous photograph:

$$\%MDR_x = 100[(RMA_x - RMA_{x-1})/RMA_x]/G$$

where RMA_x is the relative marsh area in year x and G = growth years (mid-March through mid-November is a growth year). Percent RMA_x and %MDR data were arcsine-squareroot transformed (Zar 1984), and analyzed in a blocked (by marsh) non-parametric Friedman test for the NHWZ and OHWZ separately. Marshes with missing values for one or more year were excluded from this analysis.

The relative NHWZ marsh area increased, on average, 31 percent/yr from 1990 to 1992 for the 20 marshes examined, a dramatic mean annual increase. Although RMA increased significantly between years, mean %DMR decreased non-significantly between years ($t_{Friedman}$ = 5.733, p = 0.057, n = 16, df = 2; Fig. 3). The declining rate of marsh area expansion was not significantly different between 1991 and 1992, indicating that marsh development is slowing as a function of normal successional processes, not interim flow effects.

Marshes at springs in the OHWZ, and not associated with dam operations, did not change significantly from 1990 through 1992. In contrast to the NHWZ marsh development rates, the area of OHWZ spring marshes changed only about 4 percent/yr between 1990-1992 (Fig. 1). The mean %MDR was not statistically significant between years ($t_{Friedman}$ = 1.5, p = 0.472, n = 4, df = 2).

Marsh development is occurring at approximately the same rate throughout the Colorado River corridor. A Spearman's rank correlation analysis (Conover 1980) was performed on the NHWZ %MDR and distance from Glen Canyon Dam for each year separately to determine whether processes were taking place at different rates in the lower <u>versus</u> the upper reaches of the river corridor. In each year's data there was no correlation between these two variables (Rho_{1990} = 0.433, p = 0.086, n = 16; Rho_{1991} = 0.187, p = 0.379, n = 18; Rho_{1992} = -0.161, p = 0.542, n = 19; df = 1 for each test).

2) Marsh Transects

Marsh transects established during the GCES-II program were monitored in September-October, 1992 (Table 1; Fig. 1). One m-wide, 10+ m-long belt transects were established at 10 m intervals perpendicular to the flow axis in return current channel marshes. A grid of 1.0 m plots was established and censused on bar platform marshes, such as Mile 55.5R marsh. All vegetation on 1.0 m^2 plots was identified and counted, and basal area was measured to the nearest 1 mm. Change in elevation was measured by re-surveying marsh transect lines with electronic surveying equipment. Changes in densities, basal areas and species composition on transects were compared between 1991 and 1992 using difference tests.

The GCES-II 1.0 m-wide marsh belt transects established at each site were recensused in the fall of FY92 to monitor compositional changes during the past year of interim flows. Four or more transects were recensused in each marsh, sampling basal area, stem density and species composition. Changes in soil profiles relating to deposition or erosion were determined using standard electronic surveying techniques.

We are in the process of compiling and analyzing marsh transect data and have completed preliminary comparisons of elevational and herbaceous, macrophyte and woody basal cover changes for individual 1.0 m^2 plots completed on three large return current channel marshes: 43L, 172L and 194L (Table 3). Patterns within each marsh are discussed below.

Mile 43L Marsh: Our survey data indicate that the higher elevation portions of the return current channel mouth were eroding under interim flows, while the lower elevations aggraded ($r = -0.390$, $p < 0.1$, $n = 104$; Table 3; Fig. 4). Aggraded sediments contain a high proportion of silt. The change in species richness from 1991 to 1992 was negatively correlated with elevation at this site ($r = 0.457$, $p < 0.001$, $n = 105$; Fig. 5), indicating that lower elevations were being actively colonized, while diversity is declining at higher elevations. Total basal area of the three plant groups (herb, macrophyte and woody species) showed no significant change; however, compositional changes are taking place at this marsh. In part this was attributable to successional deceleration, and overall we conclude that this marsh has not been strongly affected by interim flows, as yet.

Mile 172L Marsh: No linear regressions between elevation and change in plant group basal cover were statistically significant at this return channel marsh in lower Grand Canyon (Table 3). We examined elevation as a predictor of change in species richness, herb, macrophyte, woody and total basal area without finding statistically significant patterns (e.g. Fig. 6). The return channel portion of this marsh is somewhat perched, and therefore removed from direct daily interim flow effects. As such it is dominated by dry herb and woody taxa, which are little affected by reduced inundation. These results suggest that interim flows are exerting little discernable effect on the dry marsh at this site.

Mile 194L Marsh: We detected a significant negative correlation between elevation in 1991 and change in elevation between years ($r = -0.387$, $p < 0.01$, $n = 101$; Table 3). The significance of this relationship was driven by 6 data points that represented large decreases in elevation in 1992. These data points were associated with a beaver drag channel excavated into the thalweg of this marsh. The beaver occupying this marsh also cleared a central area of *Typha domingensis*, thereby lowering the slope of the linear regression of macrophyte basal area in 1992 in relation to 1991 values ($r = 0.322$, $p < 0.001$, $n = 101$). The return ccurrent channel mouth area of this marsh has rapidly aggraded, and high-volume month interim flows barely inundated the return current channel thalweg in August. Herb basal area decreased significantly in 1992 in relation to elevation while woody basal area increased significantly, probably a result of reduced maximum discharge associated with interim flows (Fig. 7, 8 respectively). Lower maximum stage discharge should limit the range of herbaceous taxa that require frequent inundation, but should provide for drier soil conditions favored by woody taxa. These data help explain the reduction in the slope of species richness between years at this site to 0.52 (Fig. 9), a pattern comparable to that occurring at the Mile 43L marsh.

3) Plant Water Potential Responses of Salix exigua

Coyote willow (SALICACEAE: Salix exigua) is a shallow-rooted, native, clonal willow that occupies the peripheries of fluvial marshes in the Grand Canyon. From research on Salix exigua in GCES-II, plant water potential (PWP) is known to be affected by temperature, relative humidity and somewhat on river stage. The water relations of this species are sufficiently well known to permit it to be used as an indicator species for monitoring water relations in marshes (Stevens and Ayers 1993). Nighttime plant moisture stress levels of coyote willow were sampled at four sites in high-volume (August), medium-volume (September) and low-volume (October) interim flow release months to determine whether substantial moisture deficit gradients were forming that might influence marsh development. The four sites selected for censusing (Mile 43L, 51.5L, 171.5L and 194L; Table 1) differ from our original proposal because use of Nankoweap Creek and Cardenas Creek marshes was restricted by high recreational use and closure for endangered species monitoring, respectively, and because coyote willow distribution in and around the marshes was not sufficient to guarantee the success of the monitoring effort.

Plant moisture stress (PMS) relations for Salix exigua provide a good indication of habitat moisture stress. Salix exigua grows around the peripheries of fluvial marshes and operates in a physiologically similar range of plant water potential as most of the marsh species. Unfortunately, water potential is virtually impossible to measure on marsh macrophytes directly. In this first phase of interim flows monitoring, we evaluated the significance of water stress levels on willow growth to determine whether coyote willow was really an appropriate indicator species for fluvial marshes.

Plant water potential was measured on 60 or more tagged Salix exigua individuals at four marsh sites during a consecutive day and night data collection session using standard Schollander pressure bomb techniques. Standard electronic surveying protocol was employed to provide accurate documentation of elevation and stage of the marked plants at these sites. Marshes were visited during each of the three interim flow types (low, medium and high monthly volumes), and high water surface elevations were staked. Hypsographic relationships are being determined from these survey data and will be reported for each fluvial marsh. Changes in topography related to aggradation or degradation were documented.

To ensure that PWP measurements associated with interim flows were documenting actual stress levels of significance to the willows, we also measured nodal growth on each tagged plant.

The growth and PWP data collected in this monitoring effort are still under analysis. In the present monitoring effort we observed a nighttime moisture gradient at all of the study sites, and that gradient decreased with higher monthly flow volumes. We noted limited die-back of *Typha domingensis* at high stage elevations at the Mile 43L site. In October, moisture gradients were well developed at all sites; however, high PWP readings at the very end of the growing season may not constitute a significant threat to the *Salix exigua* plants, or to the marshes around which those plants grew. If the spring of 1993 is relatively normal, with a dry period in May and June, the development of strong moisture gradients may reduce marsh vegetation growth. We intend to continue studying PWP changes in these marshes during the three spring flow-volume months (May = low-volume, June = medium volume, July = high-volume) to determine if stronger moisture gradients limit marsh growth during the active growing season.

Stevens and Ayers (1993) reported a strong correlation between stress levels in coyote willow and root crown elevation within sand bars. A preliminary analysis of willow growth in 1992 at the Mile 43L site suggests that growth rate was strongly negatively correlated with elevation above the river (Fig. 10). This analysis accounted for other major factors influencing growth, including stem age, stem length and basal area in the following equation:

$$(AS\%G92_{1992} = 9.635 - 0.079(ELEV) - 0.089(AGE) - 0.199(LTOTL) + 0.029BA$$

where AS%G92 is the arcsine squareroot-transformed percent stem growth in 1992 relative to total stem length, ELEV is relative elevation (m), age is stem age (yr), LTOTL is the $\log_n$ total stem length (cm) and BA = basal area (cm^2); $R_2 = 0.460$, $F = 35.770$, $p < 0.001$, $df = 4,159$).

Stress levels and growth are therefore negatively correlated, and therefore lowered water tables from interim flows that increase stress, reduce coyote willow growth. Coyote willow remains an excellent candidate as an indicator species for detecting water stress levels in fluvial marshes. Our initial model is being refined and validated and, in concert with the data from additional sites, will be used to predict PWP readings under different flow regimes, as well as willow and marsh production under different dam operating regimes. We anticipate completion of this model in 1993.

4) Marsh Succession

We are monitoring marsh succession in order to determine how and at what rate dam operations affect vegetation processes at the scale of germination, colonization and patch dynamics (Table 1). At each of 20 sites throughout the river corridor, nine 0.5 m^2 plots were monitored seasonally to evaluate changes in marsh development rates under interim flows (Table 1). Three treatments (simple disturbance, sand replacement and controls) were placed at each of three stage elevations (low, medium and high stage) for a total of nine 0.5m^2 patches/marsh. Plots were monitored for reestablishment and species richness through the 1992 growing season.

Data collected on this portion of the project are still being compiled. Statistical description and analyses of transect and plot data will employ changes in plant species richness, basal area or cover, and stem density between 1991 and 1992 as response variables in a factorial analysis of variance, with sites as a blocking factor. Change through time are being determined using differences between years as a response variable in an analysis of variance.

OBJECTIVE 2: MONITOR THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON THE DISTRIBUTION AND DEVELOPMENT OF OTHER NEW HIGH WATER ZONE PLANT ASSEMBLAGES BETWEEN GLEN CANYON DAM AND DIAMOND CREEK, ARIZONA.

Long-term Study Quadrats

The new high water zone (NHWZ) quadrats established during GCES-II were censused in 1992, providing a consistent database for monitoring dam discharge impacts on riparian vegetation development. During GCES-II we established a series of 20 study sites, each having one 5 m x 10 m quadrat in each of six different geomorphic settings.

All quadrats lying below the approximate 1,700 m^3/s stage were recensused in the fall of FY92. Quadrats had been divided into eight subplots for mapping purposes. Data collected in each quadrat included species composition, seedling densities, growth rates and tiller production, soil changes, ground cover, shrub cover, and litter production and decomposition rates. In addition, these quadrats provided data on colonization of non-native species. Spot sampling in the vicinity of these quadrats will be used to detect and monitor the distribution of critical native plant species in the river corridor.

During the present monitoring effort, we established, surveyed and censused a 5 m x 10 m "new dry" quadrat at each study site where interim flows protected a portion of the bar platform from inundation (Fig. 2). These new dry quadrats lie between the 566 m^3/s and 890 m^3/s stages. The new dry zone quadrats established in our study areas were devoid of vegetation at the inception of interim flows, as determined from close-level aerial photographs taken in mid-summer, 1991.

In the fall, 1992 we monitored vegetation characteristics on all new high water zone quadrats. Thus far we have analyzed basal area on 12 pairs of general beach and new dry quadrats. This is a small data set at present, and will be expanded as additional information is compiled; therefore the results of this analysis are preliminary.

We detected no critical (endemic or endangered) plant species in the vicinity of our plots, or anywhere within the range of dam operations within the river corridor. These findings corroborate those of Stevens and Ayers (1993) who reported no plant species at risk from dam operations in the Grand Canyon.

Quadrat analyses suggest that the new dry zone was extremely productive in 1992, and has become almost as densely colonized as the bar platform (general beach) zone, with little detectable difference in basal area of plant life or stem density between the two zones ($F_{1,21} = 2.979$, $\underline{p} = 0.099$; total basal area data were arcsine squareroot transformed). The new dry zone exhibited comparable basal areas of all assemblages except woody non-clonal phreatophytes when compared to the bar platform zone (Fig. 11). The bar platform and new dry zones support only about 50 percent of the species richness and basal area of the other geomorphic settings under study (Fig. 12), a finding in accord with the conclusions of Stevens and Ayers (1993).

Random Stops

To gain insight into diversity and stem density patterns in the new dry and new high water zones in coarse <u>versus</u> fine sediments, we initiated reach-based random stops throughout the river corridor. These random stops provide a measure of the representativeness of the quadrats database, as well as a larger data set with which to evaluate reach-based vegetation changes.

In October-November, 1992 we made four stops in each of the geomorphic reaches defined by Schmidt and Graf (1990), combining Reaches 2 and 3, and reaches 7 and 8, which are paired, short, narrow reaches. Two stops/reach were made at randomly selected fine-grained sediment deposits and two stops were made at randomly selected coarse-grained (cobble, talus or bedrock) sites. At each stop we censused one randomly selected 5m x 10 m quadrat in the "new dry" (566 m^3/s and 800 m^3/s stage) zone and another in the NHW (800 m^3/s to 1,150 m^3/s stage) zone. On each random quadrat the number of individuals in seedling, sapling and mature (reproductive) size classes of each plant species was recorded, along with measures of relative soil texture, percent ground cover, percent shrub cover, azimuth and dip angle.

A preliminary analysis of stem density and species composition on this large set of quadrat data was undertaken using a multivariate two-factor (zone, grain-size) analysis of covariance, with three covariates: distance from Glen Canyon Dam, and arcsine-squareroot transformed percent ground cover and shrub cover. Because data from the new dry and bar platform quadrats on the long-term study sites (above) had been collected in the same manner and were not significantly different from the random stops data (univariate $F_{2,98} = 1.538$, ns), we combined both data sets. To reduce the number of response variables, we condensed plant data into growth form groups (herbaceous, woody clonal phreatophytes, woody non-clonal phreatophytes, perennial grasses and annual species).

Like the long-term quadrats data set, this analysis demonstrates that the new dry zone has been quickly colonized, particularly by clonally expanding phreatophytes and perennial grasses (Table 4; Figs. 13 and 14). Stem density is significantly greater in lower stage deposits and in silt/sand deposits, while diversity (species richness) exhibits opposite but non-significant trends. Species diversity is positively correlated with distance from the dam, percent ground cover and percent shrub cover, and shows a trend of increasing values in coarse substrata, corroborating Stevens and Ayers (1992) findings. Both fine and coarse substrata were dominated by reproductively mature perennial taxa (clonal phreatophytes, particularly herbaceous Equisetum spp. and woody Salix exigua) and perennial bunch grasses. The largest proportion of species found in all zones were clonal herbaceous or woody phreatophytes, while annual grasses and phreatophytes were almost uniformly distributed across stage and substratum gradients.

OBJECTIVE 3: PREPARE MONITORING DATA FOR INCLUSION INTO THE GCES/NPS GIS DATABASE.

Long-term Plots Data

The data collected and compiled in this project will contribute to the GCES/NPS GIS data base and mapping effort. This will require close coordination with the GCES/NPS GIS team, and should result in deliverables that are readily included in the GIS, and augment existing data sets. We will employ surveyors from GCES and who have worked on survey projects in this system to assist in this effort. Survey protocol will follow that established by the GCES survey crew.

Detailed Vegetation Mapping

Large-scale (detailed) mapping of marsh vegetation was initiated at selected sites. This mapping effort will contribute to the Glen Canyon Environmental Studies program GIS data base development, and will provide an unparalleled database for future monitoring. Priority (GIS) sites and secondary (non-GIS) sites were identified and initially evaluated in the Colorado river corridor, including: miles -6.5R, 0R (the Lee's Ferry Gaging Station), 2.6L, 8L, 43L, 51.5L, 68R, 71L, 88R (the Phantom Ranch gaging station), 93L, 122R, 123L, 144R, 194L and 209L.

In late October, 1992, preliminary evaluation of vegetation was completed at the priority sites. Color infra-red (CIR) aerial photos were enlarged and used as base maps for the sites. While visiting sites, it became apparent that significant growth had occurred between 1990 and 1992. Newly emergent vegetation was found along the riparian zone which did not appear on the 1990 CIR photos. Shadows made photo interpretation difficult in the CIR images, since they appear black in color infra-red images. Due to this difficulty, normal color aerial photography was chosen to perform vegetation mapping in 1992, enabling interpretation of vegetation within shadowed areas and changes in vegetative growth to be recorded on maps.

Upon reviewing the 10-11 October, 1992 color aerial photos from the Bureau of Reclamation, it was discovered that the scale of the photography was inadequate for obtaining 3.0 m mapping accuracy. To conform with this Bureau of Reclamation GIS data base accuracy standard, a decision was made to obtain photo enlargements of each site. These enlargements were ordered approximately three weeks ago and are anticipated to arrive 22 January, 1993. Upon delivery of the photo enlargements, we will undertake a pilot mapping study and then proceed with preparation of site maps for the long-term vegetation study sites.

Because the Lees Ferry site in GIS Reach 2 is readily accessible, a pilot vegetation mapping effort will be conducted there during the second week of February, 1993. A vertical sketch master will be used to transfer mapped information on the photos to a base map. The map will then be taken to the site and ground truthed. As a monitoring quality control effort, a second Lees Ferry vegetation map will be prepared one week later, and compared with the initial map. Corrections will be made to the map, which will then be rectified to the base map and scan-digitized by the BOR. Established ground control points (GCP's), such as vegetation plot corner coordinates at these sites, will be used in the rectification process. Polygon attribution will be performed at the GCES office and the data will then be ready for inclusion in the GIS database. The Lees Ferry pilot mapping methodology, transfer, rectification, and input processes will be reviewed at this time and necessary adjustments made.

Upon completion of mapping the priority sites listed above, the mapped photos will be transferred to base maps at the GCES facility in Flagstaff and taken into the field to be ground truthed. After field checking polygon identities, the process outlined in the pilot study will be followed, and maps will be submitted to the BOR for scan-digitization. We have scheduled a priority site mapping river trip for March 12, 1993 through March 21, 1993. GCES GPS may be required to establish ground control for those sites not included in the GIS (e.g. Mile 8L).

DISCUSSION AND CONCLUSIONS

Monitoring interim flows effects on fluvial marshes and other riparian vegetation is important because streamside vegetation is diverse, biologically productive habitat that is subject to inundation by dam discharges. The effects of interim flows on riparian vegetation are likely to be cumulative and may take place over several years. For example, responses of fluvial marsh vegetation to interim flows may have been obscured by exceptionally high precipitation during the dry season (May-June) in 1992. Therefore, monitoring of fluvial marshes and other new high water zone habitats should be continued for the full duration of interim flows.

We observed several trends and significant effects of interim flows on the riparian vegetation in the Colorado River corridor in 1992.

1) In comparison with 1990 and 1991, the relative development rate of fluvial marshes was reduced slightly, but not significantly, under interim flows. This reduction in development rate is attributable both to deceleration of sucessional processes and the reduced inundation frequencies to which marshes are subjected under interim flows.

2) Within fluvial marshes, we detected a slight downslope shift in fluvial marsh vegetation, and minor vegetational compositional changes. Marsh vegetation changes were probably obscured by exceptionally high dry-season precipitation in 1992, and we anticipate a stronger, more apparent shift if more normal weather conditions occur in 1993.

3) We noticed rapid aggradation of return current channel mouths. The rate of in-filling appears to be sufficiently rapid that these geomorphic settings may be greatly reduced under interim flows.

4) Plant water potential studies support using <u>Salix exigua</u> as an indicator of fluvial marsh moisture stress resulting from interim flows. Our preliminary analyses suggest that plant moisture

stress and growth rates are negatively correlated in Salix exigua across the elevational gradient in which fluvial marshes exist.

5) The "new dry" zone, lying between the interim flows maximum flow stage (566 m^3/s stage) and the "normal operations" stage (ca. 850 m^3/s stage), is being actively colonized by riparian plants, particularly clonal phreatophytes and perennial grasses. Colonist density was greater on fine-grained (silt/sand) deposits, but diversity was greater on coarse (cobble/talus) deposits.

6) Although not a result of interim flows, the status of significant non-native riparian populations (e.g. Saccharum ravennae) has changed rapidly in response to changes in flow regimes, and requires prompt control efforts and monitoring.

From the data presented here, the initial year of interim flows appears to have had few negative impacts on riparian vegetation in the Colorado River corridor downstream from Glen Canyon Dam. The interim flows criteria were designed to limit negative effects of dam operations during the GCD/EIS process, and that objective appears to have been accomplished in 1992.

MANAGEMENT CONSIDERATIONS

From these analyses we conclude that 1992 interim flows did not exert strong negative effects on marsh or riparian vegetation downstream from Glen Canyon Dam. If the spring of 1993 is relatively normal, with a dry period in May and June, the development of stronger moisture gradients may enhance the nascent downslope shift of fluvial marsh and other riparian vegetation detected in 1992. Such a shift may increase the susceptibility of streamside vegetation to exceptional flow events.

We intend to continue monitoring marsh compositional changes associated with interim flows in 1993. In addition, we will continue to monitor development of moisture gradients and related effects on plant growth at the long-term study sites during the three flow-volume months. In the fall of 1993 we intend to compile a list of all patches of marsh vegetation to compare with the 1992 list presented in Stevens and Ayers (1993). These data will permit us to document changes in marsh area in a reach-based fashion, and document the extent of downslope shifting in riparian vegetation associated with interim flows.

Ravenna grass (Saccharum ravennae) is rapidly expanding in the Colorado River corridor in the Grand Canyon and around Wahweap Bay on Lake Powell. A control program should be initiated immediately if the NPS is interested in keeping this highly competitive Eurasian bunchgrass out of the system.

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Table 1: Study sites in the Colorado River corridor, Grand Canyon National Park.

MILE/ SIDE*	TYPE OF STUDY SITE	USE IN THIS STUDY
0.0R*	Observational	Detailed Mapping
19.9L	Observational	NHWZ MIPS
26.0R	Air Photos	OHWZ MIPS Control Site
43.1L	Transects, Air Photos	Transects, Detailed Mapping, NHWZ MIPS, Succession
50.0L	Air Photos	NHWZ MIPS
51.3L	Transects, Air Photos	NHWZ MIPS, Succession
51.6L	0.5 m_2 plots, Air Photos	NHWZ MIPS, Succession
Nankoweap Cr.	0.5 m^2 Plots	Succession Control Site
53.0R	Air Photos, 0.5 m^2 Plots	NHWZ MIPS, Succession
55.0R	0.5 m^2 Plots	Succession
55.5R	Grid	General Monitoring, Detailed Mapping, NHWZ MIPS, Succession
68.2R	5 x 10 m Plot	General Monitoring
69.5L	0.5 m^2 Plots	Succession
71.0L	Grid, 0.5 m^2 Plots, Air Photos	General Monitoring, Succession, NHWZ MIPS
72.0L	0.5 m Plots	General Succession
76.5R	Air Photos	OHWZ MIPS Control Site
103.9R	5 x 10 m Plot	General Monitoring
122.8L	Transects, 0.5 m Plots, Air Photos	General Monitoring, Detailed Mapping, NHWZ MIPS, Succession
136.5R	Air Photos	OHWZ MIPS Control Site
136.6R	Air Photos	NHWZ MIPS
137.0R	5 x 10m Plot	General Monitoring
139.0R	0.5 m^2 Plots	Succession
144.0R	5 x 10m Plot	General Monitoring
171.5L	0.5 m^2 Plots, <u>Saex</u>, Air Photos	Succession, PWP, MIPS NHWZ
172.1L	Transects, 0.5 m^2 Plots, Air Photos	General Monitoring, Succession, NHWZ MIPS
179.5L	Air Photos	OHWZ MIPS Control

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Table 1 (cont'd.)

MILE/ SIDE*	TYPE OF STUDY SITE	USE IN THIS STUDY
194.1L	Transects, 0.5 m^2 Plots, Air Photos	General Monitoring, Succession, NHWZ MIPS
198.0R	0.5 m^2 Plots, Air Photos	Succession, NHWZ MIPS
209.0L	0.5 m^2 Plots	Succession
213.0R	Transects, 0.5 m^2 Plots	General Monitoring, Succession
219.9R	5 x 10 m Plot	General Monitoring
225.0R	0.5 m^2 Plots	Succession

Table 2: Remote sensing data (MIPS) on changes in marsh size from 1988 through 1992, Grand Canyon National Park, Arizona. Map area was standardized for each site by remeasuring relocatable fixed points on each photograph and designating that distance as 100 map units.

MILE	NHWZ=1 OHWZ=2	RELATIVE AREA IN 1986	RELATIVE AREA IN 1988	RELATIVE AREA IN 1990	RELATIVE AREA IN 1991	RELATIVE AREA IN 1992
- 6.5	1.0	.	803.0	1018.0	.	1211.0
19.9	1.0	0.0	0.0	49.0	39.0	72.0
26.0	1.0	.	6.0	4.0	17.0	28.0
26.0	2.0	.	61.0	67.6	8.0	69.0
43.1	1.0	0.0	64.0	146.0	184.0	320.0
50.0	1.0	0.0	34.0	387.0	640.0	957.0
51.2	1.0	0.0	230.0	1806.0	2942.0	4011.0
51.4	1.0	0.0	.	1009.0	1114.0	1805.0
53.0	1.0	0.0	.	1349.0	1413.0	1841.0
55.5	1.0	0.0	136.0	1064.0	1702.0	2117.0
71.1	1.0	.	.	2836.0	3544.0	4512.0
76.5	1.0	0.0	16.0	50.0	62.0	165.0
76.5	2.0	.	534.0	549.0	561.0	626.0
122.8	1.0	0.0	0.0	246.0	665.0	688.0
136.5	1.0	0.0	117.0	351.0	453.0	692.0
136.5	2.0	.	3550.33	3532.0	3544.0	4146.2
171.5	1.0	0.0	0.0	167.0	203.0	440.0
172.2	1.0	0.0	51.0	356.0	441.0	515.0
179.4	2.0	.	4902.0	4263.0	4792.0	4980.0
194.1	1.0	0.0	0.0	512.0	1576.0	2003.0
198.0	1.0	0.0	44.0	286.0	676.0	905.0
213.0	1.0	0.0	0.0	204.0	584.0	1310.0
217.5	1.0	.	12.0	389.0	938.0	1320.0
225.0	1.0	0.0	61.0	.	293.0	457.0

Table 3: Univariate analyses of relationships between marsh elevation and vegetation variables between 1991 and 1992 at three large return current channel marshes in the Colorado River corridor, Grand Canyon National Park, Arizona. None of these relationships are statistically significant, suggesting that marsh composition has not changed relatively little during the first year of interim flows. N refers to the number of 1.0 m^2 plots re-censused.

MARSH TRANSECT SITE		SPECIES RICHNESS/PLOT	WOODY SPECIES BASAL AREA (cm)	MACROPHYTE BASAL AREA (cm)	TOTAL BASAL AREA (cm)
MILE 43L	$\bar{x}$	2.086	0.000395	- - -	- - -
	1 sd	2.272	0.001105	- - -	- - -
	N	105	105	- - -	- - -
MILE 123L	$\bar{x}$	1.647	0.000278	0.000880	0.001159
	1 sd	1.746	0.000778	0.001488	0.002197
	N	17	17	17	17
MILE 172L	$\bar{x}$	0.419	0.000237	0.000046	0.000445
	1 sd	1.882	0.002178	0.000183	0.001899
	N	74	74	67	67
MILE 194L	$\bar{x}$	-0.353	0.000599	-0.00047	-0.00123
	1 sd	1.948	0.003613	0.007773	0.008880
	N	102	102	102	102

Table 4: MANCOVA of $\log_n$ transformed+1 riparian vegetation stem density/m^2 (LDEN) and diversity (species richness, S) as a function of stage (new dry versus new high water zones), substrate type (fine versus coarse) and interaction effects between stage and substratum, with distance from Glen Canyon Dam, and arcsine-squareroot transformed percent ground cover (ASPCGC) and percent shrub cover (ASPCSC) as covariates. Data were pooled from random 5m x 10 m quadrats and long-term study quadrats (n = 108 plots).

SOURCE	WILK'S LAMBDA	APPROXIMATE F-STATISTIC	DF	*p*	SIGNIFICANCE OF RESPONSE VARIABLES*
MAIN EFFECTS					
Stage	0.912	4.437	2,92	0.014	LDEN nsd; S **
Substratum	0.937	3.099	2,92	0.050	LDEN nsd; S *
Stage x Substratum	0.953	2.257	2,92	0.110	LDEN nsd; S *
COVARIATES					
Distance	0.880	6.298	2,92	0.003	LDEN **; S nsd
ASPCGC	0.453	55.561	2,92	< 0.001	LDEN ***; S ***
ASPCSC	0.789	12.313	2,92	< 0.001	LDEN t; S ***

nsd = not significantly different
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

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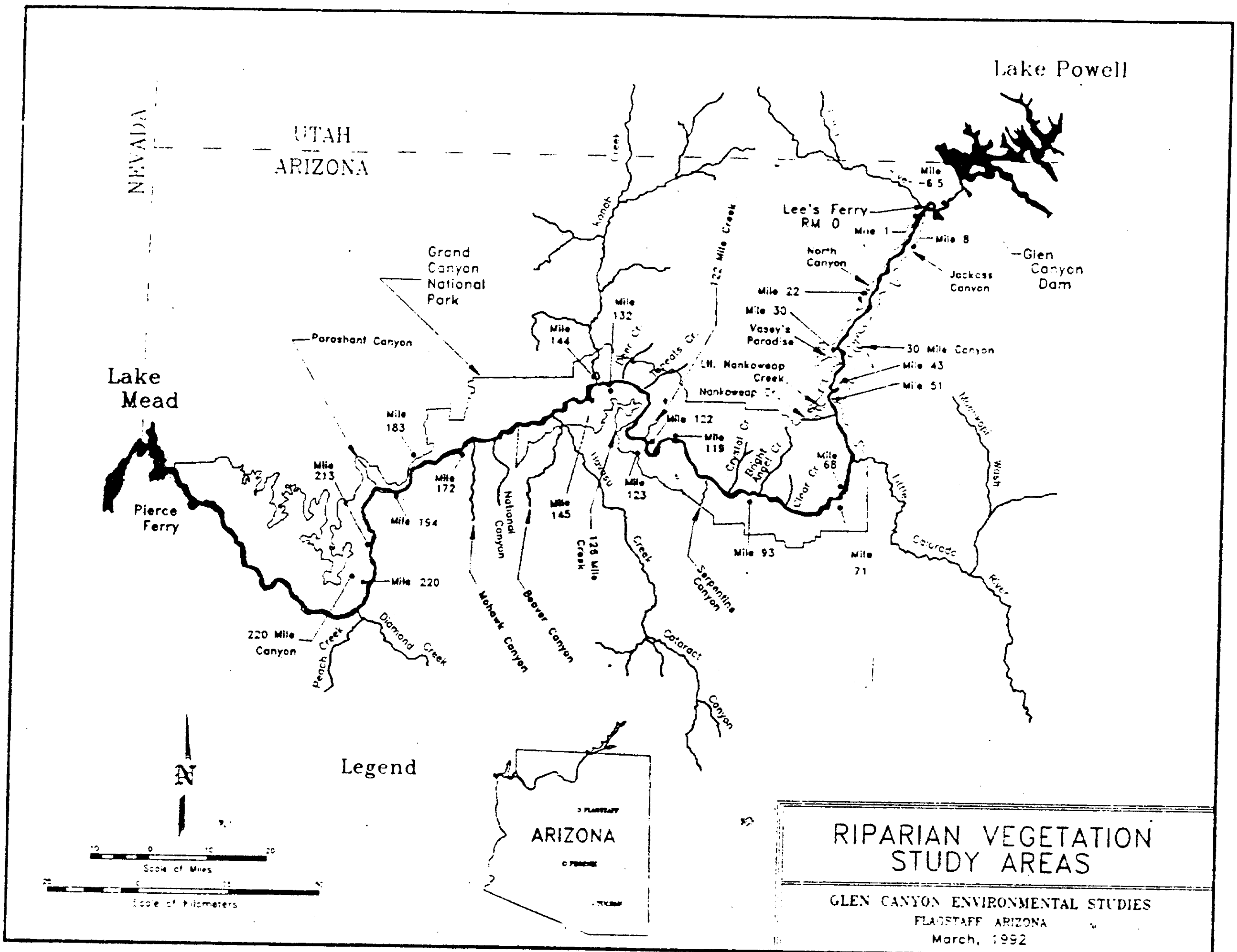

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Figure 1: Map of study areas and specific study sites used in interim flows monitoring, Grand Canyon National Park, Arizona.

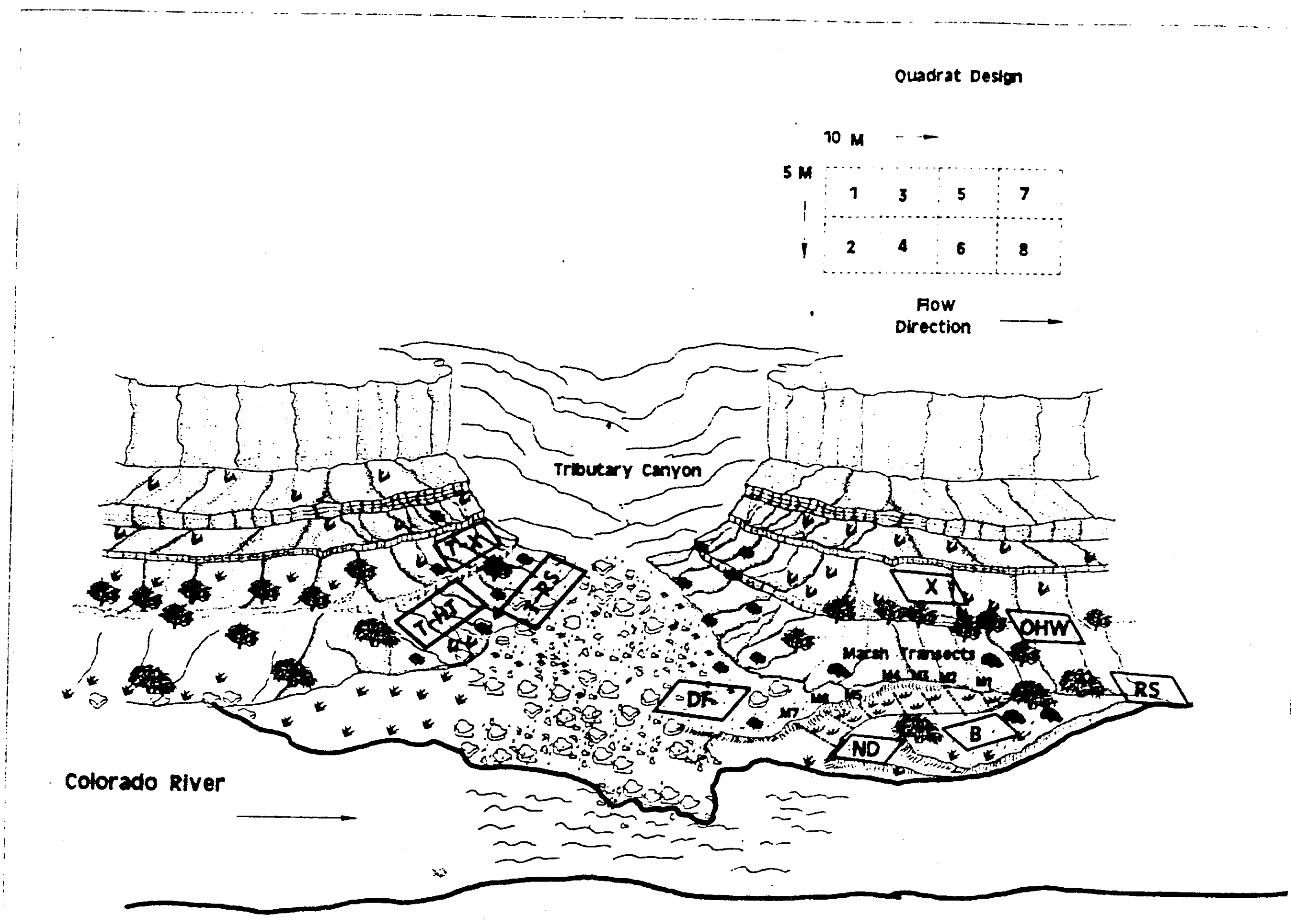

Figure 2: Schematic diagram of geomorphic settings and locations of marsh transects and 5 m x 10 m quadrats in a typical recirculation zone associated with a tributary confluence in the Colorado River downstream of Glen Canyon Dam in Grand Canyon National Park, Arizona.

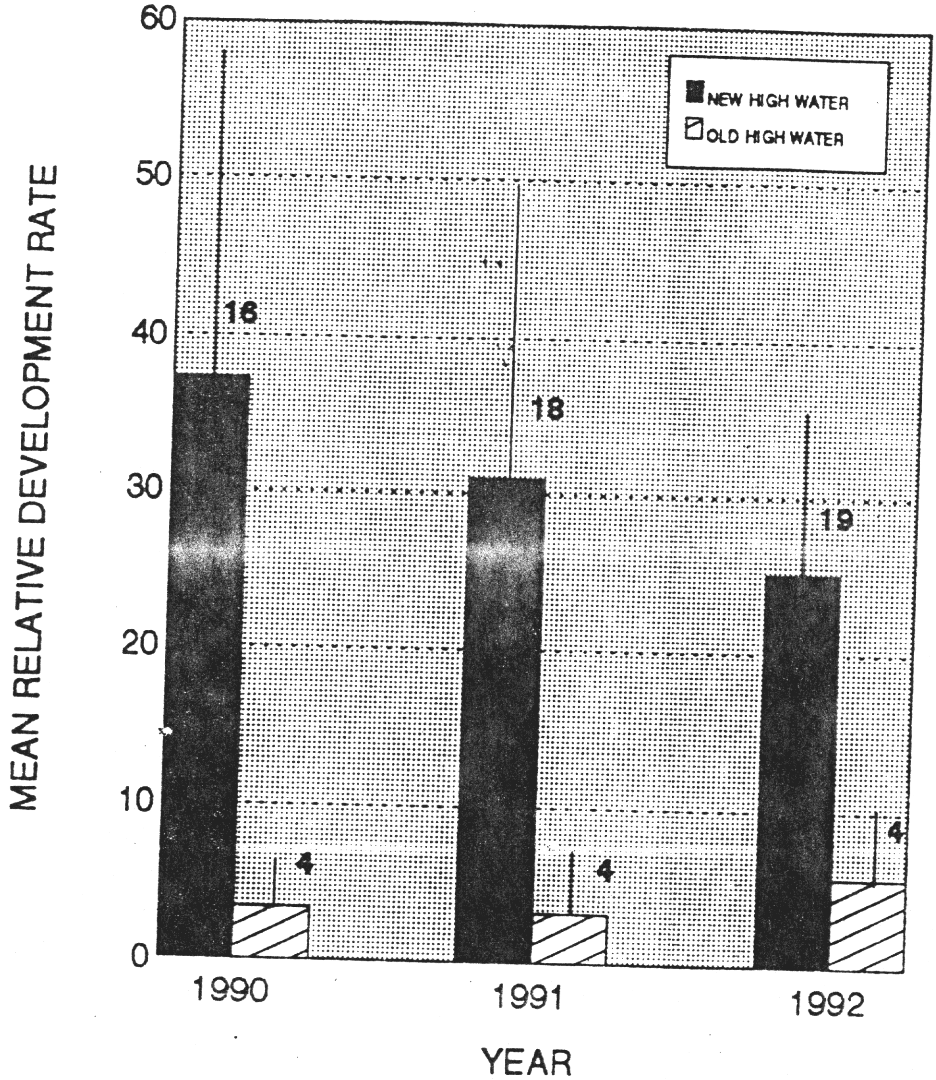

Figure 3: Mean relative marsh development rate (MRMDR) from 1990 through 1992 in the new high water zone and old high water spring marshes (control sites). MRMDR was not significantly different between years. Error bars are ± 1 sd.

ELEVATION CHANGE VS. ELEVATION (1991)

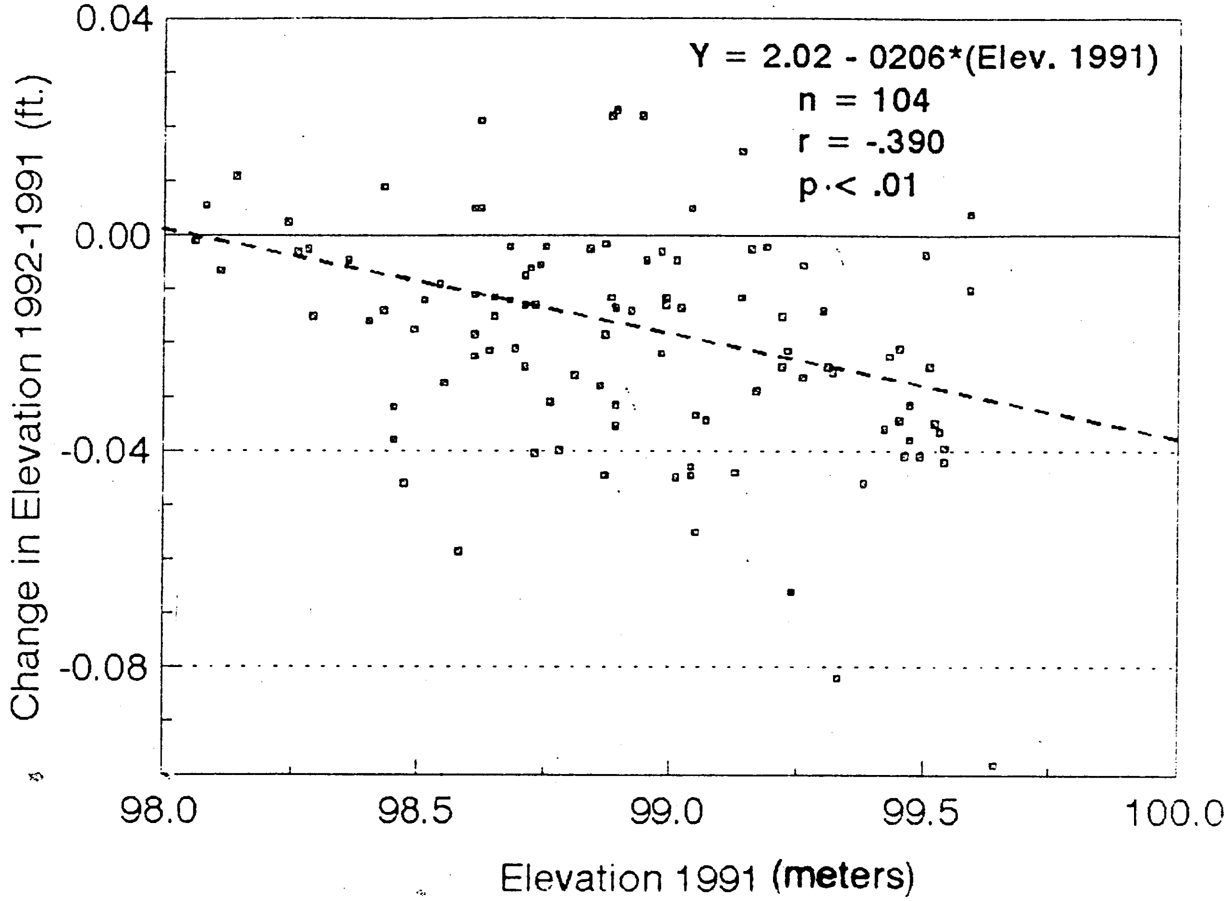

Figure 4: Change in elevation as a function of elevation in 1991 at Mile 43L marsh, a large return current channel marsh in Marble Canyon. Lower elevation positions lost elevation at this site as a function of erosion of the return current channel mouth.

Change in Species Numbers With Elevation

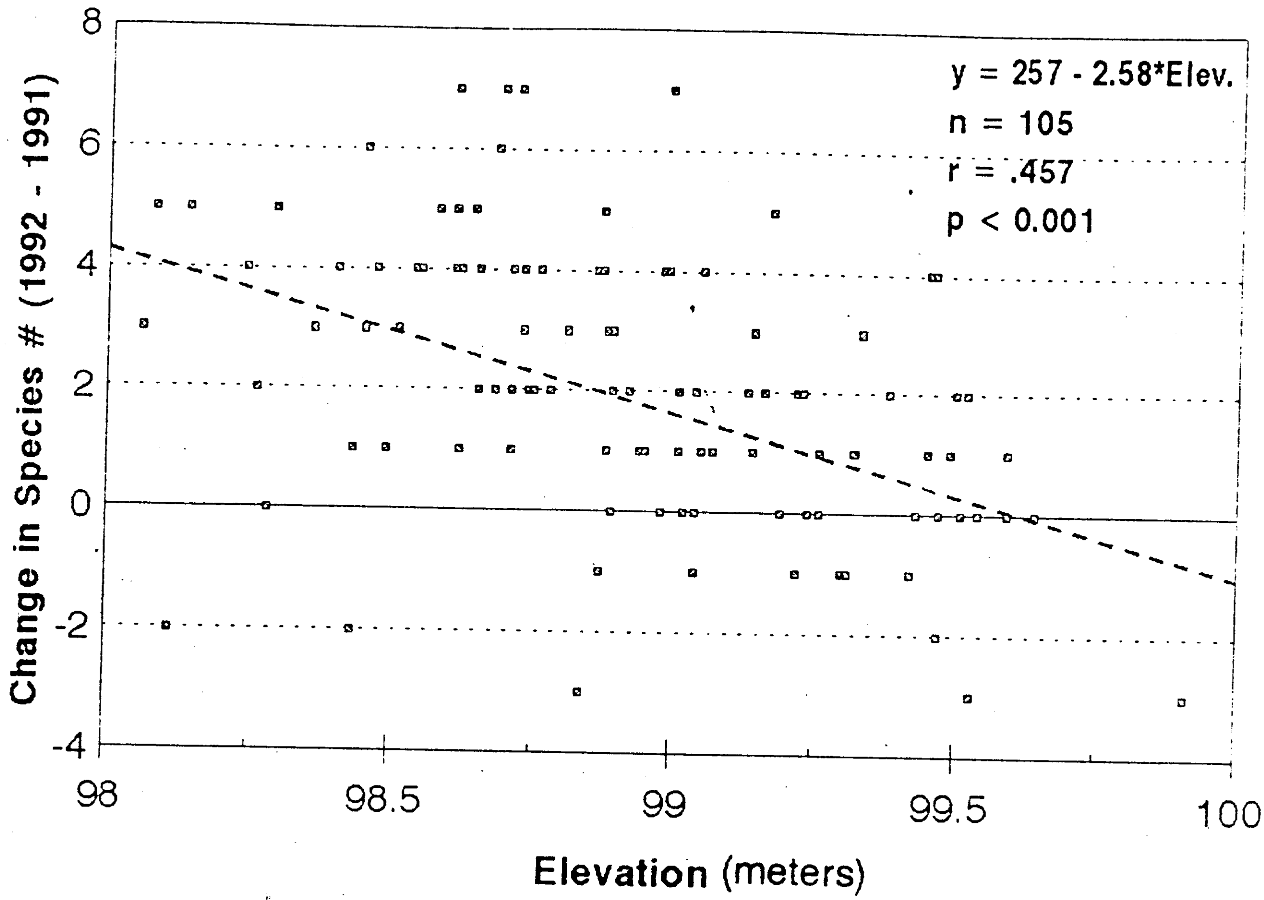

Figure 5: Change in species richness as a function of elevation at Mile 43L marsh, a large return current channel marsh in Marble Canyon. Significantly more marsh plant species occurred at lower elevations in 1992.

Change in Total Basal Area (1991 - 1992)

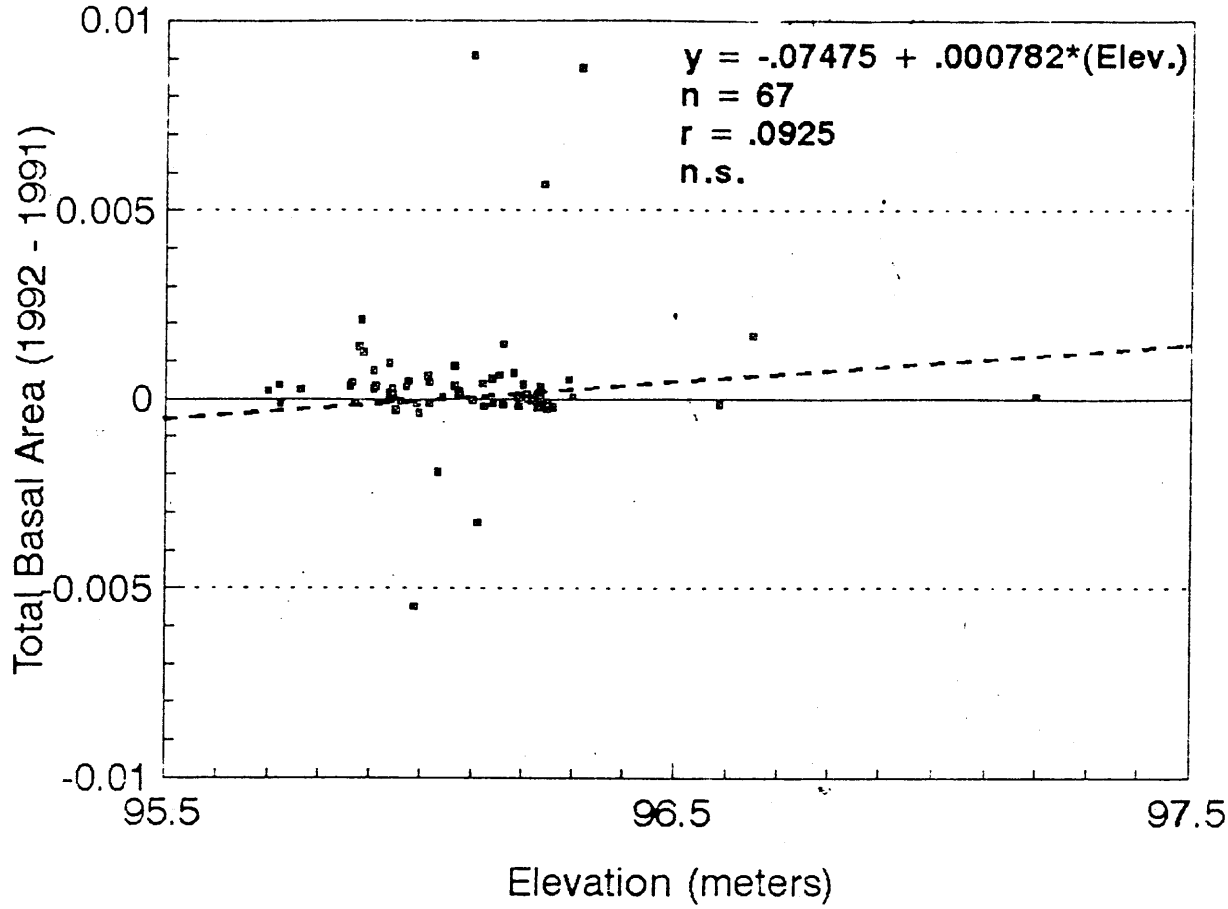

Figure 6: Change in total marsh plant basal area at Mile 172L marsh was not significant in 1992.

CHANGE IN HERB B.A. VS ELEVATION

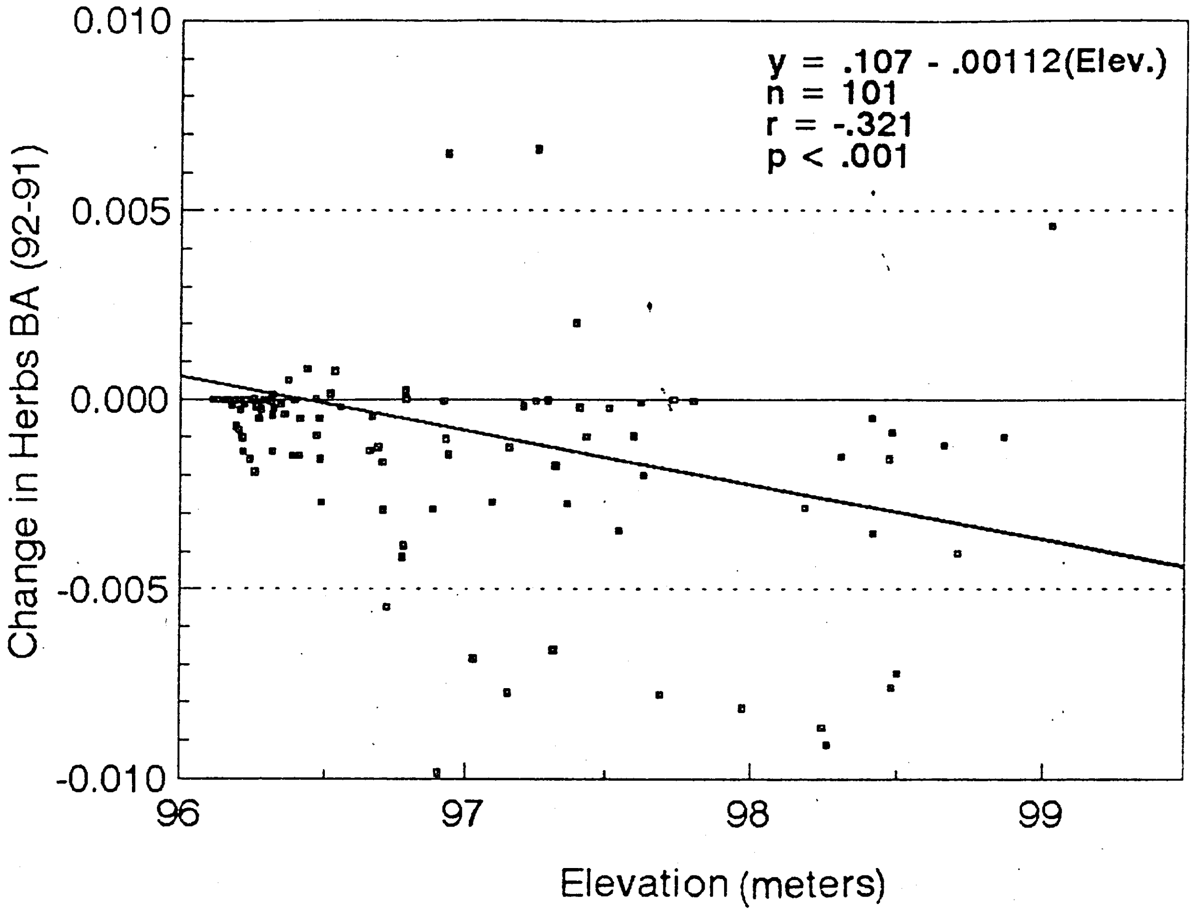

Figure 7: Change in herbaceous marsh species basal area was significantly negatively correlated with elevation at Mile 194L marsh in 1992.

CHANGE IN WOODY B.A. VS ELEVATION

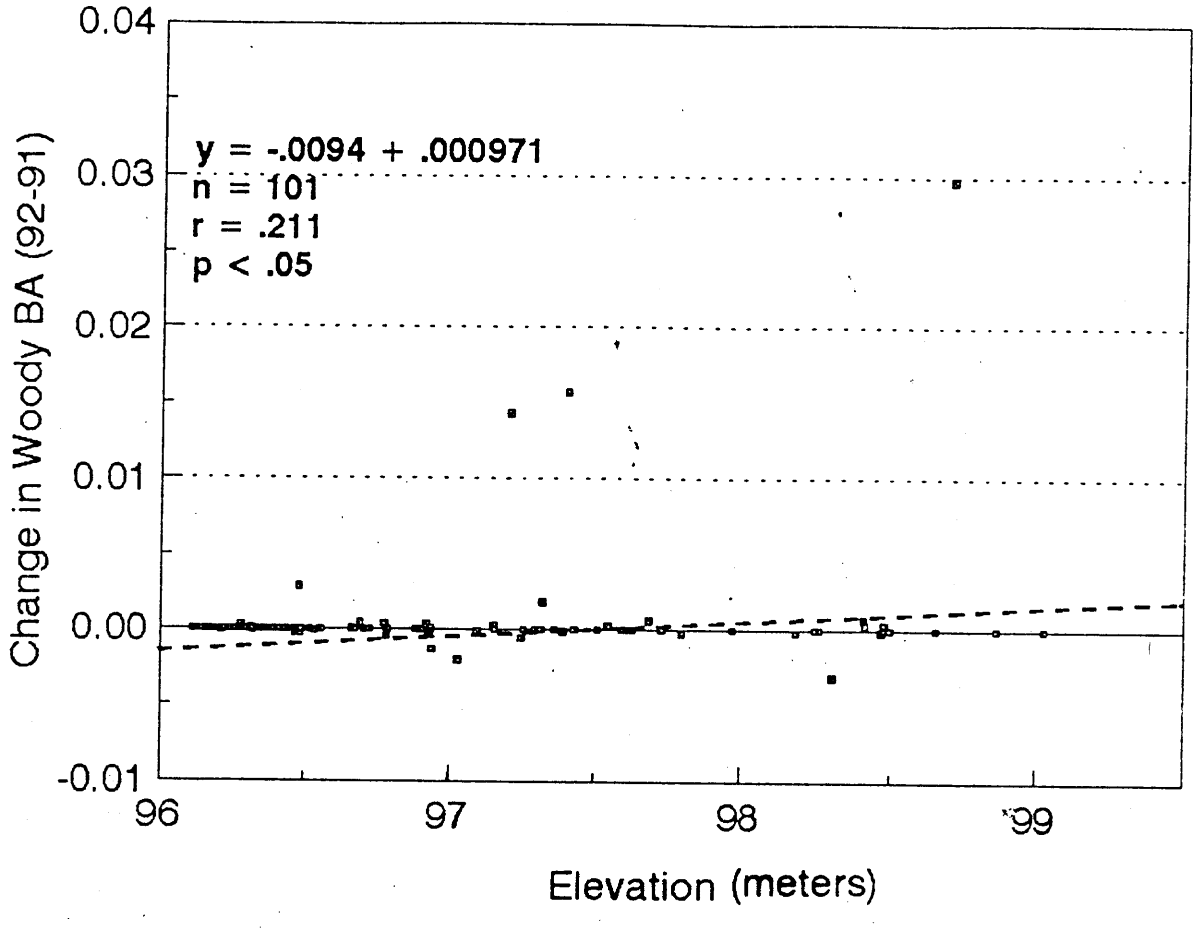

Figure 8: Change in woody marsh species basal area was significantly positively correlated with elevation at Mile 194L marsh in 1992.

CHANGE IN # SPECIES

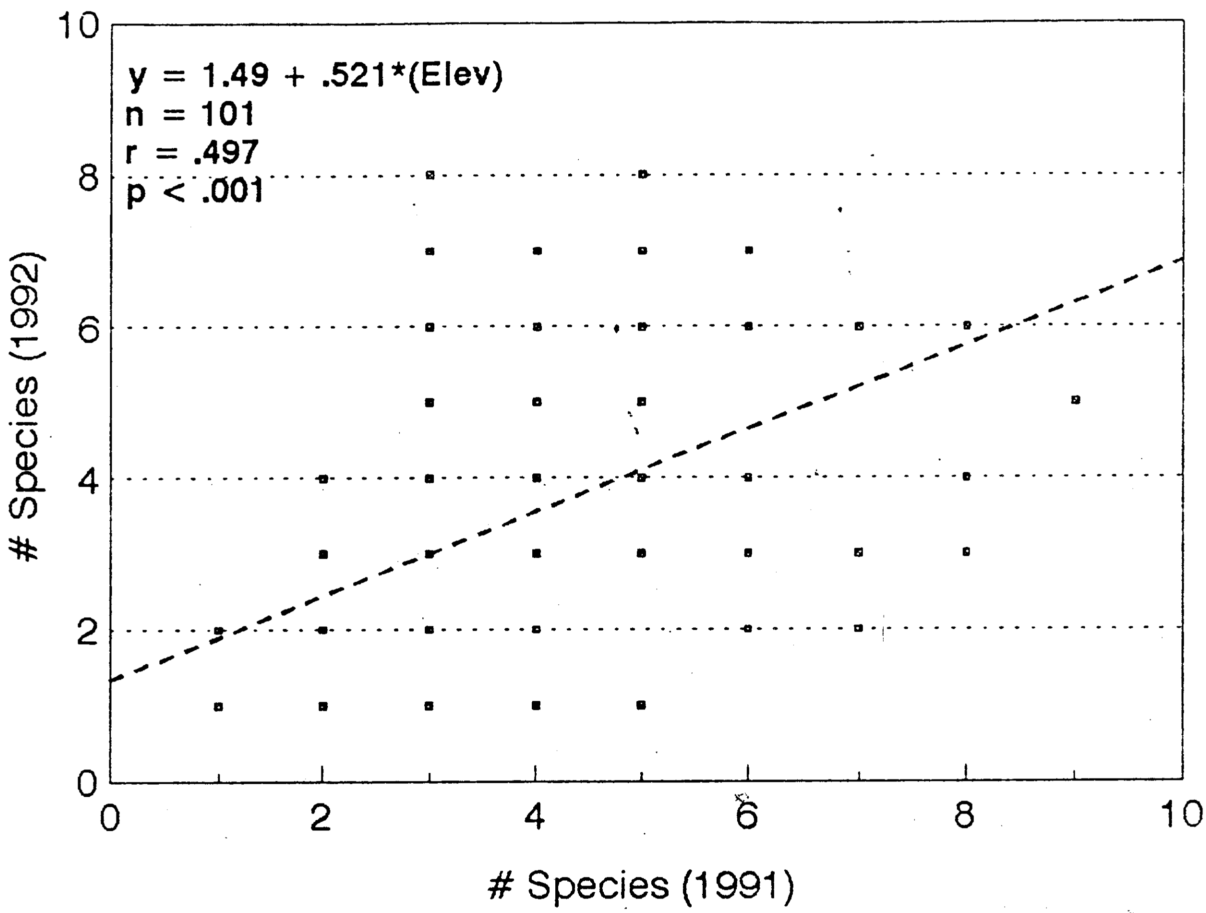

Figure 9: Change in marsh species richness at Mile 194L marsh between 1992 and 1991 was significantly positively correlated with species richness in 1991; however, the slope of this relationship is 0.52, considerably less than a 1:1 relationship.

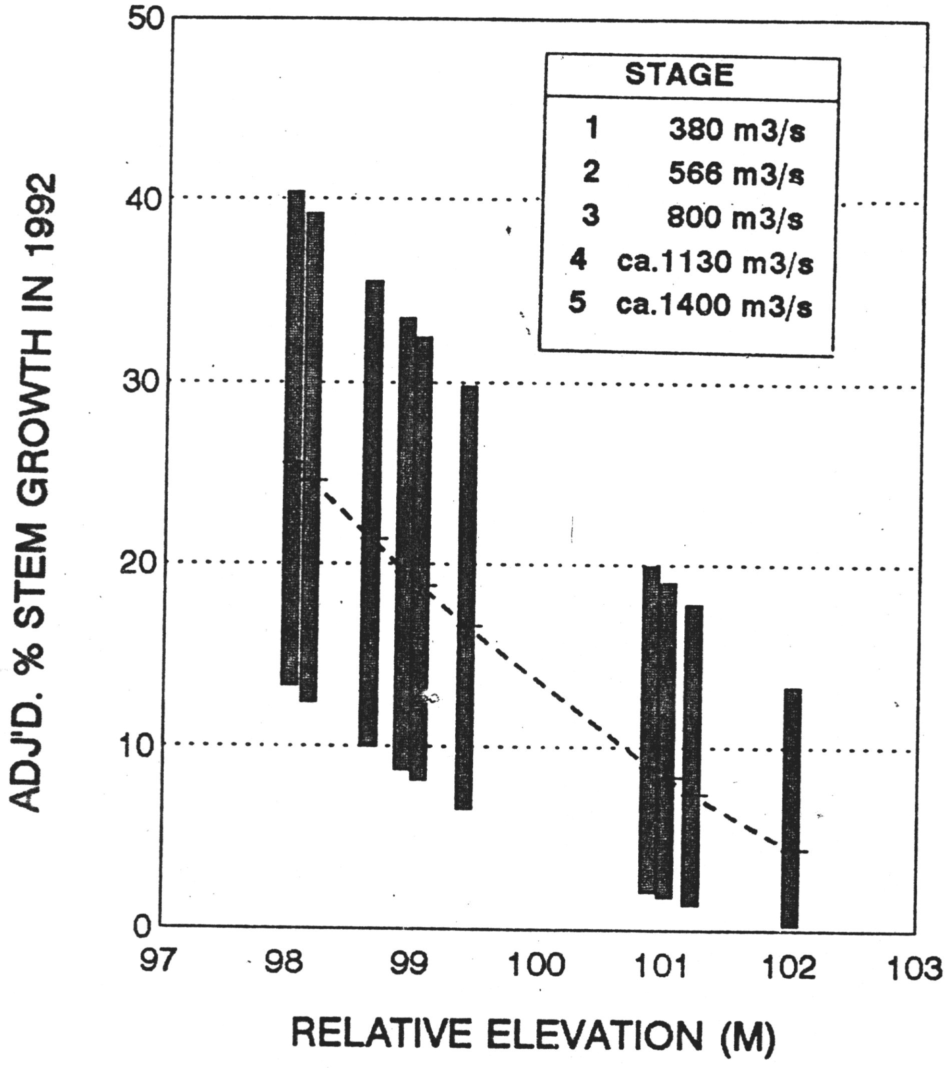

Figure 10: Adjusted percent <u>Salix</u> <u>exigua</u> stem growth in 1992 in relation to total stem length. The effects of age, 1992 plant height and basal area are factored out of this relationship. Bars represent ± 1 sd of grand mean values for covarying factor effects on age.

LTPLOT DATA (N = 12)

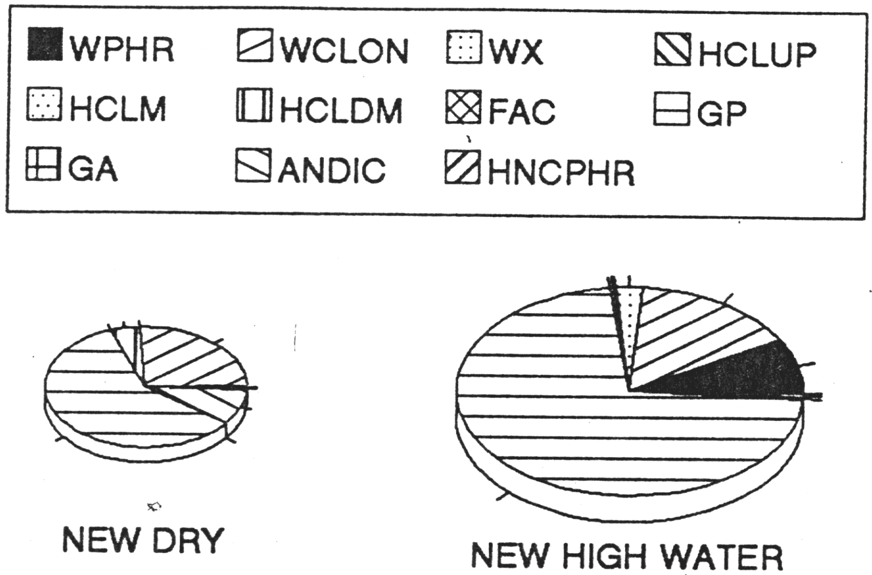

Figure 11: Analyses of basal area (cm^2) of riparian assemblages in 12 new dry and new high water quadrats throughout the Colorado River corridor, Grand Canyon National Park, Arizona. WPHR - woody phreatophytes; HCLM - herbaceous clonal macrophytes; GA - annual grass; WCLON - woody clonal; HCLDM - herbaceous clonal dry marsh; ANDIC - annual Dicotyledoneae; WX - woody xerophytes; FAC - facultative riparian perennial species; HNCPHR - herbaceous non-clonal phreatophytes; HCLUP - herbaceous clonal upland (riparian) species; GP - perennial grass.

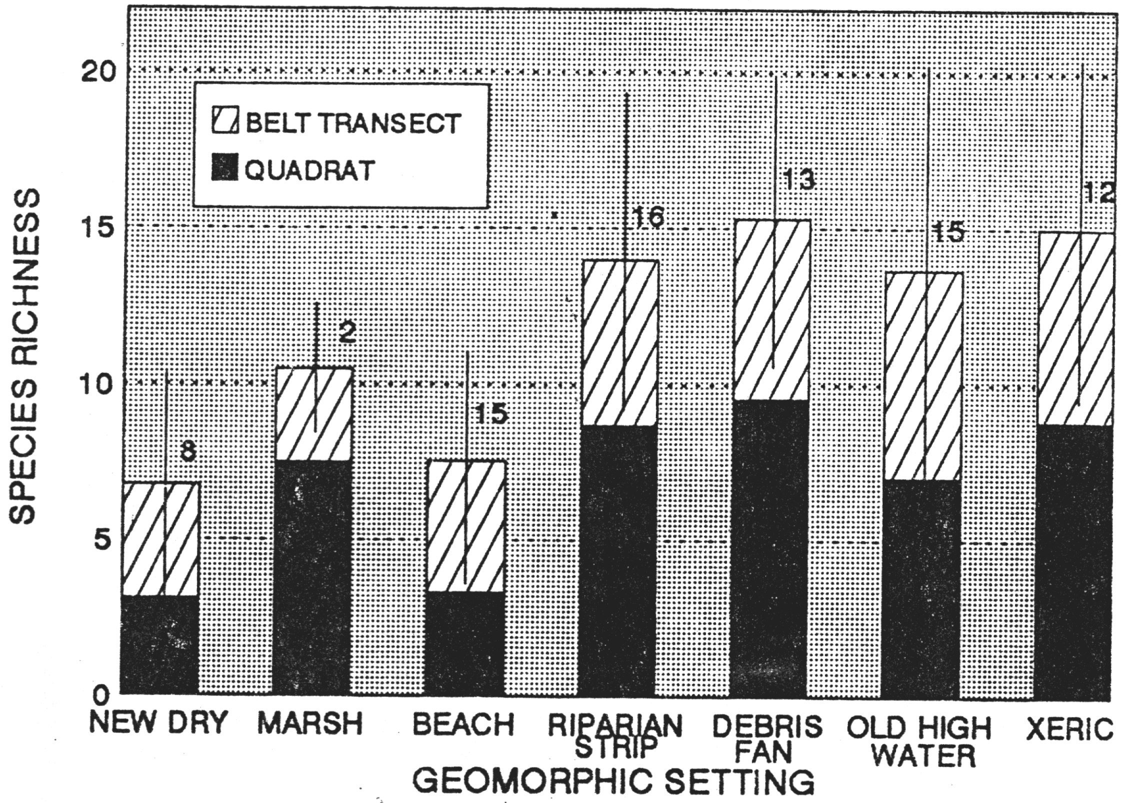

Figure 12: Representativeness and variation of mean species richness from transect and quadrat data in seven geomorphic environments in the Colorado River corridor, Grand Canyon National Park, Arizona. Note that species richness is lower in new dry and beach habitats. Error bars are ± 1 sd for the transect data.

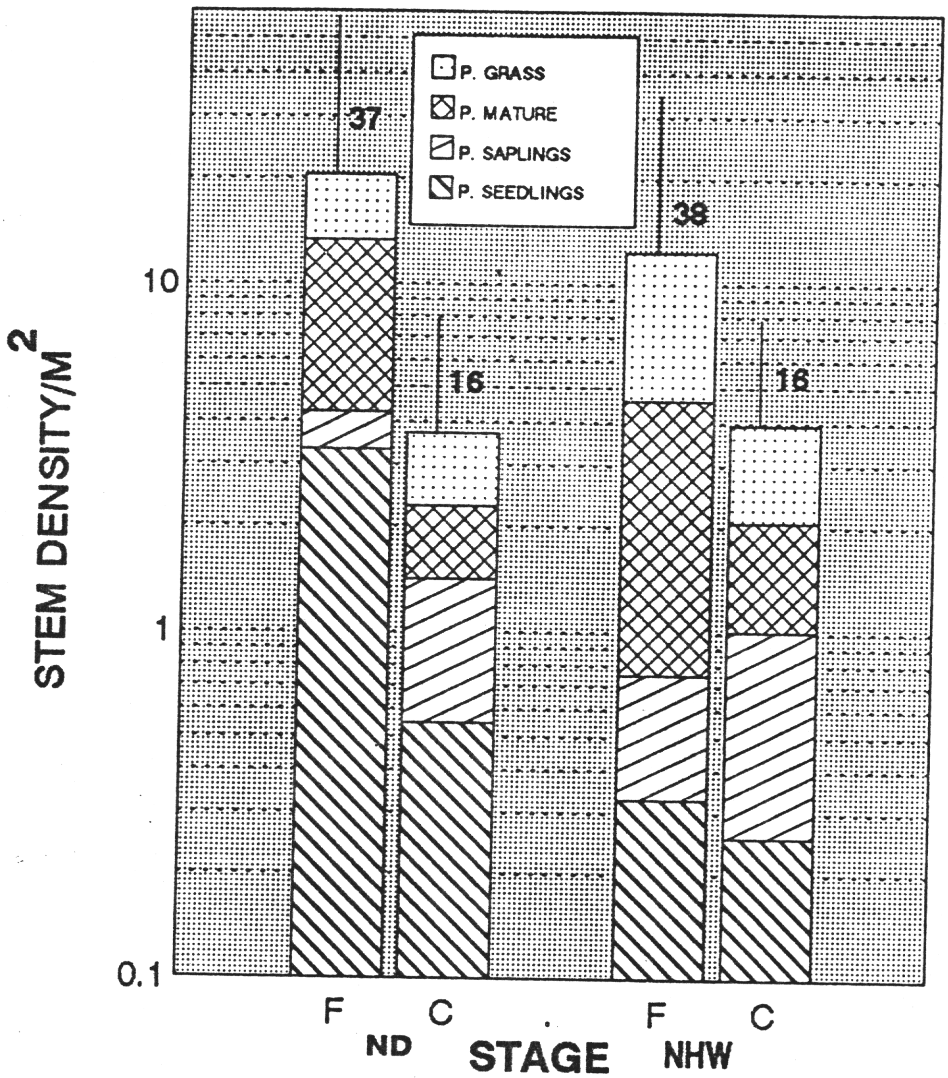

Figure 13: Stem density/m² as a function of substrate grain-size and stage elevation. F - fine-grained (silt/sand) substrata; C - coarse (cobble/talus) substrata. Data from random 54 paired 5m x 10m quadrats throughout the Colorado River corridor in 1992. Error bars are ± 1 sd for total stem density/m².

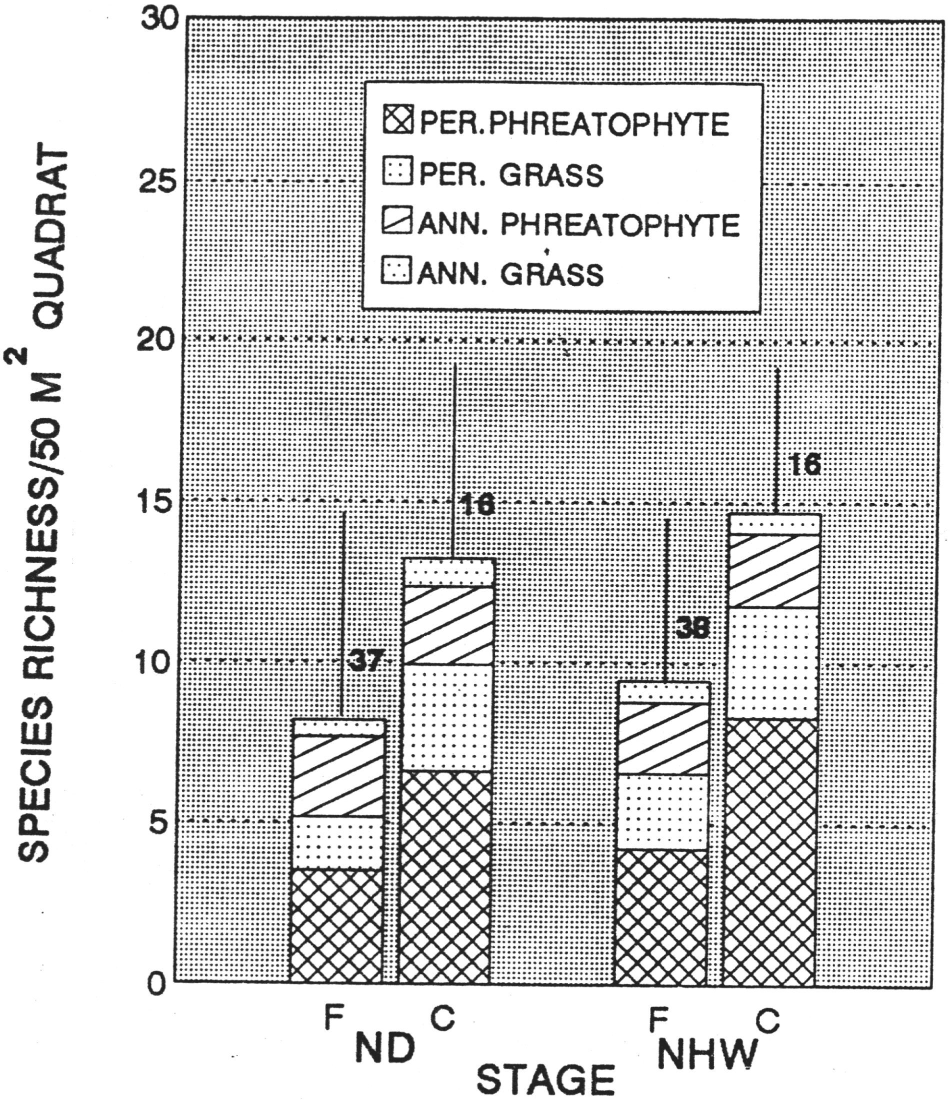

Figure 14: Species richness/quadrat as a function of substrate grain-size and stage elevation. F - fine-grained (silt/sand) substrata; C - coarse (cobble/talus) substrata. Data from random 54 paired 5m x 10m quadrats throughout the Colorado River corridor in 1992. Error bars are ± 1 sd for total stem density/m^2.

THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON RIPARIAN VEGETATION ALONG THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK, ARIZONA: 1992 DRAFT ANNUAL ADMINISTRATIVE REPORT

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Northern Arizona University
Flagstaff, AZ 86011

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ADMINISTRATIVE REPORT
BIO 35J3

ITEM		FY92		FY93		FY94		TOTAL	
		ESTIMATE	ACTUAL	ESTIMATE	ACTUAL	ESTIMATE	ACTUAL	ESTIMATE	ACTUAL
SALARY	Co-PI Ayers	$6700	-0-	$11,300		$6700		$24,700	
	Benefits		-0-						
	Crew leader	$8000	$877	$30,000		$20,000		$58,000	
	Benefits		$263						
	Photo Analyst	$4000	-0-	$16,000		-0-		$20,000	
	Benefits		-0-						
	Field Crew	$17,200	$15,165	$39,200		$19,100		$75,500	
	Benefits	$2370	$1219	$5650		$2190		$10,140	
TRAVEL		$1000	$335	$1700		$1500		$4200	
EQUIPMENT		$4000	-0-	$1040		$500		$5540	
FIELD SUPPLIES		$2000	$1066	$2000		$1030		$5030	
OFFICE SUPPLIES & ACCOUNTING		$3000	-0-	$4500		$3500		$11,500	
SOIL ANALYSES		$1500	-0-	$3000		-0-		$4500	
TOTAL DIRECT COSTS		$49,770	$18,925	$114,390		$54,520		$218,680	
TOTAL INDIRECT (20% NAU)		$9950	$3785	$22,880		$10,090		$43,730	
TOTAL		$59,720	$22,710	$42,125		$65,420		$262,410	

A SUPPLEMENTAL REPORT:

A PROPOSED PROGRAM TO CONTROL EXOTIC RAVENNA GRASS (POACEAE: SACCHARUM RAVENNAE) IN THE COLORADO RIVER RIPARIAN CORRIDOR, GRAND CANYON NATIONAL PARK

L.E. Stevens and T.J. Ayers

15 January, 1993

ABSTRACT

An exotic grass species is rapidly colonizing the Colorado River corridor in Grand Canyon National Park. Ravenna grass (Poaceae: Saccharum ravennae (L.) Murray, formerly Erianthus r.) is a large, competitive Eurasian bunchgrass that is undergoing an estimated five-fold population growth rate per year. This species was first documented near Lees Ferry in 1981, and the first plant in the Grand Canyon was located in 1989. In 1992 more than 400 plants were counted throughout the Colorado River corridor between Lees Ferry and Diamond Creek, and we estimate a 5-fold annual growth rate for this species. If control measures are not adopted before fall, 1993 (the next period of seed release) the population will become unmanageable and this species will, in all likelihood, become a dominant plant in the riparian ecosystem. A three-part plan is suggested for control: 1) immediate removal of all plants in Grand Canyon; 2) concurrent administrative action to eliminate this species in the source area (Glen Canyon National Recreation Area); and 3) a public education and monitoring program to prevent future colonization.

DRAFT DOCUMENT NOT FOR PUBLIC RELEASE

A NEW EXOTIC PLANT IN GRAND CANYON

An exotic grass species is rapidly colonizing the Colorado River corridor in Grand Canyon National Park. Ravenna grass (Poaceae: Erianthus ravennae) is a 2-3m tall, Eurasian bunchgrass. This species was planted as an ornamental by the National Park Service in and around the Wahweap Bay visitor services areas on Lake Powell, where the population numbers approximately 1,000 plants (Table 5). Ravenna grass releases seed from October to February and its wind-dispersed seeds are large, probably remaining viable through the winter. Ravenna grass is highly competitive, establishing and growing well in the shade of other streamside species. If the rapidly expanding population of ravenna grass in the Colorado River corridor is left unchecked for another year we feel certain this species will become a dominant plant species throughout the riparian ecosystem in Grand Canyon.

RATE OF COLONIZATION AND PRESENT DISTRIBUTION

Ravenna grass was first documented in the river corridor by Hartwick (1981; cited in Phillips et al. 1987) in the Lees Ferry area. No ravenna grass was observed in downstream reaches of the Grand Canyon by Stevens (1989 unpublished) during extensive vegetation sampling of the riparian corridor from 1987 and 1988. This species was first noticed in Grand Canyon National Park at Cardenas Creek (1 plant) in 1989 by N. Brian and numerous plants were observed during the GCES-II riparian vegetation project (Ayers and Stevens 1992). The latter researchers noted several dozen plants throughout the river corridor. Our late 1992 survey revealed more than 400 plants throughout the river corridor from Lees Ferry to Diamond Creek, typically in groups of 1 to 20 individuals (Table 5).

Observations on progressive colonization and the demography of this population suggest that ravenna grass is undergoing a five-fold increase from 1991 to 1992. The largest stand in the park is located at Cardenas Creek (Mile 71L) and contains a total of 307 individuals, of which 59 (19%) are mature (reproductive in 1992) and 248 (81 percent) are less than one year old. Other stands also contain 80-90 percent first year plants. Overall, we estimate a population growth rate of 500 percent/year is conservative for this species and that it represents a considerable threat to the riparian corridor.

LIFE HISTORY

The life history of ravenna grass is poorly known at present, and it has only been recently recognized as an actively colonizing species in the United States. In the Grand Canyon this species flowers annually in the early fall and releases seed in October and November. Like the native reed, <u>Phragmites australis</u>, ravenna grass produces relatively large, wind-dispersed seeds that probably remain viable through the winter months. We are presently endeavoring to learn more about the life history of this species, as well as the status and control measures in other western states where it is a problem species.

In the Grand Canyon ravenna grass is a competitive colonizer that can occupy a broad range of habitats. We found it growing on silt, sand, gravel and cobble/breccia substrata between the 15,000 cfs and the 60,000 cfs stage elevations throughout the Colorado River channel (Table 5). This species is often found growing on debris fans, which are the most species-rich habitats in the Grand Canyon. Ravenna grass is capable of growing up under the canopy of other riparian plants and is therefore capable of taking over habitats presently occupied by existing riverside vegetation. Therefore it is capable of altering the successional trajectory of riparian vegetation in this river corridor.

If a substantial population becomes established in the river corridor, Grand Canyon will serve as a seed source for invasion into tributaries and into downstream portions of the Colorado River. Tributaries of the Colorado River in the Grand Canyon are, in some cases, the most pristine riparian habitats in the western United States. Invasion of exotic species into these tributaries is therefore highly undesirable for Park management, but side streams are susceptible to invasion by exotic species, particularly those that spread through wind dispersal and are abundant in the mainstream corridor. Thus far, ravenna grass has not been observed in any Colorado river tributaries in Grand Canyon; however, as the ravenna grass population increases it represents a substantial threat to the integrity of many of these pristine drainages. This species is also not yet established around Lake Mead National Recreation Area to our knowledge.

A PROPOSED CONTROL PROGRAM

A three-part program is suggested for halting the expansion of the new ravenna grass population and for assuring that future threats of invasion are reduced. The objectives and methods of this program are:

1) Immediate removal of all ravenna grass plants in the Colorado River corridor in Grand Canyon National Park.

A removal program of all plants in the river corridor should be undertaken before seed set in the fall of 1993. Removal should be conducted as a pilot effort at Lees Ferry prior to initiation of a full-scale effort. We suggest that system-wide removal efforts in the river corridor could be accomplished from a two-boat, nine-person river trip (two 3-person control crews, two boatmen and a cook), with a duration of 16 days. Manual removal of plants will require digging up the root mass using shovels and pry-bars, and burning the plants. This considerable effort may disrupt patches of the landscape up to 10 ft^2 in area, and control staff should be trained in limited-impact removal techniques and site recovery. Because uprooted plants must be burned, the control trip should be conducted prior to the end of the river campfire season. We recommend that control efforts be undertaken in March, 1993. Careful observation for additional plants other than those listed in Table 1 should be conducted. The Cardenas Creek population (> 300 plants) at Mile 71L will require an additional or concurrent hiking effort for the control crew. Effectiveness monitoring can be conducted through the NAU Interim Flows Vegetation Project (Ayers and Stevens).

The control crew could be comprised largely of volunteers, but should be overseen by Park staff. The Colorado River Guides Association could be enlisted in this activity, thereby developing strong public support for the program.

2) Initiate concurrent administrative actions to eliminate the population(s) and use of this species as an ornamental in the Page/Lake Powell area.

To prevent future invasion of ravenna grass in the Grand Canyon, and to reduce threats of invasion to Glen Canyon National Recreation Area, the National Park Service should initiate negotiations to remove all of the more than 575 ornamental plants in the Lake Powell area. Glen Canyon National Recreation Area administration staff have been apprised of the threat of ravenna grass invasion to Lake Powell shorelines and downstream habitats. Page's primary nursery, Warner Nursery, has never distributed this species and does not intend to do so. The proprietor was informed of this species' invasive characteristics. Other local nurseries in the surrounding area should also be informed of the threats this species represents. This administrative program could easily enlist the support of outside environmental groups, including GCRG, the Grand Canyon Trust and the Arizona Sierra Club.

A press release on the control program would strengthen public perception of the National Park Service as an environmentally effective management agency. In addition, a press release would help notify other communities of the potential threat posed by this ornamental species.

3) Develop an education and monitoring program for the whitewater guides to detect additional plants that germinate after the removal program.

A low-cost monitoring program should be developed to determine whether control efforts for this species have been effective. Such a program should be developed for the NPS patrol rangers and the Grand Canyon River Guides association. These professional observers should be educated as to what ravenna grass looks like, what species it resembles, and how and to whom new observations should be reported. The annual Guide's Training Seminar could be used to educate guides and a training session could be conducted for the rangers. We do not recommend that these observers attempt to remove the plants, because that task should be conducted by especially trained control staff. Monitoring efforts should be intensive for the first three years after completion of the removal phase, and less intensive thereafter.

CONCLUSIONS

Ravenna grass (Poaceae: Saccharum ravennae) is an Eurasian bunchgrass that is actively colonizing the Colorado River corridor in Grand Canyon National Park. This species did not occur in Grand Canyon prior to 1988 and the population is expanding at a five-fold rate per year. In 1992, more than 400 plants were counted along the Colorado River. This species represents a substantial threat to the integrity of the riparian habitats along the Colorado River and its tributaries in Grand Canyon National Park, and in nearby National Park Service units. We propose a cost-effective, three-part (removal, administrative use-restriction, and monitoring) program to control this species and prevent further population expansion. This program should be initiated as soon as possible, and the removal phase should be completed prior to September, 1993, the next reproduction period for ravenna grass. This effort will minimize the duration and cost of the control program.

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Table A: Localities of <u>Saccharum</u> <u>ravennae</u> in Glen Canyon National Recreation Area and Grand Canyon National Park, 1991.

WAHWEAP BAY AREA, GLEN CANYON NATIONAL RECREATION AREA
(Examined 23 December, 1992 by L. Stevens)

1) Old NPS Headquarters Building -- ca. 200 plants;
2) Boat Trailer Parking Lot, lakeward from Old NPS HQ Building -- ca. 300 plants;
3) Wahweap Lodge -- ca 12 plants on lake side of lodge parking lot;
4) NPS housing area -- ca 30 plants in yards and gullies uplake of housing area;
5) Wahweap trailer village -- none;
6) Stateline Boat Ramp -- 3 plants on lakeside of NPS outhouses (check the small drainage just downlake);
7) Wahweap Campground -- ca 30 plants on downslope side of campground;
8) Page Airport -- 1 plant at telephone pole at front parking lot.

1992 TOTAL = ≥ 576 individuals

GRAND CANYON NATIONAL PARK
(Colorado River Mile and Side*)

0.1R (2m)**, 1.1R(?), 2.5R, 3.3L, 4.8R, 4.9R, 5.2R, 19.2R, 25.0R, 26.0R, 27.5R, 37.2R, 37.5R, 38.0R, 42.6L, 46.5R, 51.5L, 51.6R (25), 54.5L, 55.8L, 56.1R, 58.0R, 71.0L (248s, 59m), 93.0L, 128.0L (7s, 2m), 133.0L, 137.0R (16), 138.5R, 142.5L (11), 160.5L-161L, 168.5L, 169.0L, 173.5R, 177.5R, 183.5R (2), 186.0L (10), 186.1R (2), 186.5, 188.0R, 188.6R, 188.6-189.0L (10), 192.0L (4), 192.5R (25), 203.0L, 208.0L, 208.1L, 216.0R, 217.0 (4 above rapid on L)

1992 TOTAL = ≥ 419 individuals

* Mileages according to Stevens (1983)
** Numbers represent single mature plants unless parenthetic numbers of seedlings (s) and mature (m) plants are indicated.