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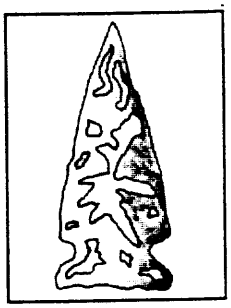
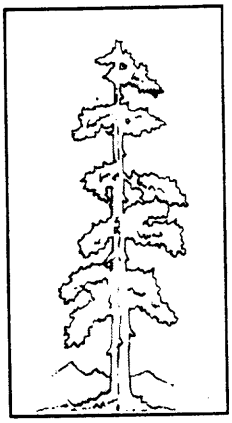
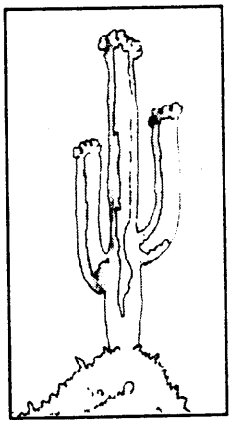
Final
Annual Report
1992

Monitoring and Evaluating the Impacts of Glen Canyon Dam Interim Flows on Riparian Communities in the Lower Grand Canyon







Submitted to

Hualapai Tribe

Submitted by

SWCA, Inc.

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ABSTRACT

This report details the baseline survey efforts for riparian studies conducted in 1992. Vegetative, avian, mammalian, and reptilian communities were studied in the portion of the Grand Canyon from National Canyon to Columbine Falls. Baseline data were collected that characterize these communities and will provide a base of comparison for future monitoring efforts.

STATEMENT OF OBJECTIVES

The riparian zone of the Colorado River through the Hualapai Indian Reservation in lower Grand Canyon is a complex and productive environment, and the Hualapai Tribe has strong cultural, environmental and economic ties to this portion of their reservation. SWCA is currently working with the Hualapai Tribe and the Glen Canyon Environmental Studies program (GCES) to assess the influence of Glen Canyon Dam interim flow operations on the natural resources of Hualapai lands.

A phased approach is being used to develop and implement the specific elements of the Hualapai interim flow riparian monitoring plan. Phase I includes the time period covered by this annual report, from approximately June 1 to December 10, 1992. The goal of this phase is to obtain baseline riparian resource data. A preliminary study site and vegetation area map for the Colorado River along the Hualapai Reservation, produced using GCES developed computer modeling with video photography, is an integral part of this report. Phase II, including fiscal years 1993 and 1994, involves establishing long-term monitoring protocols and re-censusing of vegetation plots, marshes and transects as well as avian, mammal and reptile study sites. While baseline data are the products of Phase I, comparative trend data related where possible to flow regimes are the products of Phase II.

Nine specific objectives are identified in this monitoring plan:

PHASE I

1. Review the existing literature and available data on plant and animal studies of the riparian corridor throughout the Grand Canyon.

2. Develop a baseline study site and vegetation area map with the use of the GCES Map Imaging Processing System (MIPS) and existing aerial photography.

3. Perform a baseline validation survey of the riparian communities along the lower Colorado River through the Hualapai Reservation, focusing upon the reach from Diamond Creek to Columbine Falls.

4. Establish interim flow monitoring sites and specific monitoring parameters for the lower Grand Canyon based on information collected under Objectives 1, 2, and 3.

5. Establish a Scientific Information Database (SID), consistent with GCES protocol, for data collected from interim flow monitoring sites.

PHASE II

6. Implement specific monitoring methodology, and conduct monitoring of selected study sites. Identify and evaluate changes in riparian communities and determine, to the extent possible, if they are a result of interim flows, or related to natural ecological processes. This short-

term monitoring program will provide a baseline for long-term monitoring efforts. Evaluation will be focused on effects related to monthly volumes, maximum and minimum flow levels, ramping rates, and season.

7. Identify changes in vegetative community size and composition occurring throughout the time frame of the monitoring program at representative sites, and produce an updated map of vegetative communities at specific sites in the lower Grand Canyon.

8. Integrate the riparian and natural resource results with the GCES Geographic Information System (GIS), Scientific Information Database (SID), and long-term monitoring program.

9. Develop a long-term riparian system monitoring program for the Hualapai Tribe, with site selection, monitoring techniques, and analysis protocols compiled in a long-term monitoring field guide.

The discussion below details the methodology used to meet each objective and the results of our studies.

Objective 1. Literature Review

A literature survey was conducted prior to the initiation of this study (Waring 1991), and project scientists have reviewed recent literature to ensure that study methodology and analysis techniques are current and well accepted by the scientific community. The literature review clarified issues such as the definition of geomorphic reaches, dry and wet marsh distinctions, and native and exotic plant interaction and succession patterns. The literature review bibliography is presented in Appendix C.

Objective 2. Baseline Study Site and Vegetation Area Map

Vegetated area in the lower Grand Canyon has been measured using the Map Image Processing System (MIPS) at Grand Canyon Environmental Studies (GCES). This provides a measurement of the total vegetated area in the lower Grand Canyon. Where possible, vegetation types have been measured separately, although the quality of the video photography used for MIPS and the capabilities of the system to recognize vegetation types is limited. Thus the vegetation type measurements are for general trend use only, while the overall vegetation area data are apparently quite accurate. Printouts from the MIPS, with overlays showing plot, marsh, transect and other study site information, accompany this final report.

Because the MIPS system was inadequate for this objective, i.e. mapping vegetation community changes, hand mapping of portions of the three GIS reaches in the Hualapai study area will be conducted on an annual basis beginning in 1993. This mapping will allow the study of species succession (measuring changes in size and composition of vegetation patches), inundation effects, and colonization of beach areas. These areas will be measured using MIPS on an annual basis to identify changes in vegetation area. If possible, Hualapai technicians will complete annual measurements of vegetated area in the lower Grand Canyon using MIPS and aerial or video photography. This information will be integrated with the results of hand mapping, to potentially show large-scale direct impacts to vegetation types and communities from the interim flow regime and any exceptional flows which may occur.

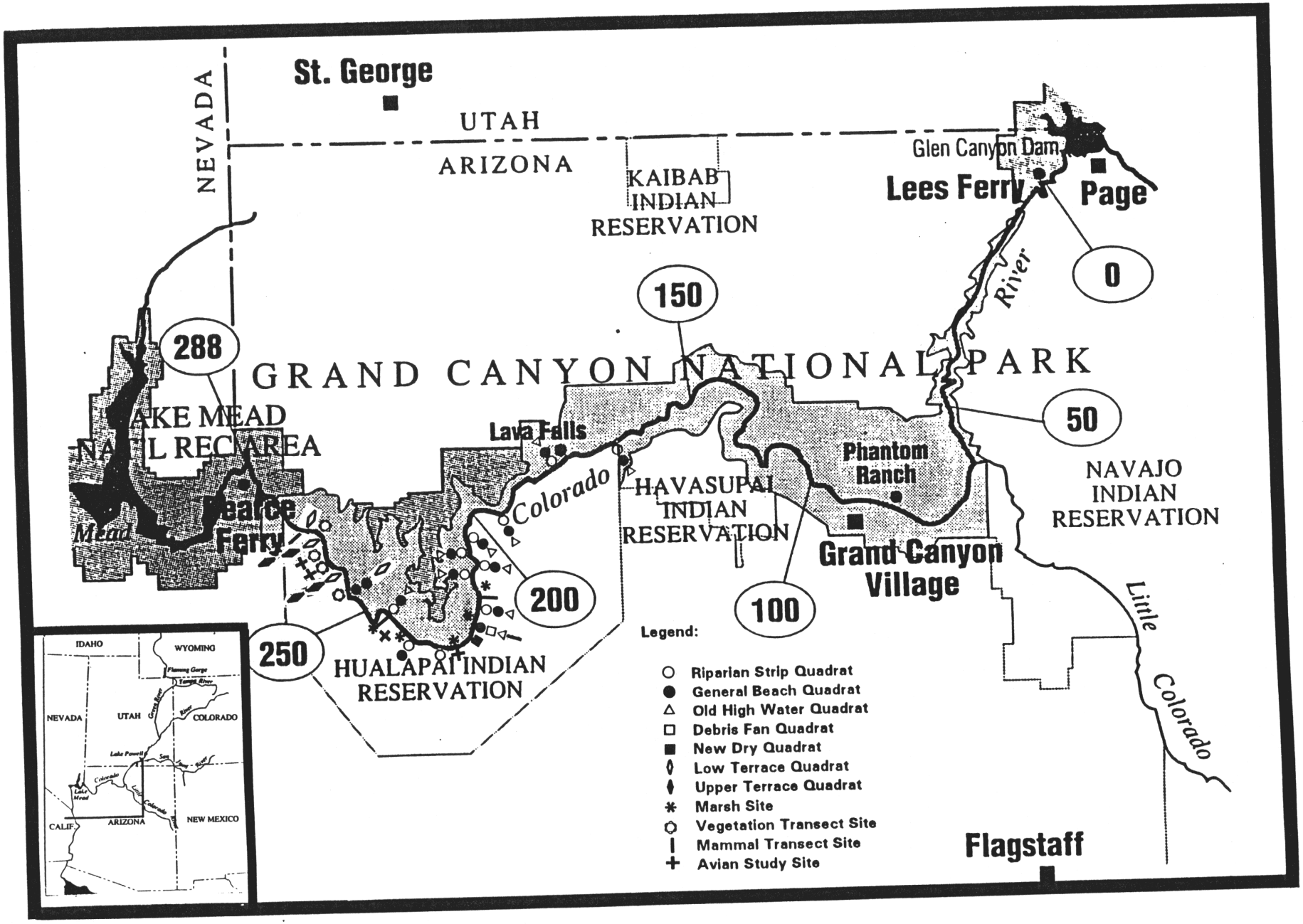

Figure 1. Site Location Map

Objective 3. Baseline Validation Surveys

A. Vegetation

Baseline vegetation surveys followed the methods of Ayers and Stevens (1991), researchers currently conducting vegetative studies under GCES contract in the upper Grand Canyon, except where conditions required use of additional methods. Surveys included three types of sites: 5 x 10m quadrats in four vegetation zones related to river level and inundation frequency; marsh sites, in areas which support dry marsh vegetation;[1] and transects in Lake Mead-influenced areas, which supported multiple zones of vegetation related to lake levels, river levels, and inundation frequency. Table 1 shows the quadrats, marsh plots, and transects established in each of the three study reaches.

Quadrats

Forty-three 5 x 10m quadrats were established in three reaches of the lower Grand Canyon. These reaches are as follows: Reach 1, river mile (RM) 172 to RM 213; Reach 2, RM 213 to RM 240; and Reach 3, RM 240 to RM 273.5. The first two of these reaches match the geomorphic reaches defined by Schmidt and Graf (1990). The third reach encompasses the Hualapai portion of the geomorphic reach from RM 240 to the Grand Wash Cliffs at RM 275. Quadrat sites were randomly placed in stratified vegetation zones. These zones have been created by separate flow regimes, which affect the river level (and thereby proximity of water table to vegetation) and frequency of inundation.

The sampled zone highest in elevation is the old high water (OHW) zone, located at the 40,000 to 100,000 cubic feet per second of river flow (cfs) level. This zone is dominated by slow-growing woody vegetation including catclaw acacia (*Acacia greggii*) and brittlebush (*Encelia farinosa*) and numerous xeric annual species. Ten quadrats were established in this zone.

The general beach (GB) zone lies closer to the water's edge, at the 28,000 to 40,000 cfs level. GB plots which occur in tributary debris areas are denoted as debris fan (DF) plots. This water level marked the average weekly flows prior to the interim flow regime. Above RM 240, the GB zone is dominated by arrowweed (*Tessaria sericea*) on sandy slopes deposited as the flood of 1983 subsided. Below RM 240, this zone includes silt terraces deposited as Lake Mead levels dropped over the last 20 years. Terraces approximating the characteristics of GB plots are identified as upper terrace (UT), while lower terrace plots (LT) more closely resemble riparian strip plots (see description of riparian strip plots below). The influence of lake levels on plots below RM 240 led to the use of transects in addition to quadrats, as described below. Lake-influenced GB quadrats are generally dominated by coyote willow (*Salix exigua*), Goodding's willow (*Salix gooddingii*), tamarisk (*Tamarix ramosissima*), and seep willow (*Baccharis salicifolia*). Emergent vegetation is prevalent in this zone both above and below RM 240. Sixteen quadrats were placed in this zone.

The riparian strip (RS) zone also lies at the 28,000 to 40,000 cfs level, in channel margins. Above RM 240, this zone supports a wide variety of species, including catclaw acacia (*Acacia greggii*), seep willow, arrowweed, horsetail (*Equisetum* sp.), and annual grasses. Below RM 240, these plots are characterized by emergent vegetation including horseweed (*Conyza canadensis*) and aster (*Aster subulatus*). Fourteen quadrats were placed in this zone.

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[1]Dry marsh vegetation is defined by Cowardin et al. (1979) as patches of emergent annual or perennial vegetation in low-lying, periodically inundated habitats.

Table 1. Study Site Locations

Mile	Vegetation Studies	Other Studies
Reach 1 (RM 172 to RM 213)		
172.2L	RS, GB, OHW	
183.2R	RS, GB, OHW	
194.0L	RS, GB, OHW	
209.0L	RS, GB, OHW	Hand mapping
213.0R	RS, GB, OHW	
Reach 2 (RM 213 to RM 240)		
217.4L	RS, GB, OHW	
220.0R	RS, GB, OHW	
228.8L	Marsh	Hand mapping, Mammal trapping
231.8L	RS, GB, OHW	
234.9R	Marsh	
235.0L	GB, DF, OHW	Mammal trapping
237.3L	ND	
239.0R	Marsh	
239.6L	RS	
Reach 3 (RM 240 to RM 273.5)		
240.5L	RS, GB	Breeding bird surveys
241.5L	Marsh	
246.0R/L	RS, GB, OHW	Mammal trapping, Breeding bird surveys
249.4L	Marsh	
254.0R	GB, ND, LT	
254.1L	Transect	
259.0L	LT, UT	
260.2L		Breeding bird surveys
261.5L	Transect	
264.5L	Transect	
265.1L		Breeding bird surveys
266.5R/L	LT, UT, UT	
269.6L	Transect	
273.1R	Transect	Hand mapping
274.7R	LT	
276.0L		Mammal trapping

Notes: RS=riparian strip; GB=general beach; OHW=old high water; ND=new dry; DF=debris fan; LT=low terrace, UT=upper terrace. River miles are followed by L or R to show left or right bank, determined when facing downstream.

The new dry (ND) zone includes beaches and terraces newly exposed as a result of the interim flows regime, at the 20,000 to 28,000 cfs level. This zone is marked by emergent vegetation, with high seedling counts and low basal cover. Species include bulrushes (*Scirpus* sp.), rushes (*Juncus* sp.), and sedges (*Carex* sp.), as well as coyote willow, Goodding's willow, and tamarisk. One quadrat was placed in this zone.

Marshes

Five marsh sites were established in areas dominated by dry marsh vegetation, usually horsetail (*Equisetum* sp.). At each site, one meter wide belt transects were established from the 20,000 cfs level, marked by the water's edge or the wet sand, to the 28,000 cfs level. Vegetation in each transect was censused and basal cover measured. Three productivity plots were randomly chosen in each marsh. Each productivity plot consisted of a circle 80 cm in diameter (1/2 m^2) cleared of all vegetation.

Transects

Five transects were established below RM 240, on silt terraces deposited through the interaction of river flows and Lake Mead. Within the first two reaches, sites containing all three vegetation zones (Riparian Strip, General Beach, and Old High Water) were selected as study sites for the establishment of long-term study plots. Quadrats were randomly established within each zone of each study site. Due to the historic influence of fluctuating water levels of Lake Mead on the lower reach, the three vegetation zones of the previous reaches did not exist or were greatly altered. Quadrats were randomly distributed throughout the New High Water zone within this third reach to examine the currently-exposed, vegetated lake bed which will be inundated when the lake level rises. This method, however, did not fully characterize all the vegetation zones found in this reach. Therefore, transects running perpendicular to the river for the length of the vegetated area (from water's edge to talus cliff) were established to characterize the vegetation colonizing all of the previously, lake-inundated zones.

These transects were placed at random sites at approximately five-mile intervals. For each transect, a permanent endpoint was established at the talus slope which marked the outer edge of the highest silt terrace. From this endpoint a transect was established perpendicular to the flow of the river. Vegetation zones and terraces were delineated and their width measured. In each zone, ten random one square meter plots were censused and basal cover measured.

The zones of a transect generally included a broad terrace dominated by coyote willow with patches of tamarisk; a narrow band of large Goodding's willow; a band of large tamarisk; and one or two zones of dead dry and wet marsh vegetation, created as the lake receded.

VEGETATION STUDIES RESULTS

Within the three reaches, 43 long term study quadrats were established in 4 vegetation/geomorphic zones (New Dry, Riparian Strip, General Beach, and Old High Water (Table 1). The New Dry zone is the newly exposed area of beaches due to the decreased maximum discharge of the interim flows begun on 1 August, 1991. This zone lies in the area inundated by discharges of 20,000 cfs to 28,000 cfs. The New Dry quadrats showed the lowest vegetation coverage of the 4 zones due to the recent availability of this area for colonization through exposure by interim flows (Figure 2). The Old High Water zone, the area not affected by flooding since regulation by the Glen Canyon Dam in 1964, contained the highest vegetation cover.

Diversity of species was lowest in the New Dry zone with only 15 species colonizing the quadrats while the Riparian Strip, General Beach, and Old High Water zones each contained more than 30 different vegetation species (Figure 3). The mean number of species per square meter, however, was similar for all 4 zones with approximately 5 to 7 species per square meter.

The New Dry zone held the highest number of individuals per square meter of the 4 zones (Figure 4) due to the high number of seedlings (Figure 5).

In the lower study reach, 5 transects running perpendicular to the river corridor for the length of the riparian vegetation were established to examine this lake-influenced reach. Transect 1 at RM 261.5L contained 4 zones defined by elevation which determine inundation by the river/lake interactions within this reach. The highest, talus-most zone, Zone 1, contained no live individuals (Figure 8) and had the highest density and cover of dead vegetation of the 4 zones (Figures 7 and 9). The lowest elevation, riverward-most zone, Zone 4, held the second highest density and cover of dead vegetation. This could be due to fluctuating flows which affect this zone. Zone 4 also had the highest number of individuals per square meter of the 4 zones.

Woody species (tamarisk, Gooddings willow, and seep willow) and woody clonal species (coyote willow and arrow weed; see Table 2) were the predominant living species (in density and cover) of all the zones. Wet marsh species (cattail, rushes, and sedges) were the predominant dead species in vegetation coverage for Zones 1, 2, and 4. These zones have been affected by changing lake levels which have been dropping since 1984. In adjusting to the decreased water level, many species and individuals have died. This is most apparent in Zone 1 which was first affected by the decreasing lake level.

Marshes, a new feature to this river corridor since the impoundment of the Colorado River by Glen Canyon Dam in 1964, were examined at five sites. There was no statistical variation in the number of individuals or cover among these five marshes. Marsh 5, however, did show a significant difference in the number of seedlings per square meter (Figure 12). *Equisetum*, a dry marsh species, dominated all of the marshes in both number of individuals and cover for both live and dead vegetation. The exception was Marsh 2 which had no dead vegetation (Figures 10, 11, 12, and 13).

Table 2. Categories of Vegetation Species Found in Marsh and Transect Study Sites along the Lower Colorado River

Annual Dicots

Conyza canadensis
Erigeron species
Gnaphalium species
Melilotus species
Oenothera elata
Pluchea purpurascens
Polygonum species
Salsola iberica

Herbaceous (perennial)

Apocynum cannabinum
Aster subulatus
Veronica anagallis-aquatica

Wet Marsh

Juncus species
Scirpus species
Typha species

Dry Marsh

Equisetum hiemale
Equisetum laevigatum

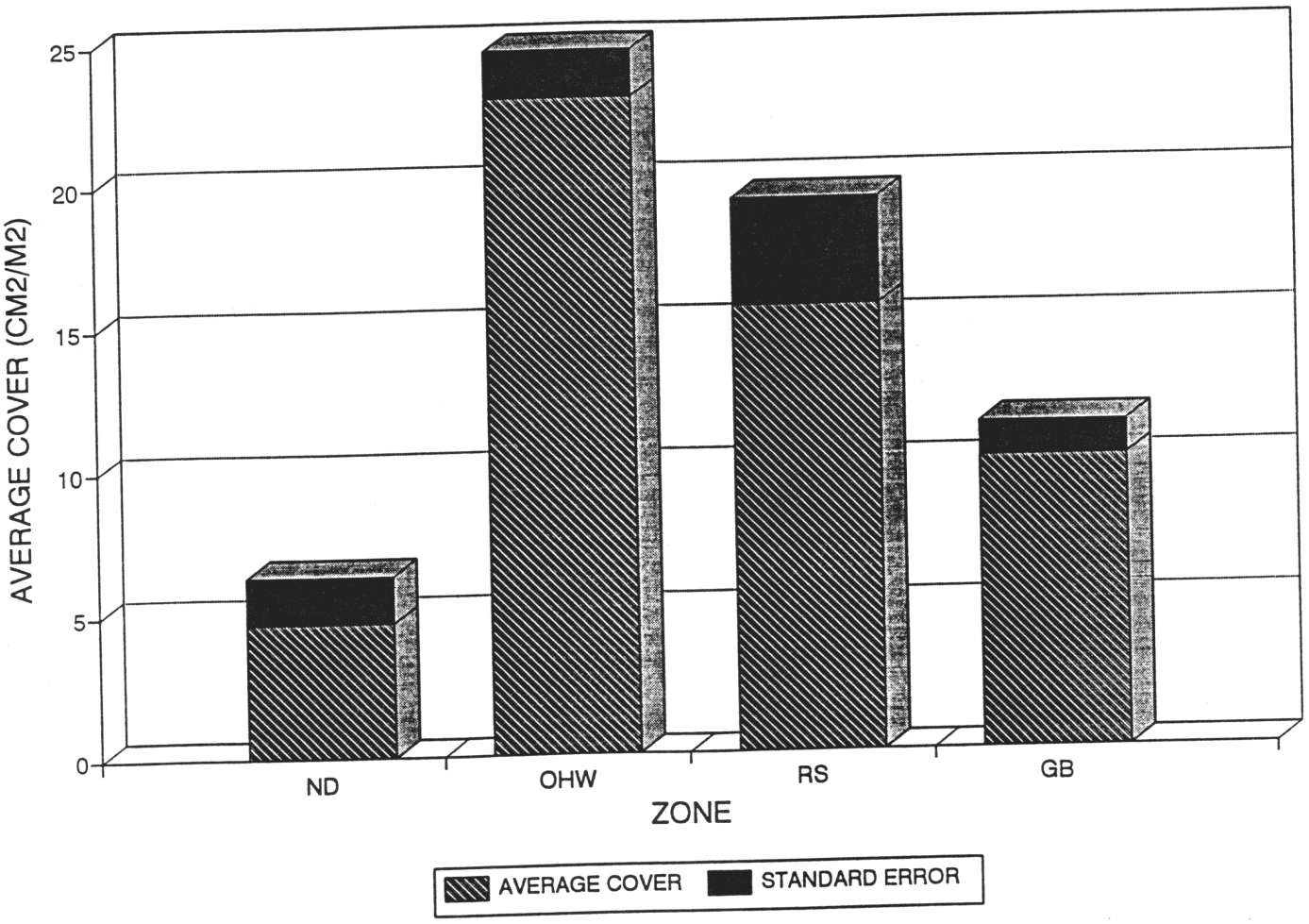
Woody

Artemisia ludoviciana
Baccharis salicifolia
Gutierrezia species
Salix gooddingii
Haplopappus acradenius
Tamarix ramosissima

Woody Clonal

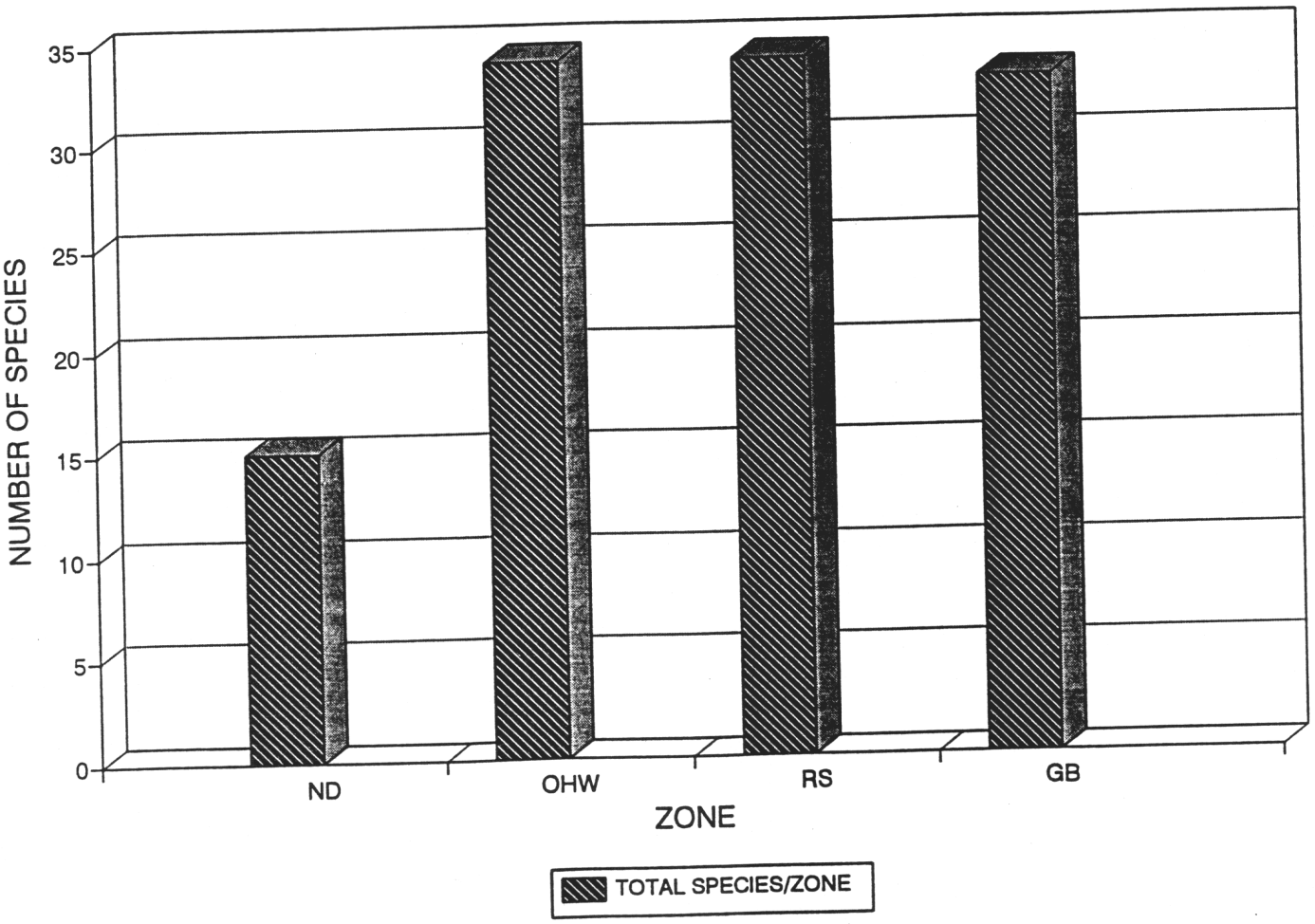
Salix exigua
Tessaria sericea

FIGURE 2. BASAL COVER IN QUADRAT ZONES



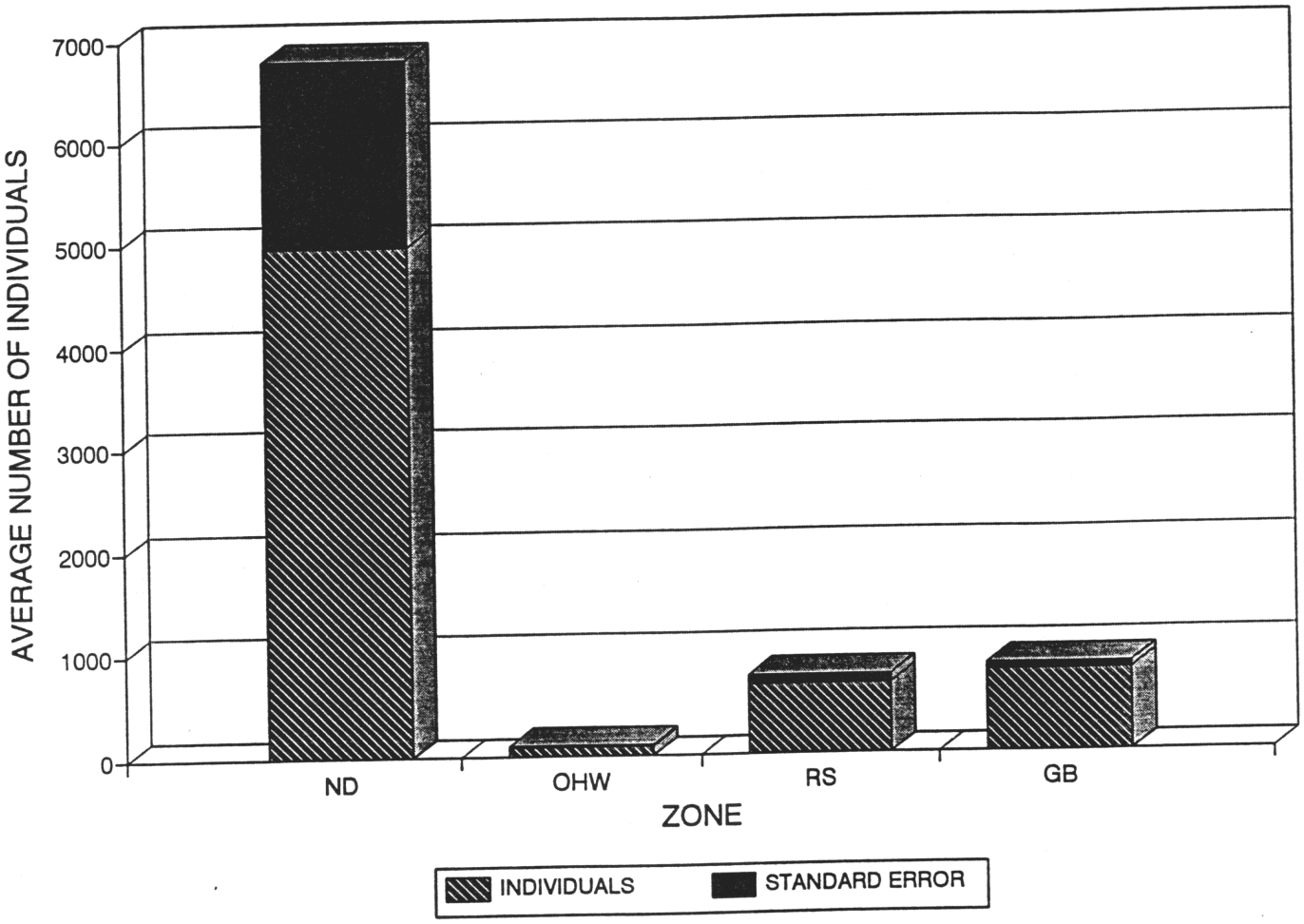
ND=New Dry Zone; OHW=Old High Water Zone
RS=Riparian Strip Zone; GB=General Beach Zone

FIGURE 3. NUMBER OF SPECIES
IN QUADRAT ZONES



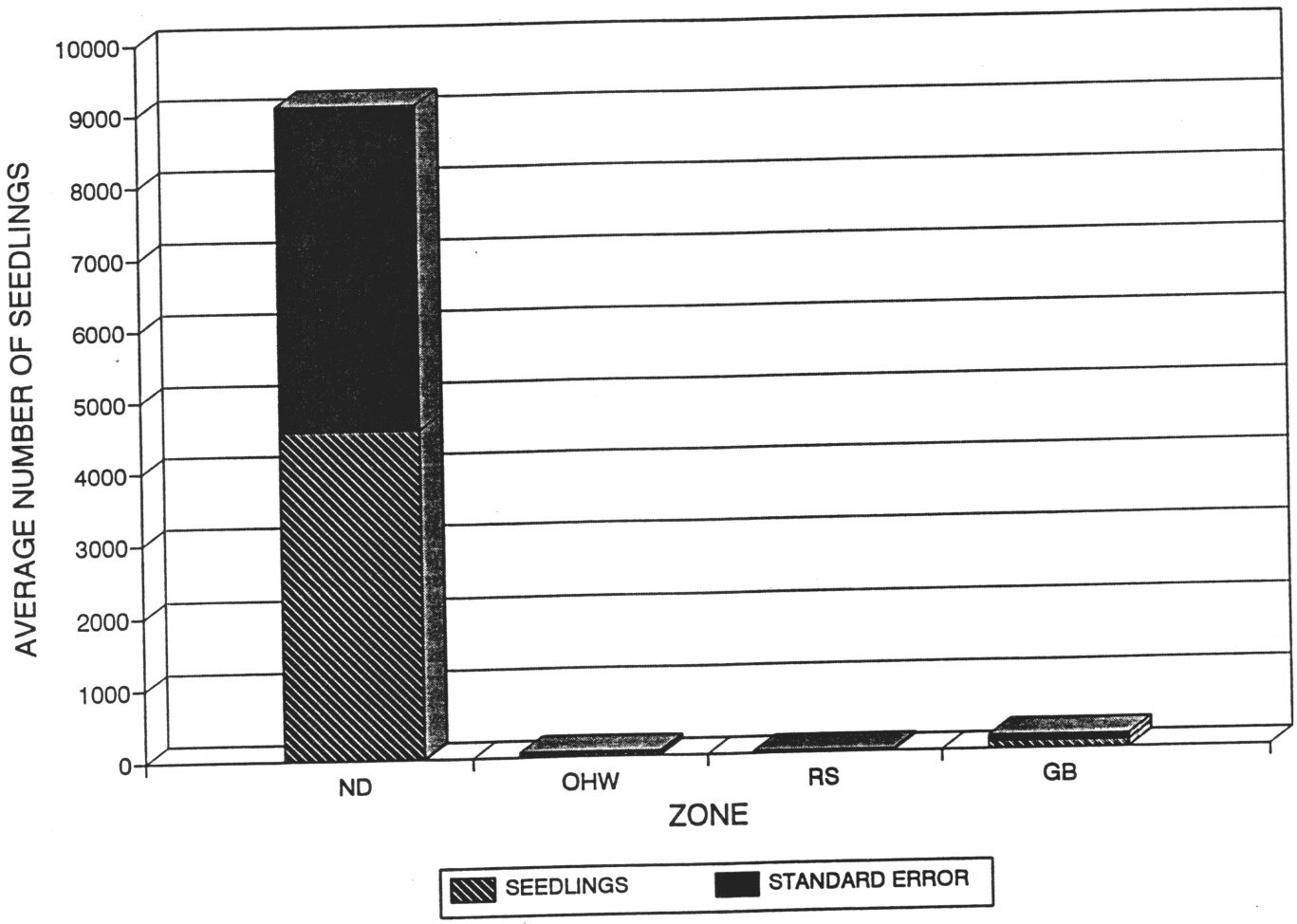
ND=New Dry Zone; OHW=Old High Water Zone
RS=Riparian Strip Zone; GB=General Beach Zone

FIGURE 4. NUMBER OF INDIVIDUALS IN QUADRAT ZONES



ND=New Dry Zone; OHW=Old High Water Zone
RS=Riparian Strip Zone; GB=General Beach Zone

FIGURE 5. NUMBER OF SEEDLINGS IN QUADRAT ZONES



ND=New Dry Zone; OHW=Old High Water Zone
RS=Riparian Strip Zone; GB=General Beach Zone

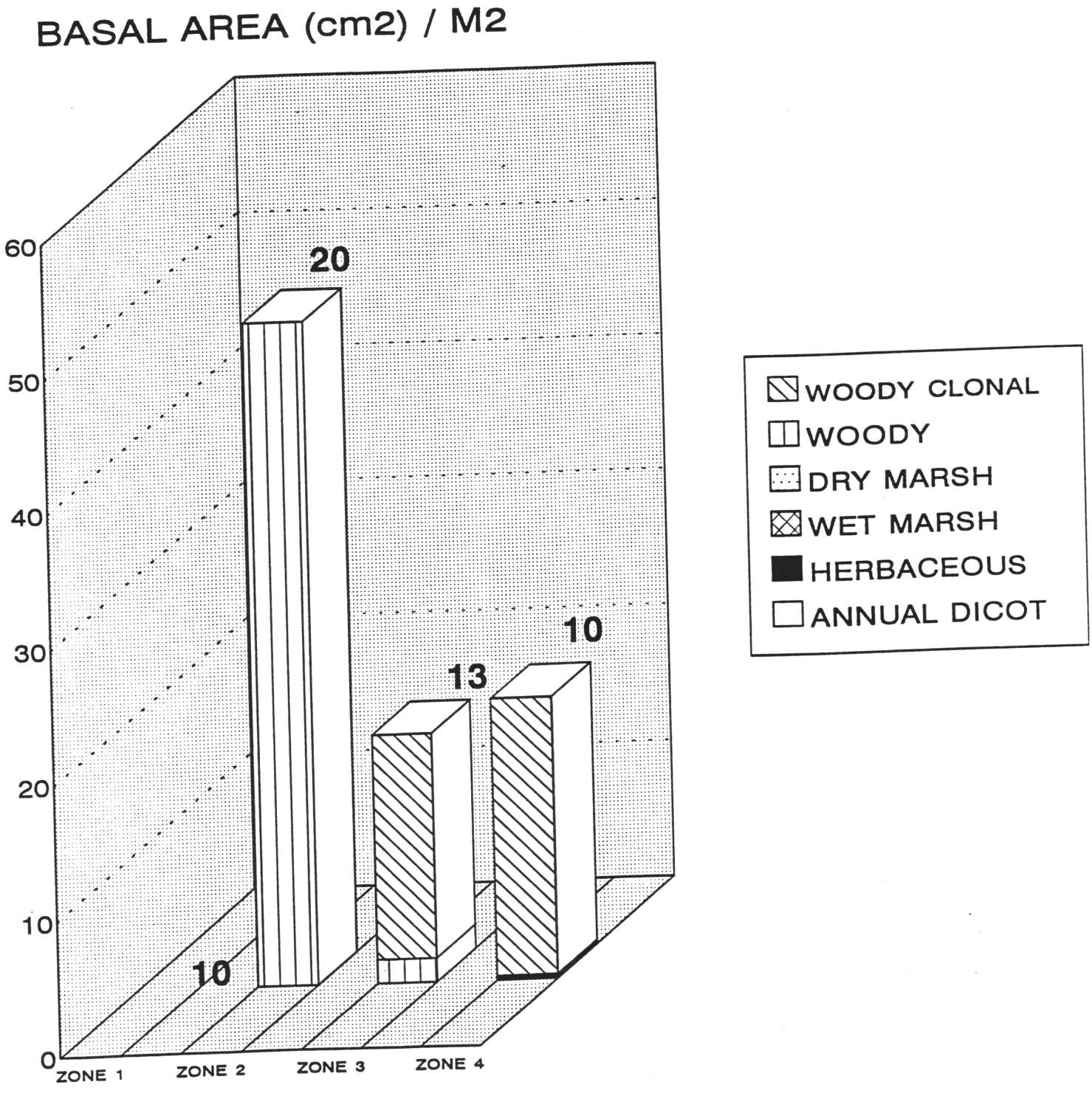


Figure 6. **Basal Cover of Live Plants in Transect 1**

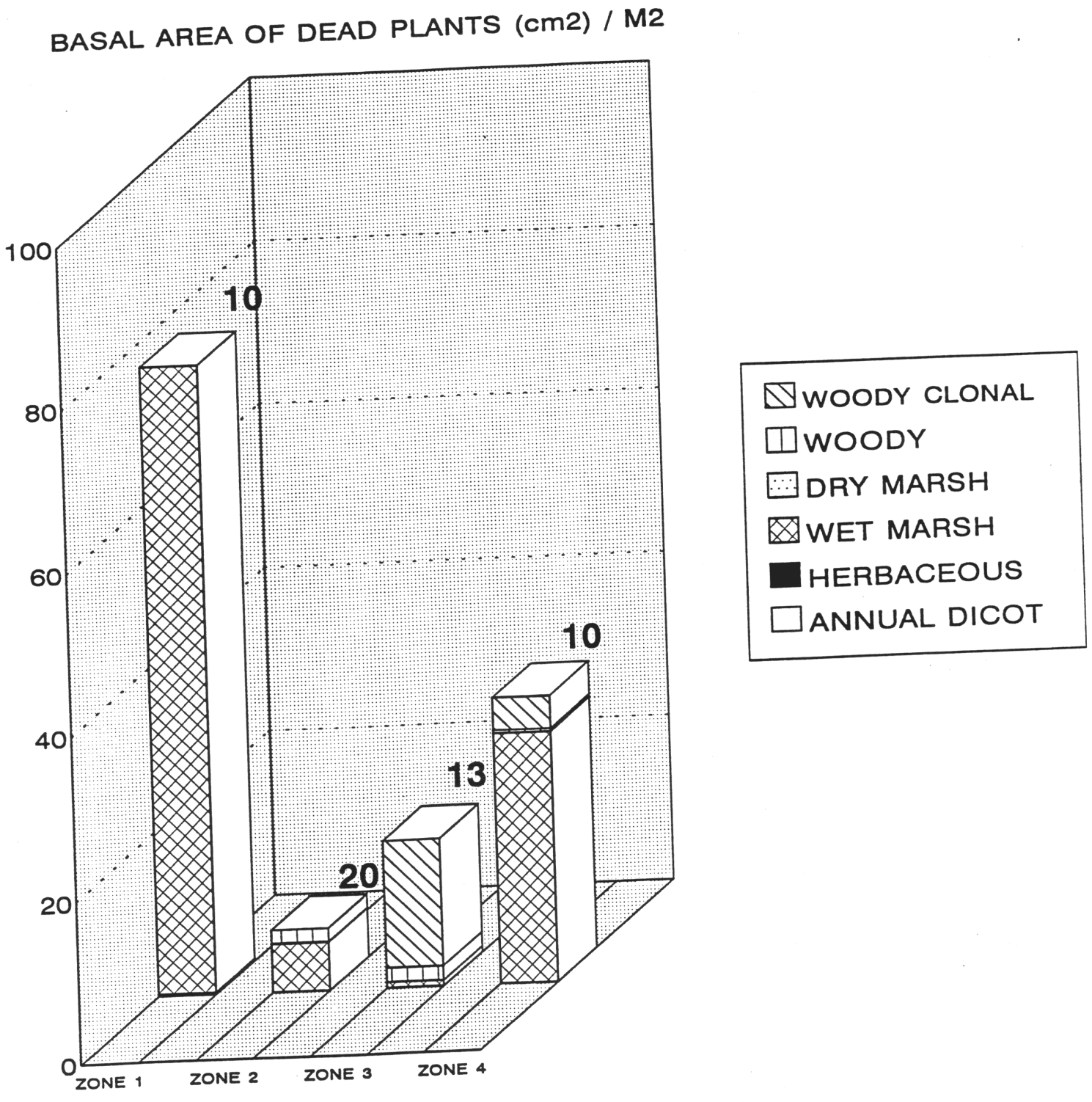


Figure 7. **Basal Cover of Dead Plants in Transect 1**

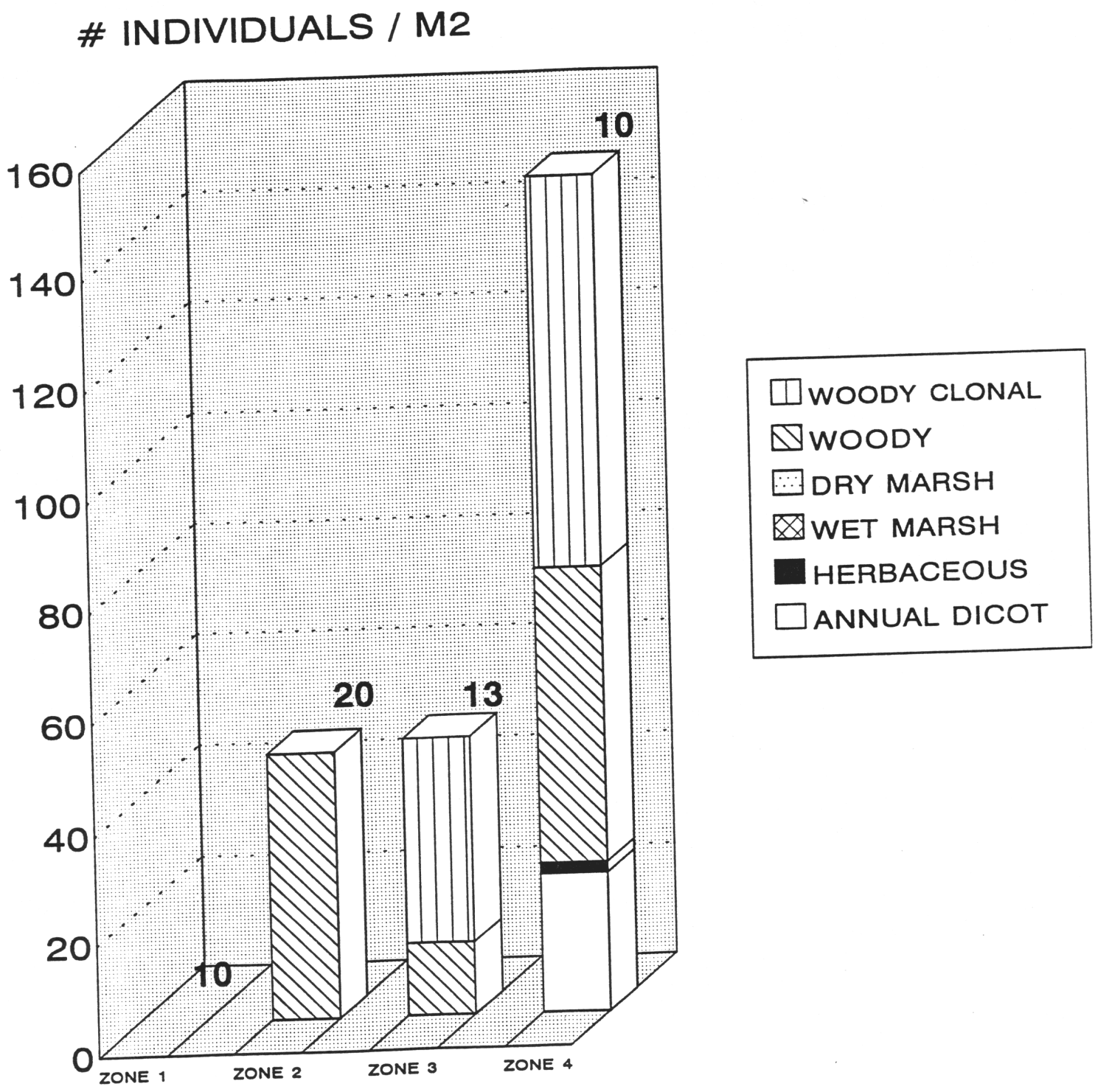


Figure 8. **Number of Live Individuals in Transect 1**

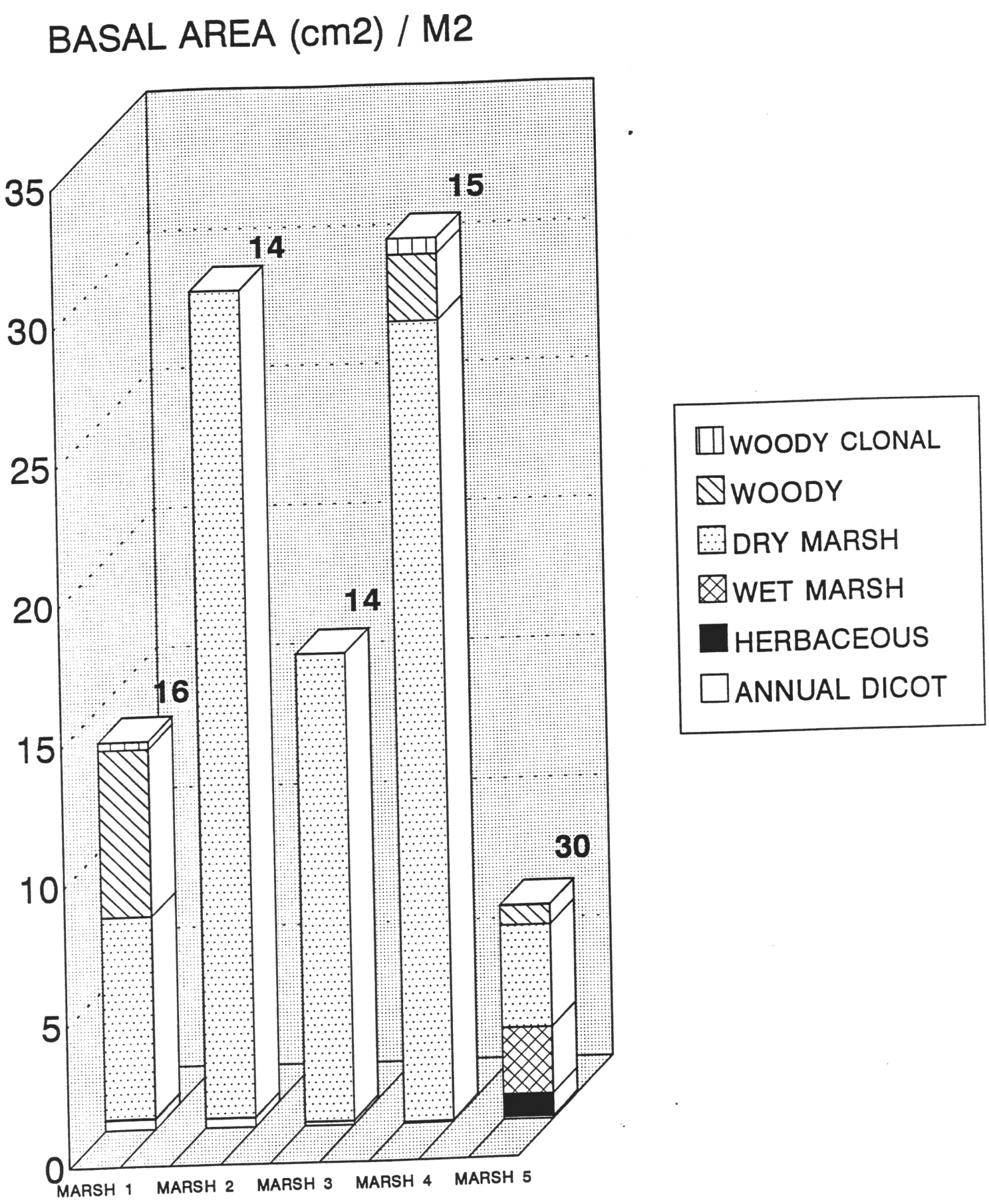


Figure 10. **Basal Cover of Live Plants in Marshes**

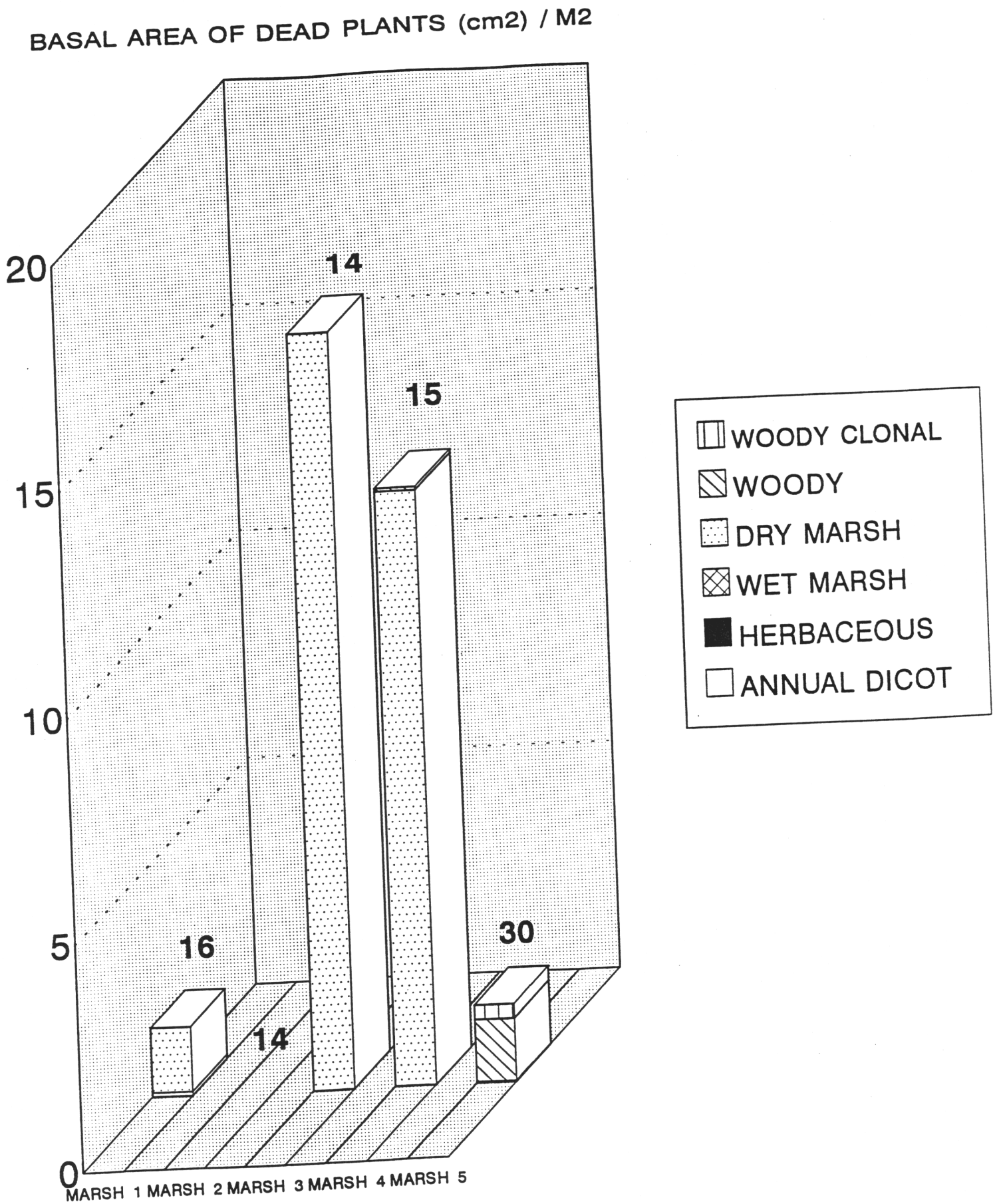


Figure 11. **Basal Cover of Dead Plants in Marshes**

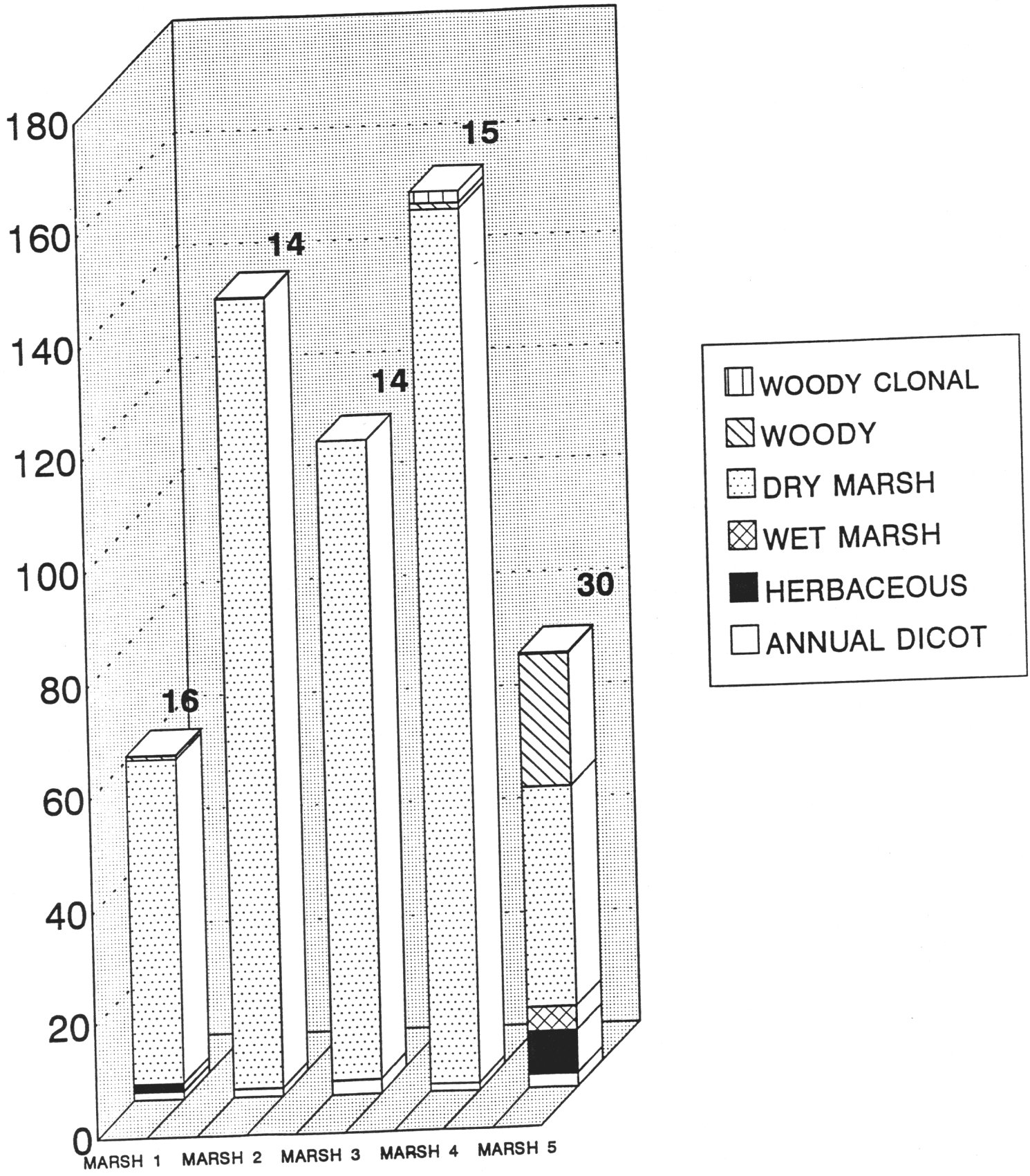


Figure 12. **Number of Live Individuals in Marshes**

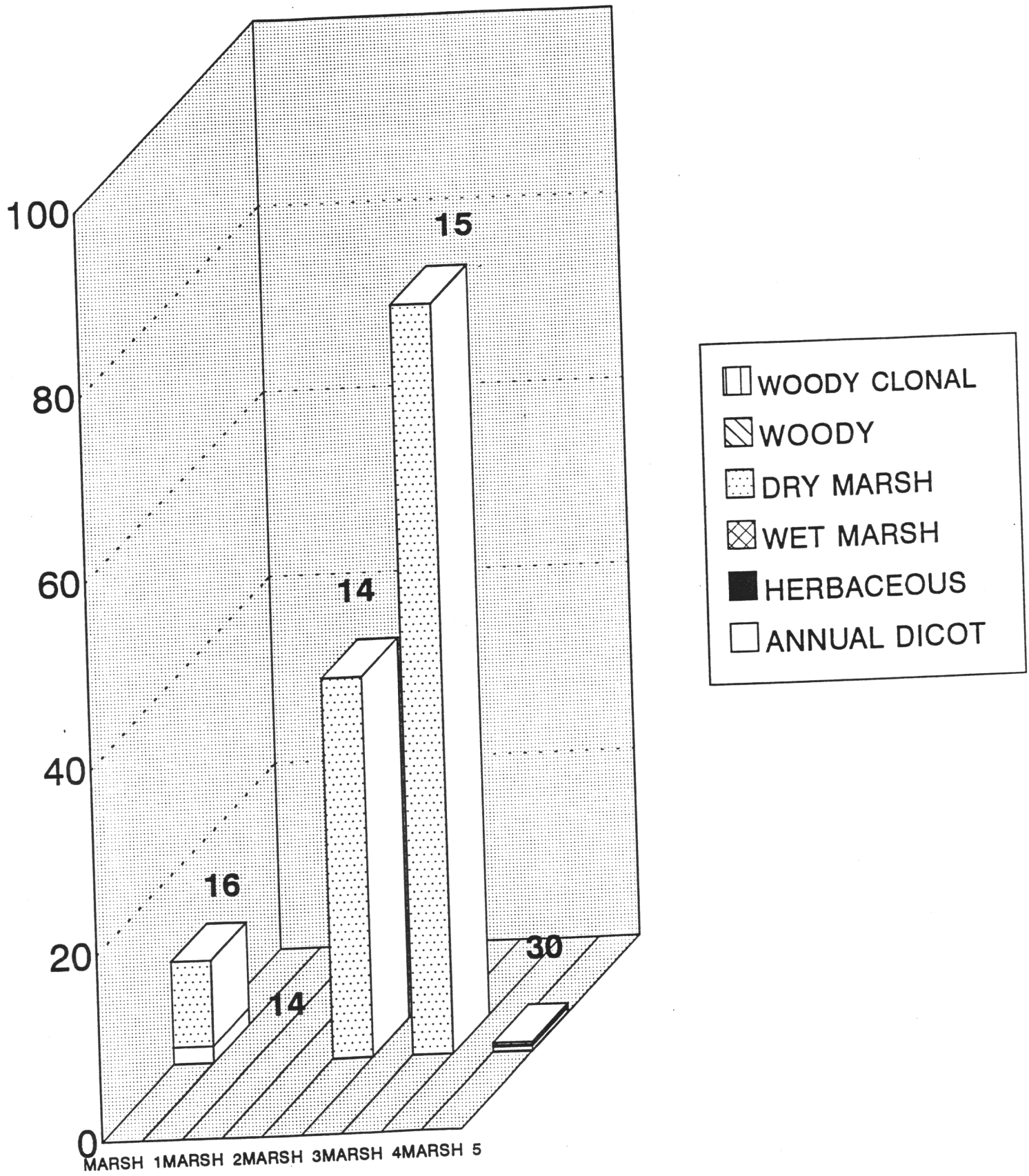


Figure 13. **Number of Dead Individuals in Marshes**

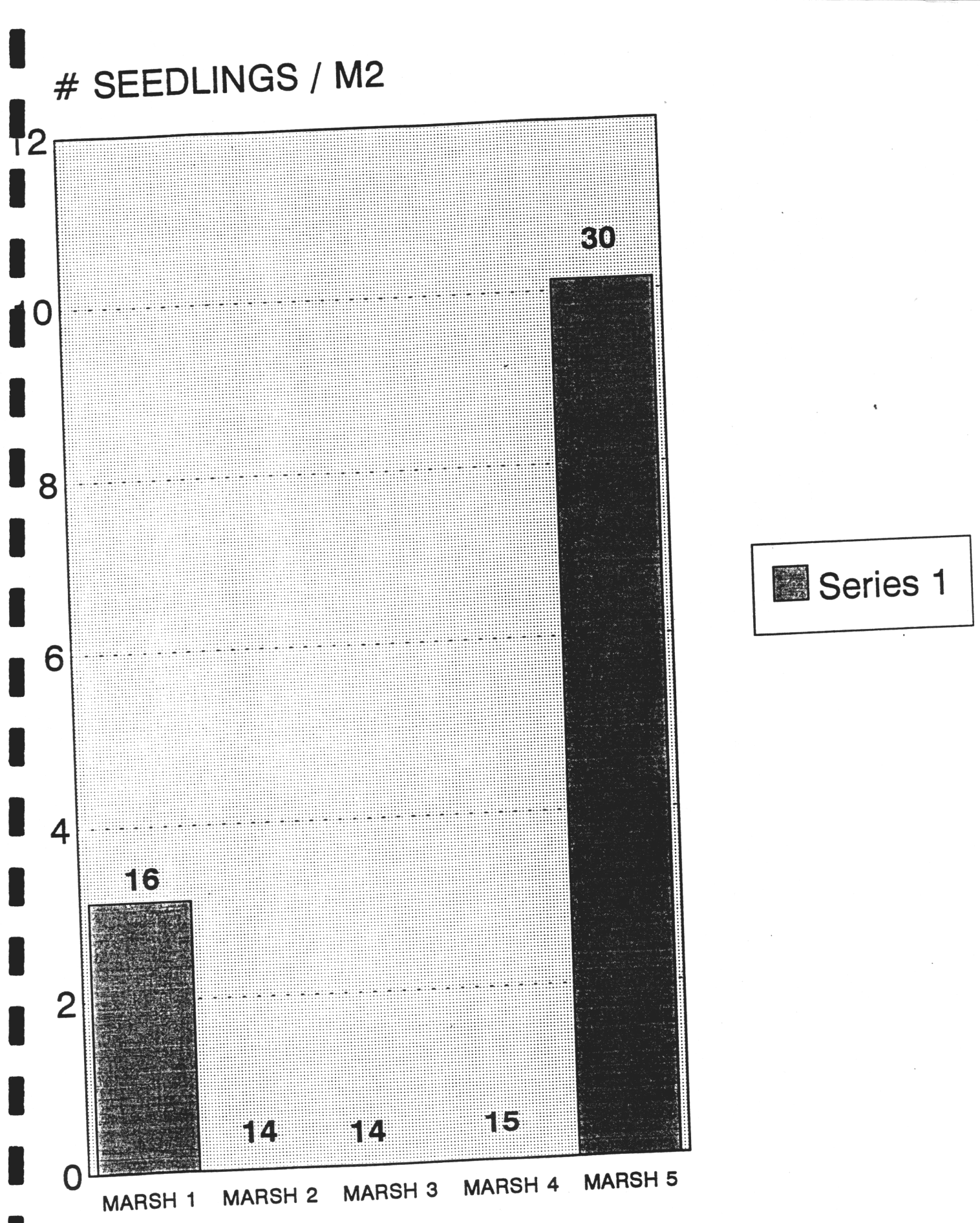


Figure 14. **Number of Seedlings in Marshes**

B. Avian Studies

Preliminary surveys of breeding birds were conducted at four sites selected during a preliminary helicopter overflight, including RM 239.5L/R, RM 246.0L, RM260.2L, and RM265.1L. Surveys indicated that the end of June, the first opportunity after contract award to conduct studies, was too late in the breeding season to conduct quantitative bird surveys at the above four sites. Many males had ceased singing altogether, or sang only sporadically. Territorial boundaries for many species had apparently broken down with the conspicuous wanderings of large numbers of fledglings. The arid heat of late June had also attracted several species, such as Mourning Doves and House Finches, to the river to acquire drinking water. These species were observed in greater numbers than would have been in evidence earlier in the breeding season. For these reasons, the results of 1992 surveys must be interpreted qualitatively until quantitative data can be gathered during fieldwork in the spring of 1993.

The potential presence of the Yuma Clapper Rail and the Southwestern Willow Flycatcher were of special concern during 1992 surveys. Large amounts of apparently suitable Clapper Rail nesting habitat (cattail marshes) were present from approximately 1987 to as late as 1991 in the area upriver of Columbine Falls. However, cattail marshes in this area have since virtually disappeared due to falling lake levels. The only remaining area that could potentially serve as habitat for Clapper Rails, the large cattail marsh up Quartermaster Canyon, was surveyed using tape-recorded calls from 0600-0730 hours on 27 June with negative results. No singing male Willow Flycatchers were detected during this preliminary survey, although relatively large amounts of apparently suitable habitat exist.

Bird species located during 1992 surveys are presented in Table 2. Study sites identified for 1993 and 1994 studies are as follows:

Study Site	Patch Location(s)	Patch Size
1. River Above Diamond Creek	RM 166.5L, National Canyon	medium
	RM 198.5R, Parashant Canyon	medium
	RM 209.0L, Granite Park	large
2. River Below Diamond Creek	RM 230.4L	small
	RM 231.5L	small
3. Spencer Canyon	RM 246.0L	medium
4. Quartermaster Canyon	RM 260.2L	medium
	RM 260.3R	large
5. Tincanebits Canyon	RM 263.8L to RM 265.1L	large

A study plan for 1993 based on these preliminary findings and study sites has been prepared and is enclosed as Appendix A.

C. Mammal and Reptile Studies

Introduction

Mammal and reptile studies in the lower Grand Canyon are intended to characterize animal populations in this portion of the Hualapai nation, and to identify relative frequency of capture as

Table 3. Bird Species Identified During 1992 Surveys

	Species	Occurrence
1.	Western Grebe	uncommon
2.	Great Blue Heron	uncommon to fairly common
3.	Black-crowned Night-Heron	uncommon
4.	Mallard	rare
5.	Teal sp.	rare
6.	Turkey Vulture	uncommon
7.	Peregrine Falcon	uncommon
8.	Mourning Dove	common
9.	White-throated Swift	fairly common
10.	Black-chinned Hummingbird	uncommon
11.	Hummingbird sp.	rare
12.	Ladder-backed Woodpecker	rare
13.	Black Phoebe	common
14.	Ash-throated Flycatcher	fairly common
15.	Northern Rough-winged Swallow	fairly common
16.	Common Raven	common
17.	Rock Wren	common
18.	Canyon Wren	common
19.	Marsh Wren	rare; localized
20.	Blue-gray Gnatcatcher	uncommon
21.	Bell's Vireo	abundant
22.	Lucy's Warbler	abundant
23.	Yellow Warbler	fairly common
24.	Common Yellowthroat	common
25.	Yellow-breasted Chat	common
26.	Summer Tanager	uncommon; localized
27.	Indigo Bunting	rare; localized
28.	Song Sparrow	abundant
29.	Red-winged Blackbird	uncommon; localized
30.	Brown-headed Cowbird	uncommon
31.	House Finch	common
32.	Merlin	rare

Notes: This list identifies those species detected during the surveys, with notes on their abundance and distribution as observed during the survey period. Species whose distribution is not discussed are widespread. All species listed are known or suspected to nest in the Grand Canyon region (Brown et al. 1987). Overall findings on the status and abundance of these species may change prior to the final report. Abundance definitions are after Brown et al. (1987).

related to vegetation type. It is intended that these studies will allow an assessment of indirect interim flow impacts on mammalian and reptilian populations, as vegetation types and densities (and the changes in vegetation due to interim flows) affect mammal and reptile populations.

Methodology

Mammal traplines consisting of 75 kill traps or 40 live traps were set in four locations in the lower Grand Canyon, including RM229.0L, 235.0L, 246.0L, and 276.0L. Determination of kill or live trap use was made based upon ambient temperatures and ant densities, factors which can make the use of kill traps inappropriate. Mammals caught in the traps were identified to species and sexed, and mammals representative of the area or in exceptionally good condition were skinned for specimens. Species found at study sites included cactus mouse (*Peromyscus eremicus*), canyon mouse (*Peromyscus crinitus*), rock pocket mouse (*Perognathus intermedius*), woodrat (*Neotoma lepida*), and kangaroo rat (*Dipodomys* sp.). Mammals trapped and specimens collected are summarized in Table 3.

Reptiles in the project area were noted as to species, and sites were identified for future reptilian trapping and potential specimen collection. These sites include RM229.0L, 235.0L, 246.0L, and 254.0R. It is anticipated that reptile studies will be more extensive in 1993.

Table 4. Mammal Species Trapped and Collected

River Mile	Species	Number Trapped/Collected
229.0L	*Neotoma lepida*	1/1
	Peromyscus eremicus	14/5
	Perognathus intermedius	4/1
	Peromyscus crinitus	1/0
235.0L	*Neotoma lepida*	1/1
	Peromyscus eremicus	10/3
	Peromyscus crinitus	1/0
246.0L	*Peromyscus eremicus*	9/2
276.0L	*Dipodymus* sp.	1/1
	Perognathus eremicus	2/0

Objective 4. Establish Monitoring Sites

It is anticipated that the majority of vegetation, avian, mammal and reptile sites used for baseline validation will be used for long-term monitoring. One vegetation studies site, at RM 274.7, has been eroded by the action of river flows and so will not be used for further monitoring. For long-term vegetation monitoring, it is proposed that OHW sites be recensused every ten years, and that all other quadrats, marshes, and transects be recensused once each year. It is also proposed that the bulk of avian, mammal, and reptile studies be conducted in the spring, with the majority of vegetation work conducted in the fall. This will take best advantage of animal breeding seasons and allow annual recensusing of vegetation. A revised proposal for 1993 and 1994 studies is presented in Appendix B.

Objective 5. Establish a Scientific Information Database

All data from these studies are entered into Lotus spreadsheet formats which together form the project Scientific Information Database (SID). The SID is periodically submitted to GCES for

inclusion in the GCES Scientific Information Management (SIM) system. As there are currently no applicable GIS data, none have been submitted to the Hualapai Tribe or GCES for inclusion in their GIS systems.

Phase II Objectives

The establishment of baseline and long-term study sites as well as the development of long-term monitoring protocols will allow the initiation of Phase II in the spring of 1993. It is anticipated that analysis of changes resulting from interim flows can begin in the summer of 1993. The timetable presented below details the projected progress of tasks and deliverables.

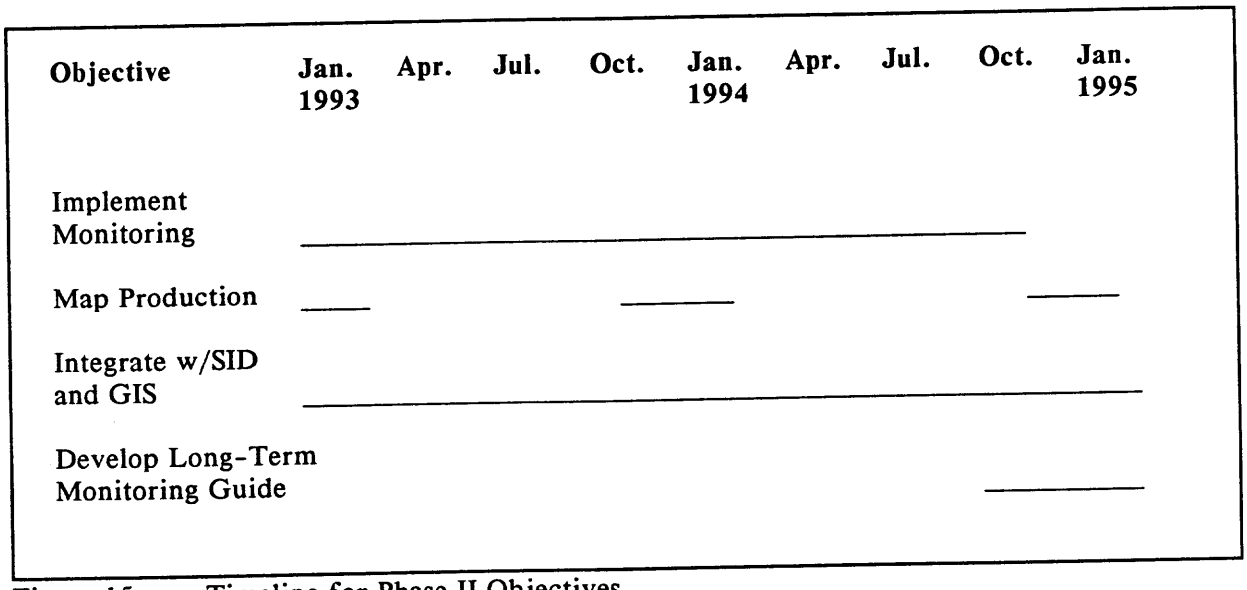


Figure 15. Timeline for Phase II Objectives

DISCUSSION AND RECOMMENDATIONS

Phase I studies in the lower Grand Canyon have for the most part consisted of baseline surveys to characterize the vegetative and animal communities along this portion of Hualapai lands. The collection of information about species, vegetation cover, marsh types, and zones of terracing along the third reach have added greatly to pre-existing data about this little-studied section of the Grand Canyon. Differences in vegetation types, colonization, and the balance of native and non-native species have been shown between the various river level zones, both in primarily river-influenced and primarily lake-influenced areas.

Problems to date have primarily been associated with use of the MIPS system. It was originally anticipated that by using the distinctive colors of different vegetation types, the system would be able to identify and measure the area covered by each type through existing software, and produce false color maps identifying those separate types. Unfortunately, current software is unable to perform these features; vegetation types must be determined by the MIPS user, and polygons drawn on screen to enable the system to measure vegetated area. As a result, the amount of personnel time needed to reach our objective of determining areal change of vegetated area over time has greatly increased. In the attached Revised Proposal, we propose an alternative to MIPS which will provide site-specific vegetation type data and will be much more likely to show flow-related changes during the three-year

period of this contract. A portion of each of the three GIS reaches in the study area will be hand mapped, with the boundaries of vegetation patches, vegetation types, and unvegetated areas delineated. This will be performed on an annual basis, allowing the precise and graphic depiction of vegetation community changes.

At this point, we anticipate analysis of trend data to begin in the summer of 1993, with full analysis taking place after plot, transect and marsh data are complete in the late fall. Several aspects of our research to date may be worth investigating, by establishing test plots or by focusing on interpretation of continuing plot, transect and marsh data. These include establishing relationships between lake levels, river levels, and succession trends which favor native species (willows) over exotic species (tamarisk); interpreting effects of interim flows and recreational activities on bank erosion below RM 240; and determining rates of colonization of newly exposed beaches and silt bars.

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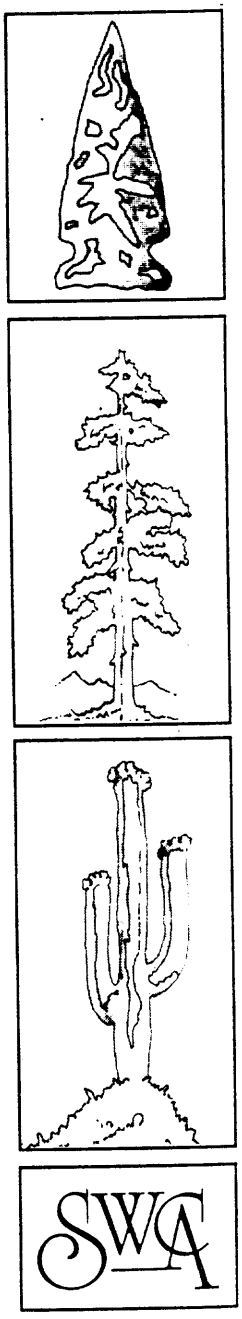
APPENDIX A

1993 AVIAN STUDIES STUDY PLAN



BREEDING BIRDS OF THE COLORADO RIVER THROUGH THE HUALAPAI INDIAN RESERVATION, ARIZONA

A Study Plan for FY93 and FY94 Research

by

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BACKGROUND

Little information exists on the birds of the Hualapai Indian Reservation in general and the Colorado River through the Hualapai Reservation in particular (Brown et al. 1987). Although historic studies have provided valuable baseline information on the birds of the river corridor through the Hualapai Reservation (Carothers and Aitchison 1976), avian density, diversity, and ecology need to be documented using quantitative techniques that will provide contemporary information for river and dam management.

Periodic fluctuations in the level of Lake Mead since the 1930s have strongly influenced the vegetation and substrate of the river corridor from River Miles 234-275 (Carothers and Brown 1991) and are suspected to have caused several cycles of episodic change in its riparian avifauna. These changes have not been documented but are assumed to have occurred. A single cycle of change would have likely involved two phases: 1) avian colonization of emergent riparian vegetation as lake levels receded, followed by 2) displacement of the resulting breeding bird community as lake levels increased. At present, the breeding bird community of the river corridor between River Miles 234-275 is approximately 4-6 years into the first phase of a new cycle of change. The probability is high that changing lake levels will continue to cause future episodic changes in breeding bird use of the river corridor through this portion of the Hualapai Reservation.

PURPOSE AND OBJECTIVES

The purpose of this study is twofold: 1) to identify the status and abundance of birds nesting in the riparian zone of the Colorado River through the Hualapai Indian Reservation; and 2) to assess, where possible, the influence of interim flows from Glen Canyon Dam on these nesting birds.

The specific objectives of this study are:

1. Quantify the density and diversity of riparian nesting birds per unit area.
2. Produce brief, annotated accounts of those bird species known or suspected to nest in or immediately adjacent to the study area.
3. Quantify aspects of riparian vegetation used for nesting.
4. Assess to the extent possible the influence of interim flows on riparian breeding birds.

Progress toward these objectives and their results will be presented in quarterly, annual, and a final project report.

STUDY AREA

The Colorado River forms the northern boundary of the Hualapai Indian Reservation in northwestern Arizona, extending from near National Canyon (River Mile 165) to near Columbine Falls (River Mile 273) at the head of Lake Mead. River Miles are place names after Stevens (1983). This 108-mile stretch of river has been divided into two reaches for logistical convenience: the 60 miles of river from National Canyon to Diamond Creek (River Mile 225), and the 48 miles of river from Diamond Creek to Columbine Falls. The physical setting and vegetation of this area have been described by Carothers and Aitchison (1976) and Carothers and Brown (1991). The study area from National Canyon to River Mile 234 has been strongly influenced by the operation of Glen Canyon Dam, while the study area from River Mile 234 to Columbine Falls has been subject to repeated inundation by Lake Mead.

METHODS

Study Sites

The study site between National Canyon and Diamond Creek will be a subset of those examined in previous studies (Brown 1987, Brown 1989). Study sites were chosen based on their logistical convenience, and to represent a wide range of habitats and patch sizes. Sizes of vegetation patches comprising the study sites, pending their exact calculation using MIPS software in 1993, were estimated in the following categories: small (<1 ha), medium (1-5 ha), and large (5-100 ha).

Study sites to be examined include:

Study Site	Patch Location(s)	Patch Size
1. River Above Diamond Creek	National Canyon	medium
	Parashant Canyon	medium
	Granite Park	large
2. River Below Diamond Creek	RM 230.4L	small
	RM 231.5L	small
3. Spencer Canyon	RM 246.0L	medium
4. Quartermaster Canyon	RM 260.2L	medium
	RM 260.3R	large
5. Tincanebits Canyon	RM 263.8L to RM 265.1L	large

Vegetation Parameters

Total vegetation volume (TVV) will be measured in each study site after the methods of Mills et al. (1991). The presence (a "hit") or absence of vegetation in 0.1 m vertical intervals along a stationary height pole and within 0.1 m of it will be recorded, so that the number of hits in each meter layer above ground will be from 0-10. Plant species responsible for each hit will be recorded; if 2 or more species are present in the same meter layer, the total number of hits in that layer will be allotted between the species according to the relative dominance of each species within the layer.

TVV will be estimated from these measurements, using the formula: $TVV = h/10p$, where h = total number of hits summed over all meter layers at all points measured, and p = number of points at which vegetation volumes were measured. TVV estimates will be in units of cubic meters of vegetation per square meter, and will provide indices of volume for each plant species, as well as indices of canopy height and percent cover (Mills et al. 1991).

TVV will be measured at 2-8 random plots chosen at regular intervals along the transect line through each study site, with more plots in larger study sites. Plot locations will be randomly chosen from points spaced at consistent intervals along, and within 30 m of, transects used to survey birds. A 20-m straight-line TVV transect will be established within each plot along a random bearing from the center of each plot. TVV measurements will be taken at 2-m intervals along the initial TVV transect and a second, perpendicular TVV transect through the center of each plot, resulting in measurements from 20 points in each plot.

Bird Censuses

Bird censuses will be similar to the methods used during baseline studies of the mid-1980s (Brown 1987, Brown 1989). The census objective is to detect singing males and to present this information in individuals/40 ha. The largest number of singing males detected in a given study site on any day during the study period will be doubled to arrive at the number of individuals present in that study site that year. The absolute count method (Emlen 1971) will be used for all study sites. The linear nature of study sites will permit a nearly-ideal application of the absolute count method.

Species maintaining Type-A territories[1] compromise the majority of species in the study area. A Type-A territory is an all-purpose area, used for nesting and feeding, that is vocally advertised, physically defended, and from which all others of the same species are excluded. A 1:1 sex ratio will be assumed for all Type-A species, in spite of the fact that sex ratios of some species may vary or will fluctuate throughout the breeding season (Mayfield 1981). Type-A species will be counted by recording detections of singing males at the peak of the nesting season and multiplying by two to account for females. Species maintaining Type-A territories but which are not sexually or vocally dimorphic, including Ash-throated Flycatcher, will be counted by recording each individual seen or heard, although this will likely underestimate their true density.

Species known to occur in the study area that do not maintain Type-A territories include Mourning Dove, Black-chinned Hummingbird, Costa's Hummingbird, Brown-headed Cowbird, and House Finch. These species will be counted by recording each individual seen or heard, although this will likely underestimate their true density. If no cowbirds are observed but a parasitized nest is discovered, then an arbitrary value of one cowbird will be assigned to the site for the season.

Tape-recorded calls will be used in an attempt to elicit responses from Yuma Clapper Rails at Quartermaster Canyon (and possibly at the large marsh near Pierce Ferry if future conditions are appropriate for a rail survey). Standardized census techniques for rails recommended for use by Ron McKinstry of the U.S. Fish and Wildlife Service in Phoenix will be used. Tape-recorded calls will be used at all study areas in an attempt to elicit responses from Willow Flycatchers.

Surveys for Nesting Peregrine Falcons

A river-based survey of nesting Peregrine Falcons will be conducted in 1994 in conjunction with research described in this study plan. This survey will take place in early May of the 1994 field season.

The status, abundance, and distribution of nesting Peregrine Falcons in the river corridor upstream of Diamond Creek was documented during 1988 and 1989 (Brown 1991). Examination of a small sample area downriver of Diamond Creek revealed that an unknown number of nesting Peregrine Falcons occur in that area.

Surveys for nesting Peregrine Falcons would be conducted after the methods of Brown et al. (1992). Highly experienced volunteers would be recruited for the surveys, greatly reducing direct costs. We propose a sample scheme whereby 10-mile sample reaches would be surveyed every 10 river-miles from National Canyon to Columbine Falls. Approximately 10 river-miles/day would

[1]For a discussion of bird territories, see Perrins, C.M. and R.R. Birkhead, *Avian ecology*. Blackie and Son, Glasgow, Scotland, 1983.

be thoroughly surveyed for falcons, for a total of 60 river-miles surveyed. Appropriate state and federal Endangered Species permits will be obtained for this research.

SCHEDULE OF WORK

FY93

Four river research trips are planned for the peak of the breeding season in 1993. Three 6-day trips from Diamond Creek to Pearce Ferry are required, on the following dates: April 18-23, May 19-25, and June 1-6. The fourth would be a 15-day trip from April 28 to May 12 to survey birds from National Canyon to Columbine Falls. In addition, a 3-day trip to Pearce Ferry to conduct a Yuma Clapper Rail survey in the large marsh nearby may take place in late May or early June, if conditions in the marsh are suitable for such a survey and if agency cooperation in conducting the survey can be obtained.

FY94

Tentatively, four research trips of approximately the same duration and timing as the FY93 trips are anticipated. Results of FY93 research may reveal certain changes needed in FY94, so the FY94 schedule of research will be not be finalized until autumn 1993.

DELIVERABLES

Results of the bird research will be synthesized and made available for inclusion in quarterly reports for 1993 and 1994. An interim report summarizing bird research results for FY93 will be prepared by 31 September 1993. The final report summarizing bird research results for FY93 and FY94 will be prepared in draft by December 1994 and in final by February 1995.

Schedule of Avian Studies Work in FY93

First Field Trip

April 18	--	launch first avian survey trip, Diamond Creek. Camp at Spencer
April 19	--	Camp at Quartermaster
April 20	--	Camp at Quartermaster
April 21	--	Camp at RM 265.1L (across from Dry Canyon)
April 22	--	Layover camp at RM 265.1L (vegetation measurements and nest searches)
April 23	--	takeout Pearce Ferry, 10 a.m.

Second Field Trip

April 28	--	launch second avian survey trip, Lees Ferry
April 29	--	deadhead to National Canyon
April 30	--	deadhead to National Canyon
May 1	--	hike in at Havasu; camp at National Canyon
May 2	--	camp at National Canyon
May 3	--	camp on right 0.5 mile above Parashant Canyon
May 4	--	layover above Parashant; vegetation measurements
May 5	--	camp Granite Park
May 6	--	camp Granite Park
May 7	--	pass Diamond Creek, resupply and personnel changes at 10 a.m.; camp at Spencer Canyon
May 8	--	camp at Quartermaster Canyon
May 9	--	camp at Quartermaster Canyon
May 10	--	camp at RM 265.1L; vegetation measurements
May 11	--	camp at RM 265.1L
May 12	--	takeout Pearce Ferry, 10 a.m.

Third Field Trip

May 19	--	launch third avian survey trip, Diamond Creek; camp at Spencer Canyon
May 20	--	camp at Spencer Canyon
May 21	--	layover at Quartermaster Canyon; vegetation measurements
May 22	--	camp at Quartermaster Canyon
May 23	--	camp at RM 265.1L (across from Dry Canyon)
May 24	--	takeout Pearce Ferry, 10 a.m.

Fourth Field Trip

June 1	--	launch fourth avian survey trip, Diamond Creek; camp at Spencer
June 2	--	camp at Spencer
June 3	--	camp at Spencer; vegetation measurements
June 4	--	camp at Quartermaster
June 5	--	camp at RM 265.1L (across from Dry Canyon)
June 6	--	takeout Pearce Ferry, 10 a.m.

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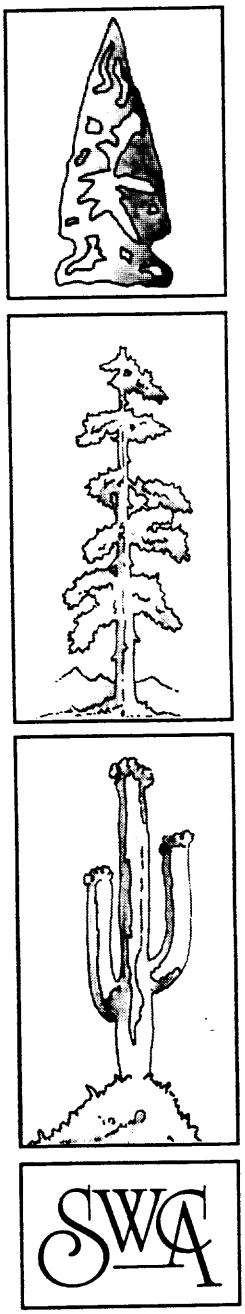
APPENDIX B

FINAL REVISED CONTRACT FOR HUALAPAI RIPARIAN STUDIES



SUMMARY OF CONTRACT CHANGES AND LOGIC

Changes to the May, 1992 proposal and contract are summarized as follows. The revised contract in its entirety is attached.

1) Page 1, ¶ 5	Change:	A preliminary baseline vegetative community map to a preliminary baseline study site and vegetation area map
	Logic:	MIPS technology is not as sophisticated as originally assumed; it can be used as a planimeter to determine areas, but not as an effective vegetation community mapping tool. Vegetation community mapping will be completed annually at three GIS sites by project biologists.
2) Page 1, ¶ 6	Change:	Data will be collected seasonally to data will be collected annually
	Logic:	Seasonal data collection at study sites would cause significant impacts to the riparian vegetation and wildlife communities due to the small size of the study area. Additionally, changes in vegetation patterns would be difficult to detect on a seasonal basis. Annual sampling will cause much less impact while still allowing the collection of trend data.
3) Page 2, ¶ 3	Change:	Develop a baseline vegetative community map to develop a baseline study site and vegetation area map
	Logic:	See change #1.
4) Page 2, ¶ 8	Change:	...using MIPS and other vegetation assessment techniques, and produce an updated map of vegetative communities in the lower Grand Canyon to ...at representative sites, and produce an updated map of vegetative communities at specific sites in the lower Grand Canyon.
	Logic:	The level of accuracy of MIPS, while quite high, is most likely insufficient to detect the small changes that will most likely occur in 1993 and 1994. We would recommend that the area of the entire riparian corridor be re-measured using MIPS in ten years to detect large-scale areal changes. Small-scale changes will be better detected by annual hand mapping of three GIS mapping sites (see change #1).
5) Page 5, ¶ 4	Change:	Paragraph reworked to discuss the establishment of three mapping sites to identify changes in vegetative community size and composition instead of using the MIPS system.
	Logic:	See change #4.
6) Page 5, ¶ 5	Change:	Paragraph deleted.
	Logic:	MIPS, as currently configured, cannot identify changes in species composition of plant communities, nor can it be used to extrapolate composition data from specific sites to general areas.
7) Page 7, ¶ 5	Change:	Delete sentence which begins: Seasonal updates...
	Logic:	This task is discussed in Objective 7, page 12. See change #4 for discussion of mapping sites and decennial use of MIPS.

8) Page 10, ¶ 4 Change: Delete sentence: Controls will be established along tributaries.
Logic: Insufficient tributaries exist in the study reaches to allow a control sample of statistically significant size.

9) Page 10, ¶ 5 Change: The fluvial marsh sites will be censused a minimum of four times during each year to the fluvial marsh sites will be censused once per year
Logic: Sampling of marsh sites more than once per year would cause significant damage to the marshes, while the data collected once per year will potentially be as valuable as that collected seasonally.

10) Page 10, ¶ 5 Change: All above-ground growth and litter will be collected from each of ten $0.5m^2$ plots... to all above-ground growth and litter will be collected from each of three $0.5m^2$ plots
Logic: Sampling of ten $0.5m^2$ plots in each marsh would destroy a large percentage of marsh vegetation, considering the generally small size of marshes and their fragility. Three plots per marsh will be sufficient to measure colonization and marsh development rates.

11) Page 10, ¶ 6 Change: A minimum of five study sites to fifteen study sites
Logic: Establishment of fifteen study sites, with a maximum of five sites in each of the three study reaches, will allow for a more complete inventory of the riparian vegetation in the lower Grand Canyon, and will increase the statistical viability of the data collected.

12) Page 10, ¶ 6 Change: Four 5m x 10m quadrats will be established... to a maximum of three 5m x 10m quadrats will be established...
Logic: The debris fan quadrats, utilized in Stevens' work above National Canyon, should be eliminated from this study as insufficient debris fans exist to allow placement of a debris fan plot at each site. In some locations in the third reach, other quadrat types such as old high water zone and riparian strip do not exist as such.

13) Page 11, ¶ 1 Change: Eliminate references to tiller production, site stability, and litter production. Also eliminate sentence which begins: One 20 cm x 50 cm plot....
Logic: Tiller production, site stability, and litter production are factors which can only be evaluated over a long-term monitoring period which is beyond the scope of this proposal, e.g. ten years or more. The data collected will provide a baseline against which these factors can be measured, should long-term monitoring occur. Herbaceous cover will be measured by the spot-sampling method rather than nested plots, following the methods of Stevens *et. al.*

14) Page 11, ¶ 4 Change: Remove reference to species density. Insert sentence noting that sufficient small mammal traps will be set to characterize the mammalian community. Insert sentence detailing the collection of five individuals of each species as museum specimens.
Logic: To study species density, a large-scale mammal study would need to be undertaken. As the goal of this study is to characterize the riparian community of the lower Grand Canyon, survey methods should be used which will be adequate for that purpose.

15) Page 11, ¶ 6 Change: Insert sentence noting that relative frequency of capture will be determined.

Logic: Relative frequency of capture allows an approximate characterization of reptile use of an area. As in change #15, species density data should not be needed for this study.

16) Page 12, ¶ 9 Change: Insert sentences detailing inventory of lake-influenced areas using five transects.

Logic: These transects will be placed below RM 246 in large vegetated areas, as they will characterize the vegetation of these areas more fully than 5m x 10m plots.

17) Page 13, ¶ 2 Change: Rework paragraph to detail annual mapping of the three mapping sites and production of a summary map with each annual report and the final report.

Logic: See change # 1.

18) Page 14, Table 2

Change: Base map of vegetative communities to base map of vegetation area and study sites.

Logic: See changes # 1 and # 4.

19) Page 14, Table 2

Change: Updated base map showing changes in areal extent and community distribution to updated base map showing changes in areal extent and community distribution at three mapping sites; the location of study sites; and the area in hectares of the riparian vegetation of the lower Grand Canyon.

Logic: See changes # 1 and # 4.

Revised Proposal

Monitoring and Evaluating the Impacts of Glen Canyon Dam Interim Flows on Riparian Communities in the Lower Grand Canyon

Prepared for

Hualapai Tribe

Prepared by

SWCA, Inc.

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ABSTRACT

SWCA, Inc. Environmental Consultants proposes to assist the Hualapai Tribe in baseline data collection and long-term monitoring through the lower Grand Canyon. Studies on the vegetative and animal communities of the Colorado River on the Hualapai Indian Reservation will be completed in coordination with Glen Canyon Environmental Studies. Changes that have occurred in these communities as a result of Glen Canyon Dam interim flow operations will be identified. Hualapai technicians will be integrated into the program to allow the Hualapai Tribe to perform future scientific monitoring, data collection, and analysis in the Colorado River corridor through the lower Grand Canyon.

STATEMENT OF OBJECTIVES

The riparian zone of the Colorado River through the Hualapai Indian Reservation in lower Grand Canyon is a complex and productive environment, and the Hualapai Tribe has strong cultural, environmental and economic ties to this portion of their reservation. SWCA proposes to work with the Hualapai Tribe and the Glen Canyon Environmental Studies program (GCES) to assess the influence of Glen Canyon Dam interim flow operations on the natural resources of Hualapai lands.

For centuries the riparian zone in the lower Grand Canyon has provided the Hualapai Tribe with resources used for consumption and for medicinal and religious purposes (Watahomigie et al. 1982). The Hualapai are committed to preserving this habitat that has figured so strongly in their history. Traditionally important plants including common reed (*Phragmites*), Goodding's willow (*Salix gooddingii*), arrowweed (*Tessaria sericea*), cattail (*Typha* sp.), seep willow (*Baccharis* sp.) and hackberry (*Celtis reticulata*) still occur in the riparian zone today, while clays used for pottery construction and minerals used for medicinal and religious purposes are also found along the Colorado River corridor.

SWCA proposes to evaluate the impacts of the interim flow operations on the development, structure and maintenance of the riparian plant and animal communities through the lower Grand Canyon. It is clear that this reach of the Grand Canyon has significant value to the Hualapai Tribe, as well as the potential to provide habitat to many riparian plants and animals.

A phased approach will be used to develop and implement the specific elements of the Hualapai interim flow riparian monitoring plan. In Phase I, baseline riparian resource data will be collected during fiscal year (FY) 1992. A preliminary study site and vegetation area map for the Colorado River along the Hualapai Reservation will be produced using GCES developed computer modeling with aerial and video photography. This map will be used in preliminary selection of study sites and will be refined and corrected as data are collected from study sites. Interim flow monitoring site selection will be based upon several factors, including the location of GCES long-term monitoring Geographic Information System (GIS) sites, stratification of the reach, and location of representative vegetation communities. Plant and animal surveys will be conducted at selected study sites to provide baseline data for Phase II monitoring.

Specific resource monitoring efforts will be designed and implemented in Phase II. Data will be collected annually at monitoring sites over a period of two years (FY 93 and FY 94). The impacts of interim flow discharge volumes, fluctuations, minimum and maximum discharges, and changes in discharge (ramping) on the riparian resources of this reach of the Colorado River will be assessed where possible. Data collected will be entered into a Scientific Information Database (SID), and will form an integral part of subsequent long-term riparian monitoring efforts.

Nine specific objectives are identified in this monitoring plan:

PHASE I

1. Review the existing literature and available data on plant and animal studies of the riparian corridor throughout the Grand Canyon.

2. Develop a baseline study site and vegetation area map with the use of the GCES Map Imaging Processing System (MIPS) and existing aerial photography.

3. Perform a baseline validation survey of the riparian communities along the lower Colorado River through the Hualapai Reservation, focusing upon the reach from Diamond Creek to Columbine Falls.

4. Establish interim flow monitoring sites and specific monitoring parameters for the lower Grand Canyon based on information collected under Objectives 1, 2, and 3.

5. Establish a Scientific Information Database (SID), consistent with GCES protocol, for data collected from interim flow monitoring sites.

PHASE II

6. Implement specific monitoring methodology, and conduct monitoring of selected study sites. Identify and evaluate changes in riparian communities and determine, to the extent possible, if they are a result of interim flows, or related to natural ecological processes. This short-term monitoring program will provide a baseline for long-term monitoring efforts. Evaluation will be focused on effects related to monthly volumes, maximum and minimum flow levels, ramping rates, and season.

7. Identify changes in vegetative community size and composition occurring throughout the time frame of the monitoring program at representative sites, and produce an updated map of vegetative communities at specific sites in the lower Grand Canyon.

8. Integrate the riparian and natural resource results with the Hualapai and GCES Geographic Information Systems (GIS), Scientific Information Database (SID), and long-term monitoring program.

9. Develop a long-term riparian system monitoring program for the Hualapai Tribe, with site selection, monitoring techniques, and analysis protocols compiled in a long-term monitoring field guide.

SWCA will implement a training program on all survey and monitoring trips, in which a Hualapai technician is paired with each senior scientist to learn survey methodology, sample collection, identification of plants, reptiles, mammals and birds, and proper data recording techniques. Each evening, project scientists will formally instruct the Hualapai technicians in field biology. This project presents a singular opportunity to provide Hualapai individuals with in-field training by highly qualified and experienced biologists. An herbarium of dried and pressed vegetation samples will be developed and maintained by Hualapai technicians with the aid of SWCA scientists. Pairing is proposed to be as follows:

Scientist	Title	Hualapai Technician
Steven W. Carothers, Ph.D.	Principal Investigator	Clay Bravo
Arthur M. Phillips, Ph.D.	Botanist	Mario Bravo
Bryan T. Brown, Ph.D.	Wildlife Biologist	Lydell Tapija
Amis C. Holm, M.S.	Ecologist/Database Manager	DeShane Quasula

The technical efforts are designed to integrate methodology and deliverables with previous and ongoing GCES research and monitoring in the Grand Canyon. This is important for several reasons: (1) the riparian corridor extending through Grand Canyon is itself an integrated system and must be studied as such; and (2) current and previous GCES studies and prior work of SWCA senior scientists, amounting to more than two decades of Colorado River research, provide compatible methodologies for the performance of vegetative and animal inventories and future monitoring.

JUSTIFICATION

Protection of all natural resources in the Grand Canyon is of profound cultural and religious significance to all members of the Hualapai Tribe. The Colorado River and the riparian zone that it supports provide the Hualapai Tribe with an economic livelihood through the development of a river recreation business and by helping to sustain the Desert Bighorn Sheep (*Ovis canadensis*) population, which is hunted through a permitting process with the Hualapai Tribe.

The riparian ecosystem on the Hualapai Tribal lands represents an important resource that has been affected by the operations of Glen Canyon Dam and which is likely to be affected by the Glen Canyon Dam interim flow operations. Limited previous information exists on baseline riparian structure in the lower Grand Canyon, providing a baseline for the proposed studies (Turner and Karpiscak 1980, Carothers and Aitchison 1976, Phillips 1976). Historic and recent studies have been limited in scope, however, and have typically ended at Diamond Creek and consequently the lower Hualapai riparian ecosystems have been ignored (Pucharelli 1988). Recently important cultural and natural resources have been identified in the lower river corridor. Marshes, vegetation in riparian systems, springs, and a Great Blue Heron (*Ardea herodias*) rookery are important resources that may be affected by the interim flow operations.

The Hualapai Tribe has been involved in the GCES and Glen Canyon Dam Environmental Impact Statement process since 1991. The Hualapai Tribe has identified the need to understand the relationship between the level of Colorado River flow and the riparian resources in the lower 108 miles of the Grand Canyon. Concern for their environmental resources dictates that the relationship between the influential operation of Glen Canyon Dam and the resources of the lower Grand Canyon be better understood.

Due to the current low level of Lake Mead, the flowing Colorado River influences all of the Colorado River corridor through the Hualapai Reservation. As significant changes in the lake level are not anticipated prior to the end of FY 92, the collection of baseline data in the area which was previously inundated by the lake but which is now actively affected by current release levels will provide valuable information regarding the impacts of interim flows on the lower Grand Canyon. The upper end of Lake Mead may provide habitat essential to the survival of the endangered Razorback Sucker (*Xyrauchen texanus*) and Yuma Clapper Rail (*Rallus longirostris*), plants, reptiles, mammals, and other species (USFWS 1991). Should the level of Lake Mead

remain low, monitoring in this area will provide an assessment of the long-term effects of interim flows for this unique section.

PHASE I

Objective 1. *Review the existing literature and available data on plant and animal studies of the riparian corridor throughout the Grand Canyon.*

A review of literature, literature studies, and existing data on plant and animal studies in the lower Grand Canyon (Carothers and Aitchison 1976, Phillips 1976, Spamer 1990, Waring 1991, Ohmart et al. 1988) will provide a solid base of historic information from which specific sampling and analysis protocols can be developed.

Survey methodologies will be established which follow scientific practice to allow accurate statistical analysis and integration of this study with other Grand Canyon corridor studies and monitoring efforts.

Objective 2. *Develop a baseline study site and vegetation area map with the use of the GCES Map Imaging Processing System (MIPS) and existing aerial photography.*

Development of a baseline study site and vegetation area map will demonstrate the selection of monitoring sites and will provide a base for the measurement and evaluation of vegetation area changes during the monitoring program. Phase I and Phase II studies will provide comparative data to aid in the evaluation of the impacts of interim flows.

Objective 3. *Perform a baseline validation survey of the riparian communities along the lower Colorado River through the Hualapai Reservation, focusing upon the reach from Diamond Creek to Columbine Falls.*

Conducting a baseline survey of the riparian communities along the lower Grand Canyon will establish an informational base for the Phase II monitoring program. Using GCES maps and the MIPS technology as well as an on-site assessment of potential sites, survey sites will be established, at which specific data concerning plant and animal communities will be collected. This base of information will then permit a comparison of data throughout Phase II monitoring and an evaluation of riparian community changes resulting from interim flows.

Objective 4. *Establish interim flow monitoring sites and specific monitoring parameters for the lower Grand Canyon based on information collected under Objectives 1, 2, and 3.*

Data from a baseline survey of the riparian communities of the lower Grand Canyon will be evaluated and used to select and establish interim flow monitoring protocols and study sites. Use of baseline data for completion of this Objective will allow the use of an incremental, logical approach in the selection of long-term monitoring sites as well as the specific methodologies used to conduct long-term monitoring.

Objective 5. *Establish a Scientific Information Database (SID), consistent with GCES protocol, for data collected from interim flow monitoring sites.*

Maintenance of all monitoring data in a comprehensive database will allow ready comparison of data, precise assessment of accuracy, and continuity in data format throughout the long-term monitoring program.

PHASE II

Objective 6. *Implement specific monitoring methodology, and conduct monitoring of selected study sites. Identify and evaluate changes in riparian communities and determine, to the extent possible, if they are a result of interim flows, or related to natural ecological processes. This short-term monitoring program will provide a baseline for long-term monitoring efforts. Evaluation will be focused on effects related to monthly volumes, maximum and minimum flow levels, ramping rates, and season.*

Monitoring of study sites over a period of at least two years will allow an initial assessment and determination of the impacts of interim flows on riparian communities. Monitoring is essential to identify changes in riparian communities, as such changes occur slowly and in ways which can be difficult to predict. Monitoring will allow the Hualapai Tribe to evaluate changes resulting from interim flows as related to overall vegetative community diversity, structure, and size. Documentation of results throughout the monitoring program will provide a solid base of scientific data for use in future Grand Canyon studies. Development of a long-term monitoring methodology will enable the Hualapai Tribe to continue monitoring changes in the lower Grand Canyon.

Objective 7. *Identify changes in vegetative community size and composition occurring throughout the time frame of the monitoring program at representative sites, and produce an updated map of vegetative communities at specific sites in the lower Grand Canyon.*

Field surveys conducted during Phase I and monitoring conducted during Phase II will be combined with site-specific vegetative community mapping. This will potentially provide an understanding of vegetative community change in the lower Grand Canyon as a result of interim flows. The three GIS sites in the study area will be used for the mapping of vegetative communities. Mapping will take place on a yearly basis and will be supplemented by MIPS planimeter data on these sites to evaluate areal as well as community changes.

Objective 8. *Integrate the riparian and natural resource results with the Hualapai and GCES Geographic Information Systems (GIS), Scientific Information Database (SID), and long-term monitoring program.*

The integration of the technical data into the long-term monitoring, as well as the GIS and SID databases is essential since management of the resources and determination of impacts is a goal of the overall interim flow and monitoring program. GCES is providing the lead in the development and utilization of the data bases. Hualapai technicians will be trained in the use of the GIS and SID systems, allowing the Hualapai to interface with long-term GCES monitoring efforts.

Objective 9. *Develop a long-term riparian system monitoring program for the Hualapai Tribe, with site selection, monitoring techniques, and analysis protocols compiled in a long-term monitoring field guide.*

Based upon two years of monitoring, a long-term monitoring program will be developed which will continue to assess changes in the riparian system of the lower Grand Canyon. Use of the results of the proposed study to develop a long-term monitoring program will allow the subsequent collection of data in a manner which coordinates with previous and ongoing GCES monitoring programs.

BACKGROUND

Riparian habitat in the Southwest supports remarkably complex and productive communities of plants and animals (Carothers and Brown 1991). Numerous GCES studies and others have documented a similar pattern in the riparian zone in the Grand Canyon -- it supports a diverse assemblage of plants and animals. Today, GCES research and monitoring is being designed to address the influence of dam operations on this ecosystem (e.g. Stevens 1989, Stevens and Waring 1988, Anderson and Ruffner 1988, Brian 1988, Brown 1988, Waring and Stevens 1988, Warren and Schwalbe 1988). These studies are providing an understanding of both the initial and subsequent effects that the flow regimes of the Glen Canyon Dam have on riparian habitat in the Grand Canyon.

Several rare, threatened or endangered species are thought to occur in the lower Colorado River corridor, including McDougal's Flaveria (*Flaveria mcdougalli)*, California Bear-Poppy (*Arctomecon californica*), Willow Flycatcher (*Empidonax traillii*), Yuma Clapper Rail, Peregrine Falcon, Desert Tortoise (*Xerobates agassizi*), Gila Monster (*Heloderma suspectum*), Zebra-tailed Lizard (*Callisaurus draconoides*), and Leopard Frog (*Rana pipiens*).

Limited studies of the lower Grand Canyon have been conducted prior to this effort, making it imperative that baseline research not be delayed. The riparian zone along the Colorado River through the Hualapai Reservation appears to be experiencing both erosion and aggradation of beaches due to Glen Canyon Dam operations. Between National Canyon and Separation Canyon there is evidence of considerable beach loss (L. Stevens, pers. comm., M. Bravo, pers. comm.), while between Separation Canyon and Lake Mead, aggradation appears to be extensive. Correspondingly, riparian communities in the upper stretch may be at risk, while in the lower stretch new communities are emerging. Riparian communities in the transition zone between Lake Mead and riverine influence represent a unique and highly valued resource.

While an increasing number of studies by GCES and others are documenting flow-related changes of specific taxa within riparian communities (Smith et al. 1991, Fenner et al. 1985), few have considered this relationship at the vegetative community level. With the Hualapai Tribe and GCES, SWCA proposes studies designed to evaluate the effects of Glen Canyon Dam interim flow operations on the vegetative and animal communities that occur along the Colorado River on the Hualapai Reservation. These studies will benefit the Hualapai by determining what species comprise these communities, how the communities are organized, and also will allow an assessment of the impacts of the current interim flow regime on these communities.

The riparian habitat along the Colorado River through the Hualapai Reservation, especially from Diamond Creek (River Mile 225) to the edge of the Grand Canyon at Columbine Falls (RM 274), is not well studied. Studies of riparian plants and animals there have been limited in scope and qualitative in nature (Phillips 1975, Phillips et al. 1977, Willson and Carothers 1978, Carothers and Aitchison 1976, Johnson and Hansen 1977), leaving us with only a preliminary sense of the extent and composition of this habitat.

METHODS

Compatibility of Methodologies Used in Upper and Lower Grand Canyon

To ensure that studies of the Colorado River through the Hualapai Reservation are compatible with methodologies used for similar studies in the upper reaches of the Grand Canyon (Ayers and Stevens 1991, 1992), meetings will be held between SWCA scientists, Hualapai researchers, and the

principal investigators for studies in the upper Grand Canyon. Two meetings are scheduled, the first prior to the performance of Objectives 1 and 2, and the second prior to the first full-length survey trip (Objective 3). Formal methodologies for baseline vegetation studies will be established, and a communication base will be formed to ensure that the data collected during both studies will be of similar precision and in similar form. SWCA principal investigators (Carothers and Kimberling) have worked extensively with GCES upper Grand Canyon researchers (Ayers and Stevens), ensuring that similar methodologies will be used.

Sampling and Analysis Techniques

PHASE I

Objective 1. *Review the existing literature and available data on plant and animal studies of the riparian corridor throughout the Grand Canyon.*

The development of the specific interim flow monitoring plan will be preceded by a review of literature, literature studies, and data sources. This literature review will be coordinated with ongoing GCES literature reviews. A review of research previously conducted in the lower Grand Canyon will be used as a factor in the selection of survey sites and in analysis of MIPS maps. Critical parameters for the selection of study sites will be established.

Objective 2. *Develop a baseline study site and vegetation area map with the use of the GCES Map Imaging Processing System (MIPS) and existing aerial photography.*

MIPS technology, making use of recent video photography, will be used to create a map of study sites and vegetated areas in the lower Grand Canyon along the Hualapai Reservation. This map will be used to show the results of MIPS planimetering of vegetated areas and demonstrate the selection of study sites. Study sites will be chosen based upon the need for a stratified random sample and the location of existing GIS sites. This map will also provide an informational base which will be used throughout the monitoring study to measure and evaluate changes in vegetated areas as a result of interim flows. GCES will train SWCA and Hualapai scientists to use the MIPS technology and will provide the necessary equipment and aerial photography.

Objective 3. *Perform a baseline validation survey of the riparian communities along the lower Colorado River through the Hualapai Reservation, focusing upon the reach from Diamond Creek to Columbine Falls.*

The study area includes both sides of the river corridor from National Canyon (RM 166) to Columbine Falls (RM 274). Study efforts will focus on the portion of the corridor from Diamond Creek (RM 225) to Columbine Falls (RM 274). A helicopter reconnaissance trip to identify potential study sites will be conducted in May of 1992. Four survey trips are scheduled for FY 92: 1) a reconnaissance trip in June to field-check MIPS maps, perform a preliminary selection of study sites, familiarize the project scientists with the current status of the lower Grand Canyon under the interim flows regime, and to establish working relationships between Hualapai technicians and project scientists; 2) an 8-day survey trip from Diamond Creek to Pierce Ferry, in which permanent study sites will be chosen and established, and surveys will begin; 3) a 15-day survey trip from Phantom Ranch to Pierce Ferry, in which the reach from National Canyon to Columbine Falls will be evaluated for establishment of future monitoring sites, comparison of vegetative and animal communities in the upper (above Diamond Creek) and lower (below Diamond Creek) reaches of the Colorado River through the Hualapai Reservation, and

Table 1. Schedule for Activities and Deliverables.

Fiscal Year 1992: Phase I

Project Initiation	May 15, 1992
Helicopter Reconnaissance	May, 1992
Meeting Between SWCA, Hualapai, and GCES	May, 1992
Production of Preliminary Vegetation Map Using MIPS	June 20, 1992
Meeting Between SWCA, Hualapai, and GCES	June, 1992
First Sampling Trip	June 1, 1992
Quarterly Report	July 1, 1992
Second Sampling Trip	July 1, 1992
Third Sampling Trip	August 1, 1992
Fourth Sampling Trip	September 1, 1992

Fiscal Year 1993: Phase II

Quarterly Report	October 1, 1992
Establish SID For All Data	November, 1992
Annual Report #1 (DRAFT)	December 15, 1992
Annual Report #1 (FINAL)	January 20, 1993
Quarterly Report	April 1, 1993
First Sampling Trip	May 1, 1993
Second Sampling Trip	June 1, 1993
Quarterly Report	July 1, 1993
Third Sampling Trip	July 1, 1993
Fourth Sampling Trip	August 1, 1993
Fifth Sampling Trip	September 1, 1993

Fiscal Year 1994: Phase II

Quarterly Report	October 1, 1993
Annual Report #2 (DRAFT)	December 1, 1993
Annual Report #2 (FINAL)	January 20, 1994
Quarterly Report	April 1, 1994
First Sampling Trip	May 1, 1994
Second Sampling Trip	June 1, 1994
Quarterly Report	July 1, 1994
Third Sampling Trip	July 1, 1994
Fourth Sampling Trip	August 1, 1994
Fifth Sampling Trip	September 1, 1994
Quarterly Report	October 1, 1994
FINAL REPORT (DRAFT)	December 1994
FINAL REPORT (FINAL)	February 1995

continued study of permanent sites in the lower reach; and 4) an 8-day survey trip from Diamond Creek to Pierce Ferry, which will conclude baseline survey efforts (Table 1).

While similar sampling methodologies will be used during Phase I in the upper portion of study area (Diamond Creek to Separation) and the lower portion (Separation to Columbine Falls), it is anticipated that the results and potentially the long-term monitoring techniques for the lower portion will be separate due to the effects of Lake Mead. The lower portion is currently affected by interim flows due to the low level of Lake Mead, and it is expected that the lake will remain low at least through
FY 92. The recent inundation of these areas by the lake and the sedimentation which has occurred there since the closing of Glen Canyon Dam will create a unique study area to assess the impacts of interim flows.

VEGETATION COMMUNITY STUDIES

Interim flow monitoring sites will be selected utilizing the locations of previous study sites, the location of the GCES GIS monitoring sites, important resource locations, and representative resource locations. Previous study sites include Bridge Canyon and Rampart Cave (Carothers and Aitchison 1976). Due to its significance to the Hualapai Tribe, Spencer Canyon will also be evaluated as a potential study site. GCES GIS monitoring sites include Diamond Creek (RM 225 to 230) and Columbine Falls (RM 273 to 276).

The reach from Diamond Creek to Columbine Falls will be statistically stratified in order to select representative sites. Sample plots will be placed randomly but within a stratified vegetational community where appropriate. The sites to be monitored will be placed in the following geomorphic settings: marsh, riparian strip, general beach (all in the New High Water Zone), and debris fan environments (Ayers and Stevens 1992). Sampling techniques will be established following the completion of Objective 1 and coordination with GCES riparian system researchers (Ayers and Stevens).

Fluvial Marsh Sites

Fluvial marsh sites will be identified using MIPS during completion of Objective 2. Four marsh sites will be chosen based upon geomorphology, inundation frequency, and vegetative cover. The fluvial marsh sites will be censused once per year during Phase I and Phase II, including low, moderate, and high interim flows. Compositional changes during the interim flows period will be identified. Transects will be established in each marsh, with data on basal area, density and species composition collected. Changes in soil profiles relating to deposition or erosion will also be noted. All above-ground growth and litter will be collected from each of three 0.5 m^2 plots annually in each marsh to monitor productivity. Colonization of these plots will be monitored to evaluate changes in marsh development rates under interim flows. Studies will be coordinated with Hualapai aquatic studies where possible.

Riparian Vegetation

Fifteen study sites will be established, covering the different geomorphic settings and including study sites placed in the study reaches by Stevens *et. al.* A maximum of three 5m x 10m quadrats will be established in each of the study sites. These study sites will be designed for monitoring Glen Canyon Dam discharge impacts on riparian vegetation development. Quadrats will be divided into eight subplots for censusing and mapping purposes, and will be used to monitor

species composition, germination, growth rates, soil changes, ground cover, and shrub cover. A species list will be compiled at each site to detect and monitor the distribution of critical native plant species in the river corridor (Phillips 1986, Ayers and Stevens 1991).

It is anticipated that placement of the study sites and quadrats will allow evaluation of plant communities which hold importance for the Hualapai Tribe, including cattail marshes, Goodding's willow and coyote willow stands, tamarisk-dominated stands, tamarisk and *Baccharis salicifolia* stands.

An herbarium collection will be made by SWCA botanists and Hualapai technicians to document the vegetative species currently found in the lower Grand Canyon.

ANIMAL COMMUNITY STUDIES

Mammal Surveys

Transects will be established within each of four vegetative community types sufficient to permit characterization of mammal populations. Three sets of trap lines, each 200m in length, will be established. Live trapping stations will be established within each site, and the area outside each site will be spot-checked to identify sign of mammals which are not identified by trapping (i.e. Desert Bighorn Sheep). These monitoring sites will be surveyed annually to determine the number of species and species individuals occurring in these communities.

All small mammal trapping will be done using folded aluminum Sherman live traps, 8 x 8.5 x 23 cm in size. The bait will be a peanut butter-rolled oats mixture. A space will be cleared of litter and vegetation where each trap will be placed to attract small mammals and locate the station. Traps will be set in late afternoon, checked in the morning, and kept closed during the day. Two traps will be set at each station. Trapped mammals will be identified by species, and after all pertinent information is collected, the mammals will be released near the point of capture except where the mammal should be kept as a museum specimen (Duncan 1990). A minimum of five individuals of each species will be collected, if possible, to provide adequate characterization of the small mammals inhabiting Hualapai lands in the Grand Canyon.

Reptile Surveys

Study sites established for mammal surveys will also be used for reptilian surveys. Pedestrian surveys of each site will be conducted in the morning and evening. Attempts will be made to capture, measure, mark and release all reptiles found. Each will be identified as to species, and relative frequency of capture will be documented. Comparisons will be made between reptile populations in the Old High Water Zone and in the New High Water Zone. In areas of appropriate habitat, drift fences with traps at each end will be used to capture snake species (Rosen and Schwalbe 1988).

Avian Censusing

Surveys will be conducted for breeding birds, Peregrine Falcon and other raptors, and the Yuma Clapper Rail. All avian surveys will be coordinated with National Park Service and GCES avian survey efforts. Modified Emlen censusing techniques known as the Absolute Count method (Carothers and Johnson 1974, Carothers and Brown 1987) will be used to census breeding birds between Diamond Creek and Separation Canyon (RM 240), while the commonly used Emlen censusing techniques, based on the spot-map method (Kendeigh 1944), will be used to census

breeding birds between Separation Canyon and Columbine Falls. Breeding bird censuses will be conducted during survey trips in May, June, and July.

A minimum of five study sites will be chosen across a range of geomorphic and vegetative types and patch sizes for breeding bird censuses. Patch sizes will vary to determine distinctions between avifauna found in small versus large patches, and to determine variations in the species composition of sites in the portion of the Grand Canyon affected by the flowing Colorado River, which are generally very small, and sites along Lake Mead, which include large cattail marshes. It is anticipated that breeding bird surveys will include the Southwest Willow Flycatcher.

Peregrine Falcon sampling surveys following the protocol of Brown (Brown et al. 1992) will be conducted at 10-mile intervals during May and July survey trips. Yuma Clapper Rail and Southwest Willow Flycatcher surveys will be coordinated with U.S. Fish and Wildlife Service and National Park Service activities in Grand Canyon, and will consist of tape recorded surveys conducted in at least two large marsh areas (Johnson et al. 1981).

Objective 4. *Establish interim flow monitoring sites and specific monitoring parameters for the lower Grand Canyon based on information collected under Objectives 1, 2, and 3.*

Based upon the results of the literature search, MIPS work, coordination with upper Grand Canyon researchers, and baseline surveys, monitoring techniques and long-term monitoring sites will be established. Study sites established in Objective 3 will become long-term monitoring sites, except in cases where new sites are established or sites are determined to be unsuitable for long-term monitoring. The logic for the selection of long-term monitoring sites will be clearly and decisively established.

Objective 5. *Establish a Scientific Information Database (SID), consistent with GCES protocol, for data collected from interim flow monitoring sites.*

A central database will be established, with protocols developed to ensure consistent data collection, entry, and manipulation throughout the long-term monitoring program. GCES has initiated development of the SID, and will provide the training and use of computers for this Objective.

PHASE II

Objective 6. *Implement specific monitoring methodology, and conduct monitoring of selected study sites. Identify and evaluate changes in riparian communities and determine, to the extent possible, if they are a result of interim flows, or related to natural ecological processes. This short-term monitoring program will provide a baseline for long-term monitoring efforts. Evaluation will be focused on effects related to monthly volumes, maximum and minimum flow levels, ramping rates, and season.*

Objective 6 begins Phase II of the Hualapai riparian monitoring project. It is anticipated that this phase will begin in the first part of FY 93 and extend through the end of FY 94 or until the end of the interim flows. The use of five transects in the reach below RM 240 to characterize and study the vegetation which has colonized depositional silt bars will allow a more complete understanding of this area than using quadrats alone. Transects will begin at the highest vegetated terrace deposited as the level of Lake Mead dropped and extend perpendicular to the river to the water's edge. In each vegetation zone, ten 1m square plots will be randomly selected and censused. Transects will be recensused during each year of Phase II.

Phase II monitoring trips are expected to resemble Phase I trips, both in timing and in coordination with low, moderate, and high flows. Approximately five monitoring trips will be conducted each year, with at least one trip each year to conduct monitoring of vegetative and animal communities between National Canyon and Diamond Creek.

Objective 7. *Identify changes in vegetative community size and composition occurring throughout the time frame of the monitoring program at representative sites, and produce an updated map of vegetative communities at specific sites in the lower Grand Canyon.*

A detailed map will be developed which a) describes vegetative communities and community changes at the three mapping sites; b) shows the area in hectares of vegetation communities; and c) details the locations of vegetation, avian, mammalian and reptile study sites. This map will allow a clear, concise presentation of study results and an evaluation of riparian community changes over time. This Objective will be completed at the end of FY 94, and will form a part of the final report.

Objective 8. *Integrate the riparian and natural resource results with the Hualapai and GCES Geographic Information Systems (GIS), Scientific Information Database (SID), and long-term monitoring program.*

Survey results will be in a format that will allow simple entry into the Hualapai and GCES GIS systems and the GCES SID system as it is developed. As methodologies will be based upon historical data as well as communications with other scientists, all studies will be compatible with the GCES long-term monitoring program.

Objective 9. *Develop a long-term riparian system monitoring program for the Hualapai Tribe, with site selection, monitoring techniques, and analysis protocols compiled in a long-term monitoring field guide.*

Based upon the findings of Objectives 6, 7, and 8 and upon an assessment of established monitoring sites, a long-term riparian monitoring program for the lower Grand Canyon will be developed. The parameters and logic for the establishment of the long-term monitoring program will be clear and will provide a stepwise reasoning for continuing monitoring efforts.

DELIVERABLES

Completion of Phase I will produce data on vegetative and animal species composition and demography in the lower Grand Canyon. An herbarium and mammal specimen collection will be established, which will be expanded as necessary during Phase II. Information collected in Phase I will provide the baseline data for Phase II monitoring and determination of changes in plant communities as a result of interim flows. Quarterly and annual reports will be produced according to the time line shown in Table 1.

During Phase II, updated maps of vegetative communities will be developed, and quantitative data on change in extent and composition of vegetative and animal communities in the lower Grand Canyon will be collected and compiled. Recommendations will be made for long-term monitoring efforts beyond FY 94. Quarterly, annual, and final reports will be produced according to Table 1. The final report will be published in a peer-reviewed scientific journal.

Table 2 details deliverables for each phase.

Table 2. Project Deliverables.

PHASE I: FY 92

1. Base map of vegetation area and study sites.
2. Logic for establishment of interim flow monitoring sites and quadrats within sites.
3. Protocol for entry and manipulation of data with Scientific Information Database.
4. Methodologies and site locations for interim flows monitoring program.
5. Quarterly and annual reports.

PHASE II: FY 93 and FY 94

1. Updated base map showing changes in areal extent and community distribution at six mapping sites; the location of study sites; and the area in hectares of the riparian vegetation of the lower Grand Canyon.
2. Quarterly, annual, and final reports detailing findings of the impacts of interim flows on the riparian community in the lower Grand Canyon.
3. Final database with protocol for analysis.
4. Herbarium collection with slides of all vegetation species collected.
5. Provide data to GCES for inclusion in GIS for the two GIS sites located within the study area.
5. Prioritized recommendations for long-term monitoring efforts beyond FY 94, including additional GIS sites if needed, and compilation of specific long-term monitoring protocols into a field guide.

INTEGRATION WITH OTHER GCES MONITORING EFFORTS

As SWCA and the Hualapai Tribe join the GCES in research, the work being proposed is designed to integrate with previous and current GCES research on plants, animals and sediments in the Grand Canyon. The riparian corridor through Grand Canyon reflects a continuum of processes from erosional to aggradational, and the proposed lower reach interim flow monitoring will help to complete an understanding of this process and its effects on associated resources. The riparian work proposed will be compatible with that ongoing in the upper Grand Canyon, and will enhance the understanding of the structure of riparian plant communities and how they are changing. Other GCES studies ongoing or planned include aquatic studies, GIS surveys, long-term monitoring, and avian surveys.

The proposed studies will contribute essential data on plants and animals to these long-term, multifaceted research efforts. Additionally, the use of MIPS to measure area of beaches, as well as plant communities in the lower Grand Canyon, will be compared with results found in the upper Grand Canyon in other GCES studies.

SCHEDULING

Quarterly and annual reports will be provided to the Glen Canyon Environmental Studies according to the schedule in Table 1. A Draft Final Report will be distributed for technical

review as specified by the GCES and a Final report will be developed at the completion of the interim flow monitoring program. The schedule outline in Table 1 will be followed for this interim flow monitoring project, but may be adjusted pending determination of the date of the actual contract initiation.

PERSONNEL

Technical Staff

Four scientists will collect and analyze data for this project. A project manager will be the contact point for the project, establish logistics, and coordinate completion of interim and final reports. Combined, the experience of these professional biologists in studying the plants and animals of the Grand Canyon totals 71 years. Each scientist is involved with ongoing work in the field of riparian ecosystem analysis. Curriculum vitae are attached. Duties will be as follows:

Steven W. Carothers, Ph.D.	Principal Investigator
Arthur M. Phillips III, Ph.D.	Botanist
Bryan T. Brown, Ph.D.	Wildlife Biologist
Amis C. Holm, M.S.	Ecologist/Database Manager
Brice J. Hoskin	Project Manager

Other Agency Involvement

The GCES will provide the primary river and helicopter logistical support and the technical expertise and equipment for the surveying efforts, except where supplies are provided by SWCA or the Hualapai Tribe. Where boats and guides are supplied by SWCA and the Hualapai Tribe, GCES will provide for further logistics including primarily provision of food supplies. The National Park Service will provide technical scientific support and input into the design and development of the monitoring site locations. The GCES will provide the technical support in the training and use of the MIPS system and the development of the GIS sites.

BUDGET

The following budget does not include the cost of logistics, which will be covered and coordinated by the Bureau of Reclamation Glen Canyon Environmental Studies Office in Flagstaff, Arizona. This budget also does not include NPS staff or travel costs, which are included in the annual NPS administrative budget associated with the GCES Program.

PROPOSED BUDGET

Personnel	Cost/ Hour	Cost + Overhead	FY92 Hours	FY92 Cost	FY93 Hours	FY93 Cost	FY94 Hours	FY94 Cost	Total Cost
Carothers	$30.00	$54.60	480	$4,368	580	$9,828	580	$9,828	$24,024[2]
Phillips	25.00	45.50	580	26,390	620	28,210	620	28,210	82,810
Brown	20.00	36.40	540	19,656	580	21,112	580	21,112	61,880
Kimberling	15.00	27.30	540	14,742	580	15,834	580	15,834	46,410
Hoskin	15.00	27.30	540	14,742	600	16,380	600	16,380	47,502
MIPS Technician	12.00	21.84	200	4,368	50	1,092	50	1,092	6,552
Total Personnel Cost				**$84,266**		**$92,456**		**$92,456**	**$269,178**
Field Supplies				2,800		2,200		2,200	7,200
Office Supplies				2,100		2,100		2,100	6,300
Total Direct Costs				**$ 4,900**		**$ 4,300**		**$ 4,300**	**$13,500**
Total Project Costs			**FY 92:**	**$89,166**	**FY 93:**	**$96,756**	**FY 94:**	**$96,756**	**$282,678**

[2]Dr. Carothers will provide 400 hours of time each year on a *pro bono* basis, as he will be writing a book concerning the Hualapai Tribe and the Grand Canyon (with Hualapai approval prior to publishing).

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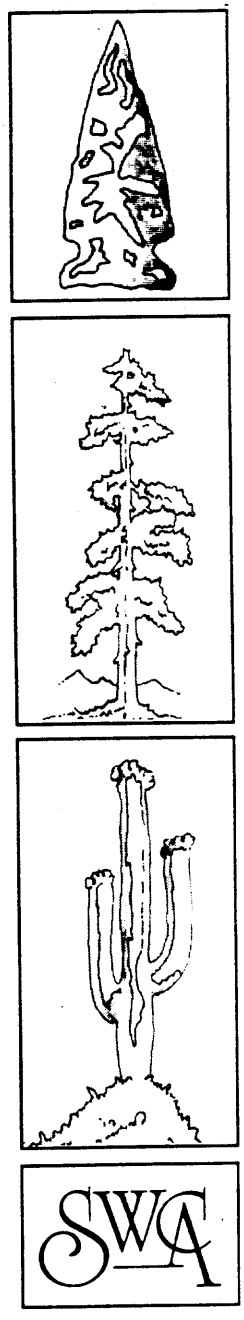
APPENDIX C

LITERATURE REVIEW



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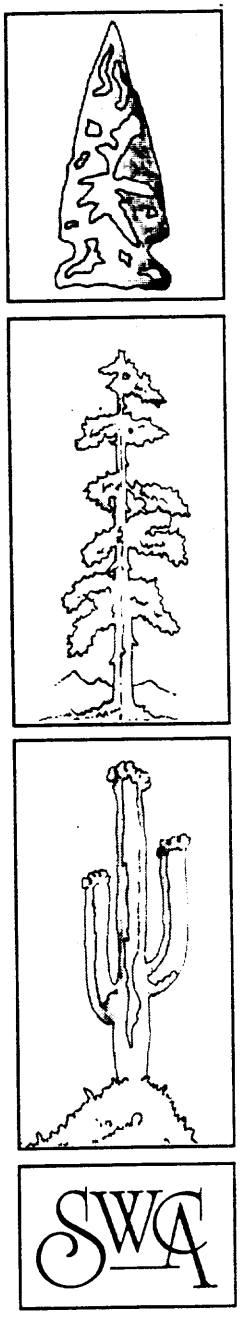
APPENDIX D

VEGETATION SPECIES LISTS



PART A: SUMMARY SPECIES LIST

Summary Species List for Old High Water (OHW) Zone

Species	Family	Common Name
Acacia greggii	Leguminosae	Catclaw acacia
Allionia incarnata	Nyctaginaceae	Trailing four o'clock
Ambrosia dumosa	Compositae	White bursage
Aristida glauca	Gramineae	
Aristida purpurea		
Aristida sp.		Three-awn
Baccharis sarathroides	Compositae	Desert broom
Bebbia juncea	Compositae	Sweetbush
Borag sp.	Boraginaceae	
Bouteloua sp.	Gramineae	
Encelia farinosa	Compositae	Brittlebush
Encelia frutescens		Brittlebush
Ephedra nevadensis	Ephedraceae	Mormon tea
Eriogonum fasciculatum	Polygonaceae	Buckwheat
Eriogonum sp.		Buckwheat
Erioneuron pulchellum	Gramineae	Fluffgrass
Erioneuron pisolum		Fluffgrass
Ferocactus acanthodes	Cactaceae	Barrel cactus
Galium stellatus	Rubiaceae	Desert bedstraw
Gutierrezia sarothrae	Compositae	Snakeweed
Haplopappus acradenius	Compositae	Jimmyweed
Larrea tridentata	Zygophyllaceae	Creosotebush
Lycium fremontii	Solanaceae	Wolfberry
Mammillaria	Cactaceae	Fishhook cactus
Mammillaria		Fishhook cactus
Opuntia acanthocarpa		
Opuntia basilaris		Beavertail cactus
Porophyllum gracile	Compositae	Poreleaf
Prosopis glandulosa	Leguminosae	Mesquite
Selaginella sp.	Selaginellaceae	
Sporobolus cryptandrus	Gramineae	Dropseed
Sporobolus flexuosus		Dropseed
Trixis californica	Compositae	Trixis
Ziziphus obtusifolia		Graythorn

Summary Species List for General Beach Zone

Species	Family	Common Name
Acacia greggii	Leguminosae	Catclaw acacia
Agrostis sp.	Gramineae	Bentgrass
Alhagi camelorum	Leguminosae	Camelthorn
Artemisia dracunculus	Compositae	False tarragon
Artemisia ludoviciana		Sage
Aster subulatus	Compositae	Aster

Species	Family	Common Name
Baccharis salicifolia	Compositae	Seep willow
Baccharis sarothroides		Seep willow
Cynodon dactylon	Gramineae	Bermuda grass
Dicoria brandegei	Compositae	Dicoria
Dicoria canescens		Dicoria
Equisetum hyemale	Equisetaceae	Horsetail
Euphorb sp.	Euphorbiaceae	Euphorb
Gutierrezia microcephala	Compositae	Snakeweed
Gutierrezia sarothrae		Snakeweed
Haplopappus acradenius	Compositae	Jimmyweed
Juncus sp.	Juncaceae	Rush
Juncus torreyi		Rush
Machaeranthera sp.	Compositae	
Oenothera hookeri	Onagraceae	Hooker's evening primrose
Oenothera pallida		Evening primrose
Plantago major	Plantaginaceae	Plantain
Salix exigua	Salicaceae	Coyote willow
Salix gooddingii		Gooding's willow
Solanum sp.	Solanaceae	Nightshade
Sphaeralcea ambigua	Malvaceae	Globe mallow
Sporobolus contractus	Gramineae	Dropseed
Sporobolus cryptandrus		Dropseed
Sporobolus flexuosus		Dropseed
Sporobolus giganteus		Dropseed
Tamarix ramosissima	Tamaricaceae	Tamarisk
Tessaria sericea	Compositae	Arrowweed
Typha sp.	Typhaceae	Cattail

Summary Species List for Riparian Strip (RS) Zone

Species	Family	Common Name
Acacia greggi	Leguminosae	Catclaw acacia
Agrostis stolonifera	Gramineae	Bentgrass
Alhagi camelorum	Leguminosae	Camelthorn
Andropogon glomeratus	Gramineae	Bushy beardgrass
Apocynum cannabinum	Apocynaceae	Dogbane
Aquilegia sp.	Ranunculaceae	Columbine
Aristida sp.	Gramineae	Three-awn
Artemisia ludoviciana	Compositae	Sage
Aster subulatus	Compositae	Aster
Baccharis emoryi	Compositae	Seep willow
Baccharis salicifolia		Seep willow
Baccharis sarothroides		Seep willow
Bothriochloa barbinodis	Gramineae	Cane bluestem
Brickellia atractyloides	Compositae	Spiny brickellbush
Brickellia longifolia		Long-leaf brickellbush
Cirsium sp.	Compositae	Thistle
Cynodon dactylon	Gramineae	Bermuda grass

Species	Family	Common Name
Encelia farinosa	Compositae	Brittlebush
Equisteum hyemale	Equisetaceae	Horsetail
Erigeron sp.	Compositae	Fleabane
Gnaphalium wrightii	Compositae	Cudweed
Haplopappus acradenius	Compositae	Jimmyweed
Juncus sp.	Juncaceae	Rush
Muhlenbergia asperifolia	Gramineae	Scratchgrass
Phragmites australis	Gramineae	Common reed
Porophyllum gracile	Compositae	Poreleaf
Sarcostemma cynanchoides	Asclepiadaceae	Climbing milkweed
Sporobolus contractus	Gramineae	Dropseed
Sporobolus cryptandrus		Dropseed
Sporobolus sp.		Dropseed
Tamarix ramosissimi	Tamaricaceae	Tamarisk
Tessaria sericea	Compositae	Arrowweed
Trixis californica	Compositae	Trixis
Typha sp.	Typhaceae	Cattail

Summary Species List for New Dry Zone

Species	Family	
Agrostis stolonifera	Gramineae	Bentgrass
Aster subulatus	Compositae	Aster
Baccharis salicifolia	Compositae	Seep willow
Carex sp.	Cyperaceae	Sedge
Equisetum laevigatum	Equisetaceae	Horsetail
Juncus sp.	Juncaceae	Rush
Oenothera pallida	Onagraceae	Evening primrose
Plantago major	Plantaginaceae	Plantain
Salix exigua	Salicaceae	Coyote willow
Salix gooddingii		Gooding's willow
Scirpus americanus	Cyperaceae	Bulrush
Scirpus sp.		Bulrush
Tamarix ramosissimi	Tamaricaceae	Tamarisk
Typha sp.	Typhaceae	Cattail
Veronica sp.	Scrophulariaceae	Veronica

PART B: PLOT SPECIES LISTS

Species List for Plots in Old High Water Zone

Mile	Species
172L	Acacia greggii
	Ephedra nevadensis
	Gallium stellatus
	Lycium fremontii

Mile	Species
	Prosopis glandulosa
	Ziziphus obtusifolia
183R	Acacia greggii
	Baccharis salicifolia
	Prosopis glandulosa
194L	Acacia greggii
	Prosopis glandulosa
213R	Acacia greggii
	Encelia farinosa
	Haplopappus acradenius
	Opuntia basilaris
	Prosopis glandulosa
	Ziziphus obtusifolia
217L	Acacia greggii
	Aristida sp.
	Bebbia juncea
	Boraginaceae
	Encelia farinosa
	Erioneuron pulchellum
	Ferocactus acanthodes
	Gallium stellatus
	Mammillaria sp.
	Trixis californica
220R	Acacia greggii
	Alllionia incarnata
	Aristida glauca
	Aristida sp.
	Bouteloua sp.
	Encelia farinosa
	Ephedra nevadensis
	Erioneuron pisolum
	Gutierrezia sarothrae
	Maammilaria tetrancistra
	Opuntia acanthocarpa
	Opuntia basilaris
	Porophyllum gracile
	Sporobolus cryptandrus
231.8L	Acacia greggii
	Aristida purpurea
	Encelia frutescens
	Haplopappus acradenius
	Porophyllum gracile
	Prosopis glandulosa

Mile	Species
	Selaginella sp.
	Sporobolis cryptandrus
235L	Ambrosia dumosa
	Aristida purpurea
	Bebbia juncea
	Ephedra nevadensis
	Eriogonum fasciculatum
	Eriogonum sp.
	Erioneuron pulchellum
	Porophyllum gracile
246L	Larrea tridentata
	Porophyllum gracile

Species List for Plots in General Beach Zone

Mile	Species
172L	Artemisia dracunculus
	Artemisia ludoviciana
	Aster subulatus
	Euphorb sp.
	Gutierrezia microcephala
	Gutierrezia sarothroides
	Machaeranthera sp.
	Oenothera pallida
	Salix exigua
	Solanum sp.
	Sporobolus contractus
	Sporobolus cryptandrus
	Sporobolus flexuosus
	Sporobolus giganteus
	Tamarix ramosissima
183R	Dicoria brandegei
	Sporobolus cryptandrus
	Tessaria sericea
194L	Salix exigua
	Sporobolus sp.
209R	Alhagi camelorum
	Cynodon dactylon
	Haplopappus acradenius
	Oenothera hookeri
	Sporobolus sp.
	Tamarix ramosissima
	Tessaria sericea

Mile	Species
213R	Baccharis salicifolia Dicoria canescens Haplopappus acradenius Sporobolus contractus Sporobolus flexuosus Sporobolus giganteus Oenothera pallida
217L	Dicoria sp. Sporobolus flexuosus Tessaria sericea
231.8L	Haplopappus acradenius Sporobolus cryptandrus Tessaria sericea
235L	Acacia greggii Sphaeralcea ambigua Sporobolus cryptandrus Tessaria sericea
240L	Equisetum hymale Tamarix ramosissima Tessaria sericea
246L	Baccharis salicifolia Salix exigua Salix gooddingii Sporobolus contractus Tamarix ramosissima
254L (A)	Aster subulatus Baccharis salicifolia Salix exigua Tamarix ramosissima
254L (B)	Salix exigua Tamarix ramosissima
259L	Baccharis salicifolia Tamarix ramosissima
266.5R (2nd Terrace)	Agrostis sp. Cynodon dactylon Juncus sp. Juncus torreyi Salix exigua Salix gooddingii

Mile	Species
	Tamarix ramosissima
266.5R (2nd Terrace)	Aster subulatus Cynodon dactylon Perennial grass Plantago major Salix exigua Salix gooddingii Tamarix ramosissima Typha sp.
266.5L (2nd T.)	Agrostis sp. Aster subulatus Baccharis salicifolia Perennial grass Juncus sp. Juncus torreyi Salix exigua Salix gooddingii Tamarix ramosissima Typha sp.

Species List for Plots in Riparian Strip Zone

Mile	Species
172L	Acacia greggi Artemisia ludoviciana Baccharis salicifolia Cynodon dactylon Equisteum hyemale Haplopappus acradenius Muhlenbergia asperifolia Sarcostemma cynanchoides Sporobolus cryptandrus Sporobolus sp. Tamarix ramosissimi Tessaria sericea
183R	Alhagi camelorum Apocynum cannabinum Artemisia ludoviciana Baccharis salicifolia Cynodon dactylon Equisteum hyemale Tessaria sericea
194L	Acacia greggi Artemisia ludoviciana Baccharis salicifolia Bothriochloa barbinodis

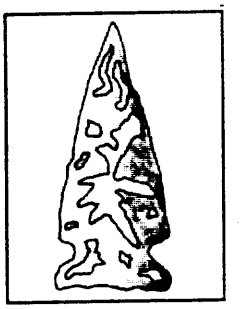
Mile	Species
	Cynodon dactylon
	Equisteum hyemale
	Sporobolus contractus
	Sporobolus cryptandrus
213R	Acacia greggi
	Andropogon glomeratus
	Aster subulatus
	Baccharis salicifolia
	Bothriochloa barbinodis
	Brickellia atractyloides
	Brickellia longifolia
	Cynodon dactylon
	Haplopappus acradenius
	Porophyllum gracile
	Sporobolus cryptandrus
217L	Cynodon dactylon
	Phragmites australis
	Tamarix ramosissimi
	Tessaria sericea
231.8L	Andropogon glomeratus
	Aguilegia sp.
	Baccharis emoryi
	Cirsium sp.
	Cynodon dactylon
	Equisteum hyemale
	Erigeron sp.
	Gnaphalium wrightii
	Muhlenbergia asperifolia
	Tessaria sericea
240R	Aristida
	Cynodon dactylon
	Encelia farinosa
	Sporobolus contractus
	Trixis californica
246R	Baccharis salicifolia
	Phragmites australis
	Tamarix ramosissimi
	Typha sp.
259L	Agrostis stolonifera
	Baccharis salicifoliaBasl
	Juncus sp.
	Tamarix ramosissimi

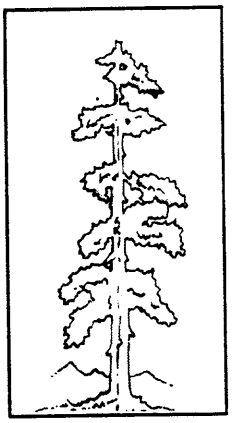
Species List for Plots in New Dry (ND) Zone

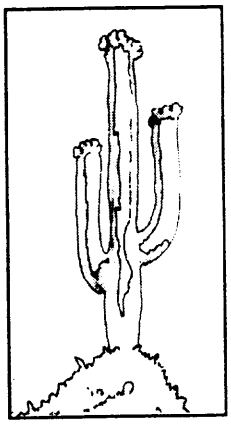
Mile	Species
237.3L	Scirpus sp.
	Tamarix ramosissimi
239.6L	Aster subulatus
	Baccharis salicifolia
	Equisetum laevigatum
	Oenothera pallida
	Plantago major
	Salix exigua
	Scirpus americanus
266R	Agrostis stolonifera
	Aster subulatus
	Baccharis salicifolia
	Carex sp.
	Equisetum laevigatum
	Juncus sp.
	Salix exigua
	Tamarix ramosissimi
274.7	Carex sp.
	Salix exigua
	Salix gooddingii
	Tamarix ramosissimi
	Typha sp.
	Veronica sp.

APPENDIX E

HERBARIUM SPECIMEN COLLECTION LIST







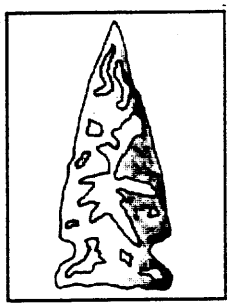
SWCA

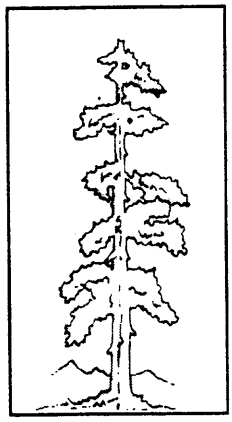
Herbarium specimens collected to date include:

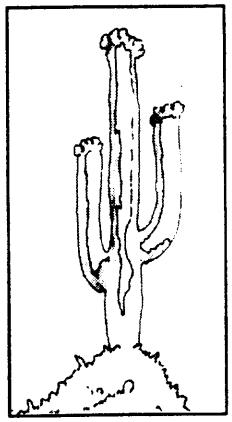
Species	Family	River Mile Collected
Aristida parishii	Gramineae	231.5L
Aster subulatus var. *ligulatus*	Compositae	228.8L, 254.0R, 239.6L
Centaurium calycosum	Gentianaceae	249.4L
Conyza canadensis	Compositae	228.8L, 239.6L
Cyperus sp.	Cyperaceae	266.5R
Eriogonum wrightii	Polygonaceae	235.0L
Juncus acutus	Juncaceae	228.8L
Juncus torreyi	Juncaceae	254.0R, 266.5R, 249.4L
Panicum capillare	Gramineae	254.0R
Panicum obtusum	Gramineae	228.8L
Pluchea purpurascens var. *purpurascens*	Compositae	249.4L
Polygonum lapathifolium	Polygonaceae	255.0R
Scirpus americanus	Cyperaceae	254.0R
Scirpus maritimus var. *paludosus*	Cyperaceae	266.5R
Solidago altissima	Compositeae	231.5L
Solidago occidentalis	Compositeae	229.9;
Sprobolus cryptandrus	Gramineae	231.5L

APPENDIX F

MAMMAL SPECIMEN COLLECTION LIST







Mammal specimens collected to date include:

Species	Sex	River Mile Collected
Perognathus eremicus	M	229.0L
Perognathus eremicus	F	229.0L
Perognathus eremicus	F	229.0L
Perognathus intermedius	M	229.0L
Neotoma lepida	M	229.0L
Perognathus eremicus	M	229.0L
Perognathus eremicus	M	229.0L
Perognathus sp.	F	235.0L
Neotoma lepida	M	235.0L
Perognathus eremicus	M	235.0L
Perognathus eremicus	M	235.0L
Perognathus eremicus	F	246.0L
Perognathus eremicus	M	246.0L
Dipodomys sp.	M	276.0L