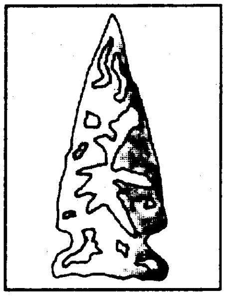
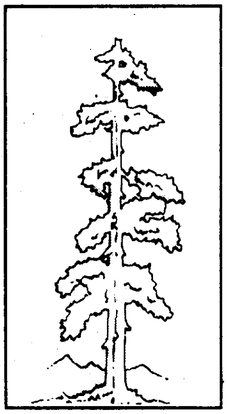
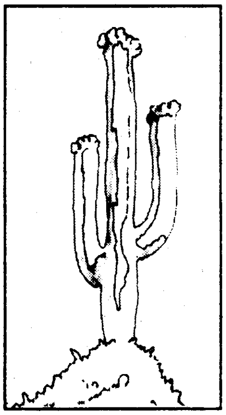
Final
Annual Report
1993

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

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ABSTRACT

This report details monitoring efforts for riparian studies conducted in 1993. Vegetative, avian, mammalian and reptilian communities were studied in the portion of the Grand Canyon from National Canyon to Columbine Falls.

Vegetation studies efforts in 1993 included recensusing of 32 long-term quadrats, 4 marshes, and 5 transects at 20 study sites. Total vegetation volume of each quadrat and transect was measured. Herbarium specimens were collected throughout the study area and catalogued. Vegetation types were mapped along the river corridor from river mile (RM) 166 to RM 273, and these data were transferred to the Glen Canyon Environmental Studies Map Image Processing System for analysis. Three of the study sites were the subject of intensive vegetation mapping.

Avian studies efforts included extensive census and analysis of riparian bird communities. Bird density and species richness were measured at eight riparian study sites along the Colorado River between National Canyon and Pearce Ferry during the 1993 nesting season. Bird densities based on absolute counts were estimated in two ways. Based on maximum detections, avian densities ranged from 217 to 1764 individuals/40 ha; based on mean detections, avian densities ranged from 154 $\pm$ 12 individuals/40 ha to 1098 $\pm$ 121 individuals/40 ha. Twenty-four species known or suspected to nest were found in riparian vegetation at the eight study sites. Total vegetation volume was measured at each of the eight study sites, and will be used to identify any correlation between vegetation volume and breeding bird density.

Mammal studies were postponed in 1993 due to the outbreak of the deadly hantavirus. Continuation of the long-term mammal studies program is planned for 1994, involving intensive surveys at three monitoring sites.

Reptile studies in 1993 included a line transect census at three long-term monitoring sites. Species composition and diversity, as well as frequency of capture, were analyzed. Intensive reptile surveys are scheduled for 1994, as we recensus study sites per the methods of Warren and Schwalbe (1986).

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, involving collection of baseline riparian resource data, was completed in 1992. Phase II, including fiscal years 1993 and 1994, involves establishing long-term monitoring protocols and re-censusing at vegetation, avian, mammal and reptile study sites. While baseline data were the products of Phase I, comparative trend data related where possible to flow regimes are the products of Phase II. Phase III will continue the monitoring efforts of Phase II until the Glen Canyon Dam EIS Record of Decision, expected in mid-1995. Phase IV will in turn be long-term monitoring, initiated after the Record of Decision but following the methodology and utilizing the monitoring sites of Phases II and III.

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.

METHODOLOGY

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

Phase I Objectives

Objective 1. Literature Review

A literature review was conducted in 1992, and the review bibliography was presented in the 1992 Annual Report.

Objective 2. Baseline Study Site and Vegetation Area Map

Vegetated area in the lower Grand Canyon in 1992 was measured using the Map Image Processing System (MIPS) at Glen 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.

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 was initiated in 1993 and will be continued on an annual basis. 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. The area of these sites will be measured on an annual basis to identify changes in vegetation area.

Objective 3. Baseline Validation Surveys

Baseline vegetation, avian, mammal and reptile surveys were conducted in 1992. These surveys were repeated in 1993 as part of Objective 6.

Objective 4. Establish Monitoring Sites

A number of the vegetation, avian, mammal and reptile sites used for baseline validation have been selected for long-term monitoring, as shown in Table 1. For long-term vegetation monitoring, it is proposed that old high water zone (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

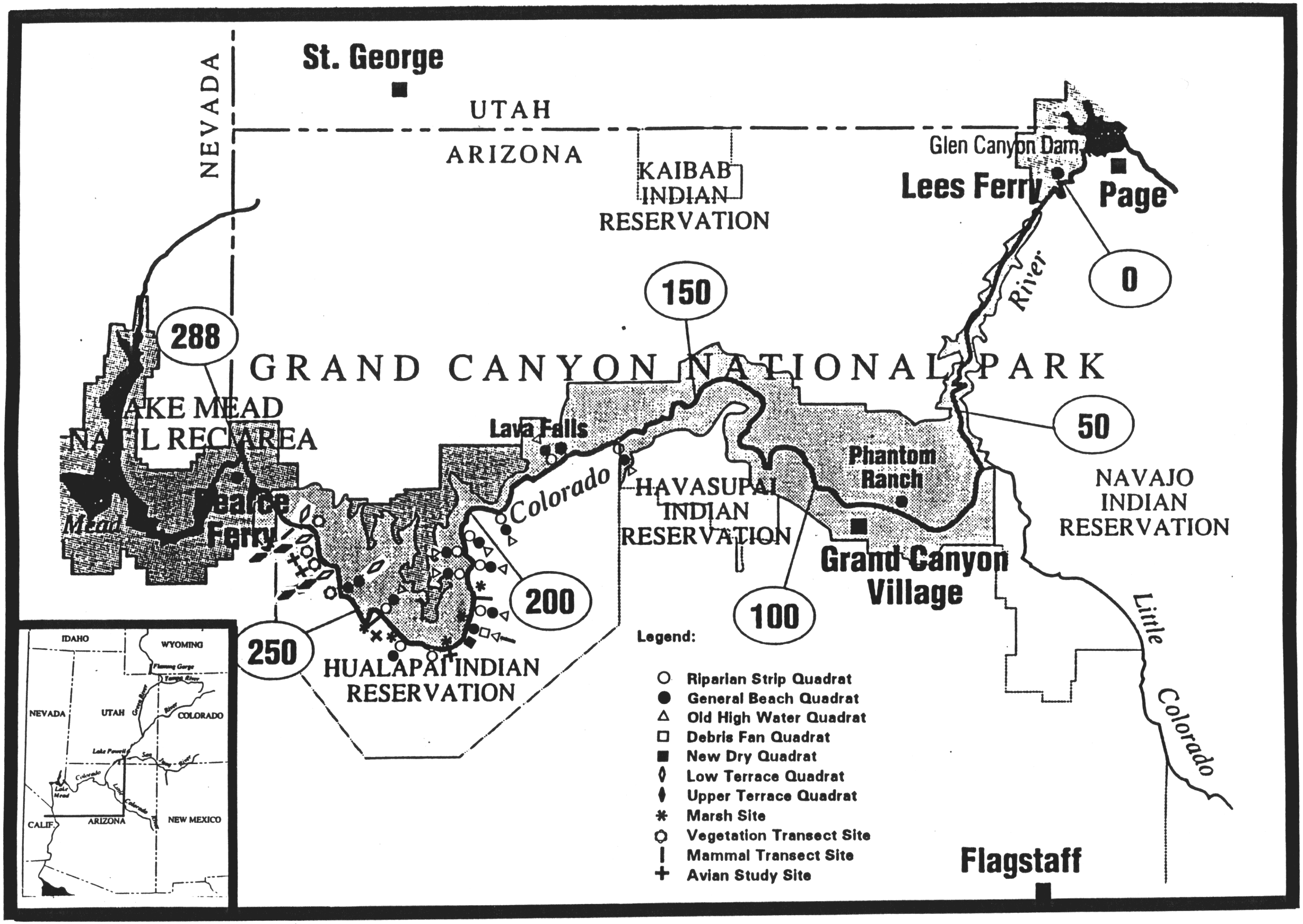


Figure 1. Site Location Map

Table 1. Long-Term Study Site Locations

Mile	Vegetation Studies	Avian Studies	Mammal Studies	Reptile Studies	Mapping
Reach 1 (RM 160 to RM 213)					
166.5L		Transect			
172.2L	RS, GB, OHW				
183.2R	RS, GB, OHW				
194.0L	RS, GB, OHW				
194.0L	Marsh				
198.0R		Transect			
209.0L	RS, GB, OHW	Transect			Hand Mapping
213.0R	RS, GB, OHW				
Reach 2 (RM 213 to RM 240)					
217.4L	RS, GB, OHW				
220.0R	RS, GB, OHW				
228.6L					Hand Mapping
228.8L	Marsh				
231.8L	RS, GB, OHW				
235.0L	GB, DF, OHW		Transects	Transects	
Reach 3 (RM 240 to RM 273.5)					
241.5L	Marsh				
243.2L		Transect			
246.0R	GB				
246.0L	OHW	Transect	Transects	Transects	
249.4L	Marsh				
254.0R	GB, ND, LT				
254.1L	Transect				
260.2R		Transect			
260.2L		Transect			
261.5L	Transect				
264.5L	Transect	Transect	Transects	Transects	
269.6L	Transect				
273.1R	Transect				Hand Mapping

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

the majority of vegetation work conducted in the fall. This will take best advantage of animal breeding seasons and allow annual recensusing of vegetation.

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. GIS data detailing the locations of long-term monitoring sites will be collected in early 1994 using the GCES survey team. This information will allow detailed computer mapping of study sites, use of sites even if river or lake events obscure site landmarks, and precise relocation of sites.

Phase II Objectives

The establishment of baseline and long-term study sites as well as the development of long-term monitoring protocols allowed the initiation of Phase II in the spring of 1993. Presented in Table 2 is a timetable for the projected progress of tasks and deliverables.

Objective 6. Conduct Monitoring of Selected Study Sites

VEGETATION STUDIES

Introduction

Vegetation monitoring surveys followed the methods of Ayers and Stevens (1991), researchers currently conducting vegetation studies under GCES contract in the upper Grand Canyon, except

Table 2. Timeline for Phase II Objectives

										[Phase III]		
Objective	**Jan. 1993**	**Apr.**	**Jul.**	**Oct.**	**Jan. 1994**	**Apr.**	**Jul.**	**Oct.**	**Jan. 1995**	**Apr.**	**Jul.**	**Oct.**
Implement Monitoring	—	—	—	—	—	—	—	—	—	—	—	—
Map Production	—			—	—			—	—			
Integrate w/SID and GIS	—	—	—	—	—	—	—	—	—	—	—	—
Develop Long-Term Monitoring Guide								—	—			

where conditions required use of additional methods. Three types of sites were established in the study area: 5 x 10m quadrats in four vegetation zones related to river stage and sediment type; marsh sites in areas which support dry or wet marsh vegetation;[1] and transects in Lake Mead-influenced areas which support multiple zones of vegetation related to inundation frequency as determined by lake levels and river flows.

Monitoring Methodology

Quadrats

Thirty-two out of an original 43 5 x 10m quadrats established in three reaches of the lower Grand Canyon were suitable for designation as long-term plots and were recensused in 1993. These reaches are as follows: Reach 1, river mile (RM) 160 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), frequency of inundation, and substrate.

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*) as well as numerous xeric annual species.

The general beach (GB) zone lies closer to the water's edge, at the 28,000 to 40,000 cfs level in a separation or reattachment deposit. Plots at similar stage levels 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. Lake 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 dominated by coyote willow (*Salix exigua*), Goodding's willow (*Salix gooddingii*), tamarisk (*Tamarix ramosissima*), and seep willow (*Baccharis salicifolia*).

The riparian strip (RS) zone also lies at the 28,000 to 40,000 cfs level, on channel margin deposits. Above RM 240, this zone supports a wide variety of species, including seep willow,

[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; wet marsh vegetation consists of patches of emergent annual or perennial vegetation in low-lying, regularly inundated habitats.

arrowweed, horsetail (*Equisetum* sp.), and annual grasses. Below RM 240, these plots are characterized by fast-growing annual vegetation including horseweed (*Conyza canadensis*) and aster (*Aster subulatus*).

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.

Marshes

Four marsh sites were studied in areas dominated by dry and wet marsh vegetation, including most importantly horsetail (*Equisetum* sp.) for dry marshes, and cattails (*Typha* sp.) for wet marshes. At each site, a baseline was established parallel to the river, at the upper (talus) edge of marsh vegetation. At regular intervals along the baseline, one meter wide belt transects were established from the baseline to the water's edge. 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. Due to the historic influence of fluctuating Lake Mead water levels on the lower reach, the three vegetation zones of the reaches above RM 240 did not exist in this area or were greatly altered. Transects running perpendicular to the river for the length of the vegetated area (from talus cliff to water's edge) were established to characterize the vegetation on silt banks influenced by Lake Mead. These transects were placed at random sites at approximately five-mile intervals. For each transect, a permanent endpoint was established on the talus slope which marked the outer limit of the highest silt terrace. From this endpoint a transect was established perpendicular to the flow of the river from the talus slope to the river's edge. 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.

Total Vegetation Volume

Total vegetation volume (TVV) of each quadrat was measured, and the TVV of each transect was sampled in each zone. TVV has been used in other studies (Mills et al. 1991) to show a close correlation between TVV and breeding bird density. All avian study sites were also intensively sampled to find the TVV of different vegetation types and of the sites as a whole.

This is the primary manner in which vegetation studies and avian studies for this project are linked. As vegetation communities are inextricably intertwined with breeding bird communities, any proven correlation will have significant management implications for the Grand Canyon and Lake Mead. Mammal and reptile transects are also carefully documented as to vegetation type, potentially allowing a similar correlation to be shown.

Herbarium Collection

Herbarium specimens have been collected throughout the study area, in order to document the diversity of plant species on Hualapai lands. All species found flowering within the main corridor, side canyons, or at springs were collected and their location documented. These specimens in turn were mounted in accordance with herbarium standards, and will be available for Hualapai Wildlife Management Department use. Further specimens will be collected in 1994 to record those species not found or not flowering during previous years.

Vegetation Studies Results

Presented in Figures 2 through 9 are graphs of 1992 and 1993 vegetation studies results. Three primary factors were analyzed: basal cover, species diversity, and individual plants. Basal cover is a measurement of the area covered by all plant stems at ground level within a given plot. This is considered to be the most accurate measure to use in comparisons of vegetation growth or change over time. Species diversity is a count of the number of plant species in a given plot. Diversity can be used as an indicator of species dominance, and in long-term comparisons as an indicator of dynamism. Sums of individual plants include all plant stems. The usefulness of this information is limited, as grasses and seedling plants can greatly increase counts while not necessarily adding to the eventual cover, diversity, or dynamism of the plot.

Basal cover generally decreased between 1992 and 1993 in quadrats above Diamond Creek, while generally increasing in quadrats and transects below Diamond Creek (Figures 2 and 3). Basal cover increased in only one of the three marshes below Diamond Creek. Most significant among the decreases are those at 217RS, 254GB, and 241M. The change at 217RS is attributable to erosion, as channel current has cut away at the lower part of this plot. The plot at 254GB is heavily influenced by the changing levels of Lake Mead. In this higher terrace plot, most individuals have died, apparently as a result of dropping lake levels in the fall of 1993. Similarly, the marsh at 241M has been subject to erosion and changing lake levels, reducing the area covered by marsh vegetation.

Significant increases in basal cover occurred at several sites, including most importantly 231RS, 254ND, 254LT, 261TR, and 264TR. The plot at 231RS is at the water's edge, and while the lower half of the plot was heavily eroded during the floods of early 1993, vegetation in the upper half of the plot grew very rapidly between 1992 and 1993. This may be due to added nutrients and sand carried into the upper half of the plot during the spring flooding. Increases at 254ND, 254LT, 261TR, and 264TR reflect the effects of cyclical rising and falling of Lake Mead. The quadrats at 254ND and 254LT were established in 1992 on bare sand and in

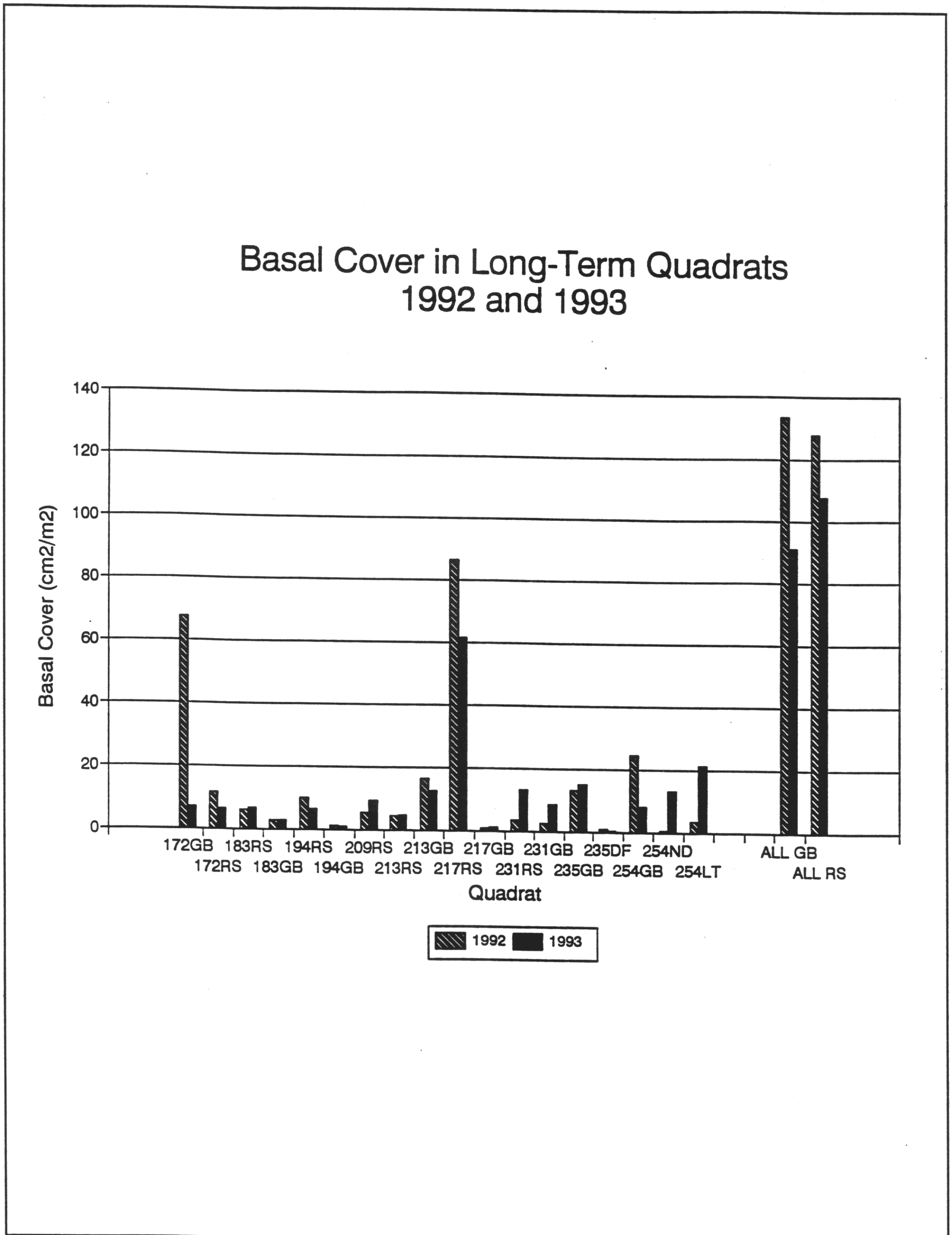


Figure 2. Basal Cover in Long-Term Quadrats

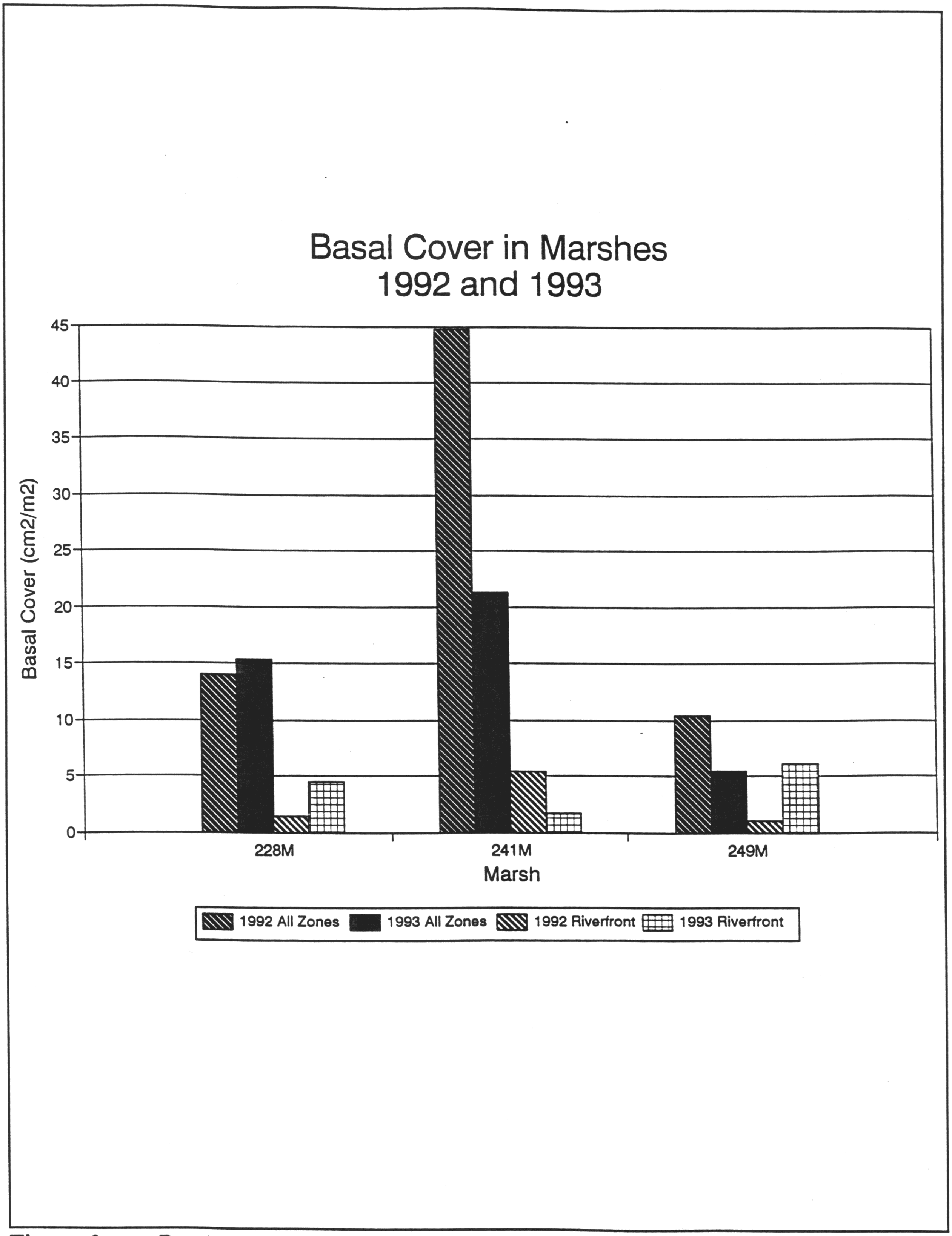


Figure 3. Basal Cover in Marshes

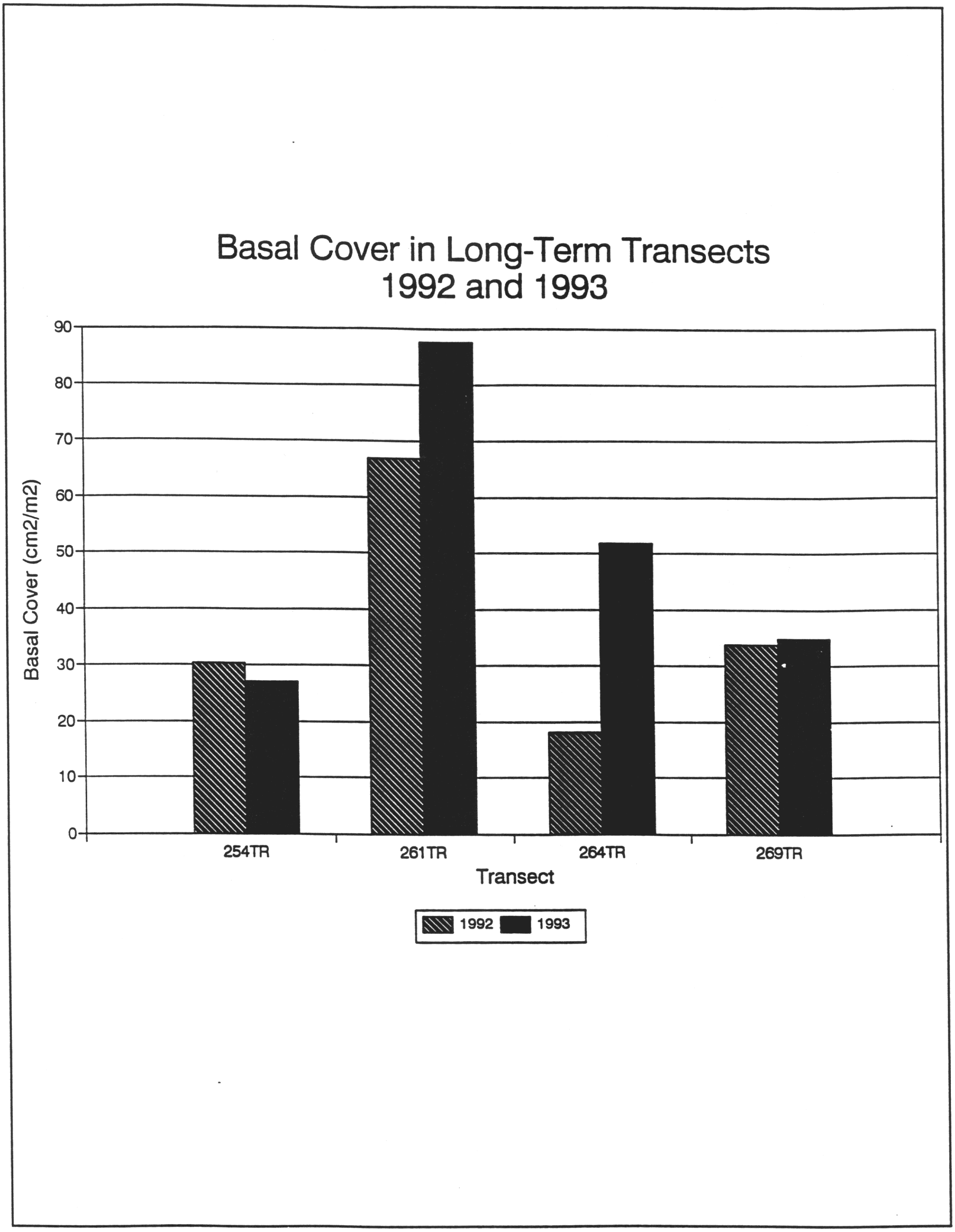


Figure 4. Basal Cover in Long-Term Transects

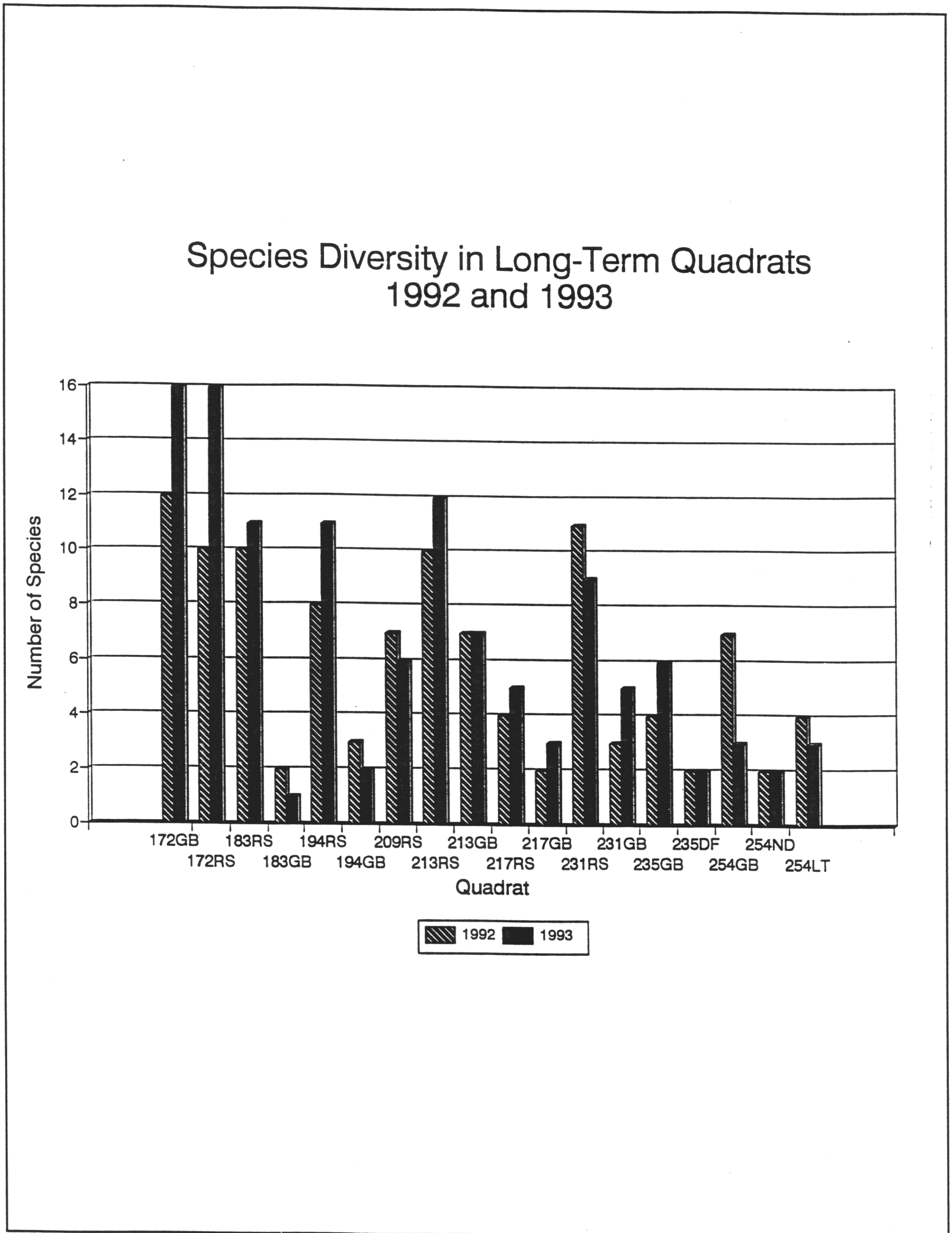


Figure 5. Species Diversity in Long-Term Quadrats

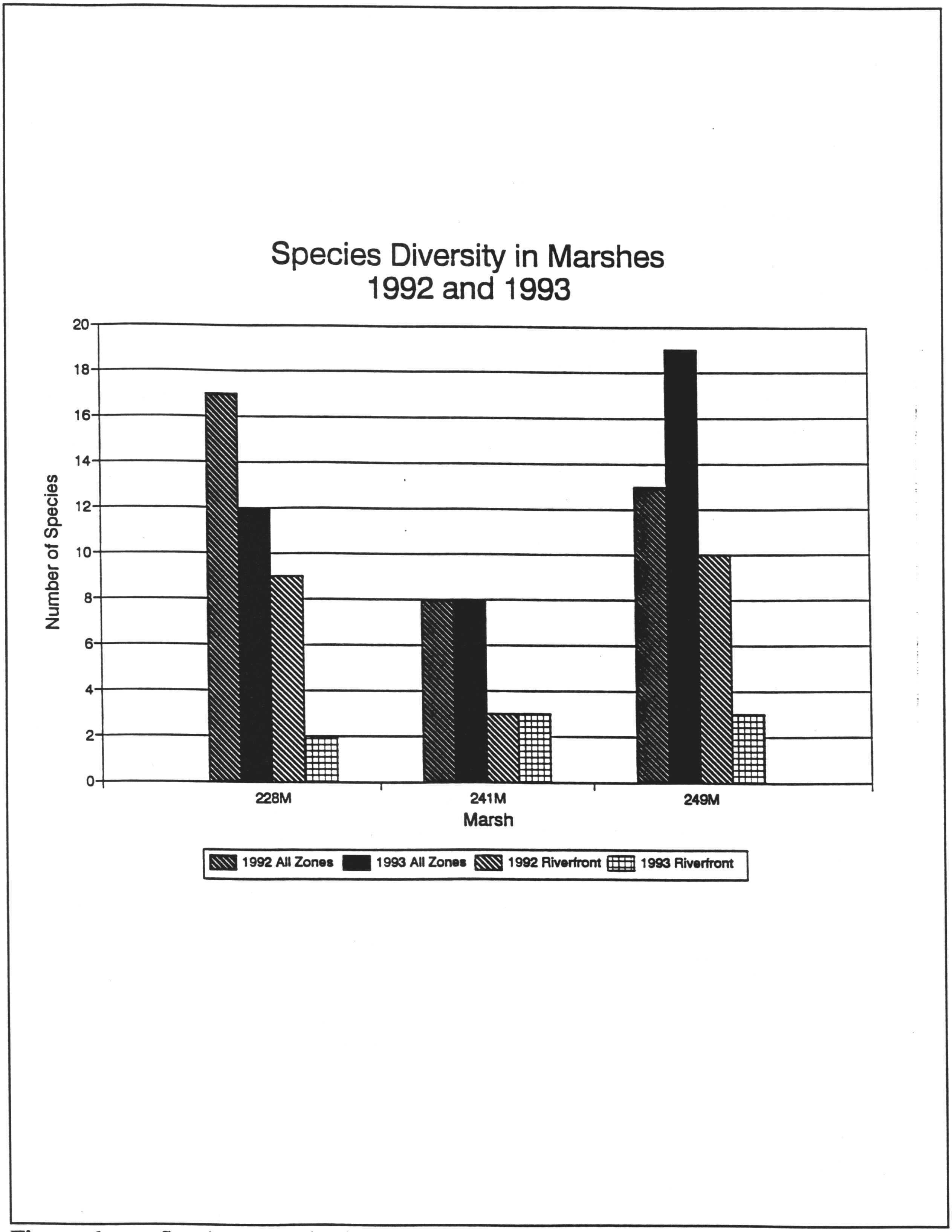


Figure 6. Species Diversity in Marshes

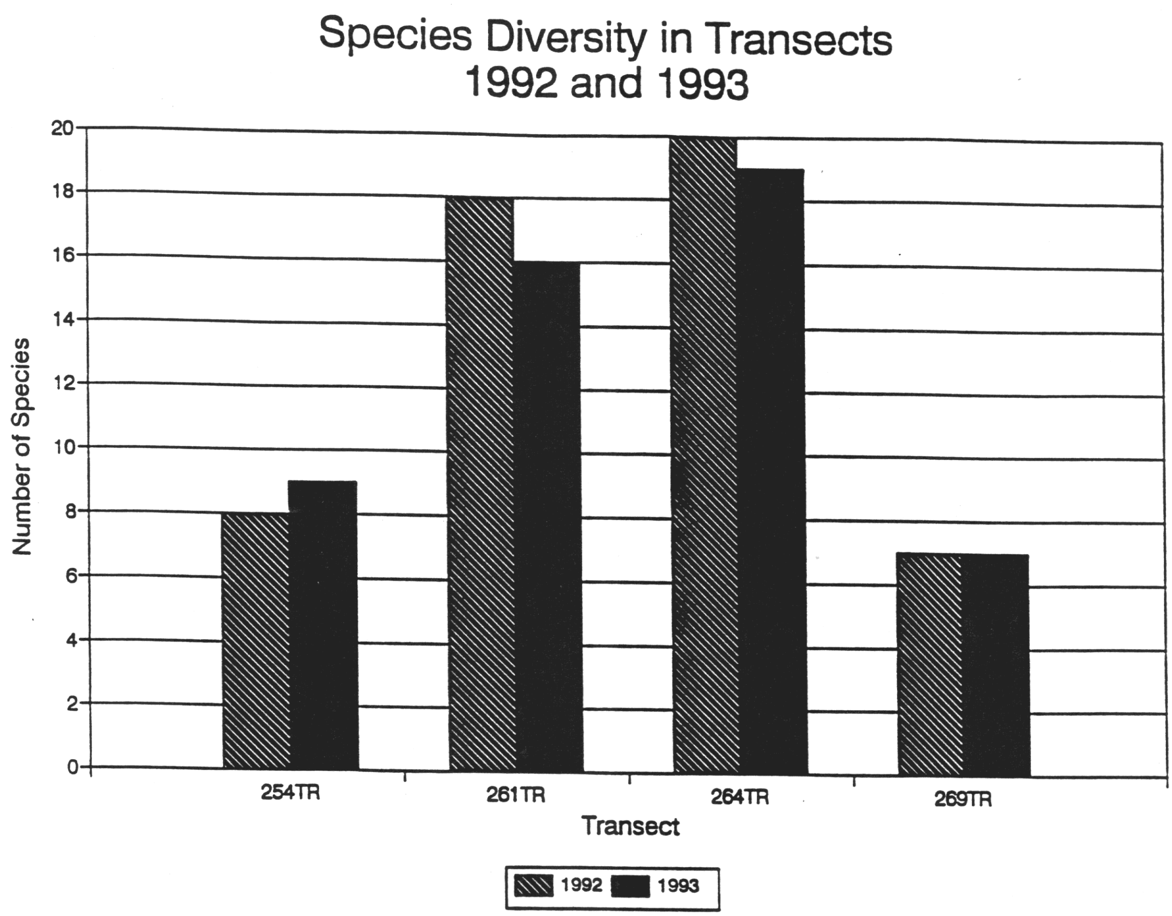


Figure 7. Species Diversity in Transects

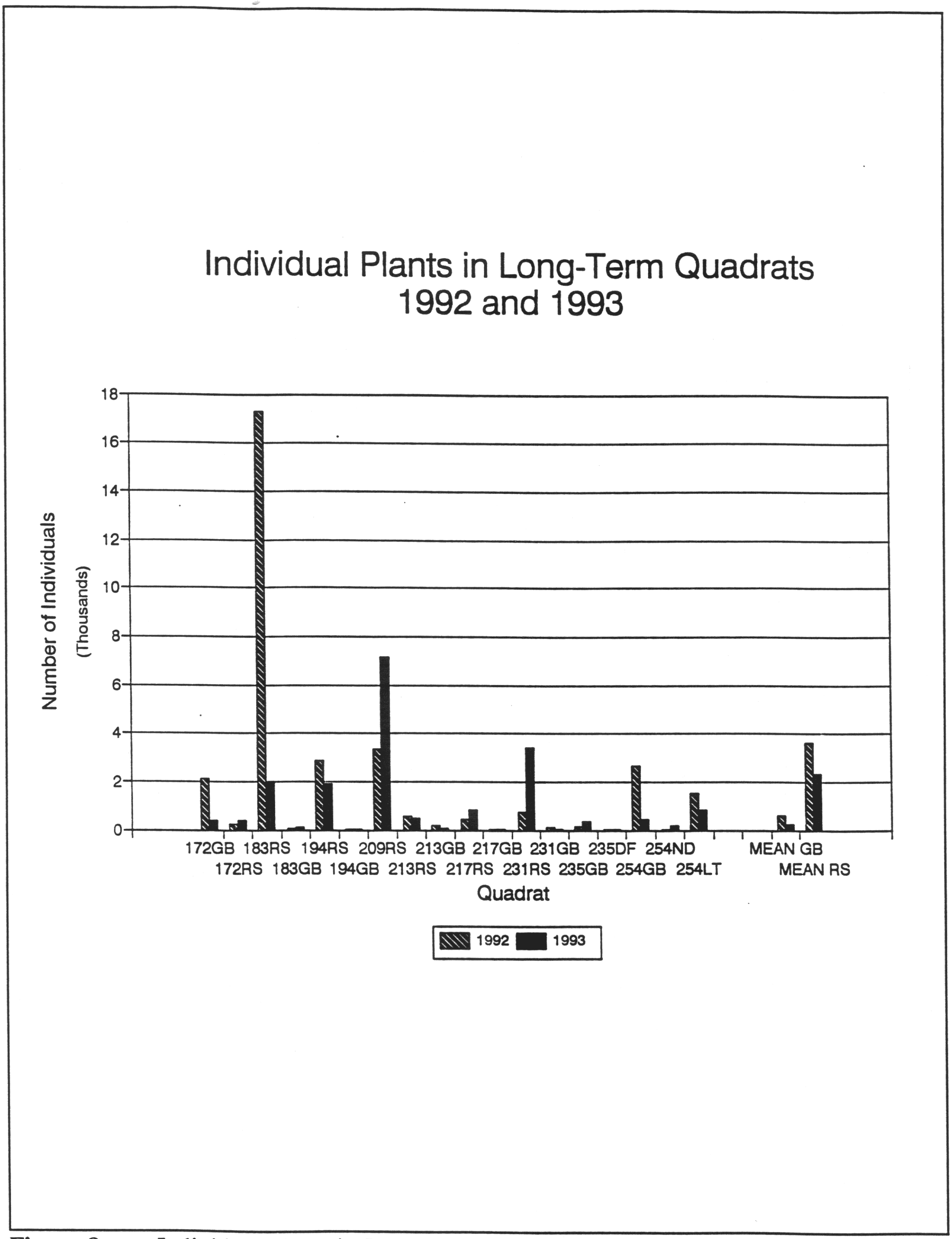


Figure 8. Individual Plants in Long-Term Quadrats

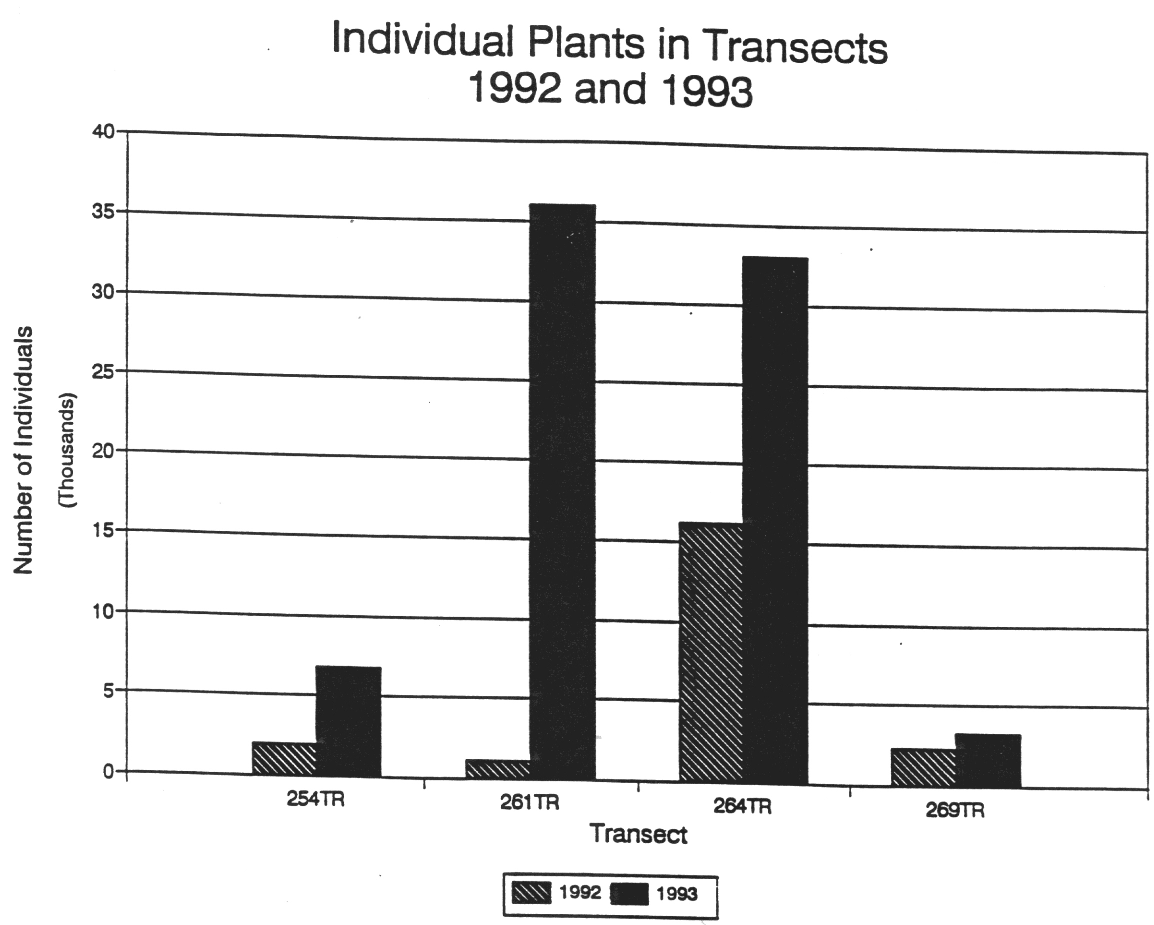


Figure 9. Individual Plants in Transects

seedling beds; by 1993, both exotic and native vegetation had overgrown these plots. The transects at 261TR and 254LT are on silt beds, a portion of which was covered by Lake Mead until approximately six years ago. Vegetation consisting primarily of tamarisk and willow has come to dominate these silt beds in that time. As such, these transects measure large areas of emergent vegetation which continue to increase in basal cover, due to lake elevations which allow the silt beds to be exposed, but also enable plant roots to readily reach the water table.

Species diversity has shown no clear trends in quadrats, marshes, or transects. While Figures 5, 6, and 7 show some differences in species diversity, the large part of these differences are of one or two species, a difference which can be due to experimental error. Shown in Figure 6 is a distinction between overall marsh diversity and the diversity of those subplots closest to the river. Diversity in riverfront plots is much lower, apparently due to the repeated inundation of these plots. Several species are able to colonize this area (tamarisk, equisetum, bermuda grass, bulrush), but other species found in plots further from the water's edge (veronica, cudweed (*Gnaphalium* sp.), horseweed, aster, *Melilotus* sp.) apparently do not colonize such areas until they are no longer frequently inundated. The preliminary nature of these assessments should be noted; further investigation during the remainder of this study and long-term monitoring will be required to accurately analyze plant colonization factors.

Numbers of individual plants in quadrats did not show a significant change between 1992 and 1993. Significant changes occurred in transects at 254TR, 261TR, 264TR, and 269TR (Figure 9). These are primarily the result of high grass and seedling counts during 1993, which was apparently the result of higher than average rainfall during early 1993.

Proposed Schedule for 1994 Vegetation Studies

Presented in Table 3 is a schedule of 1994 research trips. Long-term vegetation monitoring sites will be recensused during two helicopter trips and a 9-day research trip in the fall of 1994.

Table 3. 1994 Research Trip Schedule

Trip Name	Put-In	Place	Take-Out	Place
Site Surveying	2/2	Diamond	2/9	Pearce
Avian Studies Recon	3/14	Diamond	3/18	Pearce
Avian Studies #1	4/5	Lee's	4/19	Pearce
Herbarium Collection	4/16	Pearce	4/19	Pearce
Avian Studies #2	5/2	Diamond	5/7	Pearce
Avian Studies #3	5/14	Lee's	5/28	Pearce
Avian Studies #4	6/6	Diamond	6/11	Pearce
Mammal/Reptile Studies #1	6/15	Diamond	6/24	Pearce
Mammal/Reptile Studies #2	9/6	Diamond	9/11	Pearce
Veg Studies Heli #1	9/19	RM 209		
Veg Studies Heli #2	9/20	RM 217		
Veg Studies River #1	9/21	Diamond	9/29	Pearce

AVIAN STUDIES

Introduction

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), bird 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 RM 240-275 (Carothers and Brown 1991) and are suspected to have caused several cycles of episodic change in its riparian birds. 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 nesting bird community as lake levels increased. At present, the nesting bird community of the river corridor between RM 240-275 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 nesting bird use of the river corridor on this portion of the Hualapai Reservation.

The purpose of the bird portion of this study is twofold: 1) to identify the status and estimate the abundance and species richness 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 avian study are:

1. Estimate the density (number of individuals/unit area) and species richness (number of species) of riparian nesting birds.

2. Produce brief, annotated accounts of those bird species known or suspected to nest in the study area.

3. Quantify aspects of the riparian vegetation at bird study sites.

4. To the extent possible, assess the influence of interim flows on riparian nesting birds.

Study Area

The study area was the riparian corridor of the Colorado River between National Canyon (RM 166) and Pearce Ferry (RM 280), Arizona. The downstream portion of this area was modified substantially by the 1935 completion of Hoover Dam and the subsequent filling of Lake Mead in 1941 (Carothers and Brown 1991). Pre-dam native plant communities in the river corridor between Separation Canyon (RM 240) and Pearce Ferry were inundated, but the river corridor upstream from Bridge Canyon remained unchanged until the completion of Glen Canyon Dam in 1963.

Three riparian vegetation associations presently exist in the study area: (1) the old high-water zone (OHWZ), (2) the new high-water zone (NHWZ), and (3) the fluctuating lake-level zone (FLLZ). The OHWZ is located at and above the pre-dam average high-water mark (ca. 100,000 cfs) and is dominated by honey mesquite (*Prosopis glandulosa*), catclaw acacia (*Acacia greggii*), and netleaf hackberry (*Celtis reticulata*). Little if any riparian vegetation existed in the scour zone adjacent to the river's edge below the average high-water mark prior to the construction of Glen Canyon Dam. Glen Canyon Dam eliminated the annual floods which scoured away all developing riparian vegetation below the pre-dam high-water-mark, allowing development of the NHWZ. The NHWZ, which exists side-by-side with the relict community of the OHWZ between National and Bridge canyons, is dominated by tamarisk, coyote willow, seep willow, and arrowweed.

The FLLZ is located on silt banks deposited by the Colorado River downriver of Separation Canyon in the zone of influence of upper Lake Mead. Completely inundated when Lake Mead is full, these silt banks become exposed as lake levels periodically recede and are quickly colonized by riparian vegetation. This FLLZ of riparian vegetation is also dominated by tamarisk, willow, seep willow, and arrowweed, the same four species prevalent in the NHWZ above Bridge Canyon. As the vegetation in these two zones is very similar, the term NHWZ as used in this report is synonymous with the term FLLZ, unless a specific distinction is made.

Methods

Surveys for nesting birds were conducted at eight sites (Table 4, Figures 17 through 23) in the study area between 20 April and 6 June 1993 using the absolute count method, in which an attempt is made to count all birds in a specified area (Kendeigh 1944, Emlen 1971). This was the method used in baseline studies of nesting riparian birds along the river corridor in the 1980s (Brown and Johnson 1987, Brown 1987a, Brown 1987b, Brown 1988, Brown 1989). The small size and linear nature of the study sites, their habitat homogeneity, and the limits of time and field work scheduling made the use of this simple method preferable to more sophisticated and time-consuming techniques such as the variable circular plot method, fixed or variable-strip census, and the spot-map method (Ralph and Scott 1981). Each study site was surveyed four to eight times during the study period; study sites upstream from Diamond Creek were surveyed four times on one research trip from 1-7 May, and study sites downstream from Diamond Creek were surveyed five to eight times on four research trips spanning the entire study period.

A single observer conducted bird surveys between 05:00 and 09:30 hours by walking slowly through the small, discrete study sites. The survey objective was to detect and record singing males for those species that were primarily monogamous and exhibited Type-A territories (see below for definition), and to detect and record all individuals for those species that were either polygamous, did not exhibit Type-A territories, or did not exhibit vocal or visual sexual

Table 4. Location of bird study sites along the Colorado River between National Canyon and Pierce Ferry. Sites 1 through 3 were located on the Colorado River upstream of the influence of Lake Mead; all other sites were in the zone of influence of Lake Mead. River miles are after Stevens (1983).

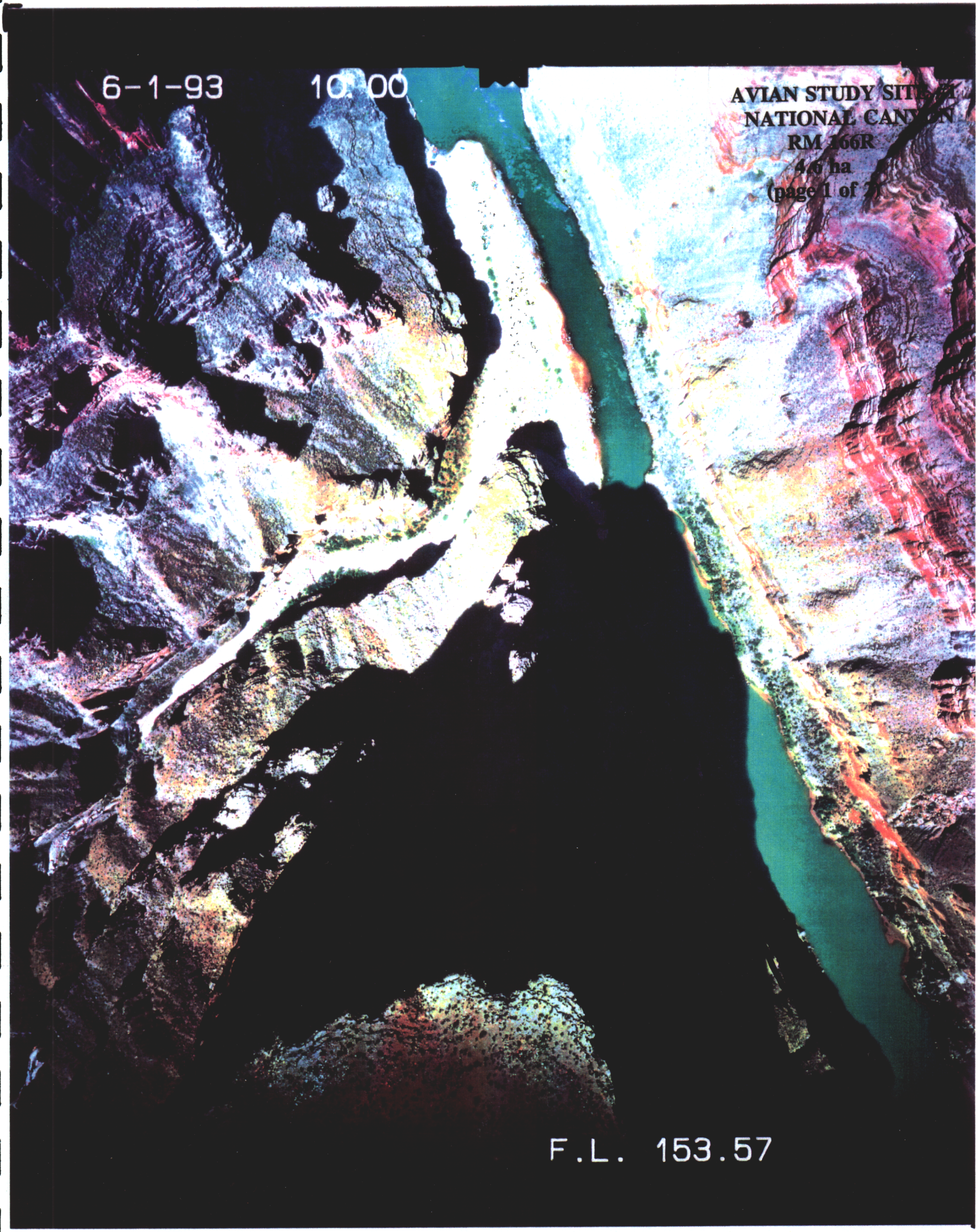
Site Number	Location	River Mile	Elevation (ft)
1.	National Canyon	166.1-167.0L	1750
2.	Parashant Canyon	198.0-198.1R	1525
3.	Granite Park	208.4-209.0L	1450
4.	Above Spencer Canyon	243.2-243.4L	1200
5.	Spencer Canyon	246.0L	1200
6.	Quartermaster Canyon	260.1-260.3L	1200
7.	Waterfall Rapids	260.1-260.3R	1200
8.	Tincanebits Canyon	263.8-265.1L	1200

dimorphism. The number of singing males in the former group was converted to number of individuals by multiplying by two (to account for the assumption of a 1:1 male:female sex ratio). This was then added to the number of individuals in the latter group and the survey results were reported as estimated numbers of individuals per unit area.

Species that were either primarily monogamous or maintained Type-A territories included: Ladder-backed Woodpecker, Bewick's Wren, Marsh Wren, Blue-gray Gnatcatcher, Phainopepla, Northern Mockingbird, Crissal Thrasher, Bell's Vireo, Lucy's Warbler, Yellow Warbler, Common Yellowthroat, Yellow-breasted Chat, Summer Tanager, Blue Grosbeak, Lazuli Bunting, Song Sparrow, and Hooded Oriole. A Type-A territory is an all-purpose area, used for nesting and feeding by the pair, that is vocally advertised, physically defended, and from which all other individuals of the same species are excluded. Therefore, monogamous Type-A species were most easily censused by recording detections of singing males (Mayfield 1981), with the assumption that each male represented a nesting pair and that all singing males were detected during the survey periods. For a discussion of avian territoriality, see Perrins and Birkhead (1983).

Species that did not maintain Type-A territories or were primarily polygamous included: Mourning Dove, Black-chinned Hummingbird, Great-tailed Grackle, Brown-headed Cowbird, House Finch, and Lesser Goldfinch. Ash-throated Flycatchers maintained Type-A territories but did not exhibit visual or vocal sexual dimorphism, so that detections could not be assigned to a male or female. For this reason, Ash-throated Flycatcher detections were recorded as individuals.

This conservative technique is likely to underestimate actual bird density, and other techniques may provide a more accurate density estimate, particularly of hummingbirds (Brown 1992). Nest searches were conducted before and after most surveys to provide supplemental information on bird densities and to identify species-specific nesting chronology.


6-1-93
10:00
AVIAN STUDY SITE
NATIONAL CAN
RM 166R
4.6 ha
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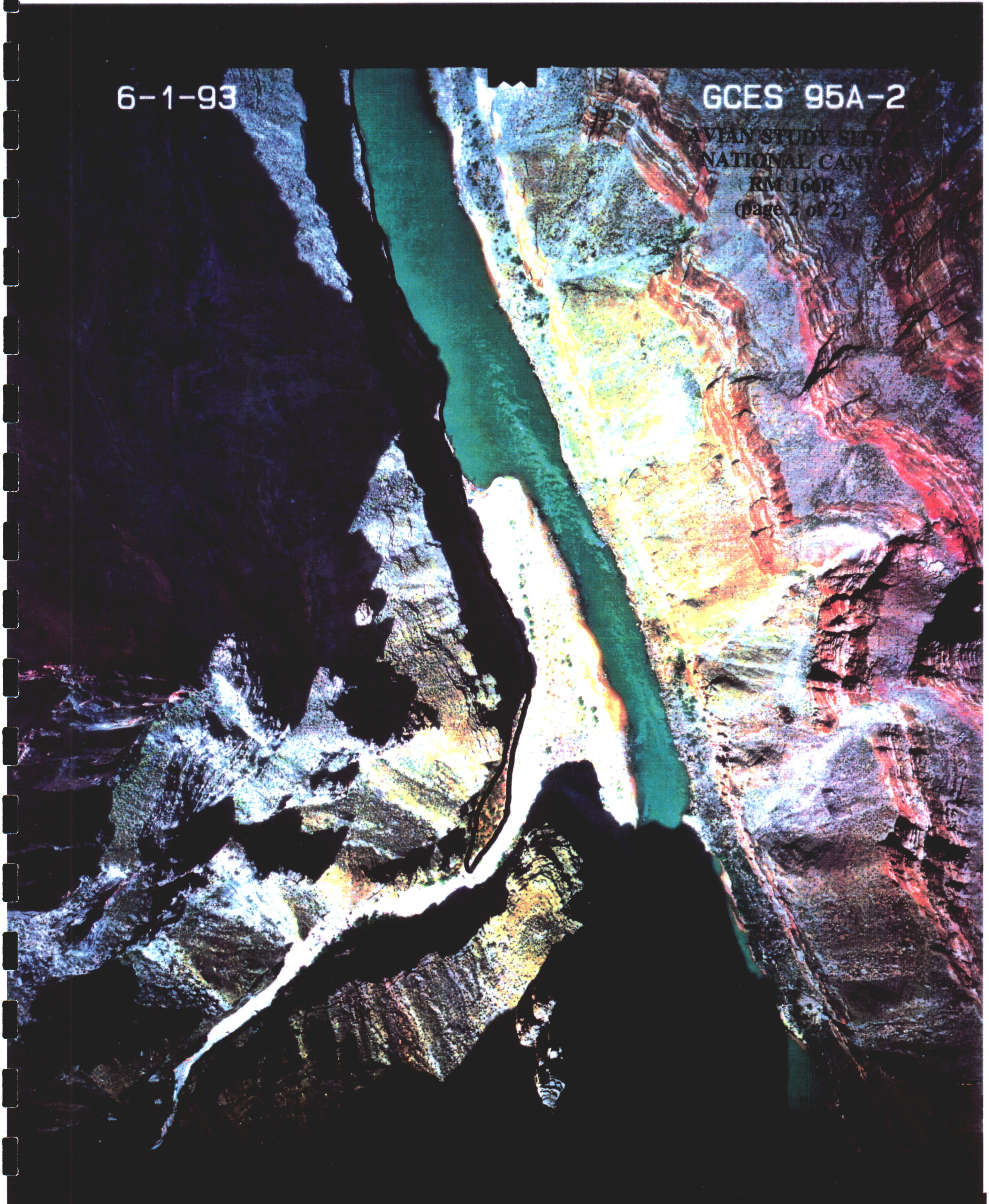
F.L. 153.57


6-1-93
GCES 95A-2
AVIAN STUDY SITE
NATIONAL CANYON
RM 166R
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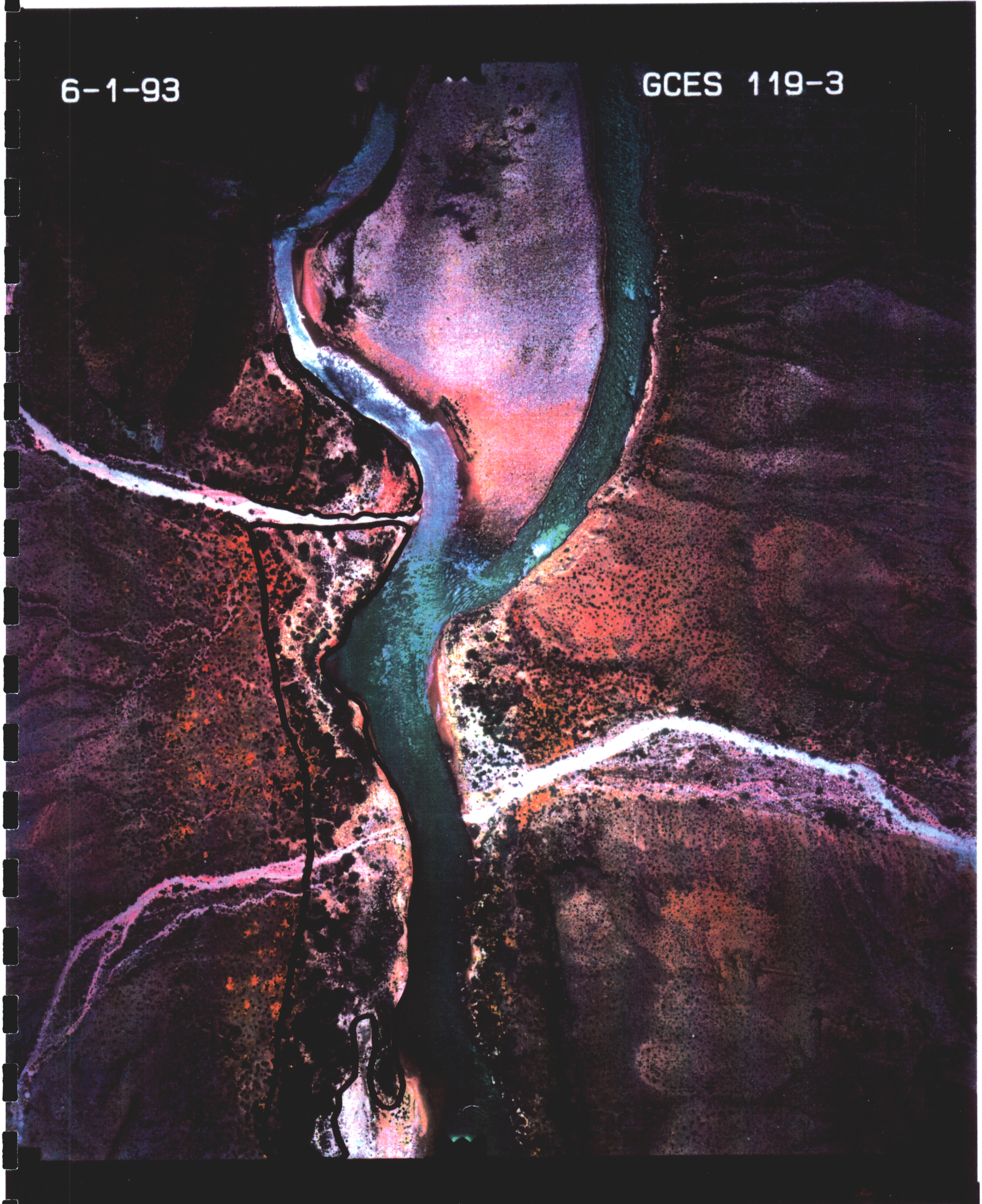
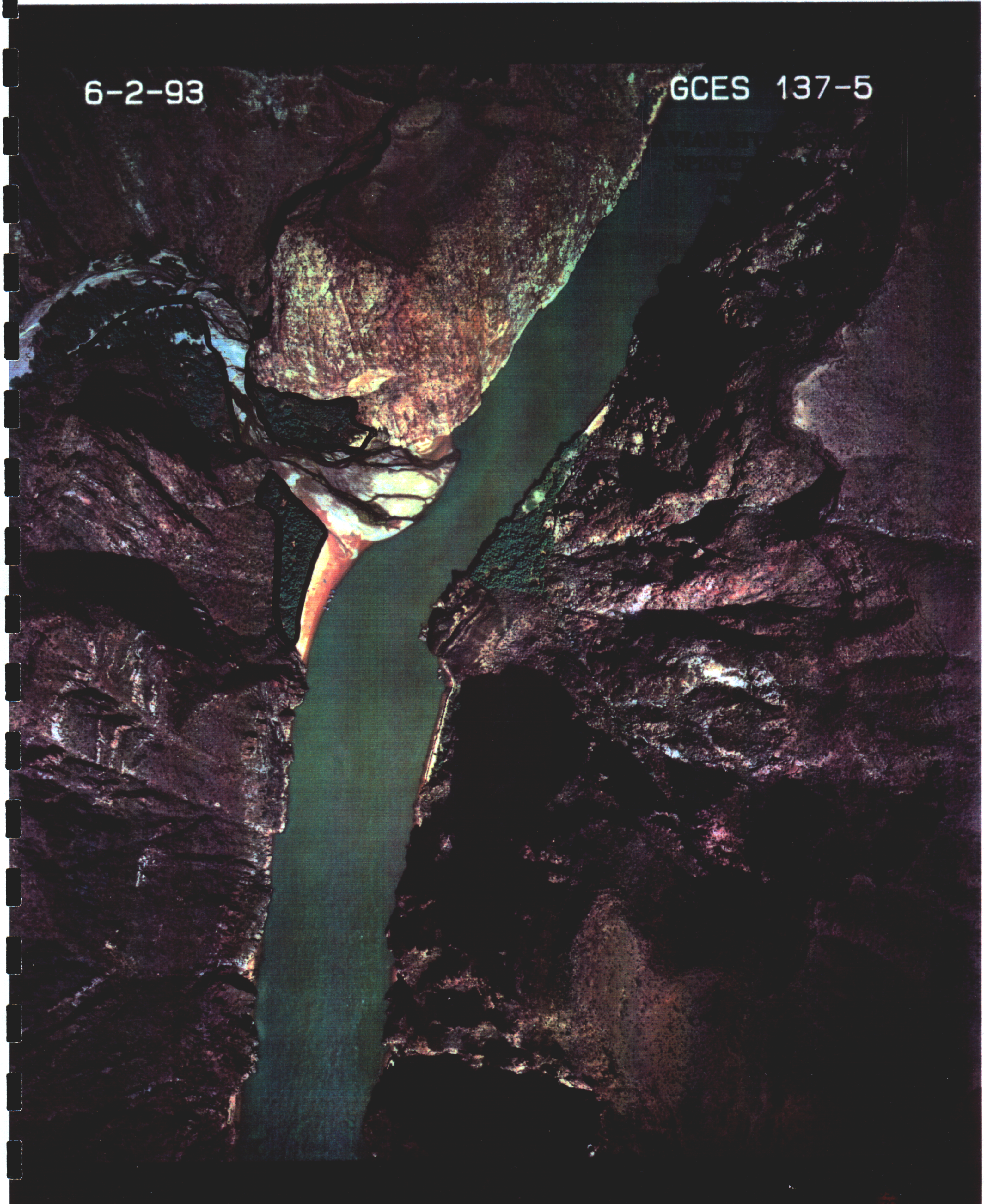
6-1-93
11: 19
H 2400 GCES 114-1
F.L. 153.57


6-1-93
GCES 119-3


6-2-93
GCES 136-4
AVIAN STUDY SITE
RM 243L
2.3 ha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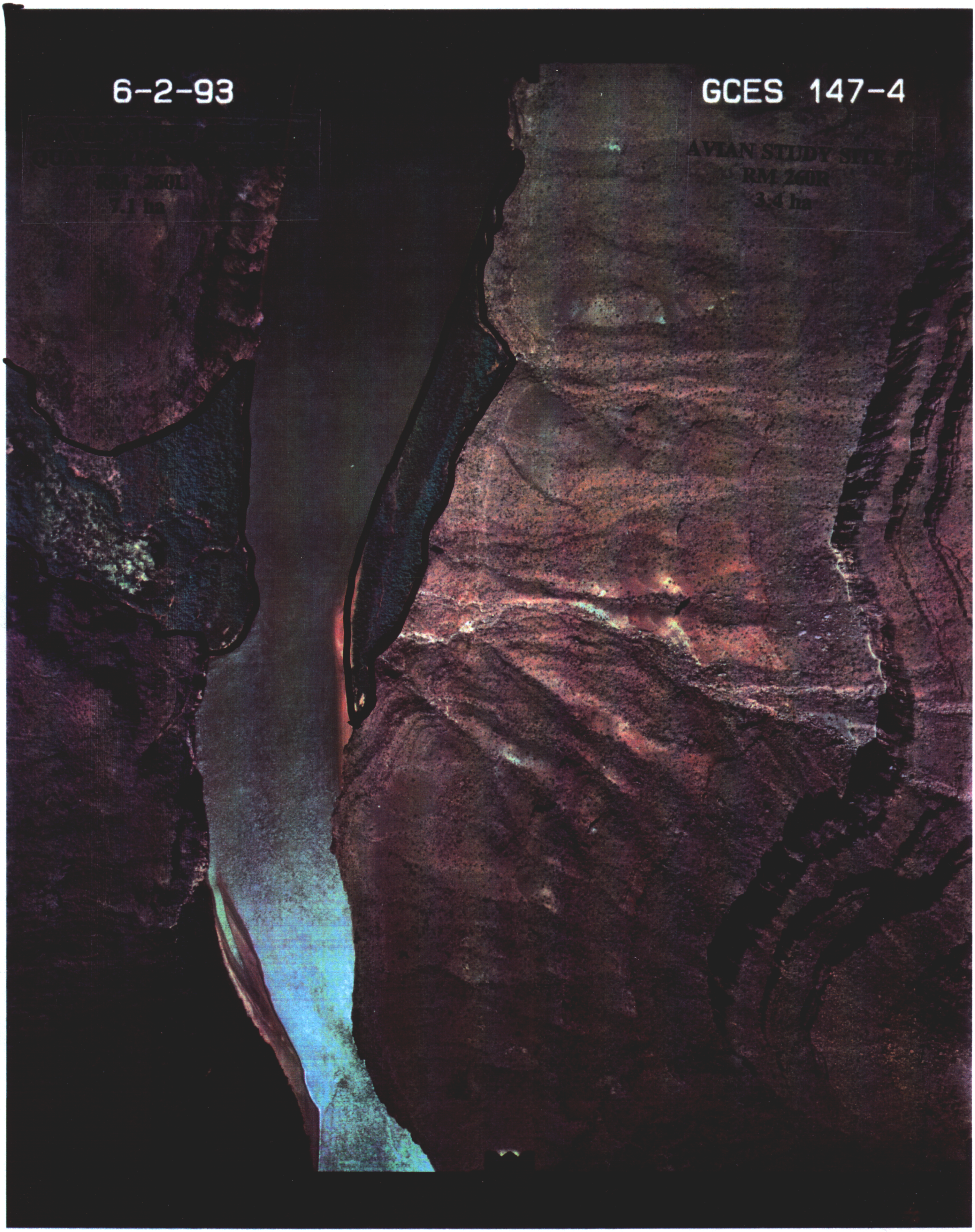
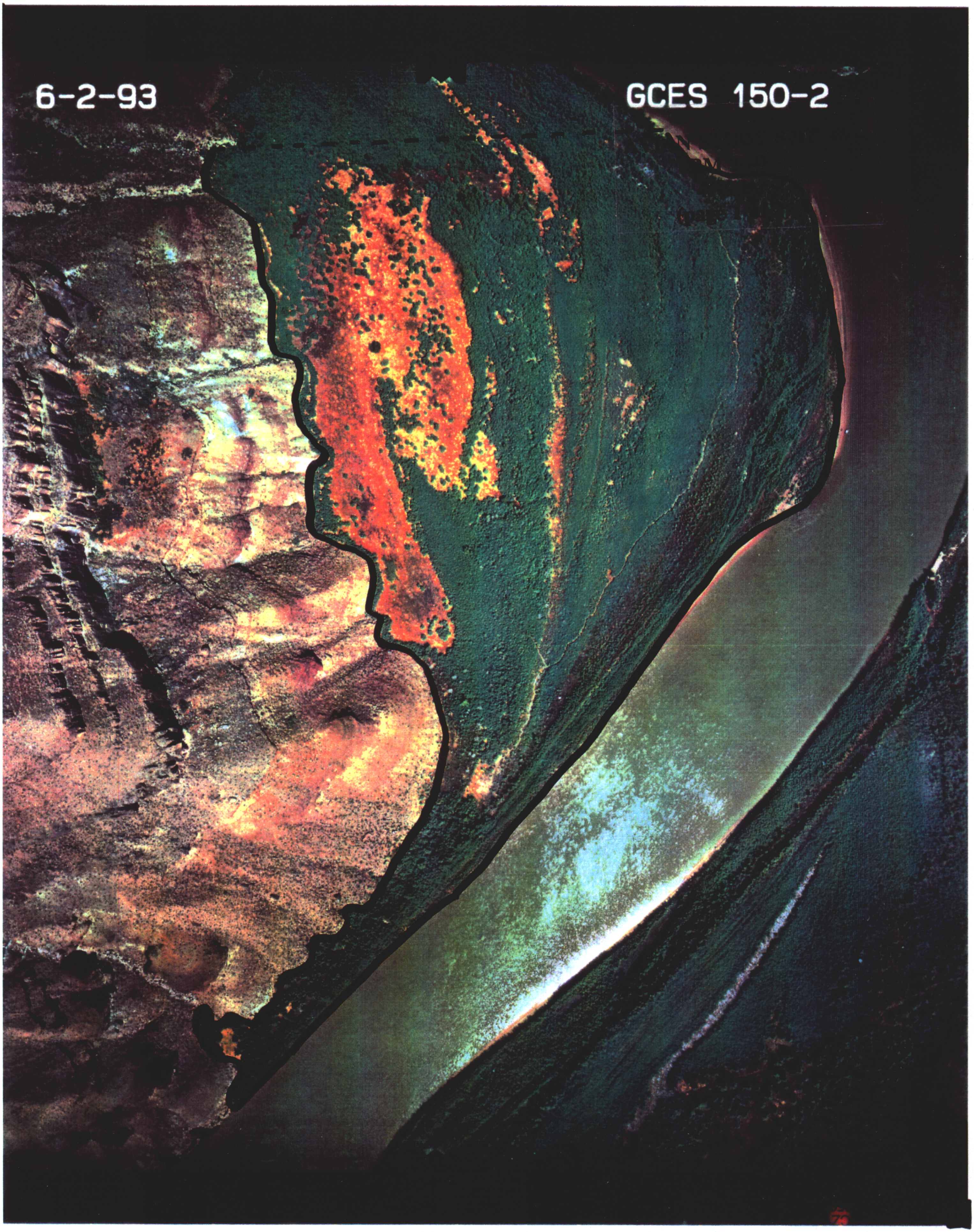
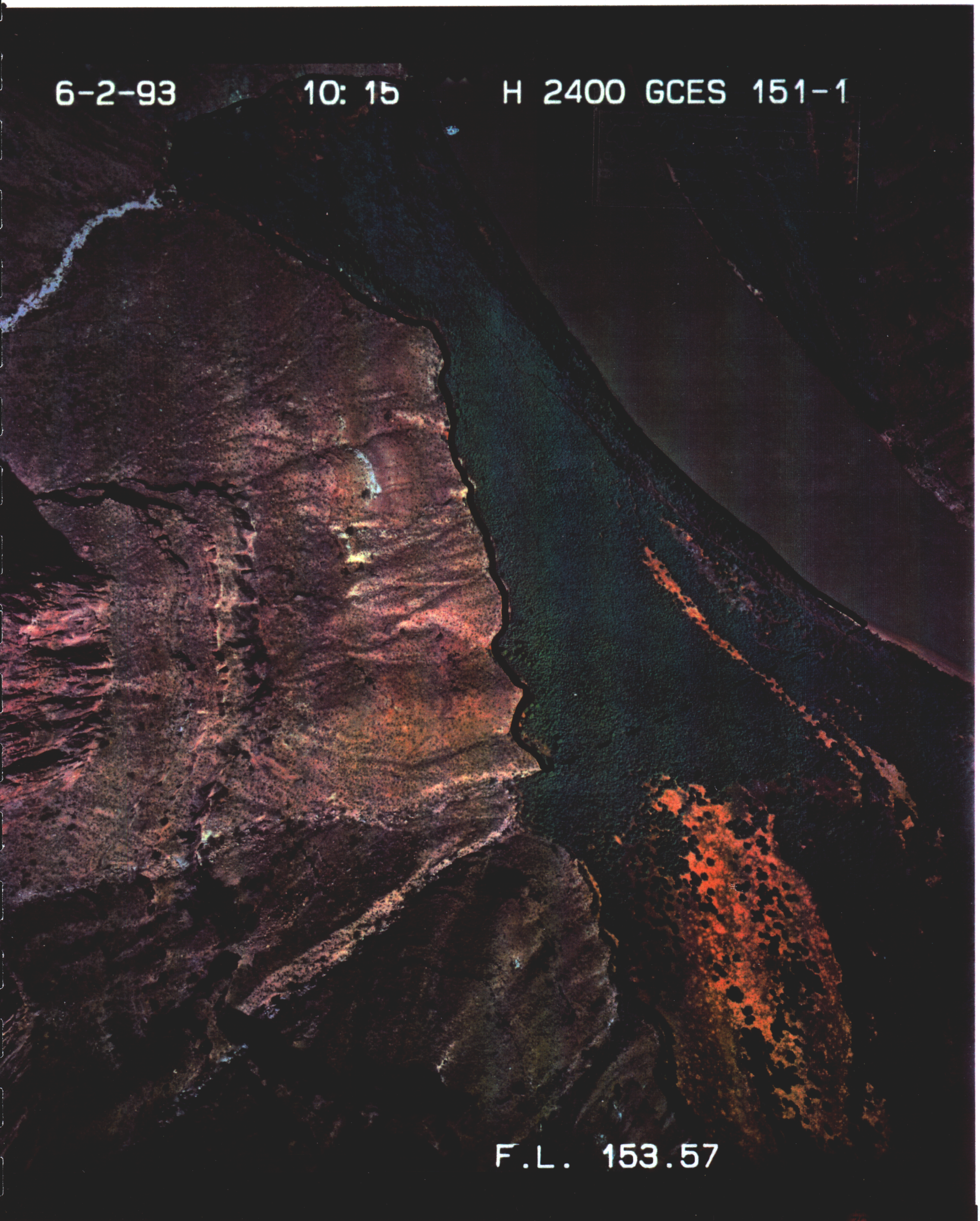
GCES 137-5


6-2-93
GCES 147-4
7.1 ha
RM 260R
3.4 ha


6-2-93
GCES 150-2


6-2-93
10: 15
H 2400 GCES 151-1
F.L. 153.57

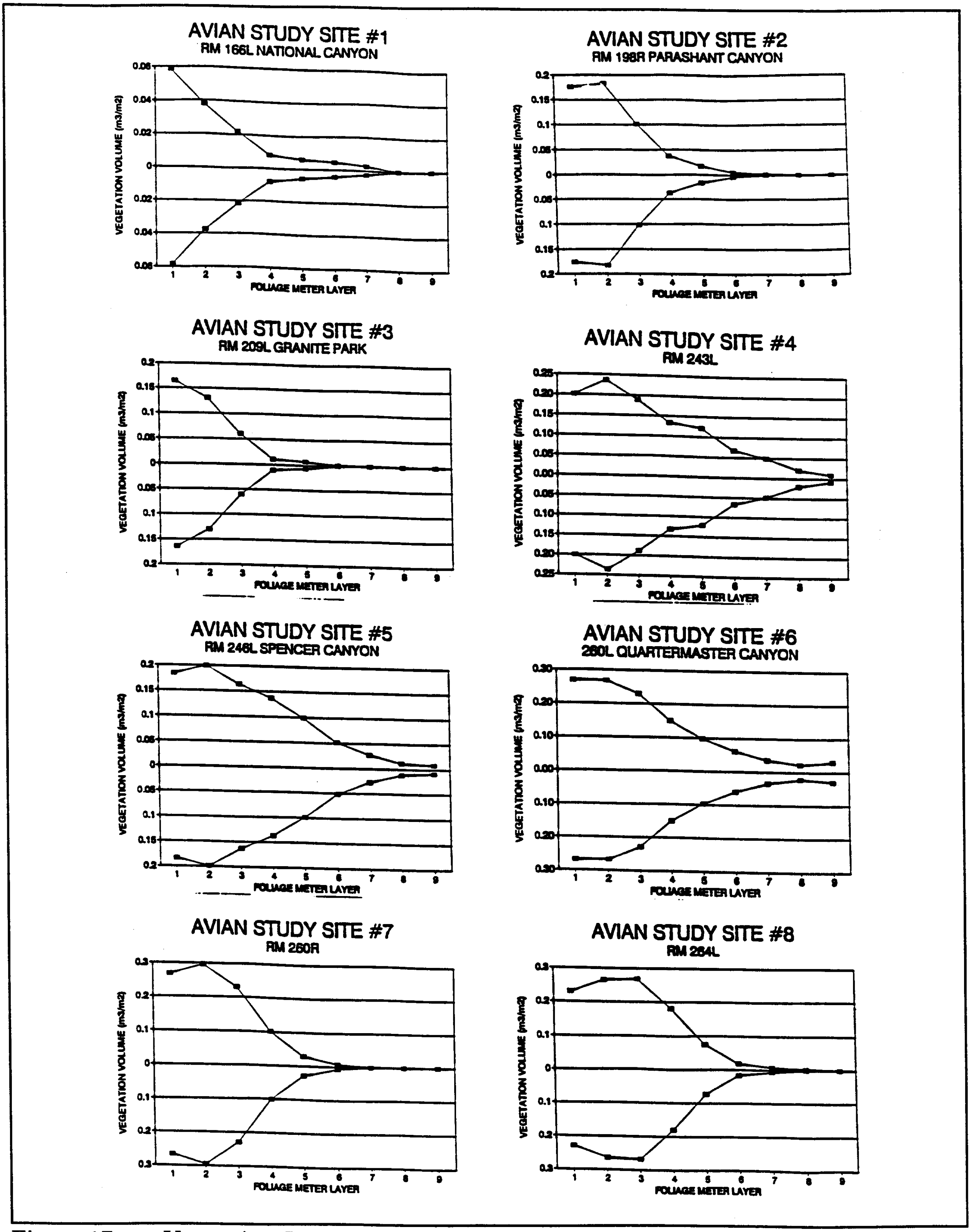


Figure 17. Vegetation Structure at Avian Study Sites

Data on vegetation structure, species composition, and total vegetation volume at each study site were gathered at each study site after the methods of Mills et al. (1991). Study site vegetational structure is displayed in Figure 17, which details the volume of vegetation by meter layer above the ground.

The size of each study site was measured with a compensating polar planimeter from 1:4800 scale aerial photographs taken on 31 May 1993.

Avian Studies Results

Survey results are presented in two ways. In the first, the maximum number of detections of each species at a study site during the season was combined and reported as an estimate of the number of nesting individuals at study sites. In the second, the mean ($\pm$ standard deviation) number of individuals detected per survey at each study site is reported for each species. Because the detectability of each species varied throughout the study period and because the maximum detectability of each species was likely just prior to or at its time of peak nesting, estimates based on maximum detections are considered to be more accurate. Densities based on mean detections likely underestimated actual densities. For species that did not arrive until mid-season, such as Yellow-breasted Chat and Brown-headed Cowbird, mean detections were calculated by using only those surveys after the species had first been detected.

Twenty-four bird species known or suspected to nest were found in riparian vegetation at the eight study sites. A brief description of each species' occurrence in the study area along with its habitat use, nesting behavior, and other information is presented in Appendix A.

Bird density estimates derived from maximum detections ranged from 217 to 1764 individuals/40 ha (Table 5, Figures 18 and 19). Density estimates derived from mean detections ranged from 154 $\pm$ 12 to 1098 $\pm$ 121 individuals/40 ha. A summary of raw data collected is presented in Appendix B.

Analyses of the influence of vegetative structure on avian density as well as the influence of interim flows on nesting birds are in progress and will be completed for the final report in 1994.

Proposed Schedule of 1994 Avian Studies Fieldwork

Fieldwork proposed for the 1994 season differs slightly from that conducted in 1993. Four trips were made from Diamond Creek to Pearce Ferry in 1993, but only one trip was made from Lees Ferry to Diamond Creek, resulting in less data for study sites upstream of Diamond Creek. In particular, species with a peak of activity in April (Costa's Hummingbird, Phainopepla, Lucy's Warbler, and Lesser Goldfinch) could not be readily surveyed during the May trip above Diamond Creek. Therefore, two trips from Lees Ferry are proposed for 1994 in order to more accurately estimate bird density and species richness from National Canyon to Diamond Creek (Table 3).

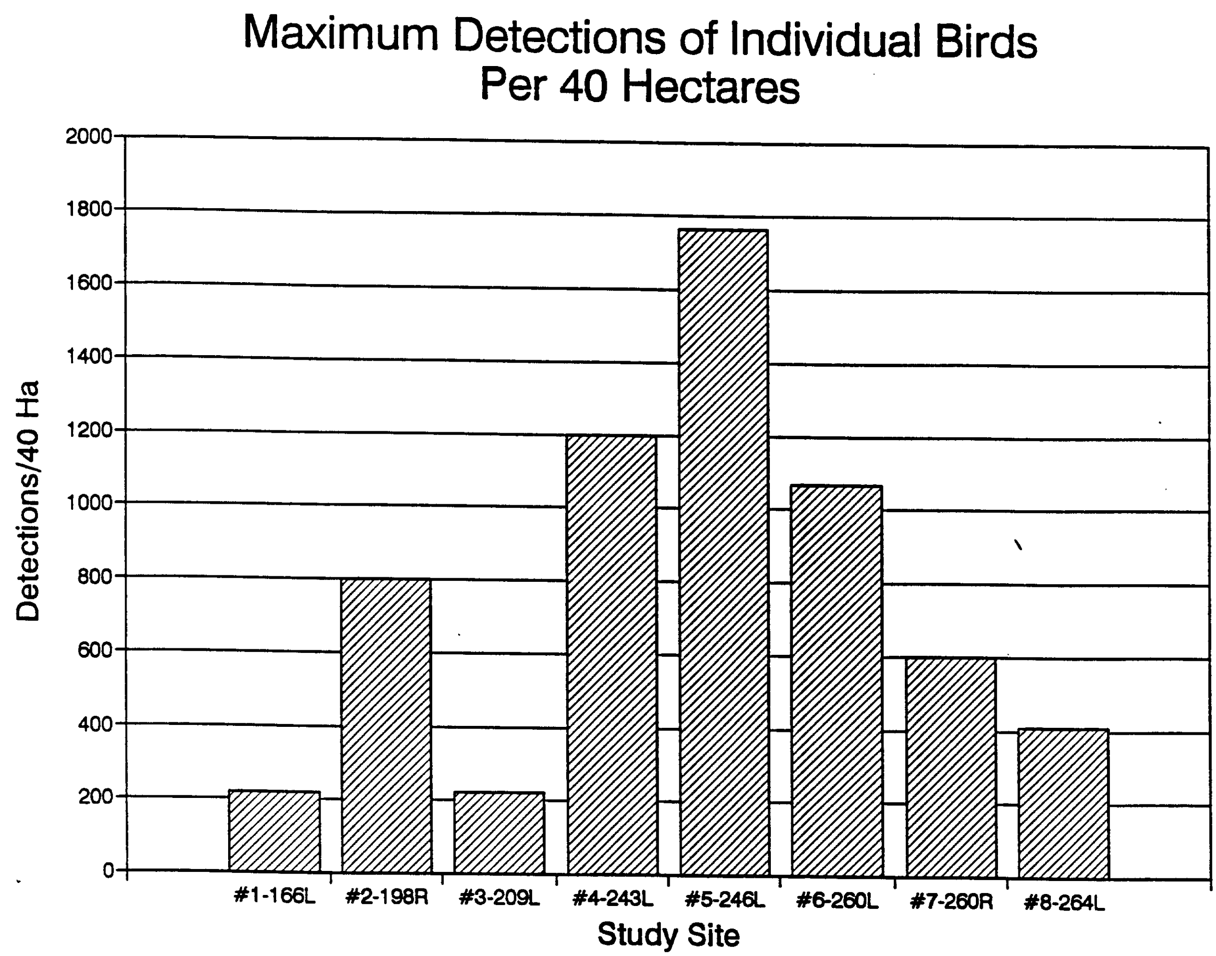


Figure 18. Maximum Detections of Individual Birds per 40 Hectares

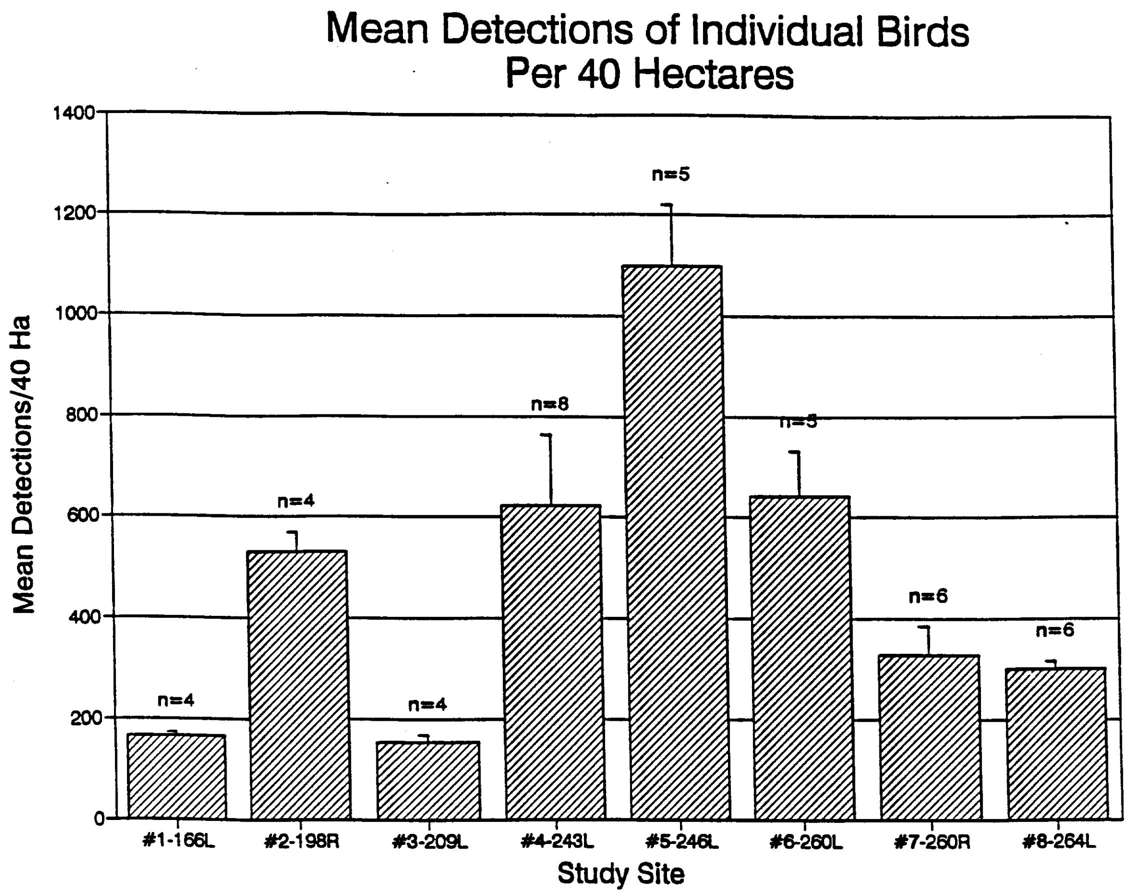


Figure 19. Mean Detections of Individual Birds per 40 Hectares

Table 5. Study site size, sample size of bird surveys/site (N), and estimated densities of nesting birds extrapolated by study site and method, Colorado River between National Canyon and Pierce Ferry, 1993. Study site numbers correspond to those used in Table 3. Raw data summaries are presented in Appendix B.

NUMBER OF INDIVIDUALS DETECTED PER UNIT AREA

			Maximum detections		**Mean detections**	
Study site	**Size (ha)**	**N**	**/5 ha**	**/40 ha**	**/5 ha**	**/40 ha**
1	4.6	4	27.2	217.6	20.7±0.9	165.6±7.2
2	3.0	4	100.0	800.0	66.3±4.8	530.4±38.4
3	11.6	4	27.6	220.8	19.3±1.6	154.4±12.8
4	2.3	8	150.0	1200.0	77.8±17.6	622.4±140.8
5	2.2	5	220.5	1764.0	137.3±15.2	1098.4±121.6
6	7.1	5	133.1	1064.8	80.1±11.2	640.8±89.6
7	3.4	6	75.0	600.0	40.9±7.2	327.2±57.6
8	47.1	6	51.2	409.6	37.5±2.0	300.0±16.0
T:	81.3	42				

MAMMAL STUDIES

Introduction

Small mammal communities are known to be dependent upon riparian vegetation for food sources, nesting material, cover sites, and breeding areas. A strong relationship potentially exists between small mammal population dynamics and vegetation volume, type, and area. Small mammal populations are apparently very sensitive to the effects of differing flow regimes, as these regimes can change the type and quantity of primary small mammal habitats. Several species are known to exist on only one side of the Colorado River, so any movement of these species across this previously impenetrable barrier would be very important for riparian small mammal communities throughout the Southwest.

Long-term monitoring of small mammals in the lower Grand Canyon focuses on three sites, where extensive trapping and limited collecting occur. The goals of this program are threefold: to characterize small mammal populations on Hualapai lands, to document any relationship between flow regimes and small mammal population or species diversity, and to identify any cross-river travel by endemic species. Monitoring at small mammal research sites was initiated in 1992. The 1993 outbreak of the hantavirus, a deadly disease carried by small mammals of several species, caused the postponement of 1993 research. In turn, an intensive research program is planned for 1994, using recommended precautions against virus infection.

Methodology

Transects were established in 1992 within each of four vegetative community types in order to allow characterization of mammal populations and an estimate of population densities by vegetation type. One or more transects were established at each of three study sites within the Hualapai Reservation. Live trapping stations were established along each transect, and the area outside each transect was spot-checked to identify sign of mammals which were not identified by trapping.

All small mammal trapping was done using folded aluminum Sherman live traps, 8 x 8.5 x 23 cm in size. Traplines were placed along the edges of riparian vegetation, both at water's edge and at the talus/riparian vegetation interface. Traps were placed under trees and in tall grass. Two traps were set at each station to facilitate capture, and wet oats were used as bait. Traps were set in late afternoon, checked in the morning, and kept closed during the day.

Trapped mammals were identified by species and vegetation type of capture location. After all pertinent information was collected, the mammals were released near the point of capture except where the mammal was 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.

Mammal Studies Results

Small mammals of five species common to the Southwest were trapped in 1992. The species caught most often in our traps belong to two genus of mice, *Perognathus* and *Peromyscus*. No clear relationship was shown during 1992 studies between vegetation type and population density or diversity. We anticipate that more intensive research in 1994 and future years will provide better knowledge of these factors.

Proposed Schedule for 1994 Mammal Studies Fieldwork

Two research trips are scheduled in 1994 to conduct small mammal trapping and collecting at three long-term monitoring sites (Table 3). These trips are planned for June and September, in order to provide an estimate of seasonal factors on mammal trapping. Extensive precautions will be required of all members of these trips in order to reduce the potential for infection by the hantavirus. This will include the use of gloves, masks, and special techniques for handling traps and small mammals.

REPTILE STUDIES

Introduction

The objective of long-term monitoring of reptile populations in the lower Grand Canyon is to characterize the reptilian community of the lower Grand Canyon and to identify any correlation between interim flow effects and reptilian abundance, population structure, and species diversity. Only informal reptile studies have been conducted in the Grand Canyon below Diamond Creek (Carothers et al. 1985). Previous studies in the upper Grand Canyon (Warren and Schwalbe 1986) focused upon shoreline, new high water, and old high water vegetation zones. In much of the lower Grand Canyon, these zones have been replaced by newly-vegetated depositional silt bars in the area influenced by Lake Mead. Our studies have utilized the methods of upper Grand Canyon researchers were possible, and adapted these techniques as necessary for the special conditions of the lower Grand Canyon.

Methodology

Three long-term study sites were chosen, with one study site in an area largely influenced by river fluctuations (Bridge Canyon, RM 235L), one study site affected by both river and lake fluctuations (Spencer Canyon, RM 246L), and one site subject to large fluctuations in lake levels (RM 264.5L). Dominant vegetation types at these sites differ as well, providing the elements necessary for an analysis of vegetation type effects on reptile populations.

We used visual belt transects, modified from the Emlen (1971) bird census technique, to census common diurnal lizard species and crepuscular amphibian species (Lowe and Johnson 1977). This method involved walking transects through dominant vegetation types and recording all individuals observed within a 1 to 4 meter wide belt, based upon the density of vegetation. Transect length varied with size of the habitat patch. We selected transect sites to sample variation within riparian habitats and in adjacent non-riparian desertscrub.

As each individual reptile was sighted, we recorded distance along the transect, dominant vegetation type, and substrate upon which it was first observed, as well as its sex and age, when possible. When individuals were in a tree, we recorded tree species and height above ground. Pedestrian surveys of each site were conducted in the morning and evening. Comparisons will be made between reptile frequency of capture in distinct vegetation types. In areas of appropriate habitat, drift fences with traps at each end will be used to capture snake species (Rosen and Schwalbe 1988).

Reptile Studies Results

Lizards of five species common to the Southwest, and amphibians of three common species were identified during 1993 surveys at three sites. Preliminary results show that rate of capture is similar between riparian and non-riparian areas, but this could be a factor of research trip timing and weather. More extensive studies are planned for 1994, during two separate seasons, to identify site and situational factors which may potentially affect results.

Proposed Schedule for 1994 Reptile Studies Fieldwork

June and September research trips are scheduled to recensus the three long-term reptile study sites (Table 3). The timing of the first trip coincides with lizard hatching and dispersal (Tomko 1976) and with other reptile activity, while the second trip will allow an analysis of cooler season effects on survey methods.

Other Phase II Objectives

Objective 7. Identify Changes in Vegetative Community Size and Composition

In the discussion section of this report are presented preliminary analyses of vegetation community changes in the one-year period since baseline data were collected. This analysis will be completed in 1994, when three years of data have been collected. Maps of vegetation communities at three sites have been produced; these maps will be updated in 1994.

Objective 8. Integrate Results with the GCES GIS, SID, and Long-Term Monitoring Program

Data from all studies are submitted to GCES for incorporation into the SID. The selection of long-term monitoring sites for these riparian studies is in coordination with the goals and needs associated with planning for the long-term monitoring program. Site locations will be included in the Hualapai and GCES GIS systems in early 1994 to facilitate long-term monitoring. Further information from studies completed or ongoing at specific sites will also be included on GIS layers.

Objective 9. Develop a Long-Term Riparian Monitoring Program and Field Guide

The long-term monitoring program is expected to closely follow the methodology used in 1992 and 1993, and to incorporate the long-term sites. A field guide describing all monitoring methodologies will be prepared as part of the Final Report.

DISCUSSION AND RECOMMENDATIONS

Vegetation Studies

The data collected in the last two years support initial observations: that interim flows have a primarily stabilizing effect on riparian vegetation above Lake Mead, and that fluctuating Lake Mead levels have strong impacts on riparian vegetation in the lower Grand Canyon. Quadrats above Separation Canyon (RM 240), while varying somewhat from one plot to the next and from riparian strip to general beach zones, were quite stable in terms of basal cover, species diversity, and erosion or other direct impacts. Plots, marshes and transects below Separation Canyon reflect the dynamism that results from Lake Mead levels changing 3 to 5 vertical feet during the time of study (first falling, then rising), and from even more drastic lake level changes shortly before the initiation of this study. Vegetation, normally tamarisk or willow, has invaded beaches that were bare in the summer of 1992. These plants have grown in height at some sites at a rate of over two meters per year. In the back portion of large silt bars, areas that were exposed as lake levels dropped in the late 1980s support five and six-year-old tamarisk and willow plants that continue to grow quickly.

The importance of the silt bars below Separation Canyon to vegetation communities and the animal communities that they support (see below) has become apparent during this study. In turn, the dynamism of this area is also apparently very important to the riparian plant and animal communities. Periodic flooding and exposure of silt bars as a result of Lake Mead fluctuations allows large, diverse areas of emergent vegetation to form. These newly-exposed silt bars provide wet marsh vegetation for migratory waterfowl, feeding and nesting areas for shorebirds, expansion areas for reptiles and the insects on which they feed, and camping areas for humans as well. In turn, rising lake levels decrease the areas available for animal nesting and feeding. SWCA, with the help of the Hualapai Wildlife Management Department GIS system and staff, is currently developing a model of lake level effects on vegetated area between RM 273 and RM 275. We anticipate that this type of modeling can be expanded to encompass the entire Hualapai reach of the Grand Canyon, and integrated with on-site monitoring to aid in understanding river and lake effects on Hualapai resources.

Continuation of the current monitoring effort will allow the current base of collected data to be used in a program providing vital information to the Hualapai Tribe, the National Park Service at Lake Mead National Recreation Area and in Grand Canyon National Park, and Glen Canyon Environmental Studies.

Avian Studies

The estimated density of nesting birds at most study sites was generally comparable to southwestern riparian habitats exhibiting similar vegetative composition and structure. The 388 pairs/40 ha (ca. 776 individuals/40 ha) estimated by Szaro and Jakle (1982) in tamarisk habitat along the Gila River drainage of southern Arizona was generally equivalent to estimated densities at most tamarisk-dominated sites in this study (Parashant Canyon, Above Spencer Canyon, Quartermaster Canyon, and Waterfall Rapids). In contrast, estimated density at Spencer Canyon, where tamarisk was co-dominant with mature, native willows and other native vegetation, was extremely high (1764 individuals/40 ha). This was comparable to the highest densities ever reported for non-colonial nesting birds, such as the 847 pairs/40 ha (ca. 1694 individuals/40 ha) estimated in riparian cottonwood forests along the Verde River of central Arizona (Carothers et al. 1974). The lowest estimates of bird density in the study area (National Canyon and Granite Park) were at sites exhibiting primarily low-density, open mesquite and acacia.

Bird density estimates from this study were compared to those reported in the 1980s (Brown and Johnson 1987, Brown 1987a, Brown 1988, Brown 1989) at the three study sites upriver of Diamond Creek (Table 6). Direct comparison of 1980s findings to those of the present study were not possible due to changes in site size, differences in vegetation structure, and different proportions of each site comprised of NHWZ and OHWZ habitat from the 1980s to the present, but generalized comparisons can be made (Table 3). Density estimates from the National Canyon site in 1993 were within the range of density estimates made during the 1980s in spite of changes in site size, but estimated density at Parashant Canyon and Granite Park were less than that reported in the 1980s. The reason for the apparent decrease in estimated density at the two latter sites is unknown. However, the apparent decrease at the Parashant Canyon site is likely related to the loss through erosion of well-developed NHWZ habitat at the water's edge since the 1980s and the 1993 inclusion of a large patch of poorly-developed NHWZ habitat that developed since the 1980s. The apparent decrease at the Granite Park site is likely related to the inclusion of a large patch of poorly-developed NHWZ habitat that developed since the 1980s.

Table 6. Comparison of study site size, species richness, and estimated bird density at three study sites upriver of Diamond Creek surveyed for nesting birds in the 1980s (Brown 1987a, Brown 1988, Brown 1989) and in this study.

Study site	Size of study site (ha)		Estimated bird density (individuals/40 ha)		Species richness (number of species)	
	1993	1984-1987	1993	1984-1987	1993	1984-1987
National Canyon	4.6	2.6	217	215-492	8	4-5
Parashant Canyon	3.0	1.9	800	1010-2084	14	12-19
Granite Park	11.6	6.6	220	272-752	14	11-16

Species richness at the Parashant Canyon and Granite Park sites in 1993 was within the range estimated for those sites in the 1980s, but richness at the National Canyon site in 1993 was much greater than that estimated during the 1980s (Table 7). The reason for this apparent increase in richness is unknown. Taking all three study sites upriver of Diamond Creek together, 22 species known or suspected to nest were found from 1984-1987; 18 were found in 1993. No new species were found in 1993 that were not found in the 1980s. The only species found in the 1980s but not in 1993 were Costa's Hummingbird, Crissal Thrasher, Lazuli Bunting, and Hooded Oriole. These species were rare to uncommon in the study area and were not always found at each study site each year in the 1980s; Crissal Thrasher was only found in one of four survey years. Therefore, their apparent absence in 1993 probably does not represent any real change in the populations, but most likely represents sample error or random fluctuations in local patterns of site-occupancy.

Marsh Wren and Song Sparrow were detected only downriver of Diamond Creek (Appendix II) in riparian vegetation developing on the silt banks of Upper Lake Mead. The Marsh Wren was only detected twice (Appendix I). The Song Sparrow has rapidly colonized new habitat created by dropping levels of Lake Mead and has increased in numbers to become one of the two most abundant riparian-nesting species in the area (the other being Bell's Vireo; see Appendix II). Riparian habitat upriver of Diamond Creek appeared suitable for nesting by both Marsh Wren and Song Sparrow, but neither was detected. The lower Granite Gorge from RM 217 to the head of Lake Mead (approximately Separation Canyon, RM 240), an area largely devoid of riparian vegetation, may present a barrier to upstream colonization by these two species.

Bird density at all three study sites upstream from Diamond Creek was probably underestimated in 1993 due to the timing of survey work. Each study site upstream from Diamond Creek was surveyed four times during a single field trip from 1-7 May, which was late in the season to survey some species and early in the season for others. Song frequency, detectability, and perhaps even the abundance of common species such as Lucy's Warbler, Lesser Goldfinch, and Costa's Hummingbird apparently had declined by early May. Likewise, the song frequency, detectability, and perhaps even the abundance of late arrival species such as Yellow-breasted Chat, Blue Grosbeak, and Brown-headed Cowbird were likely lower than they would have been later in the season. Therefore, two bird survey trips upriver of Diamond Creek are recommended for the 1994 nesting season. Regardless of the timing of 1994 survey work, bird densities will likely continue to be underestimated because of the difficulty of accurately determining the true density of certain species such as Black-chinned Hummingbirds (Brown 1992).

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APPENDIX A

ANNOTATED CHECKLIST OF KNOWN OR SUSPECTED NESTING BIRDS ALONG THE COLORADO RIVER FROM NATIONAL CANYON TO PEARCE FERRY, ARIZONA

This annotated checklist outlines those bird species known or strongly suspected to nest within the riparian corridor of the Colorado River. Only riparian or riverine-associated species that nest below the high-water mark of the river or Lake Mead have been included.

Species nesting on cliffs in close proximity to the river (swallows and swifts) have been included, whereas species nesting on cliffs well above the high-water mark have not been included: Red-tailed Hawk (*Buteo jamaicensis*), Peregrine Falcon (*Falco peregrinus*), American Kestrel (*Falco sparverius*), and Common Raven (*Corvus corax*). Likewise, desert-nesting species that may occasionally venture into the riparian zone but are not known to nest there have not been included: Greater Roadrunner (*Geococcyx californianus*), Great Horned Owl (*Bubo virginianus*), Lesser Nighthawk (*Chordeiles acutipennis*), Cactus Wren (*Campylorhynchus brunneicapillus*), Rock Wren (*Salpinctes obsoletus*), Canyon Wren (*Catherpes mexicanus*), Black-tailed Gnatcatcher (*Polioptila melanura*), and Black-throated Sparrow (*Amphispiza bilineata*).

DEFINITIONS OF TERMS

The following terms describe the species' relative abundance and status at their peak abundance in optimal habitat at the proper time of year.

Abundant: The species is present in numbers, such that more than 50 individuals are usually detected in one day.

Common: The species is easily found and almost always to be seen; between 5 and 50 individuals are usually detected in one day.

Fairly common: The species is found on a daily basis, but in small numbers; 1 to 4 individuals are usually detected per day.

Uncommon: The species is seldom or infrequently seen, and not on a daily basis; no more than several individuals are usually detected per week.

Rare: There is a very low probability of encountering the species, although it is not out of its normal range.

Permanent resident: Species is present in the study area throughout the year, although for some species different summer and winter populations may be involved. Assumed to nest at the proper season.

Summer resident: Species is present in the study area during the breeding season, and is assumed to nest.

SPECIES ACCOUNTS

Western Grebe (*Aechmophorus occidentalis*)
Apparently a common permanent resident on the impounded waters of Upper Lake Mead, where it is thought to nest. This species was taxonomically split in the 1980s to form both the Western Grebe and Clark's Grebe (*Aechmophorous clarkii*). Both species occur on Upper Lake Mead, although their status there is poorly understood. A large adult grebe (*Aechmophorous* sp.) seen with several young at RM 279 on August 27, 1978, was assumed to be a Western Grebe (Brown et al. 1987).

Great Blue Heron (*Ardea herodias*)
Common permanent resident throughout the study area, although most individuals seen in summer are not known to be nesting. The only known rookery is at Burnt Canyon, where 1 or 2 nests have been active each year from 1990 to 1993. Great Blue Herons were not known to nest in the study area prior to the existence of Lake Mead (Brown et al. 1987).

Black-crowned Night-Heron (*Nycticorax nycticorax*)
Uncommon summer resident, primarily downstream of Separation Canyon where it nests in small rookeries. Black-crowned Night-Herons were not known to nest in the study area prior to the existence of Lake Mead (Brown et al. 1987).

American Coot (*Fulica americana*)
Fairly common permanent resident on the impounded waters of Upper Lake Mead; individuals seen upstream of Separation Canyon in summer are probably not nesting. Nesting on Upper Lake Mead was confirmed by the sighting of an adult with a single young at RM 278 on June 6, 1993.

Spotted Sandpiper (*Actitis macularia*)
Fairly common summer resident throughout the study area. Nesting is assumed to occur on open sandbars and beaches (Brown et al. 1987), although a nest has yet to be discovered along the river between National Canyon and Pearce Ferry.

Mourning Dove (*Zenaida macroura*)
Common summer resident throughout the study area. Mourning Doves build flimsy stick nests in tamarisk in the NHWZ and mesquite in the OHWZ.

Western Screech-Owl (*Otus kennicottii*)
Uncommon permanent resident assumed to be nesting, although a nest has yet to be discovered in the study area. A Western Screech-Owl vocalized repeatedly from the same locale in a large patch of tamarisk scrubland at RM 265R on May 23 and June 5, 1993.

White-throated Swift (*Aeronautes saxatalis*)
Common to abundant summer resident throughout the study area, nesting in cracks and crevices in cliff faces (Brown et al. 1987).

Black-chinned Hummingbird (*Archilochus alexandri*)
Common summer resident throughout the study area, nesting almost exclusively in tamarisk in the NHWZ. Along the river upstream of Diamond Creek, patches of tamarisk less than 0.5 ha in area apparently are not suitable for nesting (Brown 1992).

Costa's Hummingbird (*Calypte costae*)
Common to uncommon summer resident throughout the study area, nesting in both the OHWZ and adjacent desert (Brown et al. 1987, Brown 1992). This species' abundance in the study area appears to vary from year to year, since males were commonly observed in the mid-to-late 1980s but no males were detected during the 1993 study period.

Ladder-backed Woodpecker (*Picoides scalaris*)
Rare permanent resident throughout the study area, nesting in riparian areas with trees large enough to accommodate their cavity nests (Brown et al. 1987). This species was detected at Separation Canyon in June 1992; also in May and June 1993 at RM 264L, where it may have been attracted to large numbers of dead and dying willow trees.

Black Phoebe (*Sayornis nigricans*)
Common permanent resident throughout the study area, building mud nests on cliffs and ledges directly over water.

Say's Phoebe (*Sayornis saya*)
Fairly common permanent resident throughout the study area, building nests on cliffs and ledges.

Ash-throated Flycatcher (*Myiarchus cinerascens*)
Common to fairly common summer resident throughout the study area, nesting in riparian areas with trees large enough to accommodate their cavity nests (Brown et al. 1987). Since trees of adequate size are relatively uncommon at locales where this species is common, nesting may also occur in cracks or crevices in cliff faces. This species is easily confused with the Brown-crested Flycatcher (*M. tyrannulus*) which occurs irregularly but is not known to nest in the study area (Brown et al. 1987).

Violet-green Swallow (*Tachycineta thalassina*)
Fairly common summer resident upstream of Diamond Creek, this species is a rare to uncommon summer resident downstream of Diamond Creek where nesting is assumed to occur in cracks and crevices in cliff faces, although no nest has been found along the river below National Canyon (Brown et al. 1987).

Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)
Common to abundant summer resident downstream of Diamond Creek, where mud nests are constructed on cliff faces and under rock ledges in small colonies. Burrow nests are occasionally constructed in vertical dirt banks at the river's edge, such as at RM 260R in early June 1993.

Bewick's Wren (*Thryomanes bewickii*)
Common permanent resident of both the NHWZ and OHWZ, apparently reaching its highest density in decadent, old-growth tamarisk. This is a cavity-nesting species, but when true cavities are unavailable it will nest in hollow logs or limbs, in crevices in tree trunks, or even on the ground under brush or driftwood piles.

Marsh Wren (*Cistothorus palustris*)
Rare permanent resident of the NHWZ whose distribution and status are poorly understood. Nesting is known to have occurred at Lees Ferry (Brown et al. 1987) and on portions of adjacent Lake Mead National Recreation Area (Blake 1978), but nesting in the study area between National Canyon and Pearce Ferry is unconfirmed. Singing males were detected at Columbine Falls in late June 1992 and at RM 264L in May 1993, but no nests were located. Large patches of apparently suitable habitat (i.e. dense stands of cattails) exist for this species downriver of Spencer Canyon, yet Marsh Wren detections in these areas are rare.

Blue-gray Gnatcatcher (*Polioptila caerulea*)
Common summer resident of both the NHWZ and OHWZ throughout the study area. Their cup-shaped nests are found in tamarisk, mesquite, and acacia.

Northern Mockingbird (*Mimus polyglottos*)
Uncommon summer resident, reported only from the OHWZ at Granite Park (RM 208L).

Crissal Thrasher (*Toxostoma dorsale*)
The status and distribution of this secretive species are poorly understood. It appears to be a rare, possibly permanent resident throughout the study area although nesting has not been confirmed. Crissal Thrashers have only been detected twice in the study area during the nesting season: a singing male heard and seen at Parashant Canyon (RM 198.0R) on June 15, 1985 (Brown and Johnson 1987), and a single individual seen and heard calling at RM 264L on June 6, 1993.

Phainopepla (*Phainopepla nitens*)
Uncommon permanent resident throughout the study area, nesting in March and April. Most nests are located in the OHWZ in mesquite, acacia, and occasionally in clumps of mistletoe, but sometimes nests are located in tamarisk in the NHWZ. Phainopeplas are only detected with regularity at three localities: Spring Canyon (RM 204R), Granite Park (RM 208L), and 220-Mile Canyon.

Bell's Vireo (*Vireo bellii*)
Common to abundant summer resident of both the OHWZ and NHWZ throughout the study area. Their hanging, cup-shaped nests are found in tamarisk, mesquite, and occasionally other woody plants. Two simultaneously active Bell's Vireo territories were documented through contemporary contacts of singing males and discovery of concurrently active nests (each with eggs) in a discrete, isolated, 0.4 ha patch at the mouth of Spencer Canyon in May 1993. Therefore, average territory size in this patch was 0.2 ha (2,000 m^2).

Lucy's Warbler (*Vermivora luciae*)
Common to abundant summer resident of both the OHWZ and NHWZ. Although normally a cavity-nesting species, their nests are also located in pseudo-cavities such as clumps of tamarisk debris, against a tree trunk under a broken limb, or even in rock crevices and ledges immediately adjacent to the riparian zone.

Yellow Warbler (*Dendroica petechia*)
Common summer resident of the NHWZ throughout the study area, although singing males are occasionally detected in well-developed stands of mesquite in the OHWZ. In the extremely large patches of tamarisk downriver of Tincanebits Canyon where Yellow Warblers have a choice of nesting either adjacent to the water or some distance from it, the great majority of territories were found at the water's edge. Their nests are found in tamarisk, willow, or rarely mesquite, usually high in the canopy.

Common Yellowthroat (*Geothlypis trichas*)
Common summer resident of the NHWZ throughout the study area. The highest Yellowthroat densities apparently occur in cattail marsh habitat, although high densities also occur in pure stands of young tamarisk that may be some distance from water. Yellowthroat nests are small, woven cups usually located less than 1 m above the ground or water.

Yellow-breasted Chat (*Icteria virens*)
Common summer resident of the NHWZ throughout the study area, although singing males are occasionally detected in well-developed stands of mesquite in the OHWZ. Their nests are conspicuous clumps of grass or the herb *Gnaphalium*, usually 2-3 m above ground. Two simultaneously active chat territories were documented through contemporary contacts of singing males and discovery of concurrently active nests (each with eggs) in a discrete, isolated, 0.4 ha patch at the mouth of Spencer Canyon in May 1993. Therefore, average territory size in that patch was 0.2 ha (2,000 m^2).

Summer Tanager (*Piranga rubra*)
Rare to uncommon summer resident of well-developed patches of tamarisk or willow in the NHWZ throughout the study area. Singing males may be secretive and difficult to observe, but their songs can be detected at long distances. Tanager nests are usually located high in the canopy.

Blue Grosbeak (*Guiraca caerulea*)
Uncommon to fairly common summer resident in both the OHWZ and NHWZ throughout the study area. Grosbeak nests resemble chat nests, being relatively large cup nests constructed primarily of grass.

Lazuli Bunting (*Passerina amoena*)
Fairly common to common summer resident in the river corridor, where most individuals are detected in the NHWZ. Nesting certainly occurs on a regular basis, although no active nest has been confirmed.

Indigo Bunting (*Passerina cyanea*)
Rare summer resident of both the OHWZ and NHWZ, although none were detected during the 1993 field season. A singing male assumed to be on territory was detected in late June 1992 at Separation Canyon. An active nest of this species in the study area has yet to be discovered.

Song Sparrow (*Melospiza melodia*)
Common to abundant permanent resident downriver of Separation Canyon, found entirely in fluctuating lake-level zone habitats on silt deposits at the head of Lake Mead. Numerous sightings exist of adult Song Sparrows feeding recently-fledged young, but no active nests of this species have been documented in the study area. Song Sparrows have greatly increased in abundance since falling levels of Lake Mead have allowed the creation of large areas of suitable habitat for them, so that it is now one of the two most abundant nesting species in the Upper Lake Mead area.

Red-winged Blackbird (*Agelaius phoeniceus*)
Common permanent resident downriver of Spencer Canyon, where nesting is assumed to occur primarily in cattail marshes along the lake margin or perennial tributaries. An active nest has yet to be documented between National Canyon and Pearce Ferry.

Great-tailed Grackle (*Quiscalus mexicanus*)
Common summer resident of the NHWZ throughout the study area, but an active nest has not been documented between National Canyon and Pearce Ferry.

Brown-headed Cowbird (*Molothrus ater*)
Common summer resident of all habitats throughout the study area. Cowbirds do not build their own nests, but lay eggs in the nests of host species which often successfully raise the cowbird young; brood parasitism by cowbirds is common between National Canyon and Pearce Ferry (Brown In Press).

Hooded Oriole (*Icterus cucullatus*)
Fairly common summer resident primarily in well-developed areas of tamarisk and willow in the NHWZ, but occasionally in areas of large mesquite or hackberry in the OHWZ. Oriole nests are graceful hanging baskets located high in the canopy.

House Finch (*Carpodacus mexicanus*)
Common to abundant summer resident of all habitats throughout the study area. Nests of this species must be numerous but are difficult to find in the riparian zone where the few nests discovered were high in tamarisk foliage; many finches nest in the adjacent desert, where most nests have been found in cholla cactus, and forage out into the riparian zones.

Lesser Goldfinch (*Carduelis psaltria*)
Fairly common to common permanent resident of all habitats throughout the study area. Most nests discovered have been relatively exposed cups of grasses located near the crown of a young tamarisk.

APPENDIX B

RAW DATA SUMMARY: MAXIMUM NUMBERS OF NESTING INDIVIDUALS DETECTED USING ABSOLUTE COUNT METHOD BY STUDY SITE ALONG THE COLORADO RIVER BETWEEN NATIONAL CANYON AND PEARCE FERRY, ARIZONA, 1993.

	Maximum number of individuals detected							
	Study site number							
Species	1	2	3	4	5	6	7	8
Ladder-backed Woodpecker	-	-	-	-	-	-	-	1
Mourning Dove	2	1	2	3	1	2	-	7
Black-chinned Hummingbird	2	5	5	4	2	4	1	4
Ash-throated Flycatcher	2	2	2	2	-	3	-	7
Bewick's Wren	2	4	2	6	8	16	6	46
Marsh Wren	-	-	-	-	-	-	-	2
Blue-gray Gnatcatcher	2	6	8	6	6	10	4	34
Phainopepla	-	-	4	-	-	-	-	-
Northern Mockingbird	-	-	2	-	-	-	-	-
Crissal Thrasher	-	-	-	-	-	-	-	2
Bell's Vireo	-	14	20	10	12	34	12	104
Lucy's Warbler	12	4	8	8	6	12	4	14
Yellow Warbler	2	4	2	4	16	26	4	32
Common Yellowthroat	-	2	-	2	10	22	4	46
Yellow-breasted Chat	-	4	-	6	10	14	6	42
Summer Tanager	-	2	-	-	2	4	-	2
Blue Grosbeak	-	-	2	2	-	2	2	18
Lazuli Bunting	-	-	-	2	-	-	-	2
Song Sparrow	-	-	-	6	12	16	6	76
Great-tailed Grackle	1	5	-	1	4	6	-	1
Brown-headed Cowbird	-	-	1	2	-	3	-	14
Hooded Oriole	-	-	-	-	2	4	-	-
House Finch	-	2	2	3	1	3	-	21
Lesser Goldfinch	-	5	4	2	5	8	2	7
Total individuals/site	25	60	64	69	97	189	51	482
Size of each study site (ha) for comparison	4.6	3.0	11.6	2.3	2.2	7.1	3.4	47.1

NOTE: Study sites are designated as follows: 1 = National Canyon, 2 = Parashant Canyon, 3 = Granite Park, 4 = RM 243L, 5 = Spencer Canyon, 6 = Quartermaster Canyon, 7 = Waterfall Rapids, and 8 = Tincanebits Canyon. Dashes indicate the species was not detected during the 1993 field season.

APPENDIX B

RAW DATA SUMMARY: MEAN NUMBERS OF NESTING INDIVIDUALS DETECTED USING ABSOLUTE COUNT METHOD BY STUDY SITE ALONG THE COLORADO RIVER BETWEEN NATIONAL CANYON AND PEARCE FERRY, ARIZONA, 1993.

	Mean number individuals ± SD			
	Study site number			
Species	1	2	3	4
Ladder-backed Woodpecker	-	-	-	-
Mourning Dove	1.3±0.9	0.3±0.4	0.8±0.8	1.6±1.1
Black-chinned Hummingbird	1.7±0.5	3.0±1.2	3.8±0.8	1.1±1.4
Ash-throated Flycatcher	1.3±0.9	1.8±0.4	1.3±0.9	1.5±0.5
Bewick's Wren	1.3±0.9	2.5±0.9	0.5±0.9	3.3±2.2
Marsh Wren	-	-	-	-
Blue-gray Gnatcatcher	2.0±0.0	4.5±0.9	6.0±1.4	3.5±1.7
Phainopepla	-	-	3.5±0.9	-
Northern Mockingbird	-	-	1.0±1.0	-
Crissal Thrasher	-	-	-	-
Bell's Vireo	-	13.0±1.7	18.0±1.4	6.8±1.7
Lucy's Warbler	10.0±1.6	3.5±0.9	5.5±1.7	6.0±1.7
Yellow Warbler	1.3±0.9	2.5±0.9	1.0±1.0	2.0±1.7
Common Yellowthroat	-	0.5±0.9	-	0.5±0.9
Yellow-breasted Chat	-	3.5±0.9	-	5.0±1.0
Summer Tanager	-	2.0±0.0	-	-
Blue Grosbeak	-	-	1.0±1.0	2.0±0.0
Lazuli Bunting	-	-	-	0.5±0.9
Song Sparrow	-	-	-	2.5±2.4
Great-tailed Grackle	0.3±0.4	1.3±2.2	-	0.1±0.3
Brown-headed Cowbird	-	-	0.3±0.4	0.3±0.7
Hooded Oriole	-	-	-	-
House Finch	-	1.5±0.5	1.0±1.0	1.3±1.0
Lesser Goldfinch	-	2.5±2.1	1.3±1.7	0.6±0.7
Study site mean ± SD	19.0±0.8	39.8±2.9	44.8±3.8	35.8±8.1
Size of each study site (ha) for comparison	4.6	3.0	11.6	2.3

NOTE: Study sites are designated as follows: 1 = National Canyon, 2 = Parashant Canyon, 3 = Granite Park, 4 = RM 243L, 5 = Spencer Canyon, 6 = Quartermaster Canyon, 7 = Waterfall Rapids, and 8 = Tincanebits Canyon. Dashes indicate the species was not detected during the 1993 field season.

APPENDIX B

RAW DATA SUMMARY: MEAN NUMBERS OF NESTING INDIVIDUALS DETECTED USING ABSOLUTE COUNT METHOD BY STUDY SITE ALONG THE COLORADO RIVER BETWEEN NATIONAL CANYON AND PEARCE FERRY, ARIZONA, 1993 (continued).

	Mean number individuals ± SD			
	Study site number			
Species	5	6	7	8
Ladder-backed Woodpecker	-	-	-	0.4±0.5
Mourning Dove	0.2±0.4	0.6±0.8	-	2.4±2.7
Black-chinned Hummingbird	0.6±0.8	1.8±1.2	0.3±0.5	2.6±1.2
Ash-throated Flycatcher	-	1.4±0.8	-	4.6±1.4
Bewick's Wren	4.8±2.7	11.6±3.4	2.3±2.7	26.8±13.2
Marsh Wren	-	-	-	0.4±0.8
Blue-gray Gnatcatcher	2.8±2.0	4.8±3.5	2.7±1.5	24.4±5.7
Phainopepla	-	-	-	-
Northern Mockingbird	-	-	-	-
Crissal Thrasher	-	-	-	0.4±0.8
Bell's Vireo	10.0±1.3	28.0±4.9	10.0±2.0	89.6±8.9
Lucy's Warbler	3.6±1.5	5.6±3.4	2.0±1.6	6.4±4.8
Yellow Warbler	13.2±1.6	16.8±5.0	2.0±1.6	23.6±7.3
Common Yellowthroat	8.8±1.0	12.8±6.0	1.7±1.4	35.2±8.2
Yellow-breasted Chat	9.5±0.9	11.3±2.5	3.7±1.4	35.6±5.3
Summer Tanager	0.8±1.0	2.0±1.8	-	0.4±0.8
Blue Grosbeak	-	0.4±0.8	0.3±0.7	6.4±6.9
Lazuli Bunting	-	-	-	0.4±0.8
Song Sparrow	5.2±4.3	10.4±4.6	2.3±2.4	66.4±5.7
Great-tailed Grackle	1.4±1.7	1.4±2.3	-	0.4±0.8
Brown-headed Cowbird	-	2.0±0.9	-	10.2±2.3
Hooded Oriole	0.8±1.0	1.6±1.5	-	-
House Finch	0.2±0.4	1.2±1.2	-	13.0±7.2
Lesser Goldfinch	2.4±1.6	5.4±2.9	0.8±0.9	4.8±1.6
Study site mean ± SD	60.4±6.7	113.8±15.9	27.8±4.9	353.4±18.6
Size of each study site (ha) for comparison	2.2	7.1	3.4	47.1

NOTE: Study sites are designated as follows: 1 = National Canyon, 2 = Parashant Canyon, 3 = Granite Park, 4 = RM 243L, 5 = Spencer Canyon, 6 = Quartermaster Canyon, 7 = Waterfall Rapids, and 8 = Tincanebits. Dashes indicate the species was not detected during the 1993 field season.