

**A REANALYSIS OF RECREATIONAL AND LIVESTOCK TRESPASS
IMPACTS ON THE RIPARIAN ZONE OF THE RIO GRANDE,
BIG BEND NATIONAL PARK, TEXAS**

**A Final Report Submitted to the National Park Service,
Southwest Region, Santa Fe, New Mexico**

PRINCIPAL INVESTIGATORS:

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**National Park Service, Sub-Coop Agreement # 1,
No. CA 7029-2-0004**

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TABLE OF CONTENTS

I	INTRODUCTION	
	Background and Overview	4
	Objectives	7
II	TRANSECT LOCATIONS	
	Site Selection	9
	UTM Coordinates	13
	Canyon Environment	14
	Non-canyon environment	20
III	RESULTS OF VEGETATIONAL TRANSECTS	
	Methodology	24
	Results	29
	Discussion	68
	Impacts	70
IV	RESULTS OF SMALL MAMMAL SURVEY	
	Methodology	81
	Results	92
	Discussion	103
	Conclusion	112
V	PHOTOGRAPHIC AND CAMPSITE ASSESSMENT	
	Transect photodocumentation	115
	Photostation reevaluation	116
	Campsite assessment	119
VI	MANAGEMENT RECOMMENDATIONS	124
VII	ACKNOWLEDGEMENTS	126
VIII	LITERATURE CITED	128

LIST OF FIGURES, TABLES, AND APPENDICES

<u>FIGURES</u>	<u>PAGE</u>
1. Permanent transect locations along the Rio Grande, Big Bend National Park, Texas.	12
2. Cross section of the Rio Grande riparian zone.	17
3. Diagram of transect and mammal trapping grid.	27
4. Impact of fire on <u>Acacia rigidula</u> , <u>Prosopis glandulosa</u> , and <u>Cynodon dactylon</u> at the Cross Canyon monitoring site.	40
5. Change in vegetation dominance (% cover) at the Sand monitoring site.	47
6. Change in <u>Cynodon dactylon</u> (% cover) at the Rabbit Ears monitoring site.	53
7. Change in vegetation dominance (% cover) revealed on transect 3 at the Gaging Station site.	64

TABLES

1. List of plants documented at the Arch transect location, Santa Elena Canyon, River Mile: 888.4, UTM: 3121 2618.	31
2. List of plants documented at the Cross Canyon transect location, Mariscal Canyon, River Mile: 834.0, UTM: 8218 0744.	36
3. List of plants documented at the Sand transect location, Boquillas Canyon, River Mile: 800.5, UTM: 0700 3530.	43
4. List of plants documented at the Rabbit Ears transect location, Boquillas Canyon, River Mile: 791.0, UTM: 0546 4515.	50
5. List of plants documented at the Entrance transect location, River Mile: 892.5, UTM: 2570 2909.	56
6. List of plants documented at the Gaging Station transect location, River Mile: 868.0, UTM: 5645 1262.	60
7. List of plants documented at the Solis transect location, River Mile: 828.5, UTM: 8445 1430.	66

LIST OF FIGURES, TABLES, AND APPENDICES

<u>TABLES</u>	(CONT.)	<u>PAGE</u>
8.	Mammals recorded in riparian areas in BBNP.	84
9.	Birds observed along the Rio Grande corridor during study.	85
10.	Birds recorded along riparian corridor by month.	88
11.	Herptiles observed along Rio Grande corridor during study.	90
12.	Results of campsite evaluation using a modified Rio Grande Ecological Survey Evaluation Sheet.	120

APPENDICES

1.	Photographs of quarterly monitoring at seven permanent, long term, ecological transect locations.	133
2.	Formulas used to determine small mammal parameters.	141
3.	Photographic reevaluation (1992) of photostations established by Schmidly and Ditton (1976).	142
4.	Campsites assessment, Rio Grande Ecological Survey Evaluation Sheet.	144

INTRODUCTION

The major riparian system in the northern Chihuahuan Desert Region is the Rio Grande and its tributaries, the Rio Conchos, and Pecos River (Strong and Bissonette, 1986). Approximately 90 miles below the confluence of the Rio Conchos, the southeast-trending Rio Grande turns to the northeast, making a gigantic arc that separates Big Bend National Park (BBNP) from the Mexican States of Chihuahua and Coahuila. Within this arc the Rio Grande riparian corridor forms the southern boundary of BBNP. It is along this 117 mile border that the flat, alluvial floodplains and canyon systems preserve characteristic biota of the Chihuahuan Desert Region. The river provides a unique opportunity to observe and study the mosaics produced when two distinct biotic communities, Riparian and Chihuahuan Desert Scrub, come into contact.

Because of the hydraulic dynamics of the Rio Grande, the drainage and vegetational patterns have been altered throughout time (Axtell, 1977; Deal, 1979). Periodic changes in the river channel and the alluvial floodplains disrupt the distribution and equilibrium of the corresponding riparian flora and fauna. Records of major flood episodes are available in the archives of BBNP. The questions that pertain to current research and management practices are: 1) how much change is associated with the activities of man and 2) can these changes be quantified by measuring the impacts on the flora and fauna?

When comparing the surveys of Torrey (1859), Denyes (1956), and Schmidly and Ditton (1976) to present conditions along the river corridor, it is evident that change has rapidly accelerated in the riparian community. Introduced plant species (i.e., Tamarix chinensis and Arundo donax) have altered the shoreline habitat (Henrickson and Johnston, 1986). Impacts created by trespass livestock have been documented along portions of the Big Bend riparian zone (Schmidly and Ditton, 1976). River levels along the park boundary are presently affected by inconsistent water releases from the Rio Conchos dams and watershed, daily and seasonal fluctuations of river levels responding to localized precipitation, and intensive land use practices upstream. These factors present a serious threat to the flora and fauna dependent upon the unique niche provided by the Rio Grande riparian corridor.

The continuous riparian corridor that constitutes the BBNP southern boundary separates the Chihuahuan Desert biogeographical region into two distinct land usage patterns. North of the river channel lies the land administered and protected by the National Park Service (NPS). This area, especially the riparian zone incorporated in the park, is subjected to intense seasonal recreational use (boating and camping) and periodic trespass livestock. The privately owned lands south of the Rio Grande experience severe land use practices of overgrazing and firewood

collection. These practices have dramatically modified the riparian habitats along the Mexican side of the Rio Grande. The current deficiencies of long range plans and cohesive land use patterns for both sides of the Rio Grande riparian corridor impedes current management practices and reduces managerial responses to future problems. The problem is further compounded by the lack of an integrated data base which provides NPS management with a better scientific base for preserving and protecting the riparian community.

Big Bend National Park indicated an interest in a reconnaissance level reevaluation of all sites investigated in the previous work of Schmidly and Ditton (1976). The goal of the NPS was twofold: 1) short term: develop an ecological site evaluation form that would reflect current conditions at a particular riparian site, and 2) long term: gain an understanding of the biological dynamics occurring within the riparian corridor derived from permanent, long term, ecological monitoring locations (i.e., transect sites) along the riparian corridor. The long term goal constitutes the nucleus of our research parameters. The data base developed by the permanent, long term, ecological monitoring stations in this study will provide the NPS with current impacts to the riparian corridor and a better scientific foundation for future management considerations.

In this report we document the results of an intensive, 12 month field survey that was designed to analyze recreational and livestock trespass impacts on the riparian zone of the Rio Grande. This was accomplished by the establishment of seven permanent, ecological monitoring sites which were monitored quarterly to record floral and faunal changes at each site. The results of the vegetational transects and live mammal trapping data, biotic community inventories for specific transect localities, and ecological site evaluation forms will provide the NPS with a sound data base for the riparian zone.

Background and Previous Work:

The current lack of long term monitoring data sets and integrated data base prevents the evaluation of modeling systems that delineate the effects and scale of change that have occurred (and are presently occurring) along the riparian border of BBNP. Examples of change are evident in literature reviews of Denyes (1956) and Schmidly and Ditton (1976). Denyes (1956) recorded Populus, Salix, Baccharis, and Prosopis as the dominant vegetation along the riparian floodplain. Twenty years later Tamarix chinensis had replaced the shrubs reported by Denyes along the riparian zone and Cynodon dactylon was the dominate grass (Schmidly and Ditton, 1976). The present investigation of the Rio Grande corridor adjacent to BBNP has indicated a decrease of

the native river grass Phragmites australis and an increase of the introduced grass Arundo donax along the riparian corridor between Mariscal and Santa Elena canyons.

Schmidly and Ditton (1976) assessed the impacts of recreational usage and trespass livestock on the riparian zone of the Rio Grande that is contiguous with the southern border of Big Bend National Park. Their study selected 64 unique riparian study locations along the BBNP portion of the Rio Grande corridor between Lajitas, TX and La Linda, Coahuila, Mexico. Eighteen of the original 64 locations were selected for detailed biotic community analysis that included: A) vegetational analysis, B) sampling for small mammals, C) campsite evaluation, and D) photostation establishment.

Vegetational analysis of Schmidly and Ditton (1976) consisted of canopy-coverage modeled after Daubenmire (1959) and standard quadrat techniques. The floral components were separated by height of canopy into three broad categories, trees, shrubs, and grasses, and the percent cover of these three components calculated. Similarity between sites was estimated on a similarity coefficient, then subjected to cluster analysis using UPMGA techniques. The resulting dendrograms reflected relative impact on each site when compared to other locations.

In the Schmidly and Ditton (1976) study, small mammals were sampled by modifications of the Calhoun and Casby

(1958) live trap method. A total of 25 species of mammals were either trapped or observed in the riparian habitat, but efforts centered in sampling small mammals as indicators of impact.

Schmidly and Ditton (1976) evaluated campsites using a Rio Grande Ecological Survey Evaluation Sheet. This form numerically ranked various attributes of a campsite (i.e., human litter, fire rings, vegetational habitat). Photostations were established for the 18 detailed study sites. The camera was placed on high ground over the study site allowing a panoramic view of the transect site, landmarks, and surrounding vegetation. At each photostation a permanent marker was placed. Data collected at the sites included compass bearing of the camera, brief description of the site, and a general description of the surrounding terrain.

The Schmidly and Ditton (1976) 18 detailed study sites were important sources to determine the impacts occurring on the riparian zone. Only two of their 18 sites were located within the canyon systems. The three canyon systems, Santa Elena, Mariscal, and Boquillas, comprise approximately 42% (50 river miles) of the BBNP southern border and constitute the majority of recreational usage (pp. 25-60: Schmidly and Ditton, 1976). Within these canyons reside the most sensitive and unique riparian habitats of the Chihuahuan Desert Region (Henrickson and Johnston, 1986). Limited

recreational camping sites within the canyon systems, coupled with large numbers of recreational users, have made these areas prime candidates for impact study. The remaining study sites of Schmidly and Ditton were on the riparian zones associated with the extensive, flat alluvial floodplains outside the three canyons. The work of Schmidly and Ditton ultimately quantified each of the 18 detailed study sites in terms of a baseline biotic community that could be monitored to detect change in the riparian community.

Objectives:

The flora and fauna of the riparian zone along the Big Bend National Park portion of the Rio Grande has received little attention. Sixteen years have passed since the completion of the Schmidly and Ditton study. Big Bend National Park indicated an interest in a study that evaluates the impacts of recreational use and trespass livestock along the riparian corridor. A team of two Sul Ross State University (SRSU) scientists with expertise in Chihuahuan Desert botanical and zoological disciplines and two graduate students (Master of Science candidates in biology) carried out the current study. The team worked interactively to inventory the biological diversity, establish permanent monitoring transect localities, and propose effective managerial recommendations.

The analysis of biodiversity and the impacts that occur to the riparian community had the following objectives:

1. Reconnoiter the riparian corridor along the Rio Grande adjacent to Big Bend National Park and reevaluate the Schmidly and Ditton original study sites.
2. Develop a data base of the flora and fauna of the Rio Grande riparian zone adjacent to Big Bend National Park by establishment of seven permanent, long term ecological monitoring stations.
Collected data would be obtained quarterly by the established methods of vegetational line transects and live mammal trapping stations.
3. Continue photographic documentation (photostations) of the 18 detailed study sites established by Schmidly and Ditton.
4. Assess impacts of recreational usage and trespass livestock on the riparian zone using a modified Rio Grande Ecological Survey Evaluation Sheet.
5. Provide the National Park Service with management recommendations that will include, but not be limited to, placement of fenced enclosure(s), continuation of periodic monitoring of the seven transect locations, control or mitigation measures to deal with impacts, and limits of acceptable change at camping locations.

TRANSECT LOCATIONS

In the original proposal we outlined a research plan that included reconnoitering the entire river corridor, identifying as many of Schmidly and Ditton's locations as feasible (n=64), and establishment of six to eight permanent, long term, ecological monitoring sites (i.e., vegetational transects and small mammal live trapping stations). We intended to use as many of the original Schmidly and Ditton detailed study sites (n=18) as feasible. The relocated study sites were to comprise the core of our long term ecological transect sites. The obvious rationale was to use the base line data of Schmidly and Ditton (1976) as a standard measure for the 12 months of data generated by our present research. The comparison of these data (past and present) would permit evaluation of prior impacts to the riparian flora and fauna.

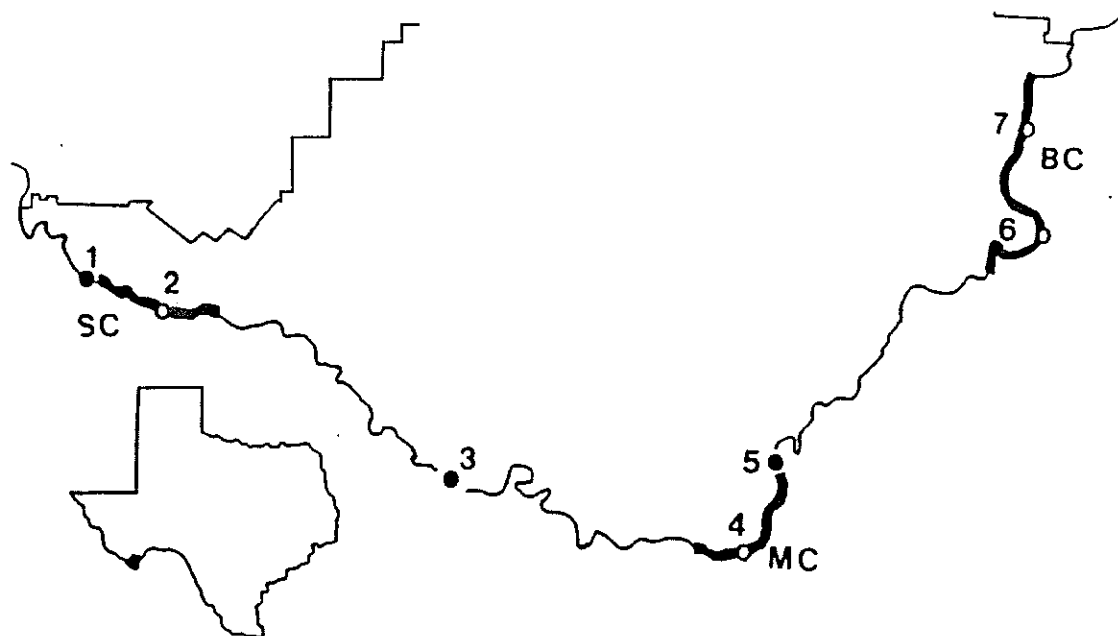
Site Selection:

The initial survey conducted by the SRSU researchers (Sept. 1992) indicated that it was not feasible to use the original Schmidly and Ditton detailed study sites (n=18). The lack of specific data pertaining to the previous study site locations, inability of the researchers to locate 17 of the 18 metal stakes that marked the original sites, effects of major floods during the intervening years, and need to give a balanced approach to the biotic communities in the

three canyon systems (areas of greatest recreational usage), required us to select sites not included in the Schmidly and Ditton study.

Although the 18 original sites were located during the survey of September 1992, the exact transects locations could not be ascertained. Therefore, another justification for the selection of new monitoring sites must be included. In the original study the exact placement of the line transects was briefly described in the Analysis of Small Mammal Fauna (pp. 12-13: Schmidly and Ditton, 1976). The appropriate data pertaining to length, interval, interval between transects, and compass bearings could not be located.

Recreational and livestock impacts on the riparian zone dominated the selection of the permanent monitoring sites during the current study. It was desirable to locate at least one half of the sites in the canyons where greatest recreational usage occurs (Schmidly and Ditton, 1976; K. Yarborough, pers. com.). The remaining sites would be located outside the canyons in areas affected by livestock (NPS, pers. com.). The sites selected for the long term ecological monitoring stations (Fig. 1) are: 1) Entrance, non-canyon, 2) Arch, Santa Elena Canyon, 3) Gaging Station, non-canyon, 4) Cross Canyon, Mariscal Canyon, 5) Solis, non-canyon, 6) Sand, Boquillas Canyon, and 7) Rabbit Ears, Boquillas Canyon. The location of these seven sites (4



BIG BEND NATIONAL PARK
BREWSTER COUNTY, TEXAS

KEY

TRANSECT LOCATION	RIVER MILE	UTM
1 - Entrance	892.5	257 291
2 - Arch	888.4	312 261
3 - Gauging Station	868.0	566 128
4 - Cross Canyon	834.0	822 074
5 - Solis	828.5	844 143
6 - Sand	800.5	069 353
7 - Rabbit Ears	791.0	054 452

CANYONS

- SC - Santa Elena Canyon
- MC - Mariscal Canyon
- BC - Boquillas Canyon
- O - Canyon Environment
- - Non-canyon Environment

canyon, 3 non-canyon) permits a balanced representation of biotic conditions and their responses to impacts that occur within the canyons systems and the broad alluvial floodplains outside of the canyons.

UTM Coordinates:

The current study utilizes the Universal Transverse Mercator Grid (UTM) to record location of the seven ecological monitoring stations and the study sites established in 1976 by Schmidly and Ditton. The seven ecological monitoring sites (Fig. 1) and the 18 detailed study locations established by Schmidly and Ditton (1976) are located along the BBNP Rio Grande corridor. The UTM coordinate for the Entrance monitoring station is ⁶2570 ³²2909. The remaining six monitoring sites established during this study and the Schmidly and Ditton (1976) 18 study locations have the north/south superscript ⁶ and east/west superscript ³² in common. Edwards (1969) recommends omitting common north/south and east/west designations for locations that are in close proximity. We also follow the standardized practice of using an eight-digit designation to locate sites to the nearest 10 m (Edwards 1969).

Canyon Environments:

The riparian habitats in the Rio Grande canyon systems of BBNP occupy narrow sand/gravel bars adjacent to massive, limestone canyon walls. The riparian zones in the canyon were subdivided into three physical sections based on relative height above normal water level: 1) beach (cobble and gravel, subjected to frequent flooding), 2) bench (deep alluvial sand deposits, infrequent flooding), and 3) talus slope (shallow, poorly developed soils with limestone rock and boulders, not subjected to flooding). Beaches were adjacent to the river and subjected to continual physical alterations with periodic changes in the water level throughout the study. The benches were subjected to occasional flooding during the study. Because the bench and talus occupied a position 1 - 3 m above normal water level, the areas did not experience physical alteration by the occasional inundation during the 12 month study.

Soils of the riparian zone within the three canyons are of the Lozier and Rock Outcrop series (Cochran and Rives, 1985). Soils of the Lozier series occur from the base of the canyon wall to the alluvial zone. They are shallow, sandy loams derived from parent limestone and river debris. The Rock Outcrop series is of thin, poorly developed gravels that are produced by erosion of the parent limestone (massive cliff walls). This series is most evident as the talus load at the base of the cliff walls.

A generalized cross section of the riparian zone in the canyon systems (Fig. 2a) shows a gradation from barren cobble with annual and perennial plants on the beach (e.g., Helianthus annuus, Nerisyrenia camporum, and Tamarix chinensis seedlings), up slope to a Cynodon dactylon bench, and talus slope that contains Chihuahuan Desert Scrub (e.g., Acacia rigidula, Prosopis glandulosa) and grasses (e.g., Bouteloua sp., Heteropogon contortus).

In this study we established four permanent, long term, ecological monitoring sites within the three canyon systems; Santa Elena (1 site, Arch), Mariscal (1 site, Cross Canyon), and Boquillas (2 sites, Sand and Rabbit Ears). All sites are located on land that is part of Big Bend National Park.

ARCH: River Mile 888.4 UTM 3121 2618

Arch is located in the middle of Santa Elena Canyon and is seldom used as a recreational campsite. The site is located upriver from a Mexican side canyon locally known as Fern Canyon. Arch occupies approximately six hectares divided equally between beach, bench, and talus slope (slope faces north-northwest). Dominant vegetation at the transect site includes Cynodon dactylon, Prosopis glandulosa, and Caesalpinia parryi. The brass marker for the permanent monitoring transect was set in concrete on the bench stabilized by C. dactylon. The transect area is adjacent to several large limestone boulders, Yucca rostrata, Trixis

californica, and P. glandulosa. The three line transects encompass the bench (1 transect), beach (1 transect), and talus slope (1 transect).

CROSS CANYON: River Mile 834.0 UTM 8218 0744

Cross Canyon is a well established campsite near the middle of Mariscal Canyon. The site is located downriver from the Tight Squeeze rapid. This location is easily distinguished by the intersection of two canyons along a fault line perpendicular to the riparian corridor. The site occupies approximately 12 hectares on a well established, large floodplain and low bench. Dominant vegetation at the site includes Cynodon dactylon, Acacia rigidula, and Prosopis glandulosa. The brass marker for the permanent monitoring site was set in concrete on the bench in the center of a Prosopis thicket and river debris. The surrounding bench contains small arroyos that are products of previous flooding events. The three line transects encompass the beach (1 transect), bench (1 transect), and bench/base of talus slope (1 transect). Transect 1 ends at the base of the talus slope (slope faces south). On 27 May 1993 a fire caused by campers burned ca. 0.5 hectares of the transect site. The burned area included vegetation located on line transect No. 1 and 2.

SAND: River Mile 800.5 UTM 0700 3530

Sand is seldom used as a campsite. The site is located 3.5 miles downstream from the entrance to Boquillas Canyon. Located across the site is Puerto Rico Canyon, a large drainage of the Del Carmen Mountains. The site occupies 10 hectares divided equally between beach, bench, and talus slope. Dominant vegetation at the transect site includes Cynodon dactylon, Arundo donax, Cenchrus ciliaris, and Prosopis glandulosa. The brass marker for the permanent monitoring station was set in concrete on the bench stabilized by C. dactylon. This area is adjacent to several large Prosopis thickets at the base of the talus slope. The three line transects encompass the beach (1 transect), bench (1 transect), and talus slope (1 transect). The talus slope faces south-southwest.

RABBIT EARS: River Mile 791.0 UTM 0546 4515

Rabbit Ears is an established campsite located three miles upstream from the end of Boquillas Canyon. The site is near a large limestone block known locally as Rabbit Ears and across the river from Rabbit Ears Canyon (a short, constricted limestone canyon on the Mexican side of the river). The site is approximately five hectares in size and is dominated by a narrow grass covered bench. Dominant vegetation at the site includes Cynodon dactylon, Celtis pallida, and Prosopis glandulosa. The brass marker for the

moderately deep, silt loams with good drainage. The Harkey soils support a majority of the species comprising the riparian flora (Arundo donax, Baccharis salicifolia, Prosopis glandulosa, and Tamarix chinensis). The Glendale series is located on the outer edges of the floodplain. Soils in the Glendale series are deep, silty clay loams that exhibit poor drainage. Vegetation found on the Glendale series includes Cynodon dactylon, species of Chenopodiaceae, and various woody shrubs.

A generalized cross section of the riparian zone in the non-canyon environment (Fig. 2b) shows a gradation from natural river levy with riparian flora (Arundo donax and Tamarix chinensis) to an expansive beach/bench containing grasses and woody shrubs (Cynodon dactylon and Prosopis glandulosa).

In the present study we established three permanent, long term, ecological monitoring sites outside canyon systems; at the base of Mesa de Anguilla and entrance to Santa Elena Canyon (1 site, Entrance), between Santa Elena and Mariscal canyons along the west river road (1 site, Gaging Station), and between the Mariscal and Boquillas canyons along east river road (1 site, Solis). All sites were located on land that is part of BBNP.

ENTRANCE: River Mile 892.5 UTM 2570 2909

Entrance is a well established campsite located at the entrance to Santa Elena Canyon. The transect location was established on a small (10 hectares) terrace that is

SOLIS: River Mile 828.5 UTM 8445 1430

Solis is a well established campsite and recreational boating take-out location below Mariscal Canyon. The monitoring location was established 100 m north of the camp area/river take-out. The area is a large (ca. 50 hectare) deep sand-silt floodplain adjacent to the Rio Grande. Dominant vegetation at the transect location includes Cynodon dactylon, Arundo donax, Tamarix chinensis, and Sorghum halepense. The brass marker was set in concrete near a disjunct stand of A. donax. The three transects are on the bench.

RESULTS OF VEGETATIONAL TRANSECTS

Efficient biological surveys must be planned in connection with an analysis of the major plant associations because of correlations in community structure. Throughout the survey of the Rio Grande riparian corridor, an extensive plant list was generated for the flora documented at the seven permanent, long term, ecological monitoring locations.

METHODOLOGY

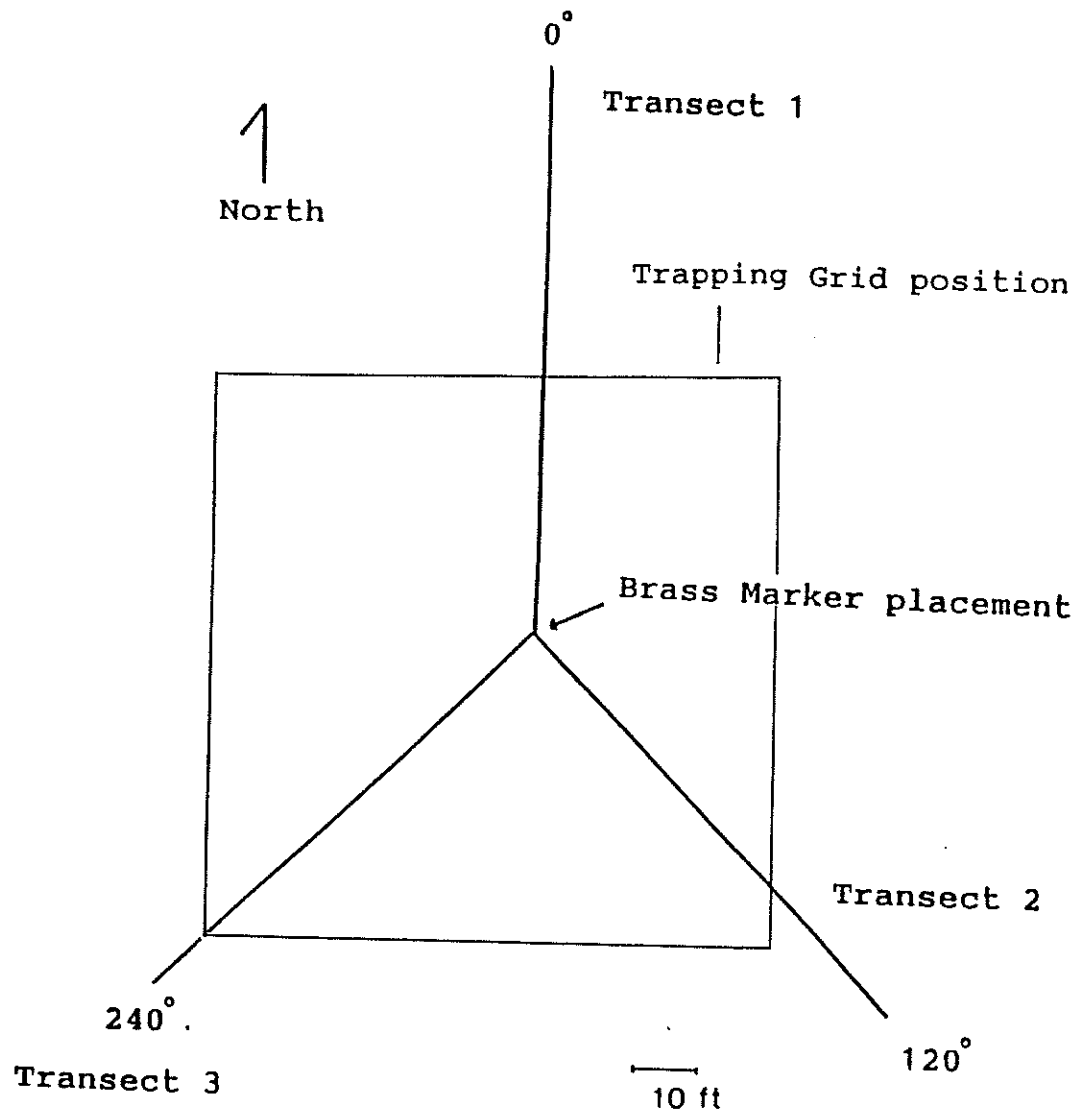
Field work on the project began 14 September 1992 and was completed 31 August 1993. The monitoring sites located at the entrance to Santa Elena Canyon (1 site) and within the three canyons (4 sites) were visited by floating the Rio Grande with canoes and rafts. The remaining two locations were located adjacent to BBNP River Road and were accessible by vehicle. The long term, ecological, monitoring sites were visited quarterly. The principal investigators spent 70 days in the field during the course of the research.

Summaries of vegetational communities located within the Rio Grande riparian corridor have been discussed in the publications of Gould (1975), Henrickson and Johnston (1986), Powell (1988), and Plumb (1992). A complete floristic investigation for the seven transect locations was lacking at the beginning of the study. The initial stages of the study centered on the abundant resources of the Sul Ross State University Herbarium (SRSC) and Correll and Johnston (1979) for a partial list of expected riparian plants. Representative plants for each transect location were compiled from fieldnotes and herbarium specimens. Plants not identified in the field were collected under NPS collecting permits, pressed, and dried according to accepted herbarium practices. Voucher specimens were identified using Correll and Johnston (1979), mounted, and accessioned into the herbarium at SRSC. Plant associations at the

transect sites and on the actual transect lines were determined during the quarterly observations.

Vegetational analysis at each of the seven long term ecological monitoring sites followed the line transect methods described by Smith (1974). Vegetation along the established transects were recorded quarterly. Each site had three line transects that extended 100 feet. The three transects radiated out from a common central point toward predetermined compass points (Fig. 3). For the purpose of our study we used the ordinal points 0° (=Transect 1), 120° (=Transect 2), and 240° (=Transect 3). Our initial survey of the three canyons indicated that these compass points worked best in the compressed riparian habitats and allowed for a fast, accurate survey in the mixed plant communities found in the canyon systems; beach, grass bench, and talus slope. The center (0') and end (100') of each transect was marked by a steel rebar stake placed in the ground. A metal tape was subdivided into 50 intervals (each interval = 2 ft) and stretched from the center point to the end point marked with steel rebar. Vegetation that crossed the tape at each interval was identified and recorded to the nearest 1/10 of a foot. A representative voucher was collected for plants not identified in the field. The voucher identification was completed at Sul Ross State University using Correll and Johnston (1979) and the herbarium resources of Sul Ross State University.

Figure 3. Diagram of transect and small mammal trapping grid.



Photographic documentation of each transect was chronicled after recording the vegetational interval along the individual transects (see Appendix 1). Two cameras were used throughout the research. An OM-10 Olympus camera and 50 mm lens with a haze filter was used for the Color slides (Kodachrome 64, ASA 200) and an OM-1n Olympus camera and 50 mm lens with a UV filter was used for the black and white photographs (Kodak Plus-XPan 125, ASA 100). The cameras were mounted side by side on a tripod. The camera lens were 1.5 m above the ground. The cameras were placed directly over the centerpoint (0') with the lenses pointing toward the end of the transect (100'). Two pictures of each film type were produced at this position. The sequence was repeated directly over the endpoint (100') with the lens pointed towards the central point (0'). Data recorded for each photograph included: 1) f stop, 2) shutter speed, 3) date, 4) brief site description, 5) time, 6) compass bearing of lens, 7) height of camera above ground, and 8) river mile and elevation. Photographs are archived in the Science and Resource Management Center, BBNP.

The total intercept length of each species was calculated after the quarterly observations using the dominance (cover %) formula of Smith (1974):

$$\text{Dominance} = \frac{\text{total intercept length, Species A}}{\text{total transect length}} \times 100$$

At the end of our study a brass marker set in concrete was placed at the central point of each long term ecological monitoring sites (Fig. 3). The brass marker was 9.0 cm in diameter and 1.0 cm thick and was placed at the central point (0' end) of the three transect lines. Future transect investigations can use the center point of the marker for the zero end of a line transect.

The outer edge of each marker contains the inscription 'U. S. DEPT OF THE INTERIOR Unlawful To Disturb NATL PARK SERVICE' and the center was stamped with the appropriate river mile, center, and site number. Because of limited space on the brass marker the sites were numbered sequentially, Entrance = No. 1 through Rabbit Ears = No. 7 (Fig. 1). The ends of each transect were also marked with steel rebar stakes and flagged with surveyor tape. Each piece of steel rebar was two feet in length and placed approximately 18 inches into the ground. At each transect location two corners of the small mammal live trapping grid were similarly marked with rebar (i.e., NE and NW corners at the Sand transect location).

RESULTS

The vegetational transect data for the seven permanent, long term ecological monitoring locations along the Rio Grande riparian corridor were generated during quarterly observations. The observations were recorded: A) Entrance;

29 Oct 92, 5 Feb 93, 31 Apr 93, 12 Jul 93, B) Arch; 1 Nov 92, 7 Feb 93, 6 Apr 93, 14 Jul 93, C) Gaging Station; 26 Sept 92, 11 Mar 93, 25 Jun 93, 25 Aug 93, D) Cross Canyon; 21 Nov 92, 7 Mar 93, 21 Jun 93, 22 Aug 93, E) Solis; 17 Oct 92, 9 Mar 93, 23 Jun 93, 25 Aug 93, F) Sand; 1 Oct 92, 19 Feb 93, 12 Jun 93, 8 Aug 93, and G) Rabbit Ears; 3 Oct 92, 21 Feb 93, 14 Jun 93, 11 Aug 93.

Canyon Environment

The confined riparian environment within the canyon systems enabled each line transect (3 transects/monitoring site) to represent the vegetational occurrence at each physical subdivision in the canyon riparian corridor; beach (1 transect), bench (1 transect), and talus (1 transect). A total of 57 species representing 20 families were documented on the line transects at the four canyon monitoring locations.

ARCH PERMANENT MONITORING SITE:

Table 1 presents the occurrence of flora on the three line transects at the Arch permanent monitoring location. The species dominance (% cover) did not change dramatically during the quarterly recordings at each transect. The beach (transect 2) experienced high water (flooding) between the recording intervals 7 Feb 93 and 6 Apr 93.

TABLE 1. List of plants documented to occur at the Arch transect site, Santa Elena canyon.

**Recorded on line transect

River Mile: 888.4
Elevation: 2100-2300 ft

UTM: 3121 2618

Agavaceae

Agave lechuguilla**
Dasylirion leiophyllum**
Yucca rostrata

Aristolochiaceae

Aristolachia coryi

Asclepiadaceae

Sarcostemma cynanchoides

Bignoniaceae

Chilopsis linearis
Tecoma stans

Boraginaceae

Heliotropium curassavicum

Bromeliaceae

Hectia texensis**

Cactaceae

Ferocactus hamatacanthus
Opuntia macrocentra
Opuntia phaeacantha
Opuntia rufida**

Chenopodiaceae

Salsola kali

Compositae

Baccharis neglectus
Conyza canadensis**
Helenium quadridentatum
Helianthus ciliaris
Machaeranthera scabrella**
Pertyle aglossa
Porophyllum scoparium
Psathyrotes scaposa
Psilostrophe gnaphalodes**
Trixis californica**
Verbesina encelioides
Xanthium strumarium

TABLE 1 CONTINUED

Cyperaceae

Carex sp.

Ebenaceae

Diospyros texana

Euphorbiaceae

Croton texensis

Euphorbia antisyphilitica**

Jatropha dioica

Gentianaceae

Centaurium calycosum

Eustoma grandiflorum

Gramineae

Arundo donax

Bouteloua barbata

Cynodon dactylon**

Echinochloa crusgalli

Heteropogon contortus

Leptochloa dubia**

Pappophorum bicolor**

Pappophorum vaginatum

Panicum antidotale**

Panicum obtusum

Poa sp.

Polypogon monospermiensis

Setaria genticulata**

Sorghum halepense

Sporobolus cryptandrus**

Tridens muticus

Hydrophyllaceae

Nama havardii

Nama torynophyllum

Labiatae

Hedeoma nanum

Salvia roemeriana

Leguminosae

Acacia roemeriana**

Astragalus emoryanus

Caesalpinia parryi**

Dalea pogonathera

Melilotus officinalis

Parkinsonia aculeata

Prosopis glandulosa**

TABLE 1 CONTINUED

Loasaceae	
	<i>Eucnide bartonioides</i>
Loganiaceae	
	<i>Buddleja marrubiifolia</i>
Malvaceae	
	<i>Abutilon incanum</i>
	<i>Hibiscus denudatus</i>
	<i>Sphaeralcea angustifolia</i>
Polygonaceae	
	<i>Rumex crispus</i> **
Primulaceae	
	<i>Anagallis arvensis</i>
Onagraceae	
	<i>Oenothera linifolia</i>
Resedaceae	
	<i>Oligomeris linifolia</i>
Sapindaceae	
	<i>Sapindus saponaria</i>
	<i>Ungnadia speciosa</i>
Selaginellaceae	
	<i>Selaginella lepidophylla</i> **
Solanaceae	
	<i>Datura wrightii</i>
	<i>Nicotiana glauca</i> **
	<i>Nicotiana repens</i>
	<i>Physalis viscosa</i>
	<i>Solanum elaeagnifolium</i> **
	<i>Solanum triquetrum</i> **
Tamaricaceae	
	<i>Tamarix chinensis</i> **
Ulmaceae	
	<i>Celtis pallida</i> **
Verbenaceae	
	<i>Aloysia gratissima</i> **
Zygophyllaceae	
	<i>Guaiacum angustifolium</i>
	<i>Tribulus terrestris</i>

Transect 1: Change in vegetation dominance (% cover) did not occur on transect 1 (bench) during the course of this study. The four observations of transect 1 recorded Cynodon dactylon as the dominant vegetation (100 % cover). The percent cover of Prosopis glandulosa increased from an initial 4.2% to 13.5% (6 Apr 93) during the study. This change is attributed to seasonal growth of P. glandulosa.

Transect 2: Cynodon dactylon was the dominant vegetation on transect 2 (bench/beach). The initial (1 Nov 92) occurrence of C. dactylon was 75.2%. The cover increased to 84.0% at the second examination (7 Feb 93). The cover of C. dactylon had decreased to 70.0% on the third observation (6 Apr 93). At the conclusion of the survey (14 Jul 93) the percent cover of C. dactylon had increased to 74.0%. One riparian species (Tamarix chinensis, 2.7%) was initially recorded on transect 2. Tamarix chinensis increased to 8.1% during the second interval (7 Feb 93), not recorded at the third interval, and occupied 4.0% of the transect at the conclusion of the study (14 Jul 93). Nicotiana glauca was observed near the end of transect 2 at the initial survey (1 Nov 92) but not recorded on the transect at this date. Nicotiana glauca was record on the three succeeding intervals (7 Feb 93, 6 Apr 93, 14 Jul 93) as 3.0%, 1.1%, and 1.1% percent respectively. Several herbaceous species (i.e., Solanum elaeagnifolium, Machaeranthera scabrella) were infrequently recorded throughout the study (% cover < 1.0).

Transect 3: Sixteen species representing 11 families were recorded on transect 3 (talus slope) during the study. The percent cover of two grasses, Cynodon dactylon and Pappophorum bicolor, remained constant during the four observations. The percent cover of woody species (i.e., Caesalpinia parryi, Dasyllirion leiophyllum) and the succulent Opuntia rufida remained constant throughout the study. Negligible decreases (% cover) of several perennial species (i.e., Trixis californica, Setaria geniculata) occurred during the second (7 Feb 93) and third (6 Apr 93) recordings.

CROSS CANYON PERMANENT MONITORING SITE:

The vegetation documented at the Cross Canyon permanent monitoring location is presented in Table 2. The initial species dominance (% cover) recorded on 21 Nov 92 did not change at the second interval (7 Mar 93). A fire at the site was reported to NPS personnel on 27 May 93 burning approximately 60,000 ft² area. The majority of Cynodon dactylon, Prosopis glandulosa, and Acacia rigidula located on transect 1 (bench/talus slope) and transect 2 (bench) were severely impacted by fire (Fig. 4). Flooding effects to the beach (transect 3) were recorded during the final monitoring period (22 Aug 93).

TABLE 2. List of plants documented to occur at the Cross Canyon transect site, Mariscal canyon.
 **Recorded on line transect

River Mile: 834.0
 Elevation: 2000 ft

UTM: 8218 0744

Agavaceae

Agave lechuguilla

Bigoniaceae

Chilopsis linearis

Boraginaceae

Heliotropium curassavicum

Bromeliaceae

Hectia texensis

Cactaceae

Coryphantha macromeris
 Echinocereus pectinatus
 Ferocactus hamatacanthus
 Opuntia macrocentra
 Opuntia rufida

Compositae

Baccharis salicifolia**
 Helianthus annuus
 Helianthus ciliaris
 Machaeranthera scabrella**
 Thelesperma sp.**

Cruciferae

Nerisyrenia camporum

Cyperaceae

Carex sp.

Euphorbiaceae

Argythamnia neomexicana
 Croton cf. texensis
 Euphorbia albomarginata
 Jatropha dioica

Fouquieriaceae

Fouquieria splendens

Gentianaceae

Eustoma grandiflorum

TABLE 2 CONTINUED

Gramineae

Aristida fendleri
Arundo donax
Bouteloua eriopoda
Bouteloua ramosa
*Cynodon dactylon***
Bothriochloa laguroides subsp. *torreyana***
Eragrostis cf. *mexicana*
*Heteropogon contortus***
Polypogon monspeliensis
*Sporobolus cryptandrus***

Hydrophyllaceae

Nama havardii
Nama hispidum
Nama torynophyllum

Labiatae

Teucrium cubense

Leguminosae

Acacia greggii
*Acacia rigidula***
*Prosopis glandulosa***

Malvaceae

Sphaeralcea angustifolia

Onagraceae

Gaura sp.

Polemoniaceae

Gilia rigidula

Resedaceae

Oligomeris linifolia

Scrophulariaceae

Maurandya antirrhiniflora

Solanaceae

Datura wrightii
Lycium berlandieri
Nicotiana glauca

Sterculiaceae

Ayenia filiformis(**)

Tamaricaceae

Tamarix chinensis

PHOTOGRAPHIC AND CAMPSITE ASSESSMENT

The current study included qualitative analysis of the riparian corridor biodiversity and impacts that occurred to the vegetative community. Photographic documentation chronicled the flora of individual transects at the seven permanent ecological monitoring sites established during the current study (Appendix 1). Photographic reevaluation of the 18 photostations initiated by Schmidly and Ditton (1976) along the Rio Grande riparian corridor revealed qualitative changes that occurred during the intervening 16 years (Appendix 3). The cameras, lens, film, and number of photographs per transect/photostation for the current study have been discussed in the Methodology section of Results of Vegetation Transects of this report.

The current study included a subjective assessment of the impacts along the Rio Grande corridor of BBNP. The effects of recreational and trespass livestock impacts at selected campsites, transect locations, and photostations established by Schmidly and Ditton (1976) along the riparian corridor were numerically rated using a modified Rio Grande Ecological Survey Evaluation Sheet (Appendix 4). Photographs were archived in the Science and Management Center, BBNP.

Transect Photodocumentation:

Photographic documentation was obtained at the seven permanent, ecological monitoring sites during the quarterly analysis. The photographs (color and black and white slides) recorded the vegetation revealed along the individual transects (Appendix 1). The photographs were intended to supplement the transect data (% cover of X species) obtained during the course of the current study.

Placement of the cameras has been discussed in the Methodology section of Results of Vegetation Transects of this report. Appendix 1 contains the pertinent data recorded for each photograph: 1) photograph number, 2) location, 3) shutter speed, 4) f stop, 5) date, 6) time, 7) compass bearing of lens, 8) type of camera used, and 9) negative number.

Photographic reevaluation:

The current study continued the photographic documentation of the 18 photostations established by Schmidly and Ditton (1976). The initial survey conducted by the SRSU investigators (Sept-Dec 1992) located the original Schmidly and Ditton photostations and photographs were taken during this time (Appendix 3). The exact camera placement was relocated for eight of the Schmidly and Ditton photostations. The camera placement at the remaining 10 sites was within 5 m of the original photostation

established by Schmidly and Ditton (1976). The exact camera locations of the photostations were difficult to locate because of: 1) inability to locate metal stakes that marked the original sites, 2) effects of major floods during the intervening years, and 3) pertinent data describing photostations could not be located. For ease of cross reference, the current study retained the photostation numbering system established by Schmidly and Ditton (1976).

Qualitative changes (e.g., flora composition, effects of flood) that have occurred in past 16 years were noted at 9 photostations (see Appendix 3 for comparison of 1976 and 1992 photographs at photostations 1, 5, 14, 21, 38, 41, 49, 50, 58, and 62). Changes in vegetational composition between 1976 and 1992 were most notable at the three following sites:

Photostation 38 River Mile 837.5 UTM 7790 0710

1976: Vegetation on the beach predominately large Tamarix cf. chinensis.

1992: Beach reveals signs of recent flooding, the vegetation includes new growth of Baccharis salicifolia, Tamarix chinensis, and species of Chenopodiaceae.

Photostation 49 River Mile 814.5 UTM 9392 2598

1976: Banks of the Rio Grande (BBNP portion) exhibit established stands of Tamarix sp. and cf. Prosopis glandulosa. Plants located in the foreground of the picture indicate abundant grasses and woody shrubs.

1992: Banks of Rio Grande (BBNP) have extensive Arundo donax stands. Plants at the camera location are Larrea tridentata with scattered C. dactylon.

Photostation 58 River Mile 796.0 UTM 0380 3894

1976: Small stands of rivercane (cf. Arundo donax) were noted on the Mexican side of the Rio Grande. The beach in the foreground appears to contain 50% Cynodon dactylon and 50% shrubs (possibly P. glandulosa or T. chinensis).

1992: Extensive stands of Arundo donax were documented on the Mexican side of the Rio Grande. The beach is now dominated by T. chinensis and Guaiacum angustifolium. Cynodon dactylon was the only grass species noted at the photostation.

The comparative effects of a large flooding event(s) (post 1976) were noted at photostation 5 (river mile 898.5, UTM 2098 3397) and photostation 62 (river mile 787.4, UTM 0764 4868). Both of these sites had large portions (> 2 ha) of the beach removed after the photographs of 1976 (Appendix 3).

Campsite Assessment:

Prior to the field work, the NPS expressed an interest in the development of a simple evaluation procedure that would reflect current conditions at a particular riparian site. The SRSU investigators and NPS personnel developed a modified Rio Grande Ecological Survey Evaluation Sheet (RGESES) that can be used in the field to assess impacts to campsites (Appendix 4). The RGESES is a subjective, simple evaluation form that numerically rates 12 impact parameters attributed to recreational usage and trespass livestock (for complete list of impact categories see Appendix 4). Each of the impact parameters was rated on a scale of 0 (no impact) to 5 (severe impact). The data were recorded on the RGESES by the principal investigators at each visit.

Table 12 is a summary of the RGESES impacts documented at the 18 photostations (established by Schmidly and Ditton, 1976) during the initial photographic reevaluation survey of the Rio Grande corridor (Sept-Dec 1992). The RGESES was also used at the seven permanent ecological monitoring sites that were established during the current study. Impacts were noted quarterly at each monitoring site during the 12 month study (Table 12). The impacts noted on the RGESES correspond with the decreases in vegetation dominance discussed in Results of Vegetational Transects.

TABLE 12. Results of campsite evaluation using a modified Rio Grande Ecological Survey Evaluation Sheet.

PH = photostation # EN = Entrance AC = Arch
 GS = Gaging St. CC = Cross Canyon SL = Solis
 SA = Sand RB = Rabbit Ears

Rating Scale: 0 (no impact) - 5 (severe impact)

Type of Physical Impact

SITE	DATE	A	B	C	D	E	F	G	H	I	J	K	L*	Ave ⁺
PH 1	29/10/92	3	1	0	0	2	5	3	0	5	3	2	0	2.00
PH 3	04/02/93	4	0	1	1	2	3	3	0	5	5	3	0	2.25
PH 5	29/10/92	3	0	0	0	0	2	0	0	3	3	5	0	1.33
EN	29/10/92	5	2	1	2	1	5	4	0	5	5	3	1	2.83
EN	05/02/93	5	1	3	0	3	5	5	0	5	5	3	0	2.92
EN	31/04/93	5	3	3	3	3	4	3	0	4	4	4	1	3.08
EN	12/06/93	5	0	3	2	3	4	3	0	4	4	3	1	2.67
AC	31/10/92	5	1	1	0	1	1	3	0	0	0	3	1	1.33
AC	07/02/93	5	0	1	1	0	0	1	0	0	0	3	0	1.50
AC	05/04/93	5	0	1	0	0	0	1	0	0	0	3	0	0.83
AC	12/06/93	5	0	1	0	0	0	1	0	0	0	3	0	0.83
PH 14	25/09/92	5	0	1	0	4	5	4	0	0	0	5	2	2.17
PH 21	27/09/92	4	0	1	0	2	0	0	0	3	0	3	0	1.08
PH 24	25/09/92	4	3	3	2	4	3	3	0	3	3	3	4	2.83
GS	26/09/92	3	0	0	0	1	1	3	0	0	0	1	0	0.75
GS	11/03/93	3	1	1	0	1	1	3	0	0	0	2	0	1.00

*Key: Type of Physical Impact

A = Total barren core E = Vegetation loss I = Livestock
 B = Charcoal F = Trails J = Manure
 C = Litter G = Soil damage K = Flood
 D = Human waste H = Graffiti L = Location

⁺Ave: Average of 12 impacts per location

TABLE 12 CONTINUED

SITE	DATE	Type of Physical Impact												Ave
		A	B	C	D	E	F	G	H	I	J	K	L*	
GS	25/04/93	3	0	0	0	0	1	1	0	1	1	1	0	0.67
GS	25/08/93	3	0	1	1	0	1	2	0	2	3	1	0	1.17
PH 32	16/10/92	3	1	0	0	0	3	3	0	2	1	0	1	1.17
PH 33	16/10/92	3	1	0	0	0	3	2	0	3	4	0	1	1.42
PH 38	20/11/92	0	0	0	0	0	0	0	0	0	0	3	2	0.42
CC	21/11/92	5	0	0	0	0	0	2	0	0	0	5	0	1.00
CC	07/03/93	5	1	1	0	1	2	1	0	0	0	3	0	1.17
CC	21/05/93	5	5	3	0	0	3	3	0	0	1	3	0	1.92
CC	22/08/93	5	3	3	0	0	3	3	0	0	0	2	0	1.58
SL	17/10/92	5	0	3	5	2	5	0	0	1	1	1	1	2.25
SL	09/03/93	4	1	5	5	2	5	3	0	3	5	2	3	3.17
SL	23/05/93	5	3	5	5	4	5	5	0	3	3	2	2	3.50
SL	25/08/93	5	2	5	5	3	5	4	0	3	3	2	0	3.08
PH 45	16/11/92	0	0	0	0	0	3	0	0	3	1	3	0	0.83
PH 46	16/10/92	1	0	0	0	0	5	3	0	3	4	3	1	1.67
PH 49	17/10/92	3	0	1	0	0	3	0	0	3	1	3	1	1.25
PH 50	17/10/92	3	1	3	0	0	3	2	0	1	1	2	2	1.50
PH 54	01/10/92	3	0	0	0	3	5	3	0	0	0	0	0	1.17

*Key: Type of Physical Impact

A = Total barren core	E = Vegetation loss	I = Livestock
B = Charcoal	F = Trails	J = Manure
C = Litter	G = Soil damage	K = Flood
D = Human waste	H = Graffiti	L = Location

+Ave: Average of 12 impacts per location

TABLE 12 CONTINUED

SITE	DATE	Type of Physical Impact												+Ave
		A	B	C	D	E	F	G	H	I	J	K	L*	
SA	01/10/92	5	0	3	1	1	3	1	0	1	1	3	1	1.67
SA	19/02/93	5	0	4	2	2	3	1	0	5	5	3	1	2.58
SA	12/05/93	5	0	3	0	1	4	3	0	5	5	3	0	2.42
SA	08/08/93	5	2	3	2	2	3	3	0	5	4	3	0	2.67
RB	03/10/92	5	0	1	0	1	1	1	0	1	0	3	1	1.17
RB	21/02/93	5	3	5	3	2	3	3	0	5	5	3	1	3.17
RB	14/05/93	4	1	5	3	3	4	3	0	5	4	2	1	3.75
RB	11/08/93	4	2	5	5	0	2	3	0	5	4	2	0	3.00
PH 58	03/10/92	1	0	1	0	0	0	1	0	1	0	3	0	0.58
PH 62	05/10/92	5	2	2	0	0	5	4	0	5	5	4	0	2.67

 *Key: Type of Physical Impact
 A = Total barren core E = Vegetation loss I = Livestock
 B = Charcoal F = Trails J = Manure
 C = Litter G = Soil damage K = Flood
 D = Human waste H = Graffiti L = Location

+Ave: Average of 12 impacts per location

Average of each impact (A thru L) for Table 12.
 The average can be used to for the "relative" weight
 for each impact.

A = 3.95	E = 1.23	I = 2.34
B = 0.91	F = 2.77	J = 2.13
C = 1.89	G = 2.34	K = 2.59
D = 1.09	H = 0.00	L = 0.66

The evaluation of riparian campsites allows NPS personnel to assess impacts occurring at a given campsite and construct a data base for impacts occurring at riparian campsites. The ultimate goal of the RGESES is to assess impacts to campsites along the Rio Grande corridor of BBNP and to provide NPS personnel with information for future management considerations. However, the dynamics of the river will continually alter most sites, making long term comparisons difficult.

MANAGEMENT RECOMMENDATIONS

1. Establish an exclosure site at the Rabbit Ears permanent monitoring station in Boquillas Canyon. The exclosure should be constructed so that it will withstand periodic flooding events, exclude livestock, and built so that the fencing material would be difficult to remove. Additional exclosure locations should be built at other sites in the future. These sites would include non-canyon sites (i.e., Solis) and control sites (sites adjacent to Rabbit Ears, Boquillas Canyon).

2. Continue cyclic monitoring of the exclosure site and seven established long term, ecological monitoring sites. This report provides NPS with quarterly (i.e., seasonal) vegetational and small mammal data. Our recommendation is that monitoring be conducted once a year. The new data sets can be compared with previous seasonal data sets.

3. Trespass livestock (primarily equine) will continue to produce managerial problems for the NPS. Until a comprehensive plan incorporates activities on both banks of the Rio Grande riparian corridor (BBNP and Mexico), trespass livestock will continue to denude the vegetation within the canyon systems and non-canyon floodplains.

4. Within future budget and time constraints, BBNP should consider: 1) defining and establishing a set number of camp sites along the Rio Grande, 2) placing seasonal (i.e., Thanksgiving and Spring Break) limits on numbers of individuals using a specific campsite, 3) initiating river inspections by NPS personnel trained in biological sciences.

MANAGEMENT RECOMMENDATIONS CONTINUED

5. The National Park Service should evaluate the current flood management plan for the Rio Grande riparian corridor. Within future budget and personnel constraints, the NPS should initiate a comprehensive research program designed to record the impacts of flood episodes. This will allow the NPS to monitor and ascertain the effects of major flood in the canyon and non-canyon environments. We suggest that NPS collect data pertaining to: 1) periodicity of flooding events and their duration, 2) recording time intervals between flooding episodes, 3) quantifying the effects of floods to canyon and non-canyon environments, and 4) documenting and quantifying the recolonization of flora and fauna in these habitats after the flood events.

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Special thanks to the commercial river outfitters who use the Rio Grande as their office; they kept the campsites clean and nice for the next campers.

Last, the principal investigators would like to state that the next river trip will be pure pleasure. Gone are the days when we loaded tons of equipment into canoes, hauled it down river, and humped it uphill to the transect sites - but they will be missed.

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Appendix 1. Photographs of quarterly monitoring at seven permanent, long term, ecological transect locations.

Entrance Monitoring Site River Mile 892.5
UTM 2570 2909

Color slides

#	Site	SS	<u>f</u>	Date	Time	Comp*
001	ENTR, General overview	250	11	30 Oct 92	1200	N/A
002	ENTR, General overview	250	11	30 Oct 92	1200	N/A
003	ENTR, T1 center to end	250	11	30 Oct 92	1200	0
004	ENTR, T1 end to center	250	11	30 Oct 92	1200	180
005	ENTR, T2 center to end	250	11	30 Oct 92	1200	120
006	ENTR, T2 end to center	250	11	30 Oct 92	1200	300
007	ENTR, T3 center to end	250	11	30 Oct 92	1200	240
008	ENTR, T3 end to center	250	11	30 Oct 92	1200	60
009	ENTR, T1 center to end	250	11	05 Feb 93	1500	0
010	ENTR, T1 end to center	250	11	05 Feb 93	1500	180
011	ENTR, T2 center to end	250	11	05 Feb 93	1500	120
012	ENTR, T2 end to center	250	11	05 Feb 93	1500	300
013	ENTR, T3 center to end	250	11	05 Feb 93	1500	240
014	ENTR, T3 end to center	250	11	05 Feb 93	1500	60
015	ENTR, T1 center to end	250	11	12 Jul 93	1000	0
016	ENTR, T1 end to center	250	11	12 Jul 93	1000	180
017	ENTR, T2 center to end	250	11	12 Jul 93	1000	120
018	ENTR, T2 end to center	250	11	12 Jul 93	1000	300
019	ENTR, T3 center to end	250	11	12 Jul 93	1000	240
020	ENTR, T3 end to center	250	11	12 Jul 93	1000	60
021	ENTR, T1 center to end	250	11	04 Aug 93	1000	0
022	ENTR, T1 end to center	250	11	04 Aug 93	1000	180
023	ENTR, T2 center to end	250	11	04 Aug 93	1000	120
024	ENTR, T2 end to center	250	11	04 Aug 93	1000	300
025	ENTR, T3 center to end	250	11	04 Aug 93	1000	240
026	ENTR, T3 end to center	250	11	04 Aug 93	1000	60

*Key: # = Number (red) on photograph in lower left corner

T1 = Transect 1

T2 = Transect 2

T3 = Transect 3

SS = Shutter speed

f = f stop setting

Comp = Compass bearing of camera lens

Center to end = Camera lens over central mark and pointing to the end of the transect (100').

End to center = Camera lens over end mark and pointing toward the 0' end of the transect.

Appendix 1 CONTINUED

Arch Monitoring Site River Mile 888.4
UTM 3121 2618

Color slides

#	Site	SS	f	Date	Time	Comp
027	ARCH, General overview	250	11	01 Nov 92	1200	N/A
028	ARCH, General overview	250	11	01 Nov 92	1200	N/A
029	ARCH, T1 center to end	250	11	01 Nov 92	1200	0
030	ARCH, T1 end to center	250	11	01 Nov 92	1200	180
031	ARCH, T2 center to end	250	11	01 Nov 92	1200	120
032	ARCH, T2 end to center	250	11	01 Nov 92	1200	300
033	ARCH, T3 center to end	250	11	01 Nov 92	1200	240
034	ARCH, T3 end to center	250	11	01 Nov 92	1200	60
035	ARCH, T1 center to end	250	11	07 Feb 93	1500	0
036	ARCH, T1 end to center	250	11	07 Feb 93	1500	180
037	ARCH, T2 center to end	250	11	07 Feb 93	1500	120
038	ARCH, T2 end to center	250	11	07 Feb 93	1500	300
039	ARCH, T3 center to end	250	11	07 Feb 93	1500	240
040	ARCH, T3 end to center	250	11	07 Feb 93	1500	60
041	ARCH, T1 center to end	250	11	14 Jul 93	0900	0
042	ARCH, T1 end to center	250	11	14 Jul 93	0900	180
043	ARCH, T2 center to end	250	11	14 Jul 93	0900	120
044	ARCH, T2 end to center	250	11	14 Jul 93	0900	300
045	ARCH, T3 center to end	250	11	14 Jul 93	0900	240
046	ARCH, T3 end to center	250	11	14 Jul 93	0900	60
047	ARCH, T1 center to end	250	11	06 Aug 93	1000	0
048	ARCH, T1 end to center	250	11	06 Aug 93	1000	180
049	ARCH, T2 center to end	250	11	06 Aug 93	1000	120
050	ARCH, T2 end to center	250	11	06 Aug 93	1000	300
051	ARCH, T3 center to end	250	11	06 Aug 93	1000	240
052	ARCH, T3 end to center	250	11	06 Aug 93	1000	60

Appendix 1 CONTINUED

Gaging Station Monitoring Site River Mile 868.0
 UTM 5645 1262

Color slides

#	Site	SS	f	Date	Time	Comp
053	GAST, General overview	250	11	26 Sep 92	1030	N/A
054	GAST, General overview	250	11	26 Sep 92	1030	N/A
055	GAST, T1 center to end	250	11	26 Sep 92	1030	0
056	GAST, T1 end to center	250	11	26 Sep 92	1030	180
057	GAST, T2 center to end	250	11	26 Sep 92	1030	120
058	GAST, T2 end to center	250	11	26 Sep 92	1030	300
059	GAST, T3 center to end	250	11	26 Sep 92	1030	240
060	GAST, T3 end to center	250	11	26 Sep 92	1030	60
061	GAST, T1 center to end	250	11	11 Mar 93	1200	0
062	GAST, T1 end to center	250	11	11 Mar 93	1200	180
063	GAST, T2 center to end	250	11	11 Mar 93	1200	120
064	GAST, T2 end to center	250	11	11 Mar 93	1200	300
065	GAST, T3 center to end	250	11	11 Mar 93	1200	240
066	GAST, T1 center to end	250	11	25 Jun 93	1000	0
067	GAST, T1 end to center	250	11	25 Jun 93	1000	180
068	GAST, T2 center to end	250	11	25 Jun 93	1000	120
069	GAST, T2 end to center	250	11	25 Jun 93	1000	300
070	GAST, T3 center to end	250	11	25 Jun 93	1000	240
071	GAST, T1 center to end	250	11	25 Aug 93	1000	0
072	GAST, T1 end to center	250	11	25 Aug 93	1000	180
073	GAST, T2 center to end	250	11	25 Aug 93	1000	120
074	GAST, T2 end to center	250	11	25 Aug 93	1000	300
075	GAST, T3 center to end	250	11	25 Aug 93	1000	240

Appendix 1 CONTINUED

Cross Canyon Monitoring Site River Mile 834.0
UTM 8218 0744

Color slides

#	Site	SS	f	Date	Time	Comp
076	CROS, General overview	250	11	21 Nov 92	1200	N/A
077	CROS, General overview	250	11	21 Nov 92	1200	N/A
078	CROS, T1 center to end	250	11	21 Nov 92	1200	0
079	CROS, T1 end to center	250	11	21 Nov 92	1200	180
080	CROS, T2 center to end	250	11	21 Nov 92	1200	120
081	CROS, T2 end to center	250	11	21 Nov 92	1200	300
082	CROS, T3 center to end	250	11	21 Nov 92	1200	240
083	CROS, T3 end to center	250	11	21 Nov 92	1200	60
084	CROS, T1 center to end	250	11	07 Mar 93	1100	0
085	CROS, T1 end to center	250	11	07 Mar 93	1100	180
086	CROS, T2 center to end	250	11	07 Mar 93	1100	120
087	CROS, T2 end to center	250	11	07 Mar 93	1100	300
088	CROS, T3 center to end	250	11	07 Mar 93	1100	240
089	CROS, T3 end to center	250	11	07 Mar 93	1100	60
090	CROS, T1 center to end	250	11	21 Jun 93	1000	0
091	CROS, T1 end to center	250	11	21 Jun 93	1000	180
092	CROS, T2 center to end	250	11	21 Jun 93	1000	120
093	CROS, T2 end to center	250	11	21 Jun 93	1000	300
094	CROS, T3 center to end	250	11	21 Jun 93	1000	240
095	CROS, T3 end to center	250	11	21 Jun 93	1000	60
096	CROS, T1 center to end	250	11	22 Aug 93	1200	0
097	CROS, T1 end to center	250	11	22 Aug 93	1200	180
098	CROS, T2 center to end	250	11	22 Aug 93	1200	120
099	CROS, T2 end to center	250	11	22 Aug 93	1200	300
100	CROS, T3 center to end	250	11	93 Aug 93	1200	240
101	CROS, T3 end to center	250	11	93 Aug 93	1200	60

Appendix 1 CONTINUED

Solis Monitoring Site River Mile 828.5
UTM 8445 1430

Color slides

#	Site	SS	f	Date	Time	Comp
102	SOLS, General overview	250	11	16 Oct 92	1830	N/A
103	SOLS, General overview	250	11	16 Oct 92	1830	N/A
104	SOLS, T1 center to end	250	11	16 Oct 92	1830	0
105	SOLS, T1 end to center	250	11	16 Oct 92	1830	180
106	SOLS, T2 center to end	250	11	16 Oct 92	1830	120
107	SOLS, T3 center to end	250	11	16 Oct 92	1830	240
108	SOLS, T3 end to center	250	11	16 Oct 92	1830	60
109	SOLS, T1 center to end	250	11	09 Mar 93	1200	0
110	SOLS, T1 end to center	250	11	09 Mar 93	1200	180
111	SOLS, T2 center to end	250	11	09 Mar 93	1200	120
112	SOLS, T3 center to end	250	11	09 Mar 93	1200	240
113	SOLS, T3 end to center	250	11	09 Mar 93	1200	60
114	SOLS, T1 center to end	250	11	23 Jun 93	1000	0
115	SOLS, T1 end to center	250	11	23 Jun 93	1000	180
116	SOLS, T2 center to end	250	11	23 Jun 93	1000	120
117	SOLS, T3 center to end	250	11	23 Jun 93	1000	240
118	SOLS, T3 end to center	250	11	23 Jun 93	1000	60
119	SOLS, T1 center to end	250	11	11 Aug 93	1000	0
120	SOLS, T1 end to center	250	11	11 Aug 93	1000	180
121	SOLS, T2 center to end	250	11	11 Aug 93	1000	120
122	SOLS, T3 center to end	250	11	11 Aug 93	1000	240
123	SOLS, T3 end to center	250	11	11 Aug 93	1000	60

Appendix 1 CONTINUED

Sand Monitoring Site River Mile 800.5
UTM 0700 3530

Color slides

#	Site	SS	f	Date	Time	Comp
124	SAND, General overview	250	11	02 Oct 92	1000	N/A
125	SAND, General overview	250	11	02 Oct 92	1000	N/A
126	SAND, T1 center to end	250	11	02 Oct 92	1000	0
127	SAND, T1 end to center	250	11	02 Oct 92	1000	180
128	SAND, T2 center to end	250	11	02 Oct 92	1000	120
129	SAND, T2 end to center	250	11	02 Oct 92	1000	300
130	SAND, T3 center to end	250	11	02 Oct 92	1000	240
131	SAND, T3 end to center	250	11	02 Oct 92	1000	60
132	SAND, T1 center to end	250	11	18 Feb 93	1100	0
133	SAND, T1 end to center	250	11	18 Feb 93	1100	180
134	SAND, T2 center to end	250	11	18 Feb 93	1100	120
135	SAND, T2 end to center	250	11	18 Feb 93	1100	300
136	SAND, T3 center to end	250	11	18 Feb 93	1100	240
137	SAND, T3 end to center	250	11	18 Feb 93	1100	60
138	SAND, T1 center to end	250	11	12 Jun 93	1700	0
139	SAND, T1 end to center	250	11	12 Jun 93	1700	180
140	SAND, T2 center to end	250	11	12 Jun 93	1700	120
141	SAND, T2 end to center	250	11	12 Jun 93	1700	300
142	SAND, T3 center to end	250	11	12 Jun 93	1700	240
143	SAND, T3 end to center	250	11	12 Jun 93	1700	60
144	SAND, T1 center to end	250	11	30 Oct 92	1700	0
145	SAND, T1 end to center	250	11	30 Oct 92	1700	180
146	SAND, T2 center to end	250	11	30 Oct 92	1700	120
147	SAND, T2 end to center	250	11	30 Oct 92	1700	300
148	SAND, T3 center to end	250	11	30 Oct 92	1700	240
149	SAND, T3 end to center	250	11	30 Oct 92	1700	60

Appendix 1 CONTINUED

Rabbit Ears Monitoring Site River Mile 791.0
UTM 0546 4515

Color slides

#	Site	SS	f	Date	Time	Comp
150	RBTE, General overview	250	11	05 Oct 92	1000	N/A
151	RBTE, General overview	250	11	05 Oct 92	1000	N/A
152	RBTE, T1 center to end	250	11	05 Oct 92	1000	0
153	RBTE, T1 end to center	250	11	05 Oct 92	1000	180
154	RBTE, T2 center to end	250	11	05 Oct 92	1000	120
155	RBTE, T2 end to center	250	11	05 Oct 92	1000	300
156	RBTE, T3 center to end	250	11	05 Oct 92	1000	240
157	RBTE, T1 center to end	250	11	20 Feb 93	1600	0
158	RBTE, T1 end to center	250	11	20 Feb 93	1600	180
159	RBTE, T2 center to end	250	11	20 Feb 93	1600	120
160	RBTE, T2 end to center	250	11	20 Feb 93	1600	300
161	RBTE, T3 center to end	250	11	20 Feb 93	1600	240
162	RBTE, T1 center to end	250	11	14 Jun 93	1000	0
163	RBTE, T1 end to center	250	11	14 Jun 93	1000	180
164	RBTE, T2 center to end	250	11	14 Jun 93	1000	120
165	RBTE, T2 end to center	250	11	14 Jun 93	1000	300
166	RBTE, T3 center to end	250	11	14 Jun 93	1000	240
167	RBTE, T1 center to end	250	11	11 Aug 93	0900	0
168	RBTE, T1 end to center	250	11	11 Aug 93	0900	180
169	RBTE, T2 center to end	250	11	11 Aug 93	0900	120
170	RBTE, T2 end to center	250	11	11 Aug 93	0900	300
171	RBTE, T3 center to end	250	11	11 Aug 93	0900	240
172	Overhead of Brass Marker	250	11	11 Aug 93	0900	60

Appendix 1 CONTINUED

Photographic documentation of recreational and
trespass livestock impacts on the riparian zone.

Color slides

#	Site	SS	f	Date	Time	Comp

TRESPASS LIVESTOCK - GENERAL						
173	SAND, Grazing near site	250	11	18 Feb 93	1100	N/A
174	SAND, Grazing damage, <u>Arundo</u>	250	11	18 Feb 93	1100	N/A
175	SAND, General overview	250	11	18 Feb 93	1100	N/A
TRESPASS LIVESTOCK - PLANTS						
176	RBTE, <u>Cynodon dactylon</u>	250	11	14 Jun 93	1000	N/A
177	RBTE, <u>Opuntia ficus-indica</u>	250	11	14 Jun 93	1000	N/A
178	RBTE, <u>Baccharis salicifolia</u>	250	11	14 Jun 93	1000	N/A
HUMAN IMPACT						
179	CROS, Fire damage at site	250	11	21 Jun 93	1000	N/A
180	CROS, Fire damage at site	250	11	21 Jun 93	1000	N/A
181	SOLS, Toilet paper	250	11	23 Jun 93	1100	N/A
182	SAND, Trampling at site	250	11	18 Feb 93	1100	N/A

Appendix 2. Formulas used to determine small mammal parameters

I. Lincoln Index to determine population size (Davis 1956):

$$N = M(n_i + 1) / R + 1$$

where, M= total Number marked

n_i = number captured subsequently

R= Recaptures

Population estimates expressed at 95% confidence level

II. Observed Range Length Method to determine Home Ranges of Small Mammals (Davis 1956):

May be inferred by using the greatest distance observed between points of capture. This distance constitutes the diameter of a circle, or an ellipse, which is the animal's estimated home range.

III. Shannon Diversity Index (Brower and Zar 1984):

$$H' = -\sum p_i \log p_i$$

where, $p_i = n_i / N$

n_i / N = proportion of the total Number of individuals occurring in species i

Appendix 3. Photographic reevaluation (1992) of photostations established by Schmidly and Ditton (1976).

Poto	Date	Site	River Mile	UTM	Compass(°)	Topo*
183	29 Oct 92	01	902.2	1850 3530	334	A
184	29 Oct 92	01	902.2	1840 3530	334	A
185	1976	01	902.2	1840 3530	334	A
186	04 Feb 93	03	900.3	1964 3295	90	A
187	1976	03	900.3	1964 3295	90	A
188	29 Oct 92	05	898.5	2098 3397	143	A
189	1976	05	898.5	2098 3397	143	A
190	30 Oct 92	11	892.5	2552 2910	161	B
191	1976	11	892.5	2552 2910	161	B
192	01 Nov 92	14	885.5	3504 2702	25	C
193	1976	14	885.5	3504 2702	25	C
194	27 Sep 92	21	N/A	4900 1821	280	D
195	1976	21	N/A	4900 1821	280	D
196	27 Sep 92	24	N/A	5258 1506	150	D
197	1976	24	N/A	5258 1506	150	D
198	26 Sep 92	27	868.0	5678 1270	120	D
199	1976	27	868.0	5678 1270	120	D
200	16 Oct 92	32	N/A	6632 0976	125	E
201	1976	32	N/A	6632 0976	125	E
202	16 Oct 92	33	838.5	6716 0886	162	E
203	1976	33	838.5	6716 0886	162	E
204	20 Nov 92	38	837.5	7790 0710	240	F
205	1976	38	837.5	7790 0710	240	F
206	17 Oct 92	41	828.5	8445 1430	94	G
207	1976	41	828.5	8445 1430	94	G
208	16 Oct 92	45	821.8	8890 1972	216	G
209	1976	45	821.8	8890 1972	216	G

*Key: Topographic Maps

A = LaJitas, TX
 B = Mesa de Anguilla, TX
 C = Castolon, TX
 D = Smoky Creek, TX
 E = Reed Camp, TX
 F = Mariscal Mnt, TX

G = Solis, TX
 H = San Vicente, TX
 I = Boquillas, TX
 J = Ernst Valley, TX
 K = Stillwell Crossing, TX

Appendix 3 CONTINUED

Photo	Date	Site	River Mile	UTM	Compass(°)	Topo*
210	16 Oct 92	46	820.2	8944 2055	220	G
211	1976	46	820.2	8944 2055	220	G
212	17 Oct 92	49	814.5	9392 2598	231	H
213	1976	49	814.5	9392 2598	231	H
214	17 Oct 92	50	814.2	9424 2636	18	H
215	1976	50	814.2	9424 2636	18	H
216	01 Oct 92	54	806.4	0250 3158	85	I
217	1976	54	806.4	0250 3158	85	I
218	01 Oct 92	54	806.4	0250 3158	170	I
219	1976	54	806.4	0250 3158	170	I
220	03 Oct 92	58	796.0	0380 3894	216	J
221	1976	58	796.0	0380 3894	216	J
222	05 Oct 92	62	787.4	0764 4868	134	K
223	1976	62	787.4	0764 4868	134	K

*Key: Topographic Maps

A = LaJitas, TX
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 E = Reed Camp, TX
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G = Solis, TX
 H = San Vicente, TX
 I = Boquillas, TX
 J = Ernst Valley, TX
 K = Stillwell Crossing, TX

Appendix 4. Campsite assessment, Rio Grande Ecological Survey Evaluation Sheet.

Type of Physical Impact	0 (slight)	1 (moderate)	5 (Severe)
1. Total barren core area	none	<25 sq.ft	50-100 sq.ft >200 sq.ft
2. Charcoal, blackened rocks	none	Small amount in single ring	Small bedrock blackened OR sign of multiple fires with charcoal
3. Litter (No. of pieces)	none	Not evident to casual observer	3-5 10+
4. Human waste	none	Some uric acid odor	Small amount of litter, partially buried feces
5. Human-caused vegetation loss	none	Slight trampling; a few branches/small bushes damaged	Veg. trampling obvious, <25% of site OR 2-4 substantial branches cut or broken
6. Social trails	none	None evident from one year to next	Two distinct trails through vegetation
7. Soil damage	none	Not evident to casual observer	Surface lightly compacted, OR small drainage channels, OR visible roots
8. Graffiti	none	All traces fade <1 yr	All traces fade <5 yrs OR or small area impacted
9. Livestock-caused vegetation loss	none	Light grazing, little trampling	Some grazing with obvious trampling, Severe grazing & trampling,
10. Manure (livestock)	none	2 or less old piles	Widely scattered piles, <25% of site affected
11. River flood effects	none	Minor changes to beach or access	Significant alteration of associated beach OR reduced access
12. Proximity to other campsites	none	Minimal contact with others	One camp fairly close w/some screening OR 2+ at a middle distance w/some screening
Campsite size (people): 1-8 9-16 17-30 Probability of Flooding: little some moderate TOTALS Access from River: good fair poor Habitat types: riparian dune gravel/rock bench River site #: Site Name: GPS: UTM: Date: Observer: Affiliation:			

TABLE 5. List of plants documented to occur at the Entrance transect site, non-canyon environment.
 ** Recorded on line transect

River Mile: 892.5
 Elevation: 2200 ft

UTM: 2570 2909

Agavaceae

Agave lechuguilla

Amaranthaceae

Amaranthus blitoides**
 Amaranthus palmeri**

Boraginaceae

Heliotropium curassavicum

Cactaceae

Opuntia kleiniae
 Opuntia leptocaulis**
 Opuntia macrocentra**
 Opuntia phaeacantha**
 Opuntia rufida

Chenopodiaceae

Atriplex canescens
 Salsola kali

Compositae

Baccharis salicifolia
 Baileya multiradiata**
 Dyssodia acerosa**
 Machaeranthera scabrella
 Parthenium confertum
 Verbesina encelioides

Cruciferae

Lesquerella fendleri**
 Nerisyrenia camporum

Euphorbiaceae

Jatropha dioica

Gramineae

Aristida cf. purpurea**
 Arundo donax
 Bouteloua curtipendula
 Bouteloua eriopoda
 Bouteloua aristidoides**
 Bouteloua barbata**
 Bouteloua trifida
 Cynodon dactylon
 Erioneuron pulchellum

TABLE 5 CONTINUED

Gramineae (continued)

Schizachyrium scoparium
Sporobolus cryptandrus**

Leguminosae

Acacia greggii
Senna sp.
Lupinus havardii
Parkinsonia aculeata
Prosopis glandulosa**

Malvaceae

Sphaeralcea angustifolia

Polygonaceae

Rumex crispus

Selaginellaceae

Selaginella lepidophylla

Solanaceae

Nicotiana glauca

Sterculiaceae

Ayenia filiformis

Tamaricaceae

Tamarix chinensis

Zygophyllaceae

Guaiacum angustifolium
Larrea tridentata**