A SURVEY AND ANALYSIS OF RECREATIONAL AND LIVESTOCK IMPACT ON THE RIPARIAN ZONE OF THE RIO GRANDE IN BIG BEND NATIONAL PARK

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ABSTRACT--Visitor usage patterns, biological conditions, and selected parameters of recreational impact (including litter, trampling, tree cutting, and human waste) were measured over a 12-month period. Use and impact were shown to be strongly and positively correlated. However, recreational impact was not significantly related to biological health of the area. Cluster analysis was used to group areas into three categories based on degree of impact; only one of every four sites was indicated as heavily impacted. Principal components analysis identified human impact parameters as best discriminators between sites.

In recent years, the Rio Grande of the Big Bend National Park (BBNP) has experienced dramatic increases in recreational and water resource use. Thus, the National Park Service (NPS) has found it necessary to secure information concerning the actual and potential impact on the river and on associated land area ecosystems from present levels of human usage.

The primary goals are to assess the impact upon the Rio Grande Floodplain in BBNP to provide baseline data for determining the "carrying capacity" of the area, use management alternatives, and strategies that may be employed to ensure that use remains within this carrying capacity.

Four factors are being investigated as follows:

1.--Resource

(a) Preliminary biotic survey of the riparian areas along the Rio Grande.

(b) The identification, distribution, and relative abundance of plant and mammalian species in riparian areas along the Rio Grande.

2.--Users

(a) To identify the extent, character, and patterns of recreational use along the Rio Grande corridor.

(b) To identify the geographic and descriptive characteristics of recreational users by user group.

3.--Impacts

(a) To determine the direct and indirect impact of human use upon plant and mammal life and other natural resources.

(b) To formulate recommendations for short-term and long-term monitoring programs of biological resources.

4.--Management

(a) To formulate recommendations for additional research needs.

(b) To suggest alternatives for management schemes aimed at maintaining and perpetuating the natural ecosystems in consonance with current NPS natural area policies.

APPROACH

After study of aerial photographs, float trips were conducted from Lajitas to La Linda and 64 major riparian areas were identified and recorded on a map. For statistical analysis purposes, each was treated as a distinct sampling entity, although they tend to form a continuum along the river (fig. 1).

Most of the riparian areas are accessible only by river. However, 26 riparian sites may be reached by roads: 18 of these are reached by a dirt road called the River Road, which becomes impassible during rainy weather. These 18 have been designated as primitive campsites. There are also eight sites that are accessible via paved roads; two (Cottonwood and Santa Elena Picnic Area) are small campgrounds and a third (Rio Grande Village) is a major campground.

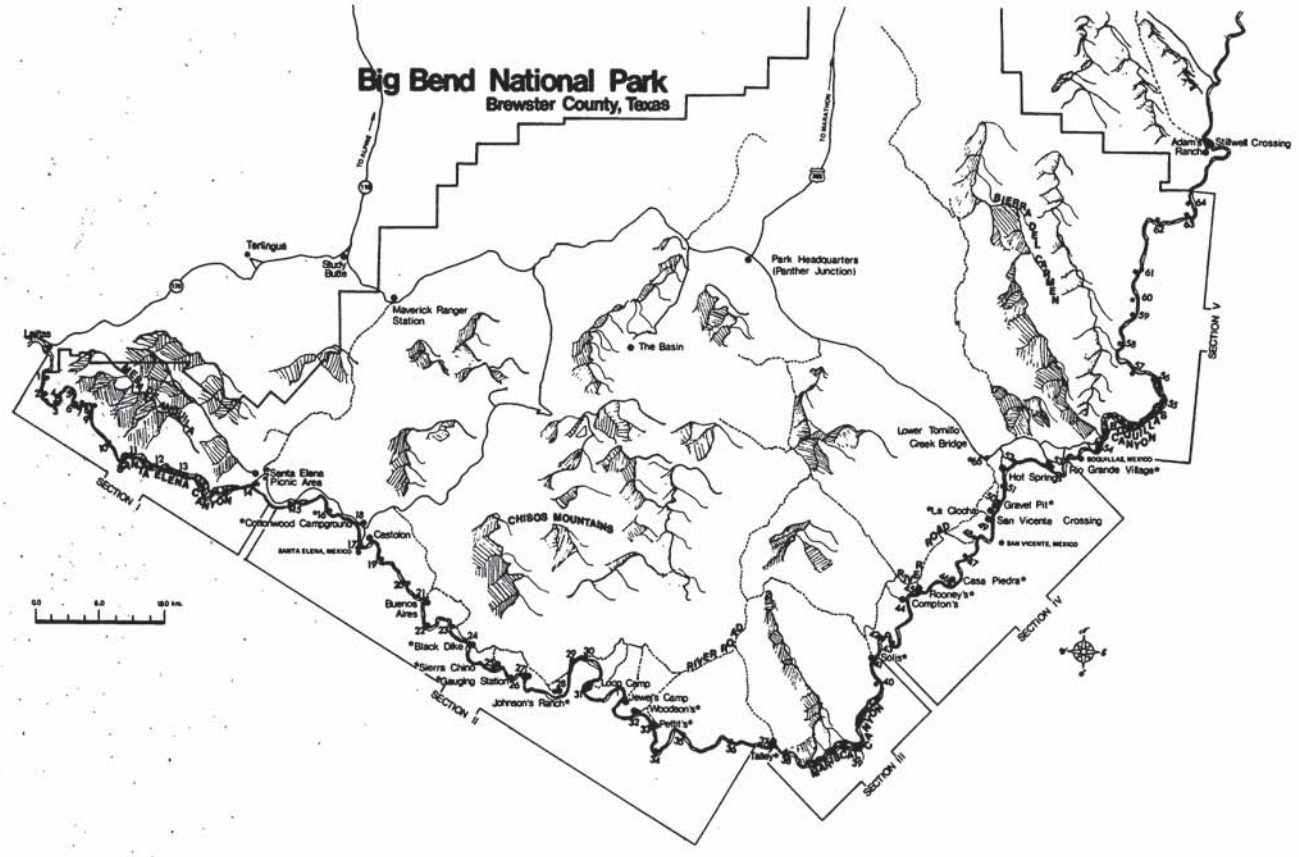

Figure 1.--*Map of the Rio Grande River corridor in BBNP showing the 64 riparian sites investigated during this study. Name places along the river represent backcountry campsites as designated by park officials. Sites with stars represent places where the rodent fauna was sampled. The five river sections discussed in the text are labeled.*

The river was divided into the following five sections based on the location of the three major canyons (fig. 1): I from Lajitas to the mouth of Santa Elena Canyon (including the canyon itself); II from Cottonwood campground to Talley; III from Talley to Solis (including Mariscal Canyon); IV from Solis to Rio Grande Village; and V from Rio Grande Village to the eastern border of the park (including Boquillas Canyon).

RIVER USE

Use occurs both throughout the park's backcountry and at three developed campgrounds where use is already carefully monitored. Use of the backcountry areas, however, is not clearly described by existing record-keeping procedures.

Because almost all of the river corridor lies in the backcountry, our analysis of visitor use patterns focused on backcountry use. Visitors to Big Bend are required to obtain a free permit from park headquarters or any ranger before camping at any backcountry area or floating the Rio Grande, which they turn in at the conclusion of their trip. The primary purpose of this backcountry information system is to facilitate visitor protection.

This system was used as the data base for establishing the extent, character, and patterns of use. The Park Service compiled these data monthly in three categories: nature road use (i.e., camping at primitive campsites with road access); backcountry use (nonvehicular); and boating use (including all forms of water craft). In our analysis, we separated backcountry use of the river from backcountry use of other areas and divided river use into float trips and nature road (River Road) use. Within these two categories, analysis yielded user group-, time- and place-specific information.

We recorded the data using three units of measure: (1) number of parties, (2) number of individuals, and (3) number of man-days. This provided a comprehensive view of use as well as insight into the best measure for establishing human impact. During the project study year (1975), the distribution of backcountry use is shown in table 1.

Table 1. *Distribution of visitors within Big Bend National Park backcountry areas in 1975*

	Parties	Total parties	Man-days	Total man-days
		Percent		*Percent*
Float trip	727	18.7	7,405.5	25.0
River road camping	849	21.8	7,151.0	24.1
Nonriver-oriented camping	2,318	59.5	15,124.5	50.9
Total	3,894	100.0	29,681.0	100.0

Table 1 shows that the Rio Grande attracts approximately 40 percent of total backcountry use (parties) while the desert and mountains account for nearly 60 percent. Using the man-days measure, however, the amount of river-oriented backcountry use is almost equal to the nonriver-oriented camping category.

Float trip and River Road camping patterns were analyzed further because these activities account for nearly all of the recreational use that is associated with the Rio Grande corridor in BBNP.

Float trip activity was broken down according to the functional river subsystems (fig. 1). The distribution of float trips across the 5 river subsystems in 1975 is shown in table 2.

The three canyons accounted for 69 percent of the total float trip parties visiting the Rio Grande Corridor in 1975 (table 2). The 25 percent figure for IV can be explained largely by short day-floats. Using the man-days measure, the three canyons collectively account for 81 percent of all float trips within BBNP. This is a better measure of the distribution of use and related impact on the river corridor because it reflects both the actual number of visitors and the time they spent on the river.

A seasonal dimension was obtained by breaking down use by month because of its value for on-site decision making. This time-and place-specific monitoring of data should signal management as to when use problems are likely to occur.

Table 2.--*Distribution of float trips throughout the Rio Grande subsystems in BBNP in 1975*

Section[1]	Parties	Total parties	Man-days	Total man-days
		Percent		*Percent*
I Santa Elena Canyon	186	22.1	1,637.7	22.1
II (between canyons)	50	5.9	278.7	3.7
III Mariscal Canyon	258	30.7	2,464.5	33.3
IV (between canyons)	210	25.0	1,130.4	15.3
V Boquillas Canyon	137	16.3	1,894.5	25.6
	841[2]	100.0	7,405.5	100.0

[1] See map (Fig. 1)

[2] Total does not agree with total number of float trip parties in table 1 because parties could have floated more than one river section.

The River Road camping category also was broken down on a site-by-site and monthly basis. Camping at designated primitive River Road campsites in Sections II and IV was concentrated at very few sites. Two River Road sites (Gravel Pit and Solis) accounted for 39 percent of total annual River Road site use (man-days) in 1975. Four more sites (Johnson Ranch, Black Dike, Talley and San Vicente Crossing) accounted for an additional 32 percent of total annual River Road use (man-days). Eight of the more remote River Road sites received less than 2 percent each.

Float trips occur mainly in Sections I, III, and V and River Road Camping is limited to designated areas in Sections II and IV except at two of the River Road campsites, Talley and Solis, which also serve as the put-in and take-out points, respectively, for the popular Mariscal Canyon Float Trip. Thus, these sites are the most heavily used areas of the entire back-country riparian corridor. In addition, they are areas where floating and car camping activities overlap.

SUBJECTIVE SITE EVALUATION

A subjective site evaluation sheet was developed as shown in figure 2. The four basic categories are: human impact (six different variables); livestock impact (two variables); site description (three variables); and wildlife characteristics (four variables). Each of the 15 variables is rated on a scale from 1 to 5: 1 represents the most desirable condition; 5, the least desirable condition. For example, 1 is assigned if no litter is present; 3 if litter is apparent; and 5 if litter is obvious everywhere. Scores of 2 and 4 are also possible. Totals were obtained for each of the four major categories. Thus, the total score for the human impact parameter could range from 6 to 30; 6 would indicate no human impact; 30 very heavy impact.

Data were obtained by visiting each of the 64 riparian sites. The number of visits per site varied from one to four and the number of persons filling out the impact forms varied from two to six. Scientists, students, and park personnel filled out the impact forms separately.

Statistical analysis of data provides a powerful "tool" upon which to base managerial recommendations. In working with large data bases, analyzing each variable individually becomes cumbersome and fails to account for the fact that variables often act together to affect a particular condition. For example, tabulation of the site evaluation sheets resulted in a large data base in the form of a 64 X 15 matrix (64 sites, 15 variables), which would be difficult to analyze by considering each variable separately. Multivariate statistics, however, allows one to analyze such a matrix by considering each variable for each site simultaneously. We used two multivariate approaches (cluster analysis and principal components analysis) to structure the site evaluation data base. The following two examples illustrate the utility of multivariate statistics in analyzing data for use in formulating managerial recommendations.

A cluster analysis was used to produce a phenogram that represents a grouping or ordering of sites (based on all 15 variables) closely connected by some relation and separated from other such groups by gaps. The cluster analysis (fig. 3) reveals three major clusters, A, B, and C. Cluster A includes those sites with high impact values; cluster B, those with intermediate impact values; and cluster C, those with

Observer: _____ Profession: _____

Date: __ __/ __ __/ __ __ River site (no.): _____
day month year

River side: M or A

Site class: A, B, C

PARAMETER	RATING	COMMENTS
A. MAN'S IMPACT		
Litter		
Trampling		
Rock moving		
Campfire		
Human waste		
Wood cutting		
TOTAL		
B. LIVESTOCK IMPACT		
Trampling		
Waste		
TOTAL		
C. SITE DESCRIPTION		
Access		
Shoreline vegetation		
Campsite potential		
TOTAL		

D. HABITAT TYPES (check those present)

_____riparian
_____dune
_____gravel beach
_____bench
_____talus slope

E. WILDLIFE CHARACTERISTICS

Habitats	
Unique combinations	
Modifications	
Values and needs	
TOTAL	

Figure 2.--*Rio Grande ecological survey riparian community evaluation sheet.*

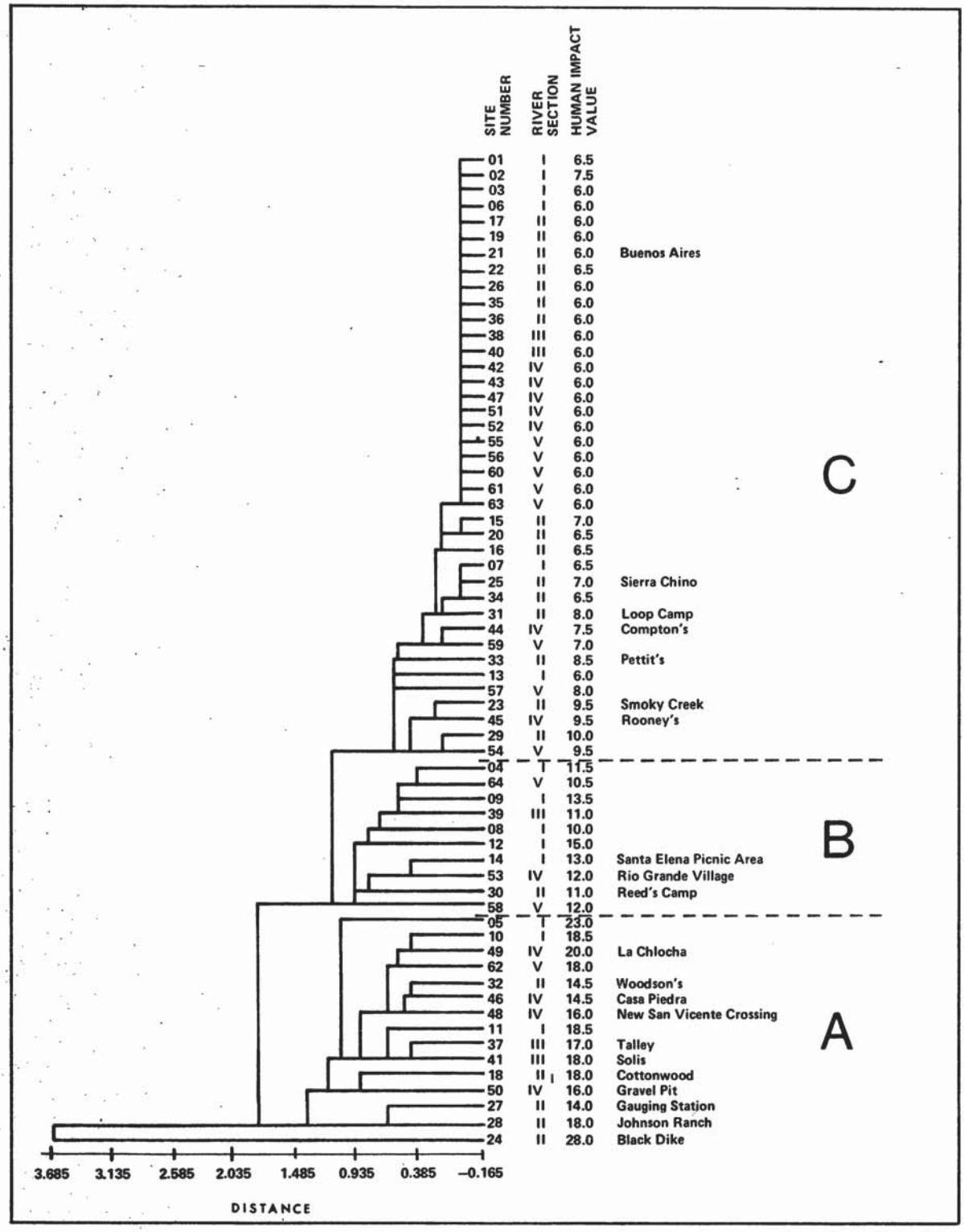

Figure 3.--*Phenogram of numbered riparian sites computed from distance matrices clustered by unweighted pair-group method using arithmetic averages (UPGMA). The major breaks in the phenogram are labeled A, B, and C. The river section and total human impact value for each site are also provided.*

low impact values. Of the 64 sites, 15 (23 percent) fall within cluster A; 10 (16 percent) within cluster B; and 39 (61 percent) within cluster C. Of the 15 sites in cluster A (heavily impacted sites), 11 (70 percent) can be reached by the River Road; whereas of the 39 sites in the least impacted cluster (C), only 7 (18.0 percent) are accessible by the River Road. So the cluster analysis reveals that (1) very few of the riparian sites may be considered heavily impacted; and (2) the majority of the heavily impacted sites are those that may be reached via the River Road.

Principal components analysis (PCA) was used to identify linear combinations of the 15 variables that account for the greatest amount of variation among sites. Principal components I and II account for 56 percent of the total variance and each of the sites is plotted with respect to these components in figure 4. Variables that load heaviest on component I (that is, those variables which account for the greatest amount of variation among riparian sites on this component) are those that relate to human impact and modification (table 3). Component II loads heavily on variables that relate to site description. The loadings for those variables reflecting livestock impact are very low on the first two components. This indicates that livestock impact accounts for very little of the differences among sites: hence, it is a constant along the entire river corridor. The major breaks along component I are depicted by lines A and B in figure 4. Sites to the right of A are the most heavily impacted ones and they correspond exactly with the heavily impacted sites in the cluster analysis. Sites between lines A & B include those that fall in the intermediate impacted category of the cluster analysis. Sites to the left of line B are those that fall into the lightly impacted

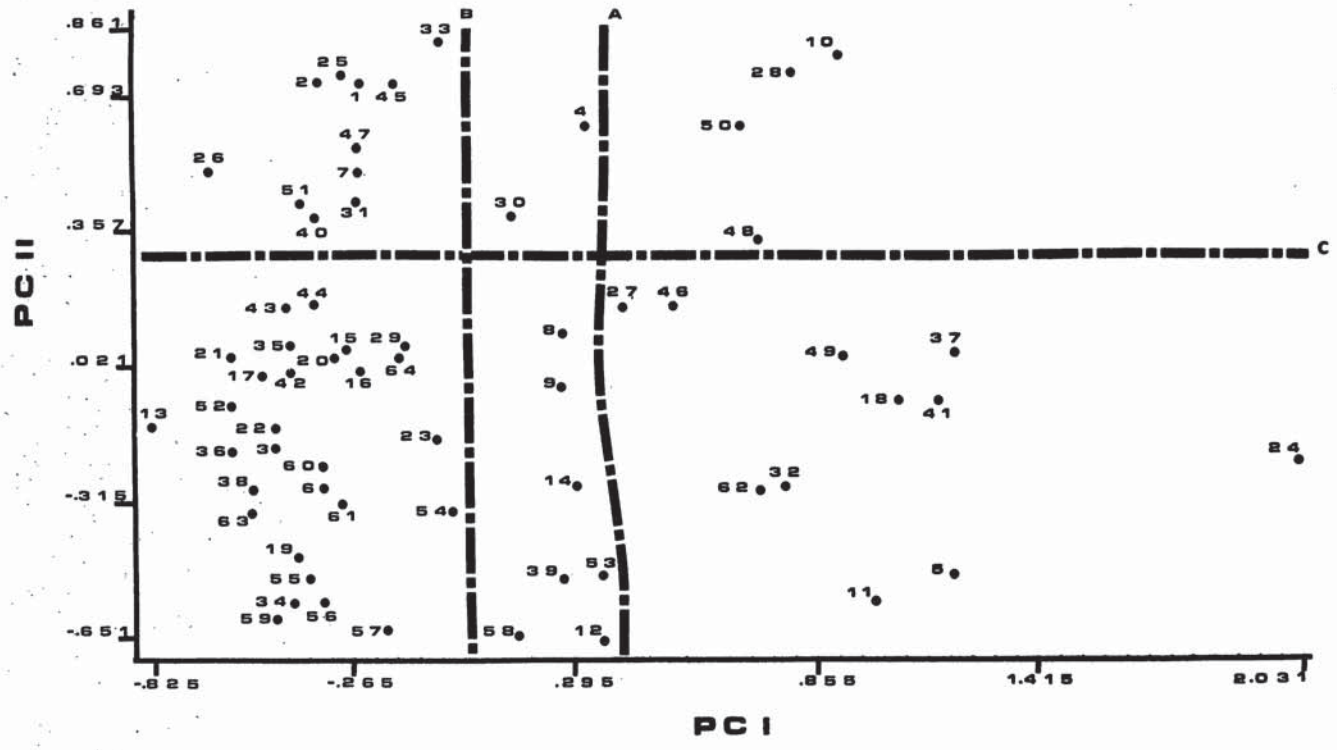

Figure 4.-- *Two-dimensional projections of the first 2 principal components illustrating the position of the 64 riparian sites. Each component represents linear combinations of all 15 variables in proportion to their importance in distinguishing sites. Lines A and B are positioned where the major breaks occur along component I; line C demarks the major break along component II.*

Table 3.--*Factor matrix (or loadings) from correlation matrix among 15 variables for the first two Principal Components. The higher the value for a particular variable the more important that variable is for distinguishing sites.*

Variables	Principal components I(37.44 percent)	II(17.92 percent)
Man's Impact		
Litter	.882	-.136
Trampling	.900	.064
Rock Moving	.864	-.077
Campfire	.868	-.110
Human Waste	.838	-.047
Wood Cutting	.821	.054
Livestock Impact		
Trampling	.305	.475
Waste	.351	.264
Site Description		
Access	.068	.865
Shoreline Vegetation	.148	.797
Campsite Potential	-.279	.763
Wildlife Characteristics		
Habitats	-.106	-.099
Unique Combinations	-.066	.432
Modifications	.851	.181
Values and Needs	.300	.390

cluster. The major break along component II is indicated by line C. Sites above this line have excellent campsite potential; sites below this line have poor campsite potential. Considering the two components together reveals a group of eleven sites in the upper left-hand quadrate of figure 4 that are characterized by having excellent campsite potential and low human impact.

Combining the results of the cluster analysis with that of PCA reveals the following: (1) Those variables that best discriminate riparian sites are those relating to human impact and modification. The sites may be segregated into three basic groups (lightly impacted, moderately impacted, and heavily impacted) on this basis. (2) Variables pertaining to livestock impact are poor discriminators of riparian sites; this indicates that this impact is a constant along the entire river corridor. (3) Very few of the riparian sites may be considered heavily impacted; of these, the majority are distributed along the River Road. (4) A group of sites can be identified that have excellent campsite potential yet very little human impact.

BIOLOGICAL RESOURCE

The biological resource monitored along the river corridor was the rodent fauna and vegetation. Rodents were chosen because: (1) the riparian habitat is the

only major vegetation type in the park in which rodents have not been intensively studied; and (2) rodent densities should be sensitive indicators of significant human and livestock impact. Rodent densities are strongly influenced by vegetative "cover" (spacing and size of the plants). Many types of human and livestock impact (especially trampling) tend to reduce cover. Hence, if severe enough, they could greatly influence the diversity and density of rodents. We sampled the riparian rodent fauna at 18 different sites along the river that exhibited varying degrees of human and livestock impact. Seventeen of these sites were designated as backcountry campsites along the River Road; the other site was located at lower Tornillo Creek bridge. Each site was trapped for 6 nights using 120 Sherman live traps (720 trap nights per site).

Twelve species of rodents occur in the riparian habitats of BBNP and the majority of these (9) are members of the families Heteromyidae and Cricetidae. The remaining three (porcupine, spotted ground squirrel, and beaver) either occur in numbers so small that they are seldom encountered or they are so large they cannot be adequately sampled with the techniques available to us. The total number of cricetid and heteromyid rodents captured at a particular site was used as an indicator of rodent density. Rodent densities (total catches) were then correlated with human and livestock impact values as follows (values represent Pearson Product-Moment Correlations):

	Human Impact	*Livestock Impact*
Heteromyid	-0.177	-0.321
Cricetid	.088	.152
Total	-.071	-.133

None of the correlations between rodent density and human or livestock impacts are significant. Hence, our data suggest that the present extent of impact along the river has not been great enough to significantly affect rodent densities.

MANAGEMENT IMPLICATIONS

Analysis of recreational use patterns or subjective impact alone is of little managerial importance. They need to be campared to determine if a significant correlation exists. The Pearson Product Moment Correlation Coefficient statistic was used to relate total subjective impact ratings by site to annual camping use by site (man-days). The analysis was only possible where we have permit data on use, namely, for the River Road sites. However, these sites are the only locations where significant use of the river corridor occurs. Analysis revealed a positive correlation significant at between the 0.02 - 0.05 (R=0.459) levels. This verifies that subjectively evaluated impact increases as use increases.

When impact and use data were related to biological data (rodent fauna studies), no significant correlations were yielded. The upshot of these two correlation analyses taken together is that site impacts have occurred as a result of recreational use, but not to the point where ecological conditions, as indicated by the biological health of rodent fauna, are in jeopardy.

This suggests that these correlations should be viewed in the context of "change" rather than "impact" (which implies damage). Any recreational use of a resource will result in some change in resource conditions. The critical task for management is to decide what is the acceptable level of physical-biological change. This requires a value judgement as to the *desirability* of changes that are anticipated or have already occurred; i.e., is there excessive deviation from the accepted standard of resource quality? And this acceptable level of change depends on the management objectives of the area.

Plugging study findings into this type of framework yields several observations. Subjective impact ratings do reflect change from natural ecological conditions, and the *relative* amount and type of change by sites. Correlation analysis links this change to levels of use intensity. The task remaining for management is to evaluate the acceptability of the situation that has been identified.

When viewed from a National Park Service-wide perspective, the total recreational use of BBNP and the Rio Grande appears very low. This might lead one to the casual and incorrect conclusion that

recreational impact on the river corridor is not really a problem. This study disaggregates possibly misleading total use figures into area-specific and time-specific data sets that indicate when and where changes exist within the river system and how serious the changes are. While it appears that existing changes have not yet reached the point of constituting serious ecological damage, the changes have been measured in terms of parameters that can be readily perceived by visitors and that are amenable to management. Hence, the observed changes, if deemed undesirable or excessive by management, can be reversed before they lead to serious damage.

Earlier, when total subjective impact scores for 64 river sites were clustered, 49 sites or 77 percent were in the moderately and lightly impacted clusters. Looking at the River Road sites, it is revealing to note that 10 of 18 are shown in the heavy impact cluster. These 10 are all generally related to convenient access; i.e., close proximity to a paved park road or special attractions like the entrance to Santa Elena, Johnson's Ranch, and Mariscal Canyon. Access can therefore be verified as a major component in explaining variation in human impact. While this verification should not be too surprising, it does emphasize the role access plays in distributing human impact.

These impacts can be controlled, shaped, or mitigated because access can be easily manipulated. This is particularly true in Big Bend where use of sites on the River Road is concentrated at 6 sites (accounting for 71 percent of total annual River Road use). Here a washed-out road may be naturally responsible for reducing use at one of the most impacted sites. Deliberate management strategy can have the same result. Use can be rotated among sites either explicitly through permit allocation or implicitly through ranger's suggestions when asked by a party where they should camp. Impacts can be reduced and distributed once management goals are established.

For example, we know how many River Road campsites are among the heavily impacted campsites (10 of 18). Further, principal components analysis indicates that the remaining River Road campsites all possess good campsite potential (also rated subjectively, figure 2) although they are lightly impacted. In other words, the spectrum of suitable campsites available to the River Road user includes 10 heavily impacted and 8 moderately or lightly impacted areas. Is this acceptable? What should the distribution be among the light, moderate, and heavily impacted clusters? Should there be no heavily impacted sites or should sites be equally distributed among these impact clusters? Once this is decided by management, we might know how to respond in terms of impact expected if, for example, the River Road is paved (as has been proposed). Clearly, given our understanding of the correlation of impact and use and the role played by access, increased use of all sites is likely to occur with associated human impacts. Further, human usage may increase to the point where use impacts are a source of significant ecological impact.

In the past, investigators have often done good, thorough research only to find that their results had little effect on resource management. This has occurred because researchers have failed to articulate their findings in terms that are useful to management personnel. It has been our goal to obtain the types of data that BBNP managers need and to present it in such a way as to serve as a useful input to normal managerial decision-making.

Consequently, our recommendations focused on suggesting ways to incorporate study findings into the process of determining management strategies that will achieve the objectives sought. Based on a review of pertinent literature relative to resource allocation decision-making, several critical decision points can be identified:

Decision 1.--Select management objectives
Decision 2.--Determine whether existing situation conflicts with management objectives
Decision 3.--If a discrepancy exists, select management tools and strategies to meet objectives
Decision 4.--Evaluate results of implementation of management strategies, including monitoring of environmental conditions.

Clearly, the selection of management objectives serves as the basis of the

entire suggested decision-making framework. This is the responsibility of NPS management personnel. Findings from this research, though, should play an important role as an input to Decisions 2 and 3, while additional research will be needed in the future before Decision 4 can be considered.

ACKNOWLEDGMENT

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