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Cooperative National Park Resources Studies Unit

ARIZONA

TECHNICAL REPORT NO. 35

NOCTURNAL RODENT POPULATIONS AND ASSOCIATED VEGETATION WITH IMPLICATIONS OF HUMAN USE AT SAGUARO NATIONAL MONUMENT, ARIZONA

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COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT
University of Arizona/Tucson - National Park Service

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by

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November 1990

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ABSTRACT

I obtained densities of nocturnal rodents in the saguaro (*Carnegiea gigantea*) forest of Saguaro National Monument, Arizona with live trapping techniques, in 1984 and 1985. I sampled vegetation density, percent cover, and foliage height diversity. My objective was to determine if humans influenced nocturnal rodents and their habitat. Rodent populations and vegetation were analyzed through 2-way analysis of variance. Few significant differences were determined for rodent numbers between experimental and control plots. My findings show that minimal impact has occurred on rodent populations and on vegetation by humans in Saguaro National Monument.

INTRODUCTION

Saguaro National Monument consists of two separate units: the Rincon Mountain Unit (RMU) established in 1933 and the Tucson Mountain Unit (TMU) established in 1961. When the monument was established, Tucson had a population nearing 35,000. Today, metropolitan Tucson's population approximates 400,000 with projections of 750,000 by 2000 (Arizona Department of Economic Security *fide* Arizona Daily Star 20 Jan. 1986). This greater than 10-fold population increase in 53 years has led to rapid urbanization of land adjacent to the monument's boundaries. The Coronado National Forest borders the southernmost, eastern, and most of the northern boundaries of RMU. Elsewhere, development has occurred next to RMU along the western boundaries. Tucson Mountain County Park buffers only part of the southern boundary of TMU. Human developments in west Tucson and Avra Valley are encroaching the unbuffered TMU boundaries.

Tucson's population growth has been paralleled by an increased demand for outdoor recreation and a subsequent increase in visitor use at Saguaro National Monument (Shand and Underhill 1985). Monument visitation was 1,671,641 in 1984, 2,274,531 in 1985, 2,484,024 in 1986, 1,989435 in 1987, and 2,126,548 in 1988 (Denver Service Center files 1986; M. Engler, pers. commun.). Monument personnel are aware that increasing urbanization and visitor use affects the monument's wildlife and plant resources, but they have not known to what extent. Impacts presently visible include vegetation destruction by trampling, theft, and vandalism (Bennett, Johnson, and Kunzmann 1987); fuelwood cutting; soil compaction and erosion; wildlife harassment by domestic pets; and the presence of food and garbage that can alter wildlife habits and populations (Duek and Mortensen 1980; Shand and Underhill 1985). Concerns about possible impacts to the monument led the Superintendent to name the proposed project, "A Human Impact Assessment, RMU and TMU", as priority number one in the monument's resources management plan (Saguaro National Monument 1983). This human impact assessment has two components: sociological/recreational and biological/ecological. The sociological report is complete (Shand and Underhill 1985). This report covers the ecological assessment. In addition, Davis and others have trapped rodents in the Rincon Mountain high country (Davis, Sidner, and Cockrum, unpubl. rep., University of Arizona, 1986; Davis and Ward 1988).

I collected data on vegetation and nocturnal rodents for the ecological assessment. The information I gathered was used to determine impacts and to serve as a baseline for easier determination of future impacts. Nocturnal rodents were censused because their population densities can be useful indicators of significant human impact (Schmidly et al. 1976; Ditton et al.

1977) and because rodents are comparatively easily censused (Hanley and Page 1981). Rodents are often the only mammals seen by visitors, therefore visitors are interested in having rodents present (Clevenger and Workman 1977). Large plot censusing was conducted during population peaks, to provide a comparable population estimate for each plot. Roadside plot trapping was not done during population peaks; but was done during time periods when the populations of each plot were comparable. The nocturnal rodents were live trapped rather than snap trapped to reduce any possible impacts to rodent populations and to conform to Park Service policy. Live traps have been shown to be more effective than snap traps (Cockrum 1947) but there is conflicting evidence (Duran 1968). Rodents are important parts of the community food-web as potential prey for many animals (Hanley and Page 1981) and in total they also consume large quantities of food. I attempted to determine if visitor use caused any long term changes in rodent populations or their habitats.

STUDY AREA

Rincon Mountain Unit ranges in elevation from 818 to 2,626 m and in vegetation from Arizona Upland to Petran Montane Conifer Forest (Brown and Lowe 1977). It is about 8 km east of Tucson, Arizona and encompasses 24,810 ha. Tucson Mountain Unit, in the Arizona Upland Subdivision of the Sonoran Desert (Brown and Lowe 1977), ranges from 612 to 1,419 m in elevation and is about 16 km west of Tucson. It has an area of 8,533 ha.

Saguaro National Monument occurs in a region with a hot, arid climate. But, compared to that occurring in Tucson (Sellers and Hill 1974), RMU is wetter, the high temperatures lower, and the low temperatures higher (Saguaro National Monument, fire weather, unpubl. files, 1986; National Weather Service, Tucson International Airport, unpubl. data). Tucson Mountain Unit (Arizona-Sonora Desert Museum data from Sellers and Hill 1974) has greater temperature highs and lows, and less precipitation than Tucson. During the study, temperatures were approximately normal in Tucson. Precipitation was above average, 1983 being one of the wettest years recorded (Figure 1). Average annual precipitation in Tucson is 28.30 cm (National Weather Service, Tucson International Airport, unpubl. data).

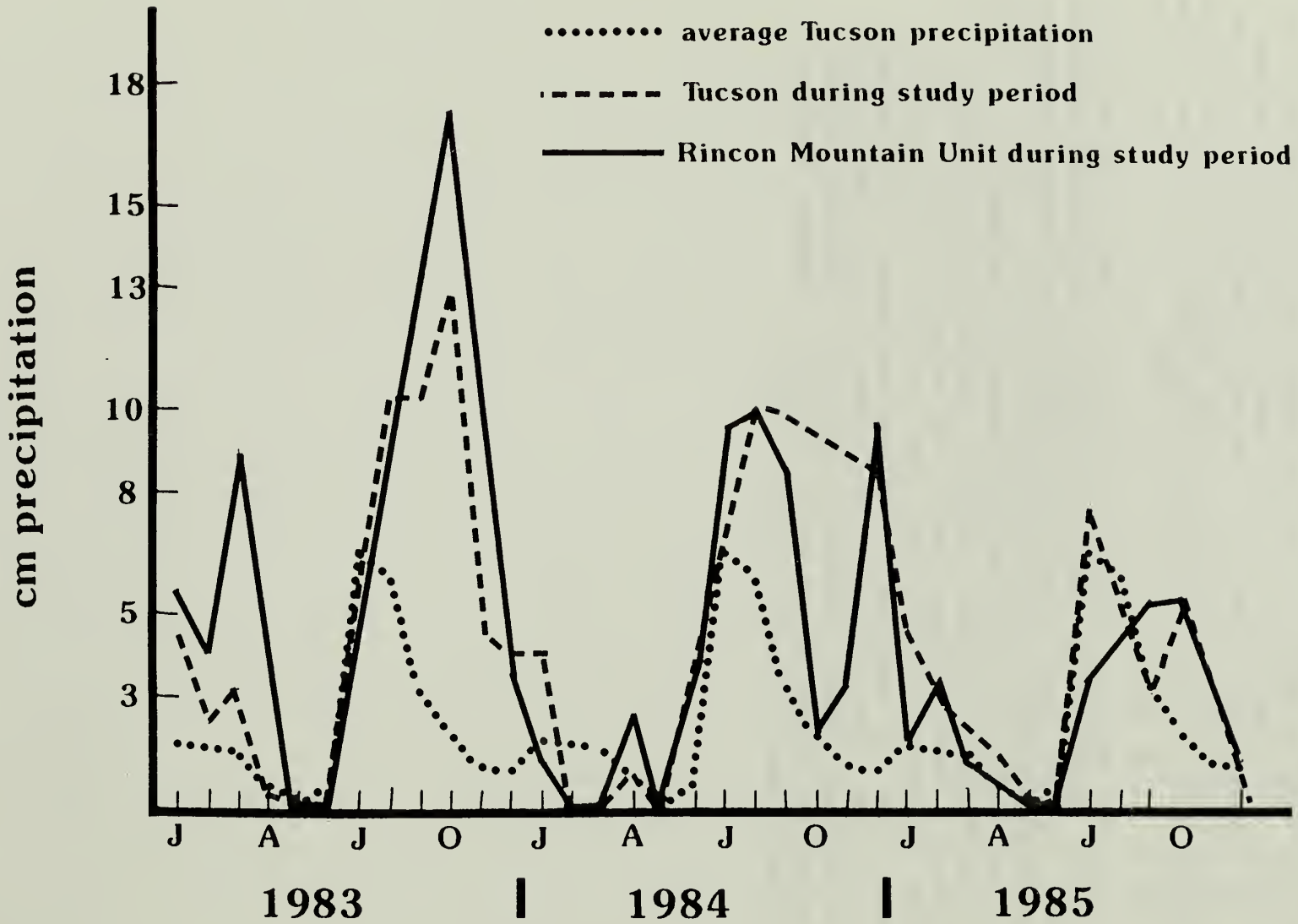

Figure 1. Monthly precipitation (cm) at Rincon Mountain Unit, Saguaro National Monument and Tucson, Arizona (1983-85), including Tucson's average monthly precipitation.

METHODS AND MATERIALS

TRAPPING

All animals were trapped within the two-week period surrounding a new moon. A peanut butter and rolled oats mixture was used for prebaiting and trap baiting. All 14 plots were trapped for one 4-6 night trapping period per year to obtain an instantaneous population estimate. The 4 to 6 night period is intermediate to the two nights reported by Y. A. Petryszyn (University of Arizona, pers. commun.) and Beatley (1969) and the 11 nights of O'Farrell and Austin (1978) and should be sufficient to determine population densities. Population estimates from longer trapping periods may be affected by death, birth, emigration, and immigration. Because of this, longer trapping periods require greater effort and larger sampling grids (O'Farrell and Austin 1978). To increase the catch, a space was prepared on the ground for locating a trapping station and attracting rodents by clearing a space of vegetation and rocks. Bait was placed at each station the night previous to the trapping period (prebaiting). Traps were set in late afternoon, checked midway through the night, and checked and picked up the next morning. Traps were not checked at night if a thunderstorm was occurring. In most cases (85%) this did not cause reduced captures. However, when the linear regressions used to determine populations were poor ($r < 0.7$), I combined that night's data with the data from the night before to the rainy night (Olding 1976). Combining nights resulted in better (higher) r values. The sequence of baiting and checking traps was alternated each day between the experimental and control areas (Clevenger and Workman 1977) to reduce bias. Aluminum Sherman live-traps, 8 x 8.5 x 23 cm were used. When a rodent was captured, I identified it to species, and gave it a uniquely identifiable toe-clip (Beatley 1969; Price 1978). I then recorded body measurements, sex, reproductive condition, and age, of each animal before they were released near the station at which it was trapped. The Mica View Picnic Area plots (trapped in January) and the roadside plots (trapped January to March) were not checked at night. Toilet paper (for warmth) and approximately 4 g of bait were put in each trap to help the rodents survive the cold nights.

I determined rodent densities using Petryszyn's (1982) methods for density estimation (see also Dice 1938). In this method, the home range radius is added to the grid boundaries to determine the effective sample area for each species (Dice 1941; Whitford 1976). The following home range radii (circular home range) were used: 14 m for the rock pocket mouse (*Perognathus intermedius*), 15 m for the desert pocket mouse (*P. penicillatus*) and white-throated wood rat (*Neotoma albigula*), 17 m for the Arizona pocket mouse (*P. amplus)* and Bailey's pocket mouse (*P. baileyi*),

20 m for Merriam's kangaroo rat (*Dipodomys merriami*)(Petryszyn 1982), 25 m for the cactus mouse (*Peromyscus eremicus*)(Bateman 1967), and 30 m for the Arizona cotton rat (*Sigmodon arizonae*)(combining values from Howell 1954 and Goertz 1964).

Large Plots

Paired experimental and control plots were trapped after the method of Clevenger and Workman (1977). These large plots were located next to human-use areas such as picnic grounds (Figures 2 and 3). Each area had an experimental plot that was placed adjacent to each human-use area, and a control plot nearby in similar but undisturbed habitat. In similar studies by Aitchison (1977) and Clevenger and Workman (1977), human use of sites was inferred rather than quantified. Differences between my plots were visually obvious because of the greater amount of bare ground on the experimental areas as found in similar studies by Foin et al. (1977) and Schreiner and Moorhead (1979). Each experimental and control plot grid had eight rows with eight stations each. Spacing between stations and rows was 15 m (Figure 4). These plots were live trapped in June and July of 1984 and 1985. Each plot was trapped one 5-day period a year.

The Mica View-Freeman Road plots were exceptions (Figure 5). Plots 1 and 3 were experimental ones and plot 2 was the control. Each plot had 50 trap stations, in five rows of 10 stations, with 15 m spacing. These plots were trapped in January 1984 and 1985, once each year, for five nights each time. Most trapping was done in the summer because rodent populations are highest then (M'Closkey, unpubl. rep., National Park Service, n.d.).

Roadside Plots

I conducted the roadside trapping portion of the study along the Cactus Forest Loop Drive at RMU by live trapping nocturnal rodents. In 1984, six areas were trapped along the Loop Drive. In 1985, three additional areas were trapped. The nine areas were distributed relatively equally along the drive. Each area had one experimental and one control plot. The experimental plot was adjacent to a road pullout that showed signs of heavy human use (e.g., trampling). The control plot was within 500 m in similar habitat that showed little human use, and was also along the road (Figure 6).

Each trap grid contained three lines parallel to the road with five traps each, 10 paced m apart (15 traps/plot). Each plot was trapped for four to six consecutive nights each trapping period,with one night of prebaiting. Plots were trapped once a year, for an instantaneous density measure. All mammals I saw or captured are listed in Appendix A (Hoffmeister 1986).

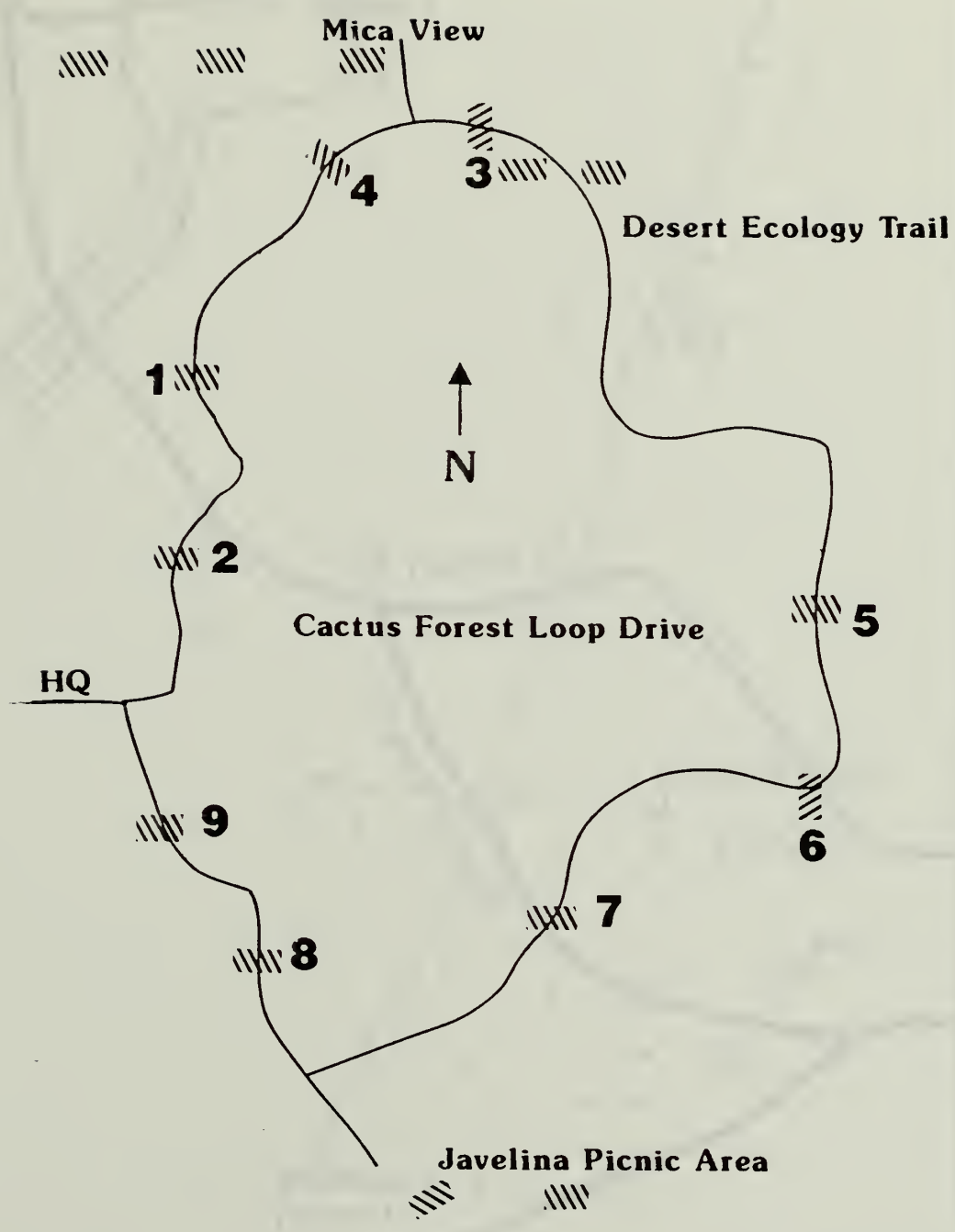

Figure 2. Map of plot locations at Rincon Mountain Unit, Saguaro National Monument, Arizona, 1984-85.

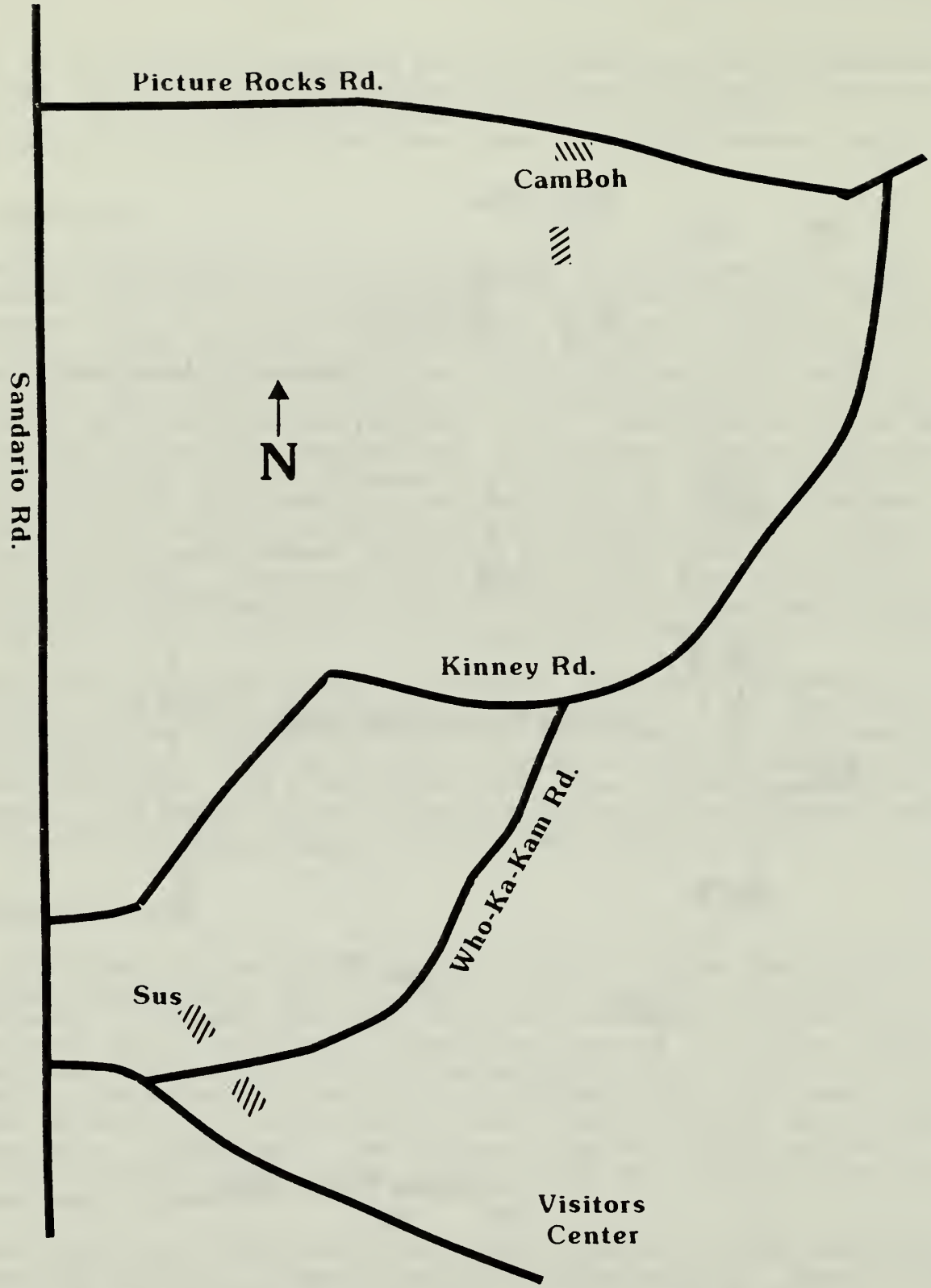

Figure 3. Map of plot locations at Tucson Mountain Unit, Saguaro National Monument, Arizona, 1984-85.

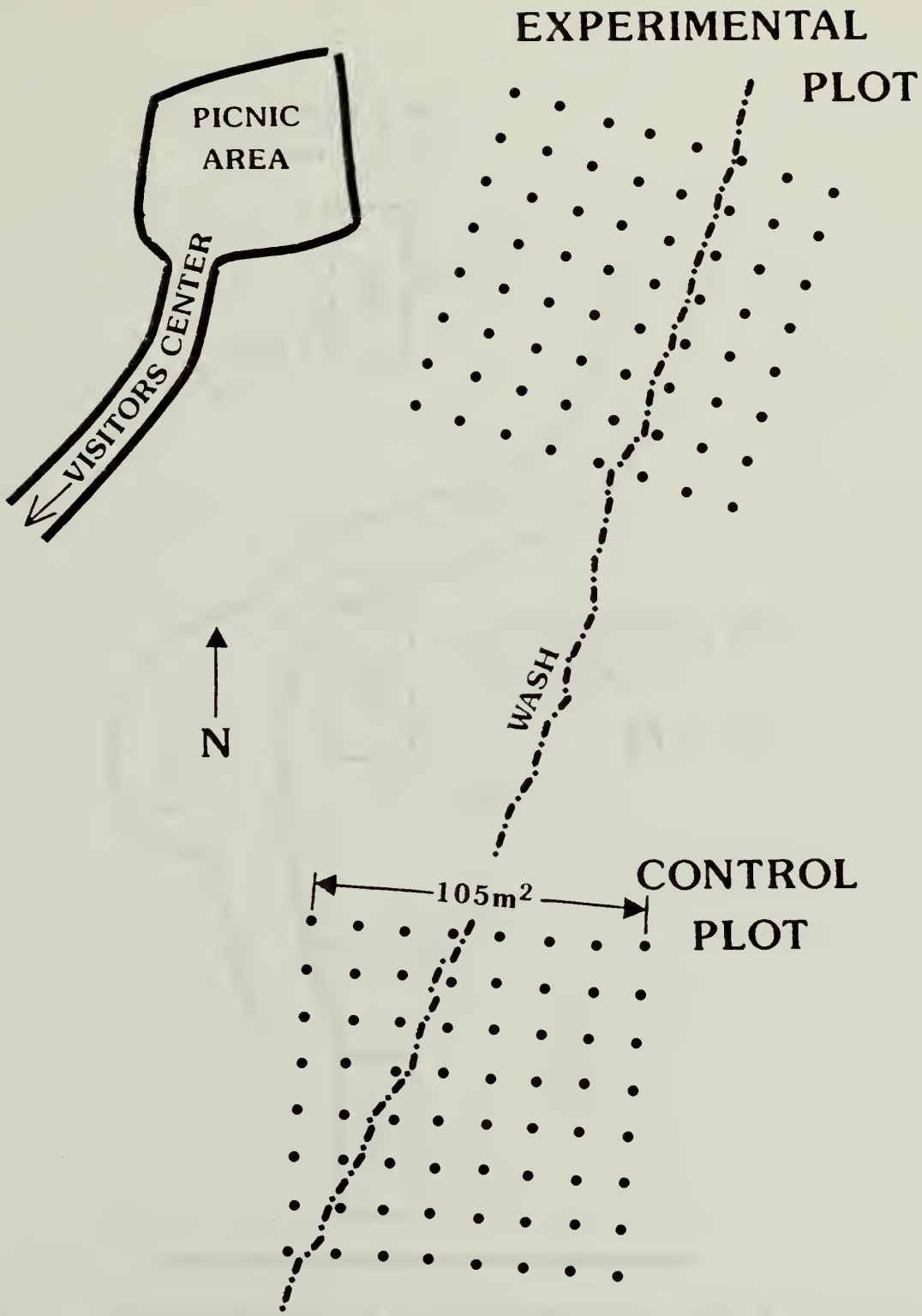

Figure 4. Example large plot layout, Javelina Picnic Area, Rincon Mountain Unit, Saguaro National Monument, Arizona, 1984-85.

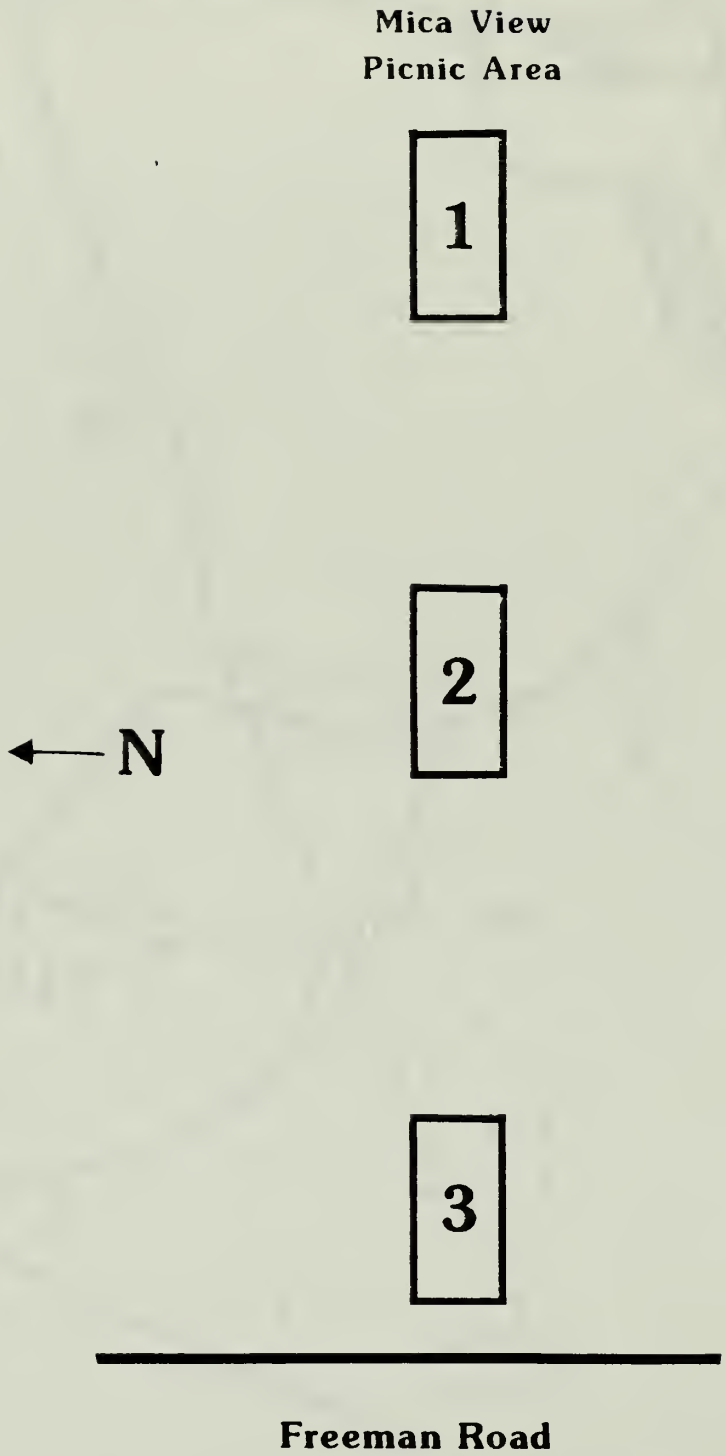

Figure 5. Layout of Mica View Picnic Area plots, Rincon Mountain Unit, Saguaro National Monument, Arizona, 1984-85.

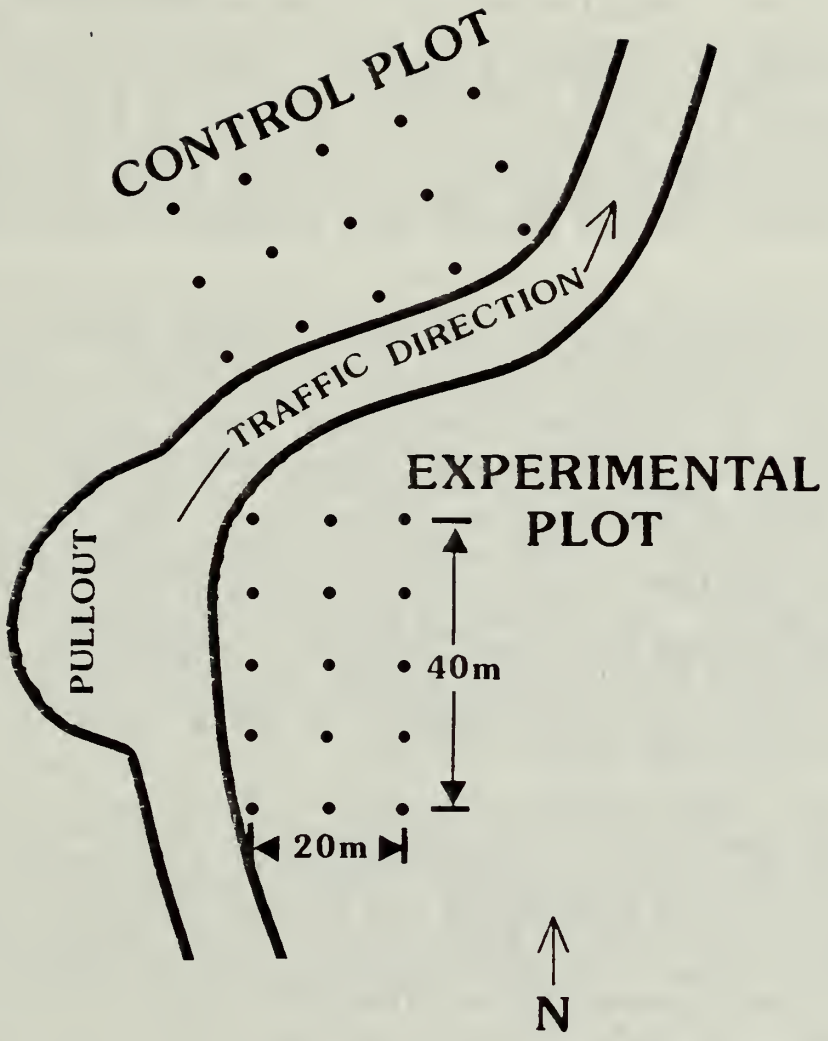

Figure 6. Sample diagram of a roadside plot, plot #3, Rincon Mountain Unit, Saguaro National Monument, Arizona, 1984-85.

VEGETATION

Large Plots

On each plot, I sampled density, percent cover, and foliage height diversity at 10 random points to describe vegetation characteristics. Sampling points corresponded with trapping stations. Random compass points were chosen with a random number table to determine transect direction. Density counts were obtained by counting the number of plants in a 4 x 8 m plot; all adult perennial plants that had 1/2 or more of their bases inside the plot boundaries were counted. Percent cover was measured using a 25 m line intercept (Mueller-Dombois and Ellenberg 1974); the live portions of all plants were measured to the nearest 0.1 m.

From the 10 random samples, the sample number needed for the entire plot was determined using the equation $\mathbf{n} = (\mathit{ts}/\mathbf{E})^2$ (Avery 1975) where **n** is number of required samples; *t* is *t* value, **p** = 0.1, 9 df; **s** is standard deviation; and **E** is the desired half-width of the confidence interval. The variable tested with the equation was number of plant species on each transect. Any additional samples required were then done. For analysis of density and cover data, the vegetation was grouped into the following categories: grass, trees, large shrubs, herbs, small shrubs, and cacti. Cacti were a subgroup not exclusive of the other categories and were used because of reports on the importance of cacti to certain rodent species (Brown, Lieberman, and Dengler 1972). Similar vegetation groupings were used by Wondolleck (1975) and Price (1978).

Because plant life-forms are important indicators of habitat structure (Thomas et al. 1976; Bossenbroek et al. 1977), I measured foliage height diversity (FHD) following MacArthur and MacArthur (1961) and Rosenzweig and Winakur (1969) to address this concern. A 5 x 23 cm board divided into rectangles was used to estimate coverage. To determine **F** (relative amount of foliage), I used Rosenzweig and Winakur's equation (1969): $(\mathbf{r}_1 + \mathbf{r}_2/2)(\mathbf{h}_1 - \mathbf{h}_2) = \mathbf{F}$, where **h** = height and **r** = reciprocal of distance measured to board. Foliage height diversity measurements were taken at heights of 7.6, 15, 30, 61, and 152 cms (corresponding to the 0.25, 0.5, 1, 2, and 5 foot measurements of Rosenzweig and Winakur, respectively).

Roadside Plots

A pace transect was used to sample vegetation on these small plots (Hays, Summers, and Seitz 1981). I paced two diagonal transects, connecting the opposite corners of each plot, making an "X" pattern across the plot. Data recorded included live annual and perennial plants, rock, and bare soil. Whatever was

visible at the boot tip at every other step was recorded. These data give percent cover for the plot. Appendix A contains a list of common and scientific names of plants (Kearney and Peebles 1951; Bowers and McLaughlin 1987).

STATISTICAL PROCEDURES

Population sizes were estimated using linear regression (DeLury 1947; Hayne 1949; Olding 1976; Petryszyn 1982). With this method, the x-axis of the regression is the total number of individuals previously caught, and the y-axis is the number of new individuals caught for one day. The x-intercept of a line fitted to the data points is the assumed population size.

Two-way analysis of variance (ANOVA) was used to test for differences between experimental and control plots for rodents and vegetation. Tests were done comparing experimental and control for each large (rodent density) and roadside (population estimate) plot for 1984, 1985, and both years combined. Vegetation data were similarly tested. Additional tests were done on each species and vegetation parameter, comparing experimental and control for 1984, 1985, and both years combined, for large plots and roadside plots. Ranked values were also tested for significant differences this way. Foin et al. (1977) accepted $p = 0.15$ as significant for some of their statistical tests. Many other studies (Beck and Vogl 1972; Reichmann and Van De Graaf 1973; Schreiner and Moorhead 1979) use a significance level of $p = 0.05$. I used a significance level of $p = 0.10$. The larger significance level, as opposed to a smaller one, is more useful in detecting changes that might otherwise go unnoticed (Daniel 1983:364), but is subject to greater error (R. O. Kuehl, University of Arizona, pers. commun.). For example, if the null hypothesis states that there has been no change, the probability that the null hypothesis will be rejected when it is true is equal to the significance level. Lower significance levels decrease the chance of failing to reject the null hypothesis when it is false (Iman and Conover 1983:210-211).

RESULTS

TRAPPING

Large Plots

The density estimates on all plots ranged from 0 to 11 Arizona pocket mice/ha, 1 to 24 Bailey's pocket mice, 0 to 28 desert pocket mice, 0 to 6 rock pocket mice, 0 to 4 Merriam's kangaroo rats, 0 to 5 cactus mice, 0 to 16 Arizona cotton rats, 3 to 30 white-throated wood rats, and from 16 to 52 total rodents/ha (Tables 1a and b). Density estimates were lower in 1985 than in 1984 with few exceptions. There was little difference between experimental and control plots.

As a comparison, I calculated home ranges for rodents I caught more than 3 times using Metzgar and Sheldon's (1974) method. Calculated home range radii were 14 m for Arizona pocket mice ($n = 3$), Bailey's pocket mice ($n = 4$), and desert pocket mice ($n = 6$); 16 m for one cactus mouse, 19 m for Arizona cotton rats ($n = 7$), and 17 m for white-throated wood rats ($n = 6$). No individual rock pocket mice or Merriam's kangaroo rats were captured more than three times.

There were no significant differences ($p < 0.10$) in my estimates of home range from previous studies for Arizona pocket mice, Bailey's pocket mice, desert pocket mice, cactus mice, and white-throated wood rats (*t*-test). Calculated home ranges for Arizona cotton rats were significantly different from expected ($p = 0.01$). Because of my small sample size, the home range estimates of the other investigators were used in the analyses.

Two-way ANOVA tests were applied to rodent densities and ranked densities to determine significant differences between experimental and control plots (Table 2). Tested were differences between experimental and control plots for a single species and all species on a plot for 1984, 1985, and both years combined. Few significant differences were found. The number of Arizona pocket mice was significantly higher on the control plots.

Number of male and female captures were tested using two-way ANOVA to determine if capture rates were different between the sexes (Table 3). More females were captured for all cases with significant differences.

Roadside Plots

Roadside plot population estimates were slightly higher in 1985 (Tables 4a and b). The estimates for Arizona cotton rat,

Table 1a. Large plot rodent density estimates, number/ha, with 95% confidence intervals (below density estimate), Saguaro National Monument, Arizona, 1984.

Plot	APM[a]	BPM[b]	DPM[c]	RPM[d]	MKR[e]	CM[f]	ACR[g]	WTWR[h]	Total
Mica View 1(X)[i]	0	13	4	0	0	0	1	6	24
		16-10	5-3				2-1	7-4	28-20
Mica View 2(C)[j]	0	9	2	0	4	0	3	13	31
		11-8	3-2		6-2		3-2	18-8	35-27
Mica View 3(X)	0	3	1	0	1	0	5	14	24
		4-1	3-0		1-1		7-3	20-8	30-18
DET[k] X	1	8	11	0	1	0	16	5	42
	2-1	10-7	15-8		2-0		19-14	8-3	47-37
DET C	6	9	20	0	0	0	8	4	47
	8-4	12-7	22-17				8-7	5-3	53-41
Javelina X	0	11	0	6	0	3	3	18	41
		12-11		8-5		3-2	4-2	19-16	45-36
Javelina C	0	20	0	1	0	5	2	20	48
		25-16		2-1		7-5	3-1	23-16	54-42
Camboh X	1	4	27	2	1	0	0	5	40
	2-1	5-4	30-24	2-1	2-1			7-3	43-37
Camboh C	1	4	28	1	1	0	0	3	38
	2-0	5-4	33-23	1-1	1-1			4-3	44-32
Average X[l]	0	8	9	2	1	1	5	10	34
Average C[m]	2	11	13	1	1	1	3	10	41
Average, total[n]	1	9	10	1	1	1	4	10	37

[a] Arizona pocket mouse
[b] Bailey's pocket mouse
[c] desert pocket mouse
[d] rock pocket mouse
[e] Merriam's kangaroo rat
[f] cactus mouse
[g] Arizona cotton rat
[h] white-throated wood rat
[i] experimental plot
[j] control plot
[k] Desert Ecology Trail
[l] average of experimental plots
[m] average of control plots
[n] average of all plots

Table 1b. Large plot rodent density estimates, number/ha, with 95% confidence intervals (below density estimate), Saguaro National Monument, Arizona, 1985.

Plot	APM[a]	BPM[b]	DPM[c]	RPM[d]	MKR[e]	CM[f]	ACR[g]	WTWR[h]	Total
Mica View 1 (X)	0	2 3-1	2 3-1	0	0	0	6 8-3	7 8-6	17 22-12
Mica View 2 (C)	0	6 9-4	1 3-0	0	3 3-2	0	4 6-3	10 12-7	24 27-21
Mica View 3 (X)	0	5 7-3	0	0	0	0	2 2-1	17 20-13	24 28-20
DET X	1 1-1	16 17-13	11 12-9	0	0	0	12 14-11	12 14-10	52 59-45
DET C	2 2-1	16 17-14	14 15-13	0	0	0	5 6-3	17 18-17	44 46-42
Javelina X	0	7 8-5	0	1 1-0	0	2 2-2	0	30 33-28	40 44-36
Javelina C	1 1-0	11 12-9	0	0	0	3 4-2	1 2-1	15 17-14	31 34-28
Camboh X	0	1 2-1	9 10-8	0	0	0	0	6 7-5	16 18-14
Camboh C	3 4-2	1 1-0	16 16-15	0	2 2-2	0	0	5 8-3	27 29-25
Sus X	10 11-8	24 25-22	1 2-1	0	1 3-0	1 1-1	0	6 7-5	43 47-38
Sus C	11 13-9	17 18-16	2 4-0	0	0	0	0	4 5-3	34 37-31
Average X	2	9	4	0	0	1	3	13	32
Average C	3	10	6	0	1	1	2	8	31
Average, total	3	10	5	0	1	1	3	11	34

[a] Arizona pocket mouse
[b] Bailey's pocket mouse
[c] desert pocket mouse
[d] rock pocket mouse
[e] Merriam's kangaroo rat
[f] cactus mouse
[g] Arizona cotton rat
[h] white-throated wood rat

Table 2. Significant (p = 0.10) two-way ANOVA test results on vegetation characteristics and rodent density estimates for all large plots, Saguaro National Monument, Arizona, 1984-85.

Year	Variable	Significance = p
Both[a]	Baileys PM[b] #[c]	0.1
Both	Arizona PM #	0.1
1985	" r[d]	0.1
Both	" r	0.1
Both	Merriam's KR #	0.1
Both	% cover #	0.025
Both	% large shrubs #	0.1
Both	large shrubs/ha #	0.025
Both	% large shrubs r	0.05
Both	large shrubs/ha r	0.05
Both	% small shrubs #	0.1

[a] both 1984 and 1985
[b] pocket mouse
[c] number values tested
[d] ranked values tested

Table 3. Significant (p = 0.10), two-way ANOVA test results on male/female captures for large plots, Saguaro National Monument, Arizona, 1984-85.

Species	Plot	Year	Most Captures	Significance = p
Arizona PM	B[a]	B	F[b]	0.05
Desert PM	B	B	F	0.1
Desert PM	B	1984	F	0.1
Total rodents	C[c]	1984	F	0.1
Total rodents	B	1984	F	0.025
Total rodents	C	B	F	0.01
Total rodents	B	B	F	0.005

[a] both experimental and control plots
[b] female
[c] control plot

Table 4a. Roadside plot rodent population estimates (#/plot), with 95% confidence intervals below, Rincon Mountain Unit, Saguaro National Monument, Arizona, 1984.

Plot		APM	BPM	DPM	RPM	MKR	CM	ACR	WTWR	Total
#1	X	0	8 9-6	0	0	0	0	1 4-0	5 7-2	14 16-10
	C	0	11 15-7	0	0	0	0	0	6 9-2	17 19-15
#2	X	1 2-0	5 6-3	0	0	2 2-2	0	0	0	8 11-5
	C	0	3 4-1	0	0	0	0	3 5-2	1 1-1	7 10-6
#3	X	0	11 14-8	1 1-1	0	0	0	0	2 2-2	14 16-12
	C	0	7 10-4	3 4-1	0	1 1-1	0	2 3-1	2 3-1	15 21-8
#4	X	2 3-1	7 9-5	7 11-4	0	1 1-1	0	0	0	17 22-12
	C	1 1-1	6 8-5	4 6-2	0	0	0	1 1-1	0	12 15-9
#5	X	0	11 15-7	0	1 1-1	0	11 12-9	0	1 2-0	24 26-22
	C	0	9 10-8	0	0	0	5 6-3	0	3 4-2	17 20-14
#6	X	0	16 20-12	0	0	0	2 3-1	3 4-2	2 3-1	23 27-19
	C	0	12 18-6	0	0	0	2 3-1	1 1-1	2 3-1	17 21-13
Average X		1	10	1	0	1	2	1	2	17
Average C		0	8	1	0	0	1	1	2	14
Total		0	9	1	0	0	2	1	2	15

Table 4b. Roadside plot rodent population estimates (#/plot), with 95% confidence intervals below, Rincon Mountain Unit, Saguaro National Monument, Arizona, 1985.

Plot		APM	BPM	DPM	RPM	MKR	CM	ACR	WTWR	Total
#1	X	0	6	0	0	0	0	2	9	17
			10-3					3-2	11-8	21-14
	C	0	8	0	0	0	0	1	15	24
			13-2					2-0	17-13	27-20
#2	X	0	9	5	0	0	0	1	0	15
			10-7	7-4				1-1		24-6
	C	1	11	0	0	0	0	4	3	19
		2-0	12-9					6-2	4-1	20-17
#3	X	0	15	2	0	0	0	0	4	21
			18-12	4-1					5-4	24-18
	C	0	11	0	0	0	0	7	1	19
			14-8					11-4	1-1	22-16
#4	X	0	3	7	0	0	0	1	1	12
			4-2	8-5				1-1	1-1	14-11
	C	1	2	2	0	0	0	3	2	10
		2-0	3-1	3-1				6-0	3-1	11-8
#5	X	0	12	0	0	0	11	0	3	26
			14-10				13-8		4-2	28-24
	C	0	15	0	1	0	0	0	3	19
			18-12		2-0				4-2	23-16
#6	X	0	4	0	0	0	0	5	2	11
			6-2					7-3	2-2	16-7
	C	0	4	0	0	0	4	5	2	15
			6-2				6-2	7-4	3-1	19-12
#7	X	0	2	0	0	0	0	5	0	7
			3-2					7-4		8-6
	C	0	9	0	0	0	5	8	0	22
			11-6				5-4	11-5		25-19

Table 4b (Continued).

Plot		APM	BPM	DPM	RPM	MKR	CM	ACR	WTWR	Total
#8	X	0	11 12-9	0	0	0	2 3-1	0	3 7-0	16 21-11
	C	0	16 18-13	0	0	0	0	0	4 5-2	20 23-16
#9	X	2 3-2	8 10-5	0	0	2 2-2	0	0	5 6-3	17 21-13
	C	1 2-0	6 10-1	0	0	2 3-1	0	1 2-0	4 5-3	14 18-11
Average X		0	8	2	0	0	1	2	3	16
Average C		0	9	0	0	0	1	3	4	18
Total		0	8	1	0	0	1	2	3	17

white-throated wood rat, and total rodent populations were higher; Bailey's pocket mice, Merriam's kangaroo rats, and cactus mice were lower; and Arizona pocket mice, desert pocket mice, and rock pocket mice showed no change.

Rodent death in traps due to cold was considered insignificant, being 4.6% (28 dead in 605 captures) in 1984 and 0.4% (3 dead in 690 captures) in 1985. Mortality was greatest in January (4.3%) and least in March (1.3%). Wood rats had the most deaths of any species (11), apparently because they would urinate on themselves and the toilet paper, drastically increasing their susceptibility to cold. The smaller pocket mice and some kangaroo rats were often torpid on colder mornings, they would be warmed up and then released near their point of capture, without any apparent ill effects. Many were recaptured later.

Population estimates and ranked population estimates were tested with two-way ANOVA. Comparisons were the same as for large plots. Differences were significant ($p = 0.10$) between experimental and control plots for several tests (Table 5).

In addition to rodents, birds and snakes were caught in traps. Cactus wrens (*Campylorhynchus brunneicapillus*) were caught seven times, a brown towhee (*Pipilo fuscus*) once, diamondback rattlesnakes (*Crotalus atrox*) twice, and a coachwhip (*Masticophis flagellum*) once. Two rodents were caught together in the same trap on two separate occasions; both times it was an Arizona cotton rat female and juvenile. Appendix A contains a list of the common and scientific names of plants and animals seen or censused.

VEGETATION

Large Plots

Vegetation characteristics sampled on the large plots include percent cover (Table 6a), plant density as number/hectare (Table 6b), and foliage height diversity (Table 6c). Data obtained from the foliage height diversity measurements, relative amounts of foliage between two heights, were: $F_{7.6-15}$, F_{15-30}, F_{30-61}, F_{61-152}, $F_{7.6-30}$, F_{15-61}, F_{30-152}, $F_{7.6-61}$, $F_{7.6-152}$, and the average distance measurements in meters at each of the five heights (7.6, 15, 30, 61, 152 cms).

Two-way ANOVA tests on vegetation characteristics revealed six significant differences (Table 2). Experimental and control plots showed significant differences for percent cover, large shrubs, and small shrubs. Many foliage height diversity showed significant differences for combined data (trees, large shrubs, measurements were significantly different between experimental and control plots but are not be considered here because

Table 5. Significant (p = 0.10), two-way ANOVA test results of vegetation and rodent population estimates for all roadside plots, Rincon Mountain Unit, Saguaro National Monument, Arizona, 1984-85.

Variable		Year	Result	Significance = p
Bailey's PM	#	1984	more on X	0.10
Arizona CR[a]	#	1985	" " C	0.10
"	#	Both	" " C	0.10
"	r	1985	" " C	0.10
Rodents	#	1985	" " C	0.05
% trees	#	1984	" " X	0.025
"	#	1985	" " X	0.025
"	#	Both	" " X	0.001
"	r	1984	" " X	0.005
"	r	1985	" " X	0.025
"	r	Both	" " X	0.001
% grass	#	1984	" " C	0.10
"	#	1985	" " C	0.05
"	#	Both	" " C	0.05
"	r	1984	" " C	0.05
"	r	1985	" " C	0.05
"	r	Both	" " C	0.005
% small shrubs	#	1985	" " C	0.025
"	#	Both	" " C	0.005
"	r	1985	" " C	0.05
"	r	Both	" " C	0.025
% plants	#	1985	" " C	0.10
"	#	Both	" " C	0.025
"	r	1984	" " C	0.10
"	r	Both	" " C	0.025

[a] cotton rat

Table 6a. Large plot vegetation survey results, 25 m transects for percent cover, with 95% confidence intervals below, Saguaro National Monument, Arizona, 1984-85.

Plot	% cover total[a]	% grass	% trees	%large shrubs	% herbs	% small shrubs	% cactus
Mica View 1(X)	45.42	8.00	14.90	14.96	1.56	6.00	15.20
	57-34	10-6	20-10	20-10	2-1	8-4	16-14
Mica View 2(C)	46.60	10.05	7.53	18.00	1.25	9.76	1.77
	52-41	12-8	11-4	21-15	2-1	12-8	2-1
Mica View 3(X)	44.91	8.84	8.99	17.77	0	9.31	6.46
	50-39	11-7	13-5	23-13		12-7	8-5
DET X	70.15	21.64	15.13	25.85	0.73	6.80	3.3
	85-55	27-16	23-8	39-13	1-0	8-6	6-1
DET C	55.25	7.44	16.70	29.23	0.14	1.74	0.02
	69-42	11-4	23-10	38-21	0-0	3-1	0-0
Javelina X	47.08	11.64	10.64	6.44	0.80	17.56	2.16
	54-40	16-7	13-8	12-1	1-0	21-14	5-0
Javelina C	42.52	8.16	4.20	14.40	1.60	14.16	4.48
	52-33	13-3	8-0	21-8	6-(-4)	18-11	7-2
Camboh X	60.08	0.88	3.08	22.52	0.80	32.80	3.88
	70-51	2-0	7-0	29-16	1-1	43-22	5-3
Camboh C	51.44	0.04	6.76	20.04	0.04	24.56	5.80
	63-40	0-0	15-0	29-9	1-0	35-15	10-2
Sus X	45.20	0	10.88	2.88	2.68	28.76	2.36
	54-37		20-1	5-0	5-0	34-24	4-1
Sus C	46.08	0.32	15.04	1.88	1.36	27.48	3.60
	55-37	1-0	22-8	4-0	3-0	32-23	5-3
Average, X	52.14	8.50	10.60	15.07	1.10	16.87	5.56
Average, C	48.38	5.20	10.05	16.71	0.88	15.54	3.13
Average, total	50.43	7.00	10.35	15.82	1.00	16.27	4.46

[a] percent total cover doesn't equal the sum of the other factors, cactus was not included in total cover. Cacti censused were either small or large shrubs.

Table 6b. Large plot vegetation survey results, 4 x 8 m plot for density (#/ha), with 95% confidence intervals (in 100's) below, Saguaro National Monument, Arizona, 1984-85.

Plot	Total	Trees	Large shrubs	Herbs	Small shrubs	Cactus
Mica View 1 (X)	4391	125	625	766	2875	328
	55-33	2-1	8-4	10-5	37-20	5-1
Mica View 2 (C)	7448	104	958	656	5729	437
	91-57	2-0	12-7	10-3	81-31	6-3
Mica View 3 (X)	2790	145	592	357	2042	725
	33-22	2-2	7-5	6-1	24-16	8-6
DET X	2869	0	597	170	2102	483
	34-23		8-3	4-0	30-12	8-2
DET C	2255	68	1209	421	557	68
	29-16	1-0	17-7	8-0	10-2	2-0
Javelina X	5688	406	313	219	4750	812
	75-39	7-1	5-1	5-0	65-30	12-4
Javelina C	5188	156	969	594	3438	1188
	69-35	3-0	16-4	14-0	50-18	17-7
Camboh X	6688	31	844	0	5813	594
	76-58	1-0	11-6		76-40	9-3
Camboh C	4406	63	563	94	3688	656
	63-25	1-0	8-3	2-0	55-18	9-4
Sus X	8156	281	344	844	6688	938
	94-69	5-1	6-1	15-2	82-52	13-5
Sus C	9875	250	250	406	8969	1094
	123-74	5-0	4-1	8-0	112-68	13-9
Average, X	5097	165	553	393	4045	647
Average, C	5834	128	790	434	4476	689
Average, total	5432	148	660	412	4241	666

Table 6c. Large plot vegetation survey results, Foliage Diversity (F) and average measurement at each height, with 95% confidence intervals for height measurements below, Saguaro National Monument, Arizona, 1984-85.

Plot	F values				Measurements[a]				
	7.6-15[b]	15-30	30-61	61-152	7.6[b]	15	30	61	152
Mica View 1 (X)	6.5	9.9	6.0	8.9	0.8	1.8	4.6	8.5	12.6
					1-1	2-1	6-3	11-6	16-9
Mica View 2 (C)	2.9	4.5	5.7	11.1	2.3	2.7	4.3	7.5	9.1
					3-1	4-2	5-3	9-6	10-9
Mica View 3 (X)	6.4	6.1	5.9	10.9	0.9	1.8	4.1	7.4	9.6
					2-1	3-1	6-2	11-6	14-7
DET X	10.9	11.0	6.8	12.4	0.6	0.9	3.4	7.3	7.4
					1-0	1-0	5-2	11-3	13-2
DET C	1.1	1.8	3.4	10.6	6.3	7.8	9.3	9.1	8.0
					9-3	11-4	14-5	13-6	11-5
Javelina X	5.4	7.6	9.4	11.3	1.1	1.7	2.3	5.8	13.0
					2-0	2-1	3-2	8-4	19-7
Javelina C	3.2	4.2	5.8	9.0	1.9	3.0	4.2	7.1	17.5
					4-0	5-1	7-1	11-3	23-12
Camboh X	7.0	13.4	18.1	19.9	1.1	1.1	1.2	3.2	8.3
					2-0	2-0	2-0	6-1	15-2
Camboh C	2.4	4.6	7.4	12.0	3.1	3.3	3.3	5.6	11.7
					6-1	5-1	5-1	6-3	12-6
Sus X	3.7	5.8	6.8	7.8	1.8	2.2	3.1	8.8	17.5
					3-1	3-1	4-2	13-4	23-12
Sus C	6.2	10.7	11.3	9.8	1.2	1.2	1.7	6.8	14.5
					2-0	2-1	3-1	13-2	21-8
Average, X	6.7	9.0	8.8	11.9	1.1	1.6	3.1	6.8	11.4
Average, C	3.2	5.2	6.7	10.5	3.0	3.6	4.6	7.2	12.2
Average, total	5.1	7.2	7.9	11.2	1.9	2.5	3.8	7.0	11.7

[a] distance in meters of measurements at each height
[b] heights in centimeters

R. M. M'Closkey (University of Windsor, pers. commun.) reports that the within-site variance is as large as the between-site variance.

Roadside Plots

Roadside (RS) plot vegetation was sampled using a pace transect. The data were grouped the same as for the large plot percent cover (Table 7).

I used two-way ANOVA tests to determine whether there were any significant differences for vegetation parameter numbers and ranks for experimental and control plots (Table 5). All six tests for trees and grass were significant. Trees were counted more often on experimental plots and grass on control plots. Four of the tests for small shrubs and plants showed significant differences.

Table 7. Roadside plot vegetation pace transect results (% hits), Rincon Mountain Unit, Saguaro National Monument, Arizona, 1984-85.

Plot	% plants	% trees	% large shrubs	% grass	% herbs	% small shrubs	% cactus
#1 X	70.3	6.8	6.8	25.4	11.9	20.4	11.9
C	72.2	3.3	4.9	27.9	0	36.1	4.9
#2 X	68.4	5.0	15.0	40.0	6.7	1.7	0
C	72.4	3.2	8.0	51.6	1.6	8.0	0
#3 X	66.9	10.9	9.6	27.4	9.6	9.5	1.4
C	72.4	0	15.1	28.3	10.0	18.4	8.4
#4 X	44.5	11.1	14.3	10.4	10.4	8.0	4.8
C	44.6	0	6.4	8.5	12.8	29.8	0
#5 X	61.6	16.3	0	20.0	9.1	16.3	1.8
C	78.7	5.4	19.7	30.4	10.7	12.5	7.1
#6 X	72.2	16.9	3.0	35.4	1.5	15.4	7.7
C	70.0	14.8	0	42.6	0	13.0	7.4
#7 X	42.9	10.3	6.8	17.2	0	8.6	6.9
C	57.6	11.1	0	29.8	0	16.7	7.4
#8 X	70.5	17.2	8.5	24.1	1.7	19.0	13.8
C	63.6	8.6	10.4	19.0	3.4	22.2	8.6
#9 X	67.1	0	20.7	25.8	18.9	18.9	6.9
C	78.5	0	15.4	30.8	1.5	30.8	9.2
Average X	62.7	10.5	9.1	25.1	7.8	13.1	6.1
Average C	67.8	5.2	8.1	29.9	4.4	20.8	5.9
Total	65.2	7.8	8.6	27.5	6.1	17.0	6.0

DISCUSSION

Many studies have been conducted to determine how human activities impact wildlife and vegetation resources: at campgrounds (Clevenger and Workman 1977; Aitchison 1977), as a result of fire (Beck and Vogl 1972), with recreational use (Ditton et al. 1977; Foin et al. 1977; Settegren 1977; Schreiner and Moorhead 1979), with roads (Oxley, Fenton, and Carmody 1974; Garland and Bradley 1984), with livestock grazing (Peck, unpubl. rep., Bureau of Land Management, 1979; Hanley and Page 1981), and with farming (LoBue and Darnell 1959). Several of the studies involved rodent trapping (Oxley, Fenton, and Carmody 1974; Ditton et al. 1977; Hanley and Page 1981). In visitor-use impact studies, it is extremely difficult to quantify effects other than the obvious ones on vegetation (Foin et al. 1977; Schmidly and Ditton 1979), as was evidenced by this study. In addition, it is difficult to separate visitor effects from environmental ones (Schmidly and Ditton 1979), especially with rodent populations since they are so variable. For example, compare rodent densities from this study to M'Closkey's (1981) data collected at Saguaro National Monument, in which his trap success was approximately one-sixth of mine. The secondary effects of human activities on rodents may be predicted from knowledge of the ecology of each species (Foin et al. 1977), which can be acquired from the literature and from minimal trapping. If a species' requirements are known, inferences may be drawn about the effect that vegetation changes will have on that species. Monitoring vegetation on established plots should provide adequate information on rodent populations.

Vegetation is a very important component of rodent habitat. All impact studies I reviewed that mentioned rodents also mentioned the importance of vegetation. Following is a review of other investigators' findings on the importance of vegetation to rodents and on human impacts to vegetation.

Studying the effects of a campground, Clevenger and Workman (1977) found different rodent numbers in the campground compared to an adjacent control area. Possible causes of some of the differences were attributed to less cover and more food from human garbage in the campground. In Big Bend National Park, Ditton et al. (1977) found no significant correlations between rodent density and human or livestock impacts. Montane vole (*Microtus montanus*) densities showed no change and deer mice (*Peromyscus maniculatus*) showed an increase in relation to visitor use in studies at Yosemite National Park (Foin et al. 1977). The effects on the two rodents were due to the secondary effects of greater food availability, trail location, and the state of the potentially impacted population. Investigating the effects of a highway in Nevada, Garland and Bradley (1984) found

no relationship between rodent proximity to the highway and home range size or life span. Beck and Vogl (1972) reported a change in mammal community composition with burning and considered the change to be directly related to vegetational changes.

In Arizona, Peck (unpubl. rep., Bureau of Land Management, 1979) noted that rodent numbers tend to increase in grazed areas, but only to a certain point. She found overgrazing to cause perennial grasses to decrease and shrubs and annuals to increase, thereby providing more cover and a greater food source for rodents. She considered vegetation density more important than plant species diversity for rodent populations. Conversely, Hanley and Page (1981) measured the effects of livestock grazing on rodents in the Great Basin, and associated low plant life-form diversity with low rodent community diversity. They also discovered that numbers of rodent species decrease in xeric areas while increasing in mesic ones that have been impacted.

Humans impact vegetation by reducing cover (Schmidly et al. 1976; Ditton et al. 1977; Schmidly and Ditton 1978; Schreiner and Moorhead 1979), injuring plants, decreasing plant vigor, and compacting the soil (Settegren 1977; Duek and Mortensen 1980). The effects of trampling are visible on all roadside plots and to a lesser extent on the large plots at Saguaro National Monument.

The results of this study show few significant impacts from visitor-use on rodents and vegetation at the lower elevations of the monument. With this study as an established baseline for comparison, future studies may be better able to determine impacts.

TRAPPING

Large Plots

The significantly larger number of female Arizona pocket mice, desert pocket mice, and total rodents captured on the large plots (Table 3) differs from most literature reports. Males are usually caught more often because they move further than females (Stickel 1948; Lewis 1972; Call 1986). Bateman (1967) captured significantly more male Arizona pocket mice (chi-square, $p = 0.01$), Bailey's pocket mice ($p = 0.05$), and total rodents ($p = 0.005$) during his study. Reichmann and Van De Graaf (1973) caught significantly more female rock and Bailey's pocket mice and Kisiel (1972) trapped significantly more male deer mice, rock mice (*Peromyscus difficilis*), and western harvest mice (*Reithrodontomys megalotis*). Duran and Samz (1973) captured male cactus mice more frequently than females. Cameron (1977) found a 2 to 1 male to female ratio for fulvous harvest mice (*R. fulvescens*). The reason more females were caught on the large plots is unknown.

The density estimates (Table 1a and b) compare favorably with those of other investigators for Sonoran Desert rodents (M'Closkey, unpubl. rep., Saguaro National Monument, no date; Olding 1976; Vaughan 1976). The two-way ANOVA tests (Table 2) comparing rodent densities between experimental and control plots show no overall impacts, except for Arizona pocket mice, which had significantly more animals on control plots for 3 of the 6 tests and for Bailey's pocket mouse and Merriam's kangaroo rat. For the rest, some plot-pairs showed a larger population of a given species on the control and others did so on the experimental plot. From these data it appears the rodents on these plots have sustained no significant impacts to their populations.

Roadside Plots

The higher roadside plot populations in 1985 are puzzling. If rodents respond to winter annuals and autumn precipitation as widely reported (Reynolds 1958; Beatley 1969; Anderson, Drake, and Ohmart 1977), more rodents would be expected in 1984 after the greater precipitation of the previous year (Figure 1). Greater populations in 1985 could be due to above-normal precipitation experienced two years running.

Two-way ANOVA tests of the population estimates and ranks indicate that RS plot rodent numbers are not significantly different though there are vegetation differences (Table 5). Continued monitoring may show that human use causes changes in the rodent communities here as has been demonstrated elsewhere (Foin et al. 1977).

VEGETATION

Large Plots

Significant differences ($p = 0.10$) for large shrub density and percent cover values were found when all plots from 1984 and 1985 were combined and tested. For the RMU plots, at least some difference is due to natural variability. The remaining variability on the RMU plots and the differences between the TMU plots might be due to human impact, since all experimental plots exhibited signs of human use (e.g. litter, trails, trampled vegetation). More precise impact determination is needed (see Ditton et al. 1977; Schmidly and Ditton 1979; Schreiner and Moorhead 1979).

Roadside Plots

Only plot 7 showed a significant difference between experimental and control. Although some of the differences between these

sites are due to natural variability, other differences may be caused by human use.

COMPARISONS OF RODENTS AND VEGETATION

Previous investigators' findings on rodent habitats will be used to show which vegetation parameters are important to a rodent species. Future vegetation studies in combination with limited rodent trapping may thus be used to monitor impacts.

Arizona Pocket Mouse

M'Closkey (1981, 1982) and Wondolleck (1975) found Arizona pocket mice in areas with many small shrubs and fewer large shrubs. Therefore, this pocket mouse should also show a positive correlation with the lower FHD measurements, 7.6, 15, and 30 cm. Such a positive correlation appears for 1984 but not for 1985 nor for both years combined. Previous studies have characterized Arizona pocket mouse habitat as areas with sparse or open vegetation with little understory (Bateman 1967; Drabek 1967; Hoagstrom 1978).

Bailey's Pocket Mouse

Prior studies have associated Bailey's pocket mouse with high shrub and tree densities (Wondolleck 1975; Hoagstrom 1978; M'Closkey 1981, 1982). In another rodent study involving foliage height diversity measurements (Rosenzweig and Winakur 1969), the presence of Bailey's pocket mouse was positively correlated with the proportion of vegetation above 61 cm (large shrubs and trees). I captured Bailey's pocket mouse on every plot. In contrast, M'Closkey's (1978, 1981, 1982, 1983) trapping at Saguaro National Monument revealed desert pocket mice to be the most numerous and widespread rodent on the monument. The difference between my study's data and M'Closkey's is mostly due to the winter and spring trapping that was done in this study, periods when desert pocket mice are torpid.

Desert Pocket Mouse

Vegetative characteristics of desert pocket mouse habitat include *Acacia* spp. and other large spinescent shrubs (Hoagstrom 1978), shrubs and trees (Arnold 1942; Hoffmeister and Goodpaster 1954), and bushes (Price 1978; M'Closkey 1981, 1982). Rosenzweig and Winakur (1969) positively correlated desert pocket mouse numbers with the proportion of vegetation above 61 and 152 cm, and Wondolleck (1975) correlated desert pocket mice with his clumped

and large bush microhabitat types. In this study, desert pocket mice seemed to occur on plots with more upper story vegetation.

Rock Pocket Mouse

My study suggests that the presence of rock pocket mice is positively correlated with tree density, but no correlations were significant because of the small numbers of rock pocket mice captured. Previous investigators describe rock pocket mouse habitat as rocky slopes or hills (Dice 1930; Hoffmeister and Goodpaster 1954; Drabek 1967; Hoagstrom 1978), with little mention of specific vegetation characteristics other than 'sparse vegetation' (Drabek 1967). Because rock pocket mice are closely related to desert and Bailey's pocket mice, I would expect it to have similar habitat requirements, i.e. upper-story vegetation.

Merriam's Kangaroo Rat

Merriam's kangaroo rat inhabits open vegetation (Dice 1930; Monson and Kessler 1940; Spencer 1941; Drabek 1967; Hoagstrom 1978) on loose or sandy soil (Grinnell 1914; Bailey 1931; Spencer 1941; Drabek 1967). M'Closkey (1981) reported that Merriam's kangaroo rat selects microhabitats containing numerous small shrubs and fewer large shrubs. In summer, Merriam's kangaroo rat preferred large open microhabitats (greater than 2 m in diameter) and in winter small open microhabitats (0.25-0.5 m in diameter) were preferred (Price 1978). Wondolleck (1975) found that these kangaroo rats favor open habitat (0.5-1 m with no vegetation, 10 m from nearest hackberry [*Celtis*] or Acacia) and clumped situations (bushes 0.5-1 m across and less than 1 m tall) and avoided large-bush microhabitats (1 bush greater than 1 m tall and 1 m across). The presence of Merriam's kangaroo rat was also inversely correlated with the proportion of vegetation below 7.6 and 30 cm (Rosenzweig and Winakur 1969). At SAGU, areas with numerous small shrubs tended to have less ground cover. In this study, Merriam's kangaroo rat made up a small portion of the catch, compared to M'Closkey's studies (1978, 1981, 1982, 1983), possibly because my plots were in less suitable habitat (rocky, denser vegetation).

Cactus Mouse

Rosenzweig and Winakur (1969) found cactus mice numbers to be proportional to the percent of foliage greater than 46 cm (trees and large shrubs). Dice (1930), Commissaris (1960), Bateman (1967), and Hoagstrom (1978) all report cactus mouse habitat as being rocky. All cactus mice captured in this study were in or near rocky habitat. Cactus mice have also been reported in riparian areas (Grinnell 1914; Bradley and Mauer 1971; Stamp and

Ohmart 1978). All plots with cactus mice also had Bailey's pocket mice, a circumstance also reported by Drabek (1967).

Arizona Cotton Rat

Normal cotton rat habitat is grassy, and grass height and density are important indicators of habitat quality (Goertz 1964; Kaufman and Fleharty 1974). Cotton rats were caught at trap stations that had more grass and other cover than other trap stations in this study (pers. obs.).

White-throated Wood Rat

A habitat's ability to support wood rats is dependent on how much protection from predators that habitat provides (Brown, Lieberman, and Dengler 1972). Previous reports characterize wood rat habitat as being rocky, in and near washes, and near cacti (Vorhies and Taylor 1940; Spencer and Spencer 1941; Ivey 1957; Bateman 1967; Drabek 1967; Brown, Lieberman, and Dengler 1972). The plots in this study where the most wood rats were captured were either rocky or contained large washes. Percent cover and cacti, however, were not positively correlated with white-throated wood rat densities on the Saguaro National Monument plots.

TOTAL RODENT DENSITY

Past studies have shown rodent densities to be strongly influenced by the spacing and size of plants (Schmidly et al. 1976). There were no apparent correlations between total rodent densities on my plots and any vegetation factors.

CONCLUSIONS AND RECOMMENDATIONS

The data gathered in this study do not show that humans are or are not significantly impacting rodents and vegetation. Combined data on RS plot vegetation show that there are significant differences between experimental and control plots for 1984, 1985, and for both years combined. It is not certain however, if the vegetational differences are due to human impact or to natural site variability. Working from the baseline provided here, it would be possible in the future to quantify, with greater accuracy, specific changes in the vegetation as well as rodents.

Duek and Mortensen (unpubl. rep., University of Arizona, 1980:20) concluded that "research done at Saguaro National Monument is inadequate and does not provide a sound data base ..... It cannot be used as a basis for managing the Monument's natural resources". As Schmidly and Ditton (1978) point out, funds or time for impact research are often short and investigators cannot adequately measure the results of visitor impacts. They found this to be particularly true of wildlife population studies, when the effects of visitor use may take several years to detect and are often secondary to other factors (weather and livestock). It is difficult to detect the secondary or indirect effects of human use (Foin et al. 1977). If information more specific than population trend analyses is needed, more detailed studies must be conducted. Future studies should concentrate on more specific determination of human impacts (Schmidly et al. 1976) and vegetation sampling. Vegetation sampling is a cheaper, easier, and quicker method than sampling both vegetation and rodents. Vegetation should be monitored at least every three years and the monitoring should follow the procedures used in this study as closely as possible to provide the most valid comparisons with the data from this study. Rodents and other animals respond quickly to vegetational changes and enough is generally known about most rodents habitat requirements to predict affects of vegetational changes on rodent populations. In addition to knowledge of use patterns, simple quantification of visitor numbers may be sufficient indication of the degree of human impact on park ecosystems (Foin et al. 1977).

Monument visitation has increased steadily and is expected to continue increasing (Shand and Underhill 1985). The focus now should be on educating visitors through proper interpretation techniques and on providing for long term ecological monitoring. Better informed visitors are better educated ecologically and will impact the resource less, thereby doubling the benefits of a good interpretive program (Shand and Underhill 1985). Most impacts are not caused deliberately but through ignorance (Ream 1979); education can help in correcting these deficiencies

(J. Bradley, unpubl. rep., Nezperce National Forest, 1977). Bradley (1979) gives three reasons for educating visitors: regulations are difficult to enforce, most visitors are ignorant, and a purely regulatory approach antagonizes visitors. He also gives three objectives of education: to reduce visitor impacts, keep regulatory action to a minimum, and teach visitors the why's behind regulations. If visitors are taught to understand how the ecosystem functions and how they might impact it, most would be more than willing to comply with regulations. Bradley (1977:1) states that education is the key: ".... without the support and understanding of the public, the most well-thought out management plans are destined to fail."

Finally, resource managers at Saguaro National Monument must determine how much of the total area is impacted and the visitors perception of those impacts (Settegren 1977). By using education to its fullest extent, in combination with proper vegetation monitoring, it would be possible to evaluate levels of human impact and determine whether those are "allowable" levels.

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APPENDIX

COMMON AND SCIENTIFIC NAMES
OF VASCULAR PLANTS AND MAMMALS SEEN OR CENSUSED,
FAMILY, GENUS SPECIES, COMMON NAME.

VASCULAR PLANTS (NAMES FROM BOWERS AND McLAUGHLIN 1987 AND KEARNEY AND PEEBLES 1951.)

Family *Genus species*	Common name
Acanthaceae	
Anisicanthus thurberi	Desert honeysuckle
Asteraceae	
Ambrosia ambrosoides	Western ragweed
A. deltoidea	Triangle-leaf bursage
Artemesia ludoviciana	Sage
Baileya multiradiata	Desert marigold
Encelia farinosa	Brittlebush
Ericameria laricifolia	Turpentine brush
Erigeron divergens	Fleabane daisy
Gutierrezia microcephala	Snakeweed
Isocoma tenuisectus	Burroweed
Hymenoclea salsola	Burro brush
Parthenium incanum	Mariola
Porophyllum gracile	Stinkweed
Psilostrophe cooperi	Paperflower
Trixis californica	Trixis
Zinnia acerosa	Desert zinnia
Bignoniaceae	
Chilopsis linearis	Desert willow
Boraginaceae	
Cryptantha barbigera	Cryptantha
Tiquilia canescens	Tiquilia
Brassicaceae	
Descurainia pinnata	Tansy mustard
Buxaceae	
Simmondsia chinensis	Jojoba

Cactaceae

Carnegiea gigantea	Saguaro
Echinocereus fendleri	Fendler's hedgehog cactus
Ferocactus wislizeni	Barrel cactus
Mammillaria microcarpa	Fishhook cactus
Opuntia arbuscula	Pencil cholla
O. fulgida	Chain-fruit cholla
O. leptocaulis	Christmas cactus
O. phaeacantha	Prickly pear
O. versicolor	Staghorn cholla
Peniocereus greggii	Night-blooming cereus

Chenopodiaceae

Atriplex canescens	Four-wing saltbush
Salsola iberica	Russian thistle

Ephedraceae

Ephedra trifurca	Mormon tea

Euphorbiaceae

Euphorbia spathulata	Spurge

Fabaceae

Acacia constricta	Whitethorn
A. greggii	Catclaw acacia
Astragalus nuttalianus	Loco
Calliandra eriophylla	Fairy-duster
Cercidium microphyllum	Little-leaf palo verde
Olneya tesota	Ironwood
Prosopis juliflora	Honey mesquite

Fouquieriaceae

Fouquieria splendens	Ocotillo

Geraniaceae

Erodium cicutarium	Heron-bill

Hydrophyllaceae

Phacelia crenulata	Wild heliotrope

Krameriaceae

Krameria parvifolia	Range ratany

Lamiaceae

Hyptis emoryi	Desert lavender
Salvia columbariae	Chia

Malpighiaceae

Janusia gracilis	Janusia

Malvaceae

Sphaeralcea emoryi	Globe mallow

Plantaginaceae

Plantago insularis	Indian wheat

Poaceae

Aristida adscensionis	Six-weeks three awn
A. ternipes	Spider grass
Avena fatua	Wild oats
Bothriochloa barbinodis	Cane beardgrass
Bouteloua curtipendula	Side-oats grama
B. gracilis	Blue grama
B. repens	Slender grama
Bromus catharticus	Rescue grass
B. rubens	Foxtail brome
Digitaria californica	Cottontop
Eragrostis echinochloidea	Love grass
Erioneuron pulchellum	Fluffgrass
Heteropogon contortus	Tanglehead
Lycurus phleoides	Wolftail
Muhlenbergia porteri	Bush muhly
Rhynchelytrum repens	Natal grass
Setaria macrostchya	Plains bristle grass

Polygonaceae

Eriogonum abertianum	Wild-buckwheat
E. wrightii	Shrubby buckwheat

Rhamnaceae

Condalia warnockii	Squaw-bush
Ziziphus obtusifolia	Gray-thorn

Solanceae

Lycium spp.	Wolfberry

Ulmaceae

Celtis pallida	Desert hackberry

Zygophyllaceae

Larrea tridentata	Creosote bush

MAMMALS (NAMES FROM HOFFMEISTER 1986)

Family *Genus species*	Common name
Soricidae	
Notiosorex crawfordi crawfordi	Desert shrew
Leporidae	
Sylvilagus audubonii minor	Desert cottontail
Lepus californicus eremicus	Black-tailed jack rabbit
L. alleni alleni	Antelope jack rabbit
Sciuridae	
Ammospermophilus harrisii	Harris' antelope squirrel
Spermophilus variegatus grammurus	Rock squirrel
S. tereticaudus neglectus	Round-tailed ground squirrel
Geomyidae	
Thomomys bottae modicus	Botta's pocket gopher
Heteromyidae	
Perognathus amplus taylori	Arizona pocket mouse
P. intermedius intermedius	Rock pocket mouse
P. penicillatus pricei	Desert pocket mouse
P. baileyi baileyi	Bailey's pocket mouse
Dipodomys merriami merriami	Merriam's kangaroo rat
Muridae	
Peromyscus eremicus eremicus	Cactus mouse
P. leucopus arizonae	White-footed mouse
Sigmodon arizonae cienegae	Arizona cotton rat
Neotoma albigula albigula	White-throated wood rat
Canidae	
Canis latrans mearnsi	Coyote

Felidae

Felis rufus baileyi	Bobcat

Tayassuidae

Dicotyles tajacu sonoriensis	Collared peccary

Cervidae

Odocoileus hemionus crooki	Mule Deer