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Effects Of Off-road Vehicles On Vertebrates And Habitat Quality In The Mojave Desert

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of the requirements for the degree of
Master of Science in Biology

by

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ABSTRACT

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The use of off-road vehicles (ORVs) in the California desert has become increasingly popular during the past 15 years. This study was designed to assess the impact of this activity on habitat quality and the small vertebrate fauna in the creosote bush community of the Mojave Desert. Two ORV-frequented sites in each of two localities and four control areas (one for each experimental site) were compared. Vegetation, small mammals and reptiles were sampled during late spring. Density and diversity of mammalian and reptilian vertebrates were significantly lower in all ORV-used areas, as was habitat quality. Moderately used areas contained 49% as much perennial plant cover, supporting 81% as many individuals

and 76% as many species of vertebrates as the control areas. Where vehicular activity is concentrated, areas become denuded, supporting little or no animal life or vegetation. These "pit areas" averaged 5.3% as much plant cover as controls, while the number of individuals and species was 12.4% and 34.5% of the controls, respectively. These results indicate that ORVs have a detrimental effect on the desert habitat proportional to the degree of usage.

INTRODUCTION

The desert areas of the southwestern United States, once feared and dreaded by early travelers, have now become a vast playground for the public. Modern vehicular transport coupled with an extensive highway system have allowed easy access to virtually any area. In recent years a new type of vehicle, the off-road vehicle (ORV) has been developed. Not restricted to roads, these modern toys give access to the desert an entirely new meaning. The use of ORVs has blossomed beyond versatile transportation; it has become not only a sport enjoyed by an increasing number of people, but a multi-national, multi-million-dollar industry as well.

The desert lands of California encompass some 6.8 million hectares (A.A.A.S., 1974), reaching south from Mono Lake to the Mexican border and east from the Antelope Valley to the Colorado River. The geography of the region is richly varied, ranging from steep, snow-capped mountains to dry lake beds and sand dunes. Dry washes, rugged canyons and broad valleys are commonplace. Average annual precipitation, which occurs mainly during winter months, is less than 25 cm. Summers are warm, with highs from 35° C at higher elevations to 43° C in low valleys. Extremes exceeding 55° C have been recorded (Jackson, 1975). Winters are usually mild, averaging 10° C to 20° C, although snow occurs in mountainous areas. The proximity of the Pacific Ocean does exert an influence on the weather, with marine air moving inland in the form of gusty westerly winds, especially during spring. Desert biota is unique as a rule, being adapted to extremes in temperature and lack of water, and Mojave Desert life is no exception. Creosote bush (*Larrea tridentata*) dominates most of the Mojave Desert within California, with scattered stands of Joshua tree (*Yucca brevifolia*) woodland. Several species of saltbush (*Atriplex spp.*) are common in low sinks and around lake beds, while juniper (*Juniperus spp.*) occupies higher elevations. A variety of herbaceous annual plants also survive in the desert, usually sprouting and blooming after early spring rains. Desert fauna is likewise diverse, with many species having adapted there since the Pleistocene (Bury, et al., 1977). Some have become so highly specialized that they are restricted to certain habitats. Pupfish (*Cyprinodon spp.*), for example, are in fact remnant populations from the Pleistocene hydrologic system which once occupied the region (Stebbins, 1974). Humans have also occupied the Mojave Desert for some time. Artifacts of this occupancy date back some 12,000 years (Stebbins, 1974). Many of the geological, biological, palentological and archeological features of the Mojave Desert are unique and poorly understood (Carter, 1974).

Once thought of as wasteland, today the desert has a variety of uses. Abundant natural resources are utilized to help support the growing population of California. Mining first brought people in significant numbers during the previous century; boom towns grew overnight--and died as quickly (Jackson, 1975). Today the desert still produces borax, sulfur, copper, iron and other minerals (Jackson, 1975). Grazing livestock also had its beginnings in the nineteenth century, and continues to this day. The southwest deserts comprise one of the largest remaining wild places in the United States, and thus serve as the last open range for sheep and cattle. Until this century, agriculture (aside from livestock) was extremely limited in the Mojave Desert because of its aridity. The completion of aqueducts bringing water from the Colorado River and Owens Valley have changed this. A wide variety of crops including citrus, alfalfa, grain and cotton are produced from formerly parched soil. Since World War II the military establishment has utilized the region for its open space and remoteness. Several bases are in the Mojave, as well as reserves for bombing and gunnery. Aerospace research and development is routinely conducted at China Lake Naval Weapons Test Center and Edwards Air Force Base (Hutchinson, 1969).

During the past few decades, however, the majority of desert visitors have come for recreation. The unique geography and geology of the region allow unparalleled sightseeing, hiking and rockhounding. Human artifacts are preserved by the dry climate, creating a paradise for relic scavengers, while the open space and pleasant weather allow year-round camping, hunting and recreational vehicle use.

The ever-growing population of California has placed severe stress on the resources of the region, especially during the twentieth century (Bury, et al., 1977). Demands for mining, agriculture and housing have increased dramatically, and the limited water supply has been increasingly diverted to supply coastal cities. Recreational use has increased also. Fostered by a "get-away-from-it-all" attitude, there has been an immense increase in human activity in wild places. In 1968, five million visitor days were spent in the deserts of California; by 1971 that number showed a 50% increase. Estimates for the beginning of 1980 range as high as 23 million (A.A.A.S., 1974). Certainly part of the reason for this increase lies in a desire to see more of the back country, a wish easily fulfilled with an ORV. Remote places that would take days to reach on foot can now be visited in a few hours. The ORV industry has been quick to promote the image (and sales) of its products; in our consumer oriented society, an entirely new market opened for business (Stebbins, 1974). Up until 20 years ago, very few ORVs existed. Ranchers and miners used 4-wheel-drive trucks as part of their business; recreational use was limited to army surplus jeeps, underpowered trail bikes or do-it-yourself modification kits. Business competition has spurred vast improvements in ORV technology and diversity. Modern machines can withstand more abuse, attain higher speed and climb steeper hills, allowing access even to the most rugged terrain. Manufacturers now produce models suitable for every age group. Some of the leading motorcycle companies offer up to 25 models with some degree of off-road capability. These machines first appeared in significant numbers in the desert in 1968 (Stebbins, 1974); as of August, 1982, 411,877 are registered in California (Dept. of Motor Vehicles, pers. comm.). The types of ORV activity vary from individuals or family groups sightseeing and exploring new trails to massive, organized races.

Responsibility for managing desert land in California rests with the Bureau of Land Management (BLM). Its Riverside district covers about half (3.4 million hectares) of the desert within the state, including parts of Inyo, Kern, Los Angeles, San Bernardino, Riverside and Imperial counties. The BLM was founded in 1946 as part of the U.S. Grazing Service (Carter, 1974), and as such did little to control ORVs. Early studies showed damage was being done by the machines; a 1968 BLM survey showed a 58% vegetation reduction in one race staging area (Luckenbach, 1975). On February 8, 1972, then President Richard Nixon issued Executive Order 11644 charging federal agencies with responsibility for managing ORVs on land under their control (Bury, et al., 1977). That year the BLM organized a desert management staff and in 1973 released its interim management plan. Under this program approximately 4% to federal desert land was closed to ORV use, 7% was open and unrestricted, and the remainder required vehicles to remain on existing or established roads and trails (Luckenbach, 1975). In addition, special-use permits were required for all organized events, such as races. ORV groups responded vigorously; under this pressure the plan was revised and released November 1, 1973. The modifications basically reduced the amount of closed land by 25% (Stebbins, 1974). Criticism to the BLM plan has come from all sides. ORV enthusiasts, feeling cheated, quickly became organized and filed suit (Luckenbach, 1975). Many conservationists felt the plan was too lax, since it allowed unrestricted vehicle use on major sand dune systems and other sensitive areas. Most objectionable was the official sanctioning of massive races, perhaps the most destructive ORV activity. A BLM study of the 1974 Barstow-to-Las Vegas race showed a 90% reduction in small mammal populations along the race course (Wilshire and Nakata, 1976). Another cause for concern was the 58% of desert where ORVs were restricted to "existing roads and trails". Unfortunately, the definition of a road or trail was too vague; if the track of a single motorcycle can be construed as a trail (since it may last many years), where is the restriction?

The desert management plan of the BLM has been re-evaluated on a regular basis since it was first released (BLM, pers. comm.). Decisions concerning ORV management cannot be made without adequate knowledge about the extent of the damage being done in specific areas; for this reason quantitative information is required. Excellent studies concerning ORV effects on vegetation (Davidson and Fox, 1974) and lizards (Busack and Bury, 1974) have been reported for Dove Springs Canyon, Kern Co., California. Bury, et al. (1977) studied vehicular impacts on vertebrates in four localities southeast of Barstow, San Bernardino Co., California. I present this report in order to further the understanding of the overall impact of ORVs on Mojave Desert ecosystems.

MATERIALS AND METHODS

Sites for this study are located in San Bernardino County, California, approximately 32 km. northwest of Victorville (Fig. 1). Only areas relatively free from disturbances such as power lines, highways, housing subdivisions and grazing were chosen; therefore ORV use and associated camping activities would constitute the major impact. Four one-half hectare paired sites were established, two experimental and two control, in each of two localities, and are designated as follows:

Lake Bed Sites

A_c	Control
A_e	Moderate-use
B_c	Control
B_e	Pit area

Shadow Mountains Sites

C_c	Control
C_e	Moderate-use

D_c	Control
D_e	Pit area

The experimentals were classified as moderate-use or pit areas, depending on the degree of vegetation destruction. Moderate-use areas are characterized by having most perennial shrubs intact, although some show damage. Pit areas generally have little plant life of any kind remaining. The four controls were chosen on the basis of their close proximity (within 2 km.) and similarity to the experimentals in topography, vegetation, soil, and degree of direction of slope. Pristine land is not obtainable in that part of the desert; thus the control sites all showed signs of vehicle activity. Perennial and annual vegetation in these areas appeared reasonably intact, therefore direct ORV influence was considered to be minimal.

The first locality to be sampled lies approximately 2 km. northwest of El Mirage Dry Lake at an elevation of 880 m. Granite outcrops rise to the west of the study sites, producing a gentle (3 - 4%) slope to the east. The soil was generally sandy with fine granitic gravel. Perrenial vegetation at the control areas (A_c, B_c, Fig. 2 and 3) consisted mainly of creosote bush (_Larrea tridentata_) with subdominants including saltbush (_Atriplex spp._), burro bush (_Hymenoclea monogyna_) and scattered Joshua trees (_Yucca brevifolia_). Annuals included orange cups (_Oneothera brevipes_), pincushion flower (_Chaenactis fremontii_), desert dandelion (_Malacothrix elabrata_) and various

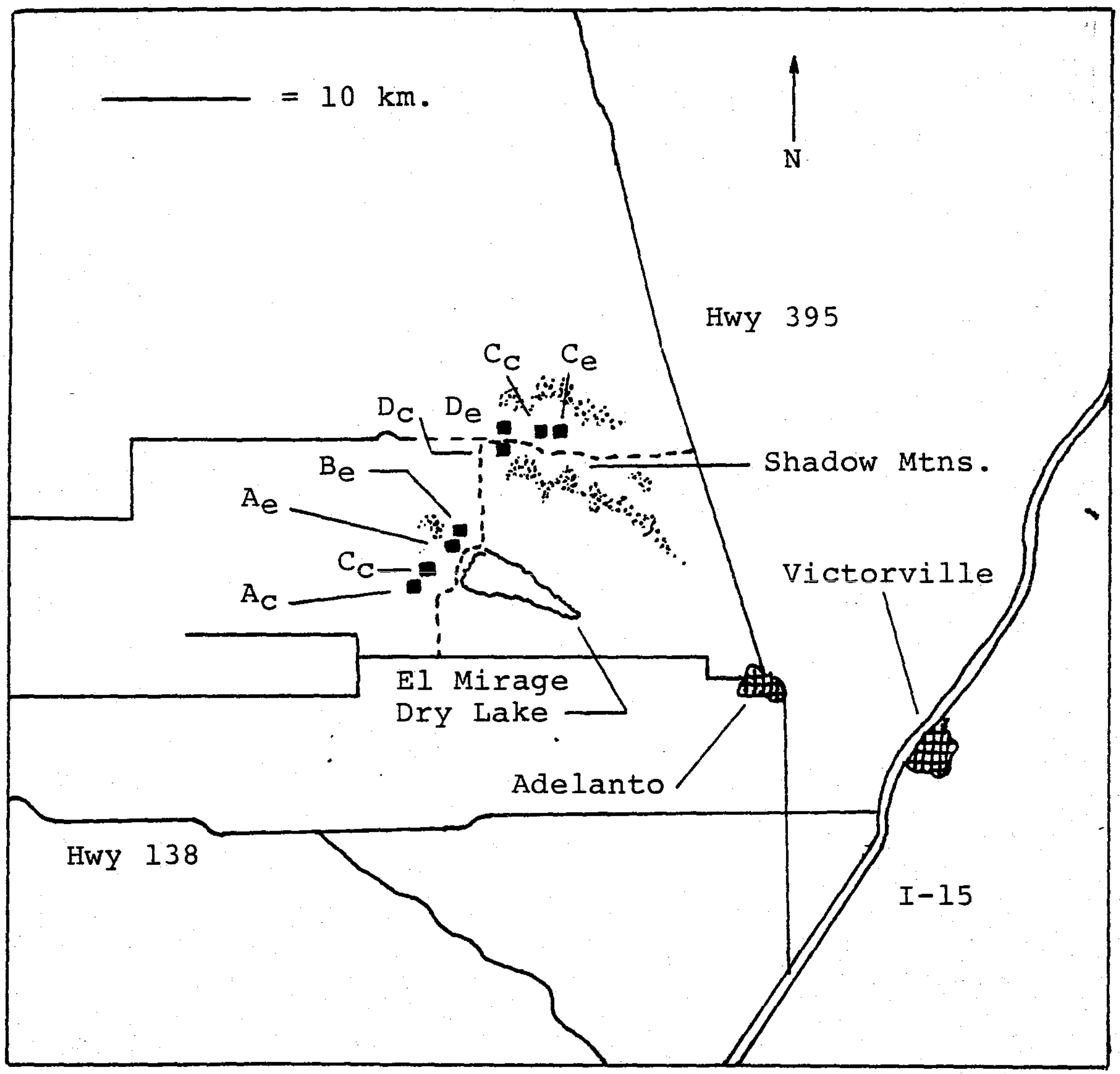
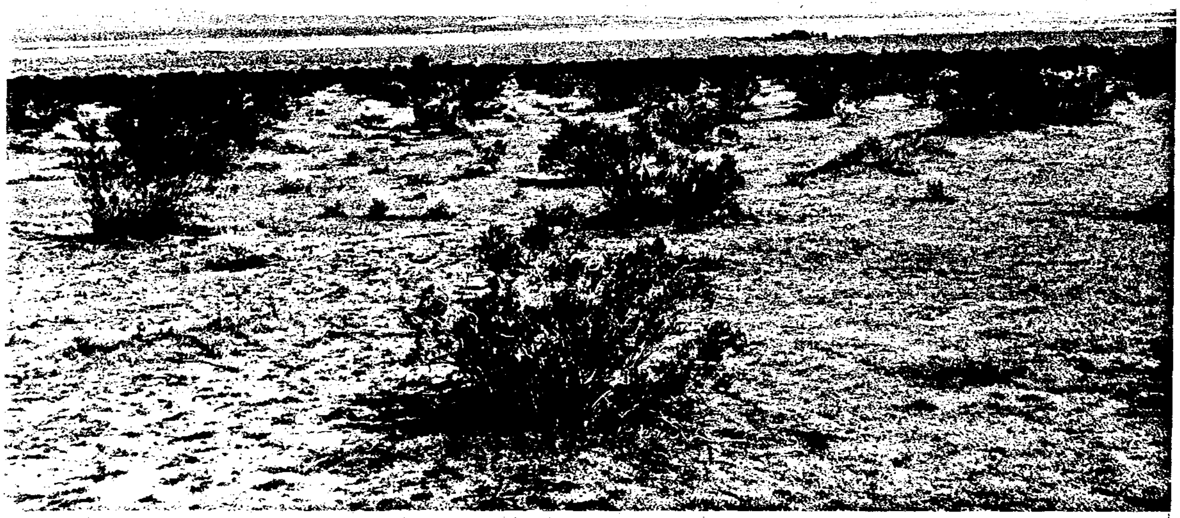


Figure 1. Location of study sites.

grasses. The moderate-use site (A_e, Fig. 2) contained almost exclusively creosote bush with only a few subdominant shrubs present. Annual plants were absent except among and immediately around shrubs. The pit area (B_e, Fig. 3) was totally denuded, containing no plant life of any kind. Garbage and discarded motorcycle parts were strewn about; a rock outcrop adjacent to the site was defaced with graffiti.

The Shadow Mountains' locality is at an elevation of 1,000 m., 8 km. north of the dry lake bed. One pair of sites (pit area and its control; D_e, D_c, Fig. 5) were on an alluvial fan sloping to the west, while the other pair (moderate-use and control) were in a small valley within the mountains (C_e, C_c, Fig. 4). Soil at these areas was sandy with gravel, much like the dry lake sites, although considerably rockier and somewhat thinner. Vegetation was similar as well, although the pit area was not as thoroughly devastated as the land bed pit area.

Annual plants at all sites were sampled in late April, at the peak of growth, to determine relative biomass. Four 80 m. transects (two north-south and two east-west) crossed each study area, and five 1-square-meter plots were sampled at 20 m. intervals. Annual vegetation was removed along with approximately 5 cm. of topsoil. Samples were placed in a screen-bottomed box, shaken to remove soil, and placed in paper bags. Later, when the plant matter had thoroughly dried, the samples were weighed,



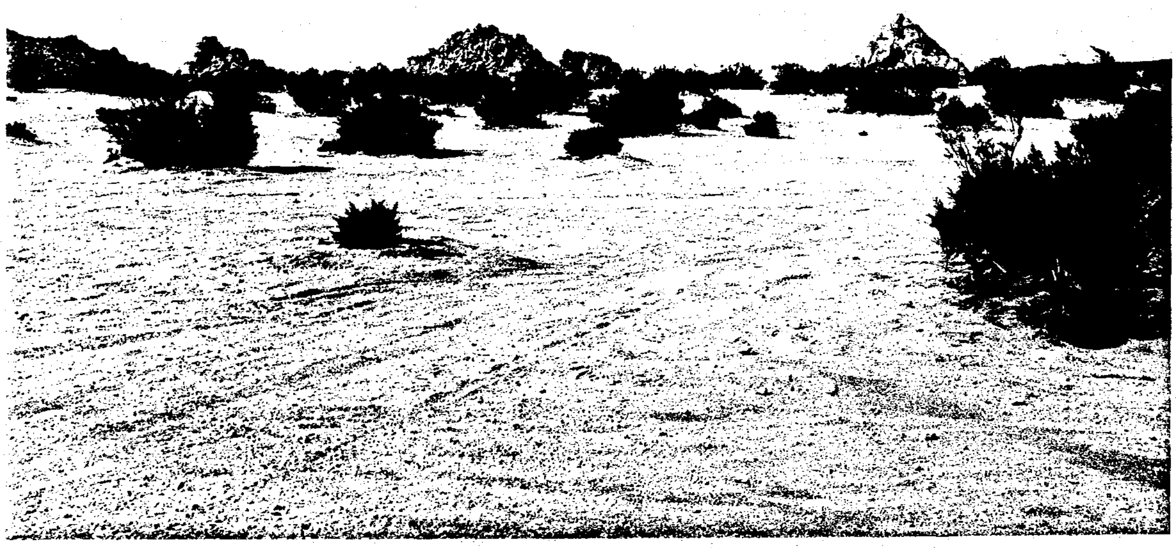


Figure 2. Lake bed locality habitat. Top: Control site (A_c). Bottom: Moderate-use site (A_e). Photographs taken September, 1982.

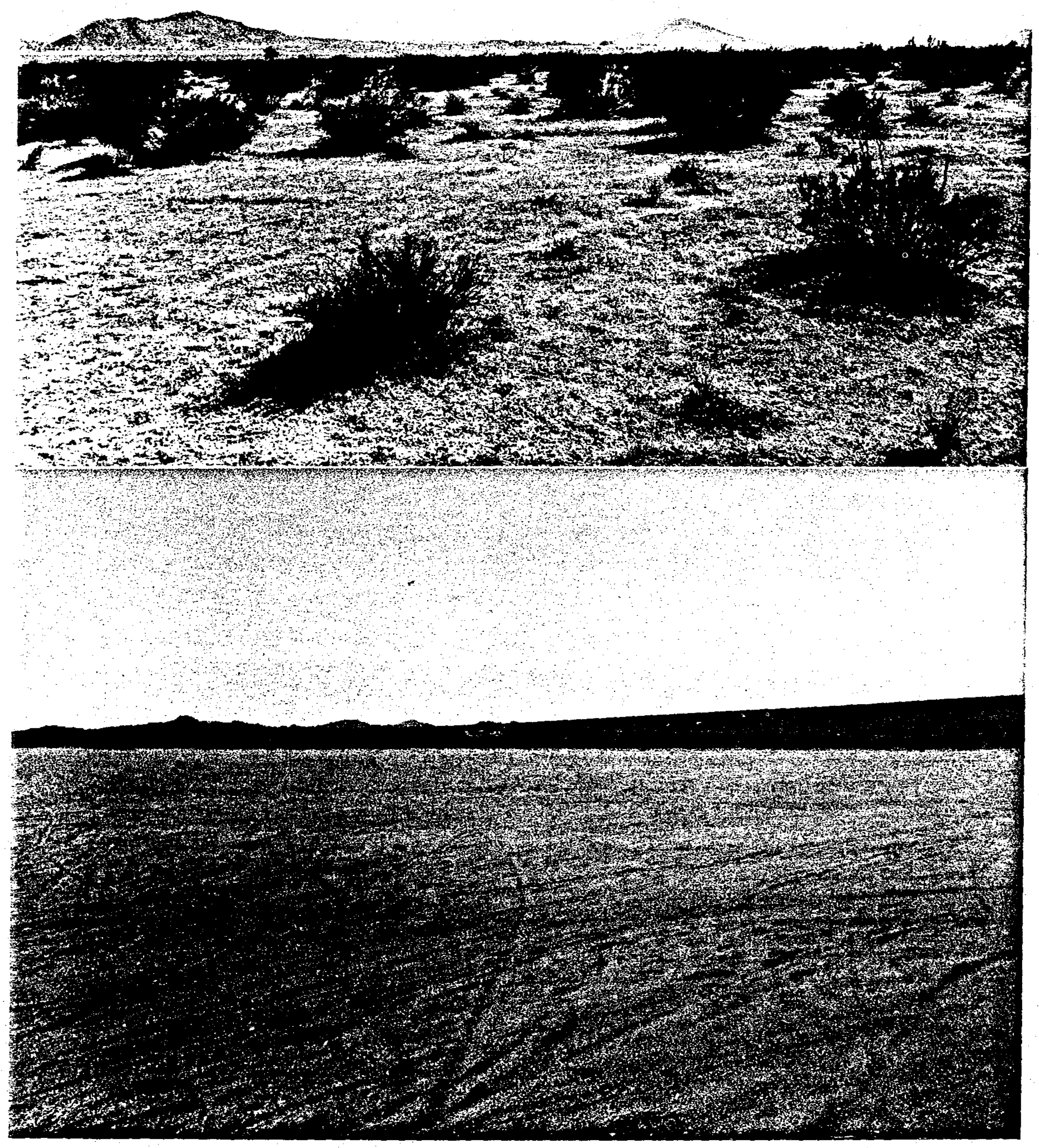


Figure 3. Lake bed locality habitat. Top: Control site (B_c). Bottom: Pit area (B_e). Photographs taken September, 1982.

Figure 4. Shadow Mountains locality habitat. Top: Control site (C_c). Bottom: Moderate-use site (C_e). Photographs taken September, 1982.

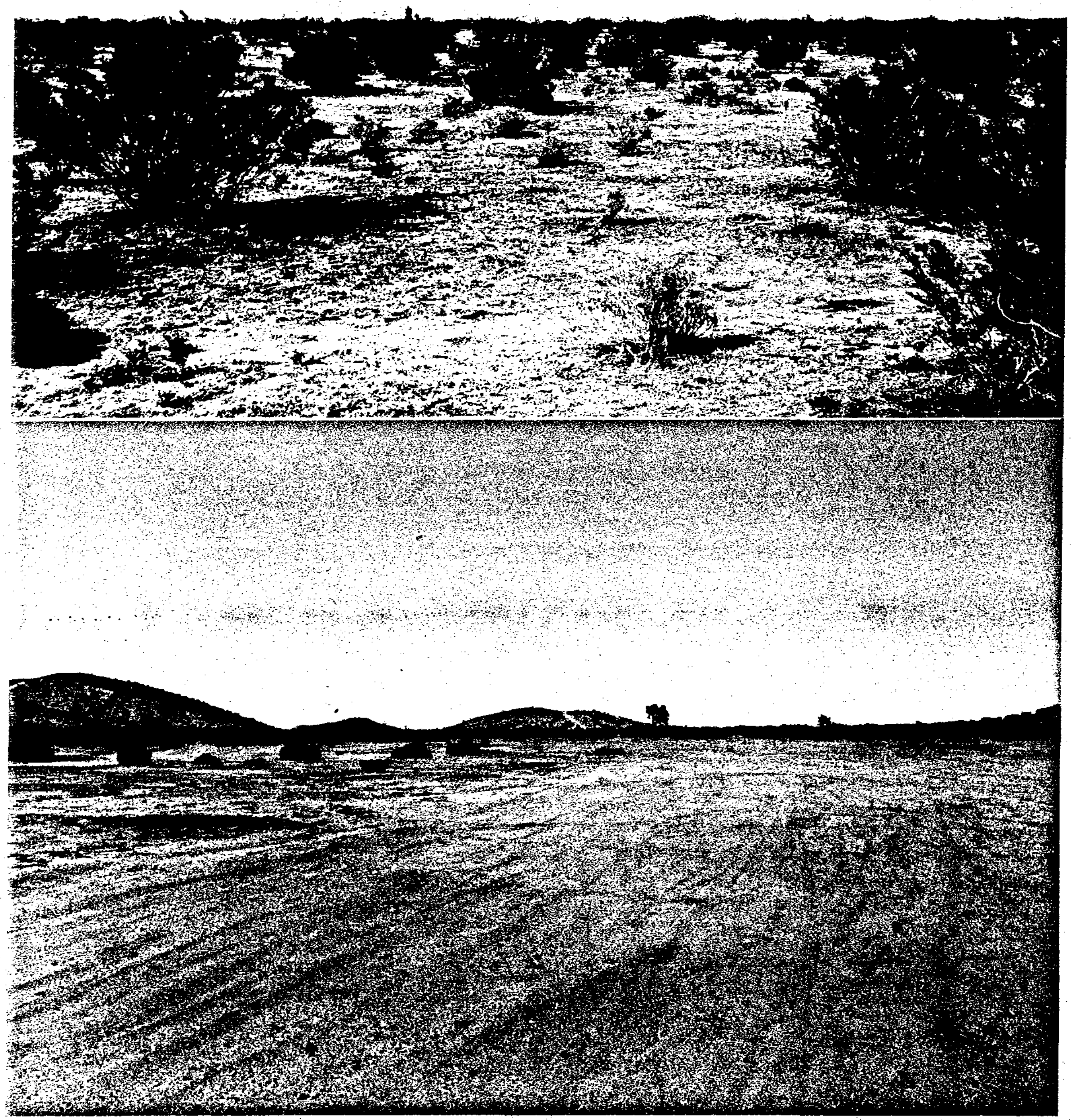


Figure 5. Shadow Mountains locality habitat.

Top: Control site (D_c). Bottom: Pit area (D_e).

Photographs taken September, 1982.

and the data from the 20 sample plots from each study site were averaged. Perennial vegetation was measured by line transect as described by Canfield (1941). Each site was crossed by 25 m. transects, 24 north-south and 24 east-west. Measurements were made to the nearest 0.1 m. on standing plants; shrubs which were broken off at ground level by vehicular activity were not counted. These data were also averaged for each site. In addition, the data for the transects in sites A_c and A_e were analyzed by analysis of variance, as described by Sokal and Rohlf (1969). Finally, annual plant biomass and perennial ground cover were averaged for all control, moderate-use, and pit areas, respectively, in order to assess the relative vegetation loss due to different levels of ORV activity.

Small mammals were collected using 10 x 3 x 3 inch (25.4 x 7.6 x 7.6 cm.) Sherman live traps. The trapping configuration (Fig. 6) consisted of two parallel census lines 35.4 m. apart, each containing 17 traps spaced every 10 m., as per O'Farrell (1977). Crushed peanuts and apple slices were used as bait for the first two trap-nights, but halved peanuts were used thereafter when it was discovered that ants removed the small pieces. Traps were baited and set between 1630 and 1830 hours, and checked from 0530 to 0730 the following morning. Captures were individually transferred from the traps to a holding-and-marking cage constructed of wire bars on a wooden base. This device measured 50 x 50 x 150 mm.; a median sliding

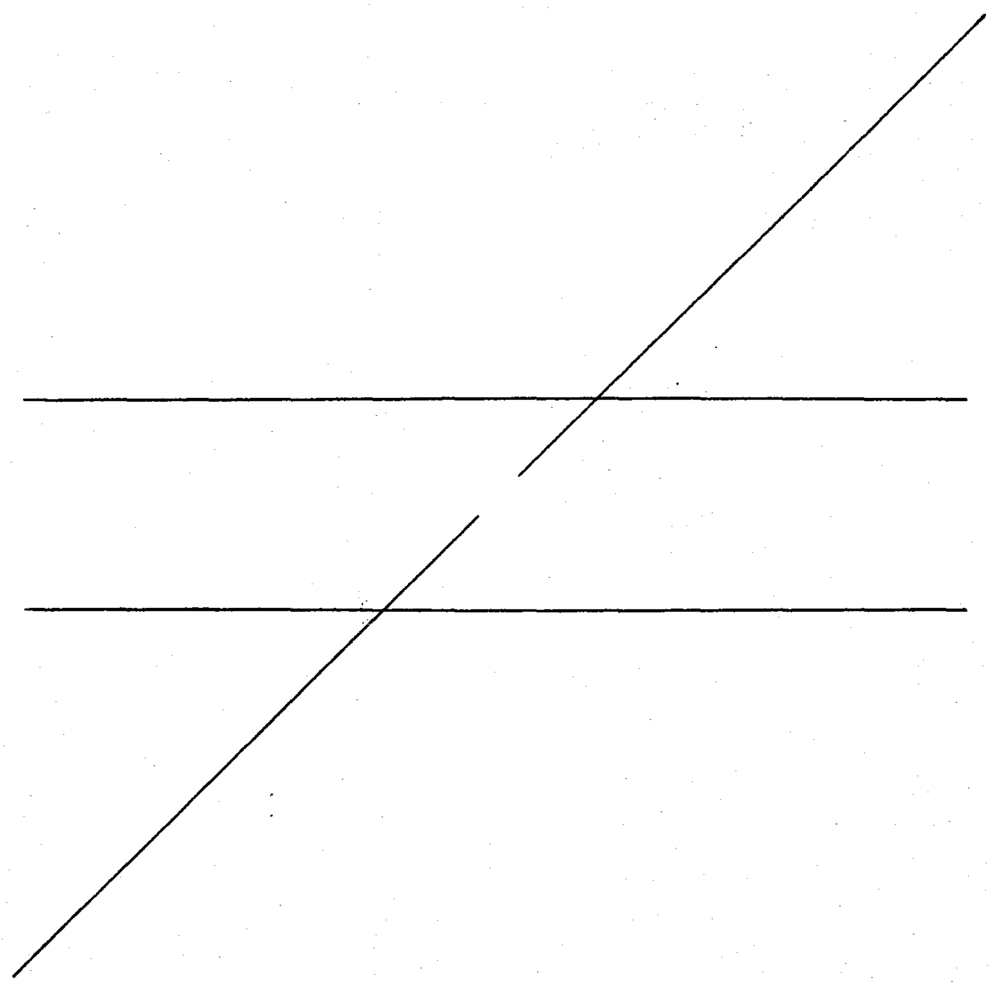


Figure 6. Mammal trapping configuration. Census lines (horizontal) are intercepted by the assessment lines at a 45 degree angle.

divider reduced the interior length to 75 mm. for smaller species. Animals in the cage were restricted in their movements and thus could be easily identified and marked. My fingers were also spared numerous bites. Animals were marked with permanent red marks-a-lot on their ears, tail and dorsal fur; recaptures were re-marked each time to insure positive identification. Certain individuals proved quite adept at cleaning their fur; however, the ink stained their ears and tails deeply enough so as not to be removed. After marking, small mammals were immediately released at the site of capture to minimize handling time and reduce the chances of trauma.

Trapping began at the dry lake sites on 18 April, 1982, and continued six nights per week until eight trap-nights per area had accumulated (5 May). Saturday nights were avoided because of intensive camping and vehicle use. Paired sites were sampled on an alternating basis; the moderate-use area and its control one night, the pit area and its control the next. This method allowed two ORV-used areas to be sampled concurrently with a limited number of traps. Experimental sites were always sampled the same night as their corresponding control areas to reduce bias. The number of each species of mammal was recorded for each study site. The Simpson index of species diversity, as described in Odum (1975), was then determined using the formula

$$D = \Sigma(n_i/N)^2 \qquad (1)$$

where n equals the number of each species and N equals the total number of individuals captured. Diversity is then expressed as

$$1 - D \qquad (2)$$

By the eighth trap-night the recapture rate had stabilized at approximately 75%, and assessment lines were set up on 9 May. The rationale for spending extra time with assessment lines is that accurate density determination is not possible without knowledge of the amount of area being sampled. This area is usually larger than the trapping configuration due to the fact that small animals are mobile and bait can attract them from some distance. The area of effect, number of small mammals it contained, and the resultant density values were obtained for each study area using the assessment lines and methods described by O'Farrell, et al. (1977). Each line contained 12 traps spaced every 10 m., and ran at a 45-degree orientation to the census lines (Fig. 6); this configuration maximized the number of traps within the area of effect around the census lines (Smith, et al., 1975). Assessment line trapping continued in the same alternating manner as with the census lines, until three trap-nights per area had accumulated (14 May). After the last night of assessment line trapping, the entire procedure was repeated at the Shadow Mountains locality from 16 May through 11 June.

Originally pitfall traps augmented with hand noosing had been planned for lizard sampling. However, the sheer volume of ORV traffic and proximity of campers (especially in the pit areas) made that plan unfeasible. Hand capture also proved too slow and tedious with agile and wary species such as western whiptail lizards (Cnemidophorus tigris). Ultimately removal censusing with 22-caliber dust shot was utilized. Desert tortoises (Gopherus agassizii) were marked with red marks-a-lot on the posterior margin of the carapace and released where found. Snakes were not included in this study since many are nocturnal and encounters are fortuitous.

Reptile sampling was done between 0900 and 1130, during the period of peak reptile activity, from 2 May through 10 May at the lake bed sites and from 16 May through 24 May at the Shadow Mountains sites. Paired sites were sampled concurrently for four days; one hour was spent in a control area and the next hour in its corresponding experimental site. The order of patrolling was alternated (control area first, or vice versa) to reduce daily temporal bias. Most specimens were collected during the first 40 minutes of patrolling, with few added in the last 20 minutes. Each area was patrolled first around its perimeter, then across in a grid pattern; finally it was crisscrossed diagonally to ensure thorough coverage. Species diversity was determined in the same manner as for mammals; density figures were not recorded, since assessment lines were not compatible with the method of censusing used in this study. The average number of individuals and species of reptiles were determined for each category of study site (pit area, moderate-use, or control), as well as for each of the eight study sites.

RESULTS

Plant cover for all study sites is summarized in Table 1. All ORV-used areas had lower figures than did the controls, especially for annual vegetation. Control areas averaged 9.9% perennial ground coverage and 185 grams per square meter of annual plant biomass. In the moderate-use sites the surface area between perennial plants was denuded and the soil compacted; many shrubs were damaged by vehicular activity. Perennial cover averaged 4.8%, 49% of the control mean. Creosote bush comprised 86.4% of that figure, as compared to 66.6% in the control areas. In

Table 1. Vegetation at 8 study sites.

Site	Average Perennial Ground Cover (%)	Average Annual Plant Biomass (g/m^2)
A_c	10.92	192
A_e	5.2	22
B_c	10.45	206
B_e	0.0	0
C_c	9.45	255
C_e	4.48	46
D_c	8.72	87
D_e	1.04	0

fact, most of the difference in perennial ground cover (between the moderate-use sites and the controls) is due to loss of smaller subdominant shrubs: creosote bush averaged a 36.5% reduction from the control figure; subdominant perennial plants averaged an 80.0% loss. Annual vegetation was unevenly distributed, being preferentially eliminated from open areas between larger shrubs. Moderate-use areas averaged 34 g/m^2 of annual plant biomass, 18.4% of the control value.

Vegetation in the two pit areas showed extreme destruction by vehicles. The dry lake pit area contained no plant life whatsoever, while a few battered creosote shrubs survived at the Shadow Mountains site. Average perennial cover was 5.3% of the control mean; annual vegetation was too sparse to measure.

Terrestrial vertebrates showed a marked reduction in numbers and diversity in areas frequented by vehicles. The data for mammals and reptiles were pooled and plotted against perennial ground cover (as a measure of habitat quality) in figures 7 and 8. Highly significant correlations between habitat quality and the number of individuals ($r = 0.89$) as well as the number of species ($r = 0.95$) can be seen. Control sites averaged 35.75 individual mammals and 4.25 species; species diversity averaged 0.433 (Table 2). On moderate-use areas, 8.45% fewer individuals and 17.65% fewer species were found, while the species diversity there averated 0.271. Results from assessment line trapping indicated that the area of

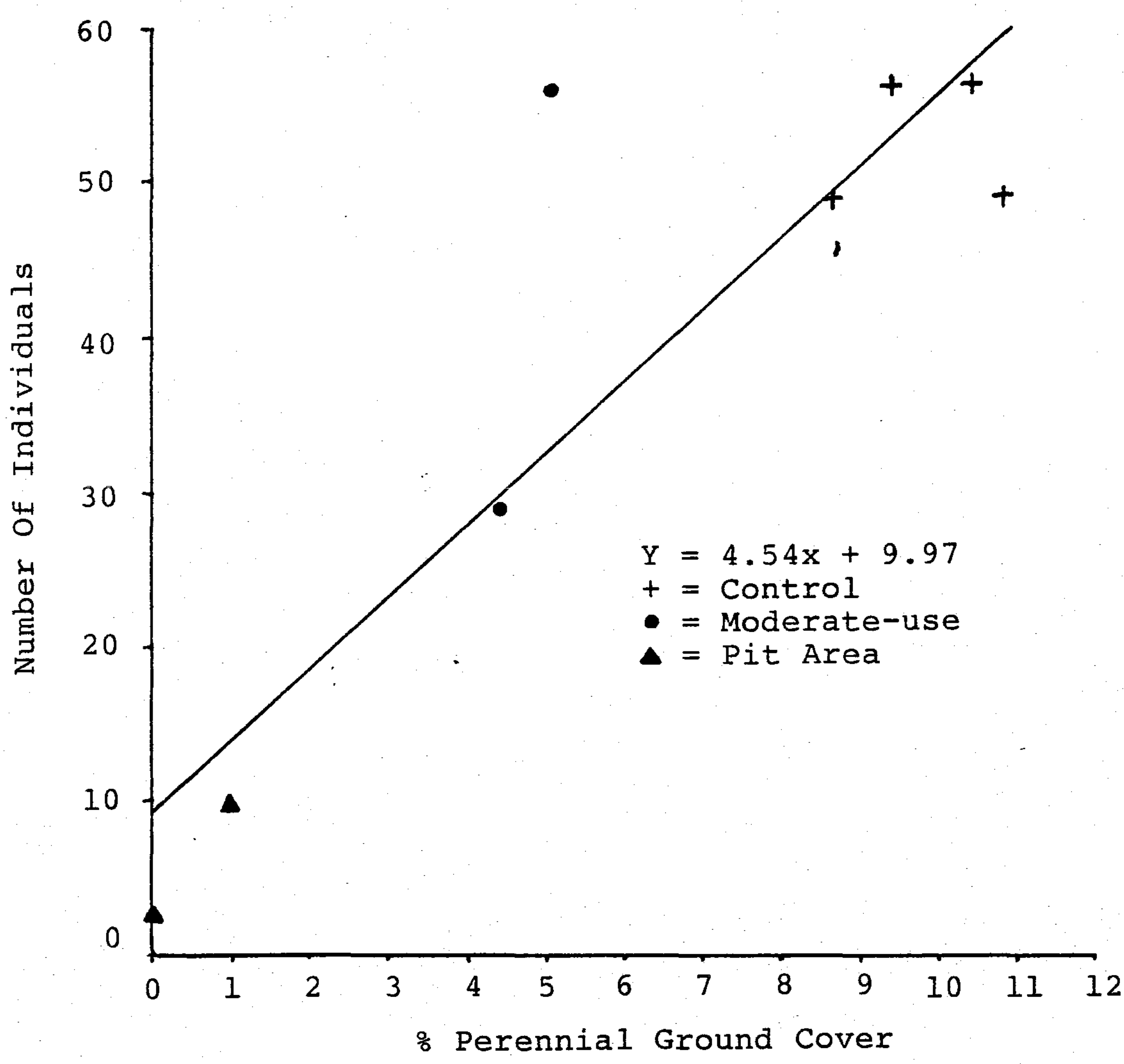


Figure 7. Number of individual mammals and reptiles captures as a function of perennial ground cover.

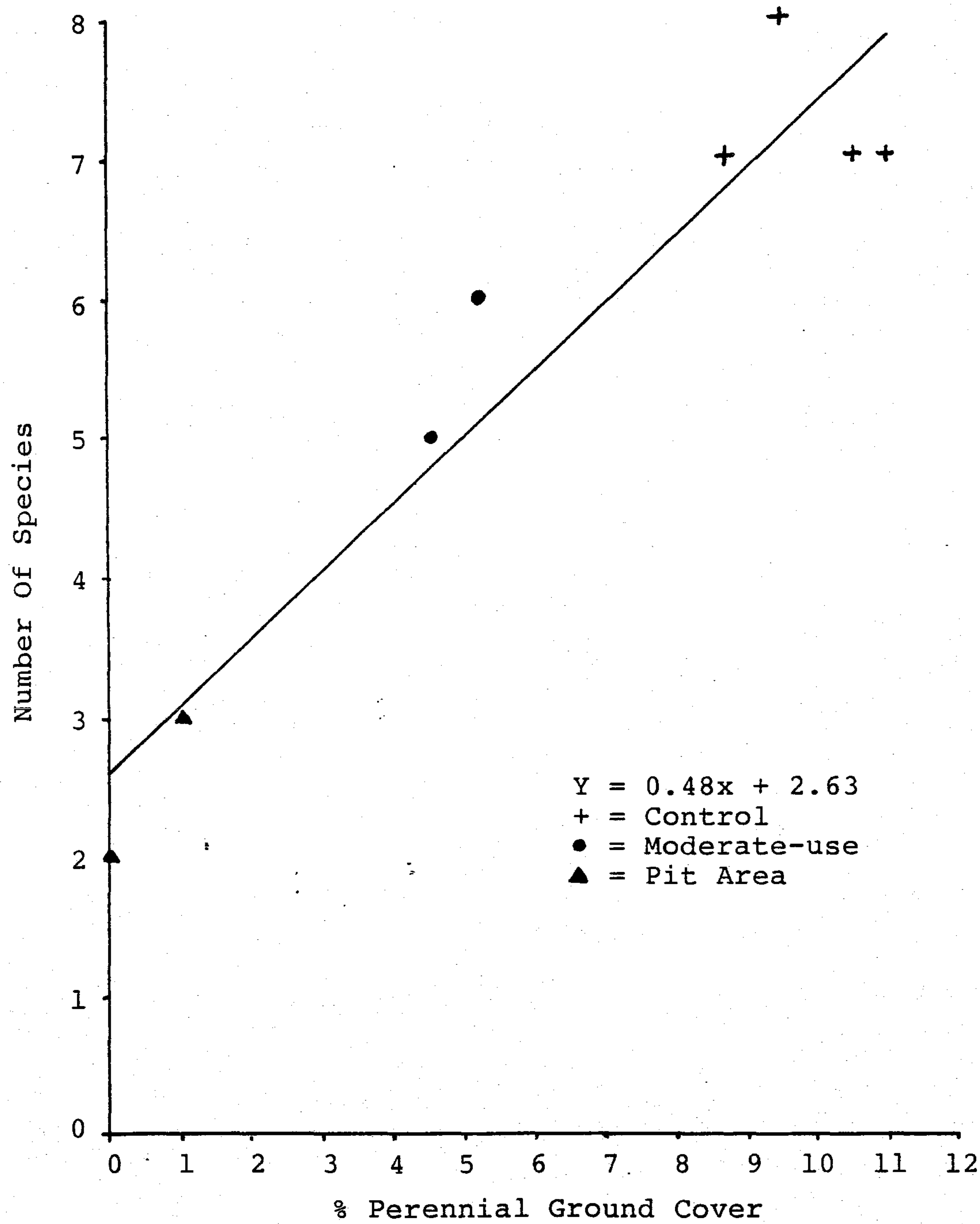


Figure 8. Number of species of mammals and reptiles as a function of perennial ground cover.

effect around the census lines was 4.79 ha in all study areas. Rodent density averaged 14.5 ha in the control areas (Table 2), while moderate-use area density averaged 13.8% less.

No recaptures were made at the dry lake pit area (B_e), therefore a reliable density figure could not be obtained. However, the two specimens captured at that site probably were transient animals, since no burrows could be found there. For that reason I am confident that the density for that particular site is zero. Density in the remaining pit area was only 2.07% of the control figure; if the two areas are averaged, then the density represents only 1.03%. Species diversity at the dry lake pit area was also zero; averaging both pit areas gives a figure of 0.222.

In terms of numbers, Merriam's kangaroo rat (Dipodomys merriami) was the dominant rodent in all areas (Table 2). The species represented 73.1% of all mammals in control sites, 84.7% in moderate-use areas and 83.0% of pit area captures.

Reptile counts also demonstrated reductions in patterns similar to those recorded for mammals. Control areas averaged 16.75 individuals and 3 species, with species diversity at 0.553 (Table 3). Moderate-use areas contained an average of 40.3% fewer individuals and 33.3% fewer species; pit areas averaged 85.1% fewer individuals and 66.7% less species. Species diversity values were

Table 2. Individual mammals collected on study sites.

Locality and Species	Number			
Dry Lake Sites	A_c	A_e	B_c	B_e
Ammospermophilus leucurus			2	
Dipodomys deserti		2		
D. merriami	27	38	27	2*
D. panamintinus	1			
Onychomys torridus	2	4	3	
Peromyscus eremicus	3	1	3	
Total	33	45	39	2
Density (number/ha)	12.6	16.6	15.0	0.0
Species Diversity	0.318	0.277	0.480	0.0
Shadow Mountains Sites	C_c	C_e	D_c	D_e
Dipodomys merriami	24	17	26	4
Onychomys torridus	5	2	4	2
Peromyscus eremicus	4	1	1	
Perognathus longimembris	2		3	
Spermophilus mohavensis	2			
Total	37	20	34	6
Density (number/ha)	16.2	8.4	14.2	0.3
Species Diversity	0.544	0.265	0.391	0.444

* Individuals captures at site B_e are considered transient and not included in density calculation.

likewise reduced, averaging 0.305 for the moderate-use areas. Only one species was recorded in each pit area, resulting in zero diversity. Of the 88 individual lizards encountered, western whiptails were the most numerous, accounting for 54.5% of the total (Table 3). Side-blotched lizards (Uta stansburiana) proved to be the second most numerous, at 29.5%. Four desert tortoises (Gopherus agassizii) were found, all on control site (A_c). An additional specimen was discovered on control site (C_c), but it was not included since the find was made during the

Table 3. Individual reptiles collected on study sites.

Locality and Species	Number			
Dry Lake Sites	A_c	A_e	B_c	B_e
Cnemidophorus tigris	11	10	8	
Gopherus agassizii	4			
Phrynosoma platyrhinos			2	
Sceloporus magister		1		1
Uta stansburiana	1		7	
Total	16	11	17	1
Species Diversity	0.461	0.165	0.595	0.0
Shadow Mountains Sites	C_c	C_e	D_c	D_e
Callisaurus draconoides			2	
Cnemidophorus tigris	7	3	9	
Sceloporus magister	2			
Uta stansburiana	10	6	4	4
Total	19	9	15	4
Species Diversity	0.576	0.444	0.551	0.0

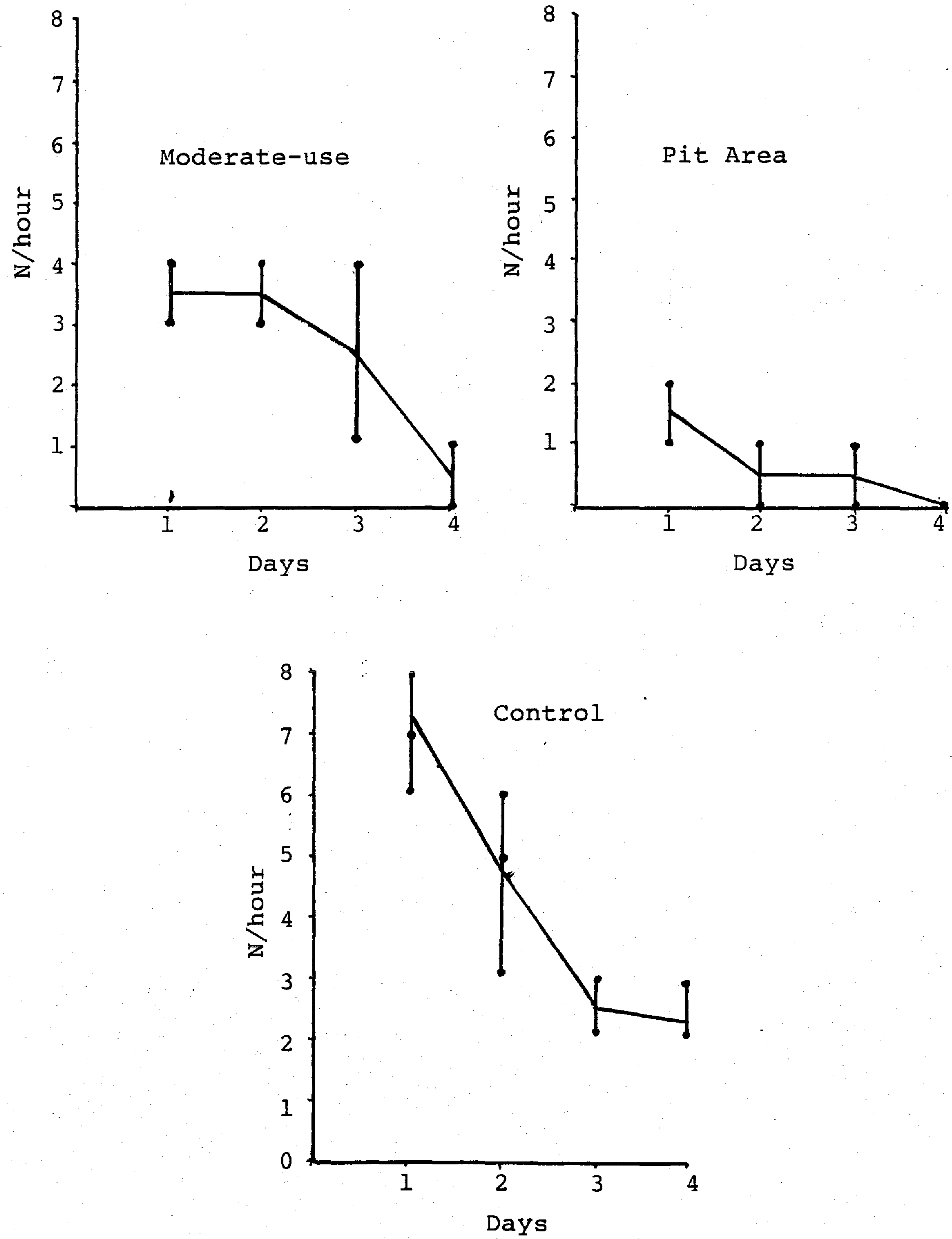


Figure 9. Reptile captures per hour.

vegetation survey after the reptile census of that area was complete.

Figure 9 shows the average rate of capture for reptiles in the ORV-used areas and the controls. As would be expected with removal censusing, the majority of individuals (46.1%) were captured on the first day. The second, third and last days yielded 27.8%, 20.0% and 6.1% of the total number captured, respectively.

DISCUSSION AND CONCLUSIONS

The structure and composition of the creosote shrub community, like any other, is affected by several biotic factors. Soil depth, degree and direction of slope and elevation all result in variations from one locality to the next. The study sites for this experiment were chosen in part because their close proximity to control areas minimized local variations. Therefore, the biotic differences should be due primarily to the influences of concentrated camping activities and ORV use. Although removal censusing is less time-consuming, the behavior of the subject animals may be altered (O'Farrell, et al., 1977); for that reason live trapping was utilized for small mammals. The same rationale also applies to reptiles; however circumstances dictated removal.

A number of difficulties encountered during this study are worth mentioning. ORV activity around El Mirage Dry Lake and the Shadow Mountains is spread out over a wide area. Since some vehicle activity occurs on virtually every part of the region, control areas are not without some damage. This may have affected the results obtained, but the extent of influence is unknown; numerical data on light ORV use is unknown to me. Certainly such impacted areas are in need of study to determine whether or not they are valid controls. Unfortunately such areas themselves would require almost unobtainable pristine land as controls. The ORV-impacted areas in this experiment are used extensively; vehicles are present on an almost daily basis, especially in pit areas. During this study vehicles crossed the pit areas during almost every trapping period, sometimes as late as 2300 hours. In addition, the attitude of many ORV users is one of careless disregard for private property or natural beauty. Vandalism is rampant; rocks are defaced with graffiti, houses are broken into and shot up. I had traps crushed by vehicles during the night and three stolen while preparing bait. For fear of theft, my vehicle could never be left unlocked.

One moderate-use area (A_e) had more individual mammals (45, Table 2) than any control site. A number of factors may have contributed to this unexpected finding. Certainly statistical variation must be considered; sampling many areas would presumably correct that. Another possibility is that the degree of habitat destruction was not severe enough to reduce the rodent population. That site contained 5.2% perennial ground cover; creosote bush alone provided 5.08%. An analysis of variance as described by Sokal and Rohlf (1969) was performed on the data from the line transects from that site and its control. The results indicated that no statistical difference in creosote bush cover existed between the two areas at a 5% level of significance. Many rodents excavate their burrows among the roots of these shrubs and the relative abundance of these plants may support a large population.

ORV use affects desert vertebrates in a number of ways, both direct and indirect. Animals can be killed or maimed outright in direct encounters with vehicles. Especially vulnerable are diurnal lizards which often bask in open ground frequented by ORVs. Larger, more visible animals [e.g., coyote (*Canis latrans*), jackrabbit (*Lepus californicus*)] are often pursued to the point of exhaustion; I have witnessed this on several occasions. Such harassment places a considerable energy burden on these organisms which must already cope with a harsh environment. Vehicles also crush nests and burrows which constitute vital retreats for a variety of desert animals. ORVs, especially motorcycles and dune buggies, tend to be noisy, and that alone can affect wildlife in a variety of ways. Startle or fright reaction is usually the response to sudden noise (Dufour, 1980). Habituation to such intermittent noise has been demonstrated in rodents (Borg, 1979) and may occur in other wildlife. However, associated stress responses such as an elevation of blood pressure, serum cortisol, and blood sugar, and changes in lipid levels become more pronounced with chronic exposure rather than lessened by habituation (Dufour, 1980). Stress tends to be compounded in animals which cannot escape the offending stimulus, as might be the case for a rodent in its burrow. Anthony, et al. (1959) discovered that compounding noise stress actually reduced the lifespan of rodents. Reduced reproductive capacity, in the form of reduced fertility and interrupted gestation results from chronic noise exposure (Dufour, 1980). Abnormal behavior patterns, including reduced social interaction and heightened aggression have been documented; Merriam's kangaroo rats, normally docile towards human handling, become pugnacious immediately following desert motorcycle races (Brattstrom, pers. comm.). Persistent noise can cause a breakdown of social structure, and result in some animals abandoning their habitat to seek a new one, with a considerable expenditure of energy. Home ranges of rabbits (<u>Sylvilagus</u> <u>spp</u>.), for example, changed size in response to snowmobile noise (Soom, 1972). Predator-prey relations can also be altered; Bondello and Brattstrom (1979) investigated the effects of vehicle noise on Mojave fringe-toed lizards (<u>Uma</u> <u>scoparia</u>), desert kangaroo rats (<u>Dipodomys</u> <u>deserti</u>), and spadefoot toads (<u>Scaphiopus</u> <u>couchi</u>). Cumulative exposures to such sounds resulted in reduced auditory sensitivity in the reptiles and rodents. Both these species depend on acute hearing to detect and escape predators such as snakes and owls. Reduction in hearing sensitivity clearly leaves these organisms more susceptible to predation. The effects on Scaphiopus were more direct. This anuran burrows at the fringes of sand dunes, emerging during summer thunderstorms to reproduce in the temporary rain pools. Apparently thunder is the stimulus for emergence, and taped ORV noises match the sound spectrum enough to cause the animals to emerge in laboratory tests. In the wild, vehicle noise could evoke emergence during the wrong season, with disastrous consequences.

By far the most serious threat to desert vertebrates is the destruction of their habitat. A typical motorcycle will impact about 1 ha in 80 km. of travel, while a 4-wheeled vehicle will affect 3.3 ha over the same distance (Wilshire, 1980). When rolling on firm ground, the main stress transmitted to the substrate by tires is compression. On soft surfaces and while hillclimbing, however, shear becomes dominant. Ancillary equipment such as tire chains and special-design tires (knobbies and paddle tires) greatly increase shear, displacing incredible amounts of soil. Wilshire (1980) reported that motorcycles may displace 450 to 1800 kg. per km., and 4-wheel-drive vehicles may displace 1800 to 27,000 kg. per km. Stability of desert soil depends primarily on plants, desert pavement (a thin layer of small stones), and chemical crusts. Such features are extremely fragile; a single vehicle pass may destroy them. As the desert soil is destabilized, erosion by wind and water is greatly exaggerated. Wind causes deflation, carrying away topsoil in dust plumes extensive enough to be photographed from space (Nakata and Wilshire, 1976). Wilshire (1980) reported that the 1974 Barstow-to-Las Vegas motorcycle race produced more than 610,000 kg. of airborne particulate matter. Erosion by water is often more noticeable, carving deep gullies into denuded hill-sides, stripping away topsoil and burying vegetation (at the base of the hills) under fans of alluvium. Wilshire and Nakata (1977) measured the soil loss from a single motorcycle trail at 150 metric tons; a heavily used hill-side was estimated to have lost 11,000 metric tons.

Not only does intensive vehicle use destroy desert plant life, but it also inhibits the revegetation of damaged areas. Compression of the soil and removal of plant cover alters the thermal characteristics and hydrology of the substrate. Root penetration is greatly inhibited, regrowth of annual grasses is retarded, and the germination strategies of the seeds of many species are upset (Liddle and Moore, 1974; Zimmerman and Kardos, 1961; Taylor and Gardner, 1963; Snyder, et al., 1976; Fribourg, et al., 1975). Even the noise of ORVs may have an adverse effect; Woodlief, et al. (1969) discovered that random noise retarded the growth of tobacco plants. To my know-ledge no data exists for desert shrubs in the field, but it is a potential problem worthy of investigation.

ORV enthusiasts often contend that the desert is tough and can tolerate limited vehicle use (a view once held by myself). By not restricting ORV activity to certain areas (i.e., open the floodgates) the impact will be "diluted" over a wide area, and the desert will remain intact. I agree with Bury, et al. (1977) that this idea, however attractive, is false. The creosote shrub community is an ancient and fragile one, easily destroyed. Many of the perennial plants are decades old and will require a correspondingly long time to be replaced. Wells (1961) reported that the revegetation of 33-year-old Nevada ghost town streets was still incomplete. Other biological features are utterly irreplaceable in human time scales, such as clonal creosote bush rings. These formations have been estimated to be 1,500 to 3,000 years old (Vasek, et al., 1975); thus replacement times would probably be measured in millenia. Low revegetation potential, coupled with the fact that vehicle tracks in the desert last many years, indicate that even light ORV use will have a cumulative effect upon the environment. Even when most perennial plants survive, vehicles alter soil conditions and scatter seeds, undoubtedly affecting the germination potential of annual plants. This vegetation represents a major course of food for many vertebrates and its loss compounds stresses already imposed by ORVs. Recruitment into the vertebrate population is reduced, especially for those species with low reproductive potentials and long maturation time. Western whiptails and leopard lizards (<u>Crotaphytus wislizenii</u>) are estimated to live at least seven or eight years by Turner, et al. (1969a, 1969b). The females of these species begin reproducing at an average age of 22 months, usually laying one clutch of two or four eggs per year. The reproductive ecology of these animals is closely tied to the productivity of perennial shrubs and their associated arthropods; poor conditions result in smaller females which lay fewer eggs. Therefore, in addition to direct mortality, ORVs adversely affect these species by further reducing their already low reproductive rates. Most lizards are low-order consumers, supporting a host of reptilian, avian and mammalian predators. The secondary and tertiary effects of their loss from an area are not fully known.

Increasing use of ORVs progressively damages the desert habitat. Coupled with intensive camping, much activities utterly devastate some areas. In one of the pit areas studied here, no vegetation of any kind remained, and the vertebrates were completely eliminated (the captures recorded there were made near the periphery and no doubt represent transient animals). Clearly these places will require many years to recover.

This study investigated the effects of ORVs on a limited sampling of vertebrate taxa, and in no way gives a complete picture of the impact on all desert biota. Desert ecology is not completely understood, and the interrelationships between organisms are highly complex. For this reason other groups are in need of study. The desert contains many predatory forms, reptilian, avian and mammalian. Reduction of prey species would certainly have a detrimental effect on their populations. Annual plants are usually first to be eliminated by vehicular activity (Davidson and Fox, 1974). They produce vast quantities of seeds necessary for the survival of many birds, rodents and invertebrates. The impact of widespread light ORV use has been surmised, but not assessed in quantitative terms. Finally, more studies are needed for different habitats frequented by ORVs, such as chaparral, oak woodland and coniferous forest.

The problems facing any agency attempting to regulate ORVs are numerous. The BLM has a vast area under its jurisdiction, with limited manpower and legal authority. In my opinion it is little more than a "paper tiger" with respect to ORVs. Unfortunately this regrettable situation is not likely to improve within the foreseeable future. The attitude of the current federal government is one of cutting budgets and a "multiple use" concept for its lands. This trend is reflected in the recent reduction of BLM personnel and its policy of opening more land to unrestricted vehicle use (BLM, pers. comm.). Unless manpower and funds are allocated to properly manage ORVs, the unique and fragile desert habitat will continue to be decimated.

This study examined ORV impact on four sites at two locations, and a number of comparisons were made of the data obtained. The results showed the effects of ORV use to be detrimental in all areas studied. Habitat quality is inversely proportional to the degree of vehicle use and camping activity. The general pattern of degradation involves the loss of annual vegetation first, followed by small subdominant perennial shrubs; finally, the remaining dominant shrubs are destroyed. Likewise, the samples show reductions in vertebrate numbers and diversity (Fig. 6, 7; Table 2, 3). These data correlate well with results obtained by Busack and Bury (1974), Davidson and Fox (1974), and Bury, et al. (1977), and I feel they are applicable in other desert areas with ORV activity.

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