Effects of Off-Road Vehicles on Vertebrates in the California Desert

by

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Abstract

Off-road vehicle (ORV) use provides a form of outdoor recreation that is increasingly popular. The purpose of this study was to examine the impact of these machines on creosote shrub habitat and associated wildlife in the western California Desert. Comparisons at eight paired sites (Control and ORV use) demonstrate that ORV-use areas have significantly fewer species of vertebrates, greatly reduced abundance of individuals, and noticeably lower reptile and small mammal biomass. Diversity, density, and biomass of reptiles and small mammals are inversely related to the level of ORV usage. The number of individuals found in heavily used and pit areas was 55% and 20%, respectively, of that present in undisturbed sites. Biomass estimates were even lower (23% and 17%, respectively). Censuses at three localities also showed decreased diversity, density, and biomass estimates of breeding birds in ORV-used areas. Present evidence indicates that off-road vehicles have a negative effect on desert wildlife over large areas. This widespread impact must be recognized to manage and conserve resources in ORV-use areas.

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Introduction

Driving of off-road vehicles (ORV) is a popular form of outdoor recreation in the California Desert. Use of ORV's has markedly increased in recent years but few regulations governing how and where they may operate are in effect. The impact of ORV use upon desert wildlife, while suspected to be great, has not been conclusively documented.

The California Desert, a geographic region extending from the coast range of southern California to the Colorado River, is one of the largest wild areas in the continental United States. Measuring about 480 km from north to south and 120 to 320 km in breadth, it consists of 6.9 million ha, over half of which is National Resources Land (public domain).

Annual precipitation is usually less than 25 cm over most of the California Desert. In addition to aridity and hot summers, these desert lands are characterized by rough, unsettled terrain. The landscape includes alkaline dry lakes, large sand dunes, remote springs, rugged hills, and steep mountains interwoven with expanses of gravelly or sandy soil. The predominant vegetation is creosote shrub habitat. There is a great diversity of plants and animals; many specialized forms have either invaded the region or evolved there since the Pleistocene. Physical, geological, archeological, and paleontological features of the California Desert are striking and largely unexplored (Grant 1973; Carter 1974; Stebbins 1974).

Resources of the region are increasingly stressed by demands for mining, grazing, agriculture, subdividing for homes or land speculation, and recreational use. One of the gravest threats to the area at this time is the use of ORV's, which permit access to most of the desert. An estimated 1 million motorcycles and 500,000 dune buggies or four-wheel-drive vehicles are used for recreation in southern California. The U.S. Department of Interior (1974) reported 14.5 million visitor-use days on the California Desert in 1974, reflecting a 20% increase over 1973 and a growth rate 10 times that of the national average for outdoor recreation. An estimated 25% of this recreation was ORV use, but these figures may be exaggerated as there are no actual counts over large areas.

The magnitude of ORV activities is indicated by statistics of the Bureau of Land Management (BLM) which recorded a total of 163 special-use permits issued in 1974 for recreation events involving 120,000 participants. Besides these organized events, individual ORV use for rock hounding, sightseeing, play, camping, hunting, and picnicking is popular on both public and private lands. Clearly, motorized vehicle use today is common and widespread over the California Desert.

United States Executive Order 11644 (8 February 1972) charged Federal agencies with the responsibility for developing and issuing regulations for the control of ORV's on lands under their custody and control. Management and regulation of ORV's in the California Desert is primarily the responsibility of the BLM. In 1973, the BLM released its Management Program for Recreational Vehicle Use on the California Desert. This program, an improvement over the prior lack of regulation, required special-use permits for organized events on public lands, established a Desert Ranger force, planned inventories of wildlife for large areas, accomplished environmental assessment for an occasional large event, and channeled recreational use of the desert into special-use areas. However, only 3% of BLM lands were closed to ORV use whereas 6% were open and 8.5% were designated "special design" pending future decisions on their uses. Although the program restricted ORV use to existing or designated roads and trails for the remainder of the desert, critics saw this as unenforceable and the BLM plan was challenged by environmental groups as being too lenient in its regulation of ORV's.

Earlier, the U.S. Department of Interior (1971) had stated that there was absolutely no question that environmental impairment occurs as a result of the use of ORV's. Its ORV Task Force, however, discovered a paucity of factual information regarding long-range or irreparable environmental effects due to motorized recreation vehicles. Several authors have recently suggested that various types of off-road vehicles detrimentally affect plants and wildlife (Baldwin and Stoddard 1973; Hoover 1973; Lodico

1973; Greller et al. 1974; Heath 1974; Rickard and Brown 1974; Liddle and Moore 1974; Liddle and Greig-Smith 1975; Bury 1976), but documented evidence of ORV disruption of desert communities is scarce.

A team effort, organized by Berry (1973), examined the effects of ORV's on physical and natural features at Dove Springs Canyon and in the Fremont Valley, Kern County, California. Their reports showed negative effects of ORV's on lizard populations (Busack and Bury 1974) and desert plants (Davidson and Fox 1974). Snyder et al. (1976) reported that motorcycles on hills at Dove Springs Canyon eradicated the vegetation and loosened the soil material, making it highly susceptible to wind and water erosion. Wilshire and Nakata (1976) found that, on alluvial fans, soil compaction is the dominant consequence of motorcycle use. Further, they suggest that motorcycles denude plant cover and strip desert pavement, causing a significant increase in the potential for erosion. In a study with limited use of vehicles in a creosote shrub community, Vollmer et al. (1976) concluded that there was a definite effect on vegetation but variable impact on lizards and small mammals.

General accounts of the impact of ORV's on the California Desert are provided by Carter (1974), Stebbins (1974), Fialka (1975), and Luckenbach (1975). Papers given at the 1976 symposium on the effects of ORV's on the California Desert are being prepared for publication by the Southern California Academy of Sciences.

Management of ORV's requires documented evidence of the impact of vehicular activities on plant and wildlife communities.

Table 1. *Description of 16 test sites in San Bernardino County, California (See text for explanation of Shrub Index and Habitat Quality.)*

Location	Site	Elevation (m)	Date	Creosote shrub N/ha	Creosote shrub Index	Creosote shrub Rank	Habitat quality
Sidewinder Road,	A	780	24-26 May 74	229	211	4	Control
10.5 km S & 5 km	B	750	28-30 May 74	242	137	9	Moderate
W of Barstow	C	750	28-30 May 74	218	69	11	Heavy Use
	D	740	30 May-1 June 74	153	146	8	Control
Stoddard Wells,	E	1,040	5-7 May 75	287	272	2	Control
12.9 km N & 17.7 km	F	1,040	5-7 May 75	74	41	13	Heavy Use
E of Victorville							
Stoddard Wells,	G	950	8-10 May 75	328	293	1	Control
15.3 km N & 8.9 km	H	950	8-10 May 75	65	24	14	Pit Area
E of Victorville							
Anderson Dry Lake,	I	1,020	12-14 May 75	229	87	10	Moderate
13.7 km N & 16 km	J	1,020	12-14 May 75	149	4	15	Pit Area
E of Lucerne Valley							
Anderson Valley,	K	1,100	15-17 May 75	287	227	3	Control
17.7 km N & 13.7 km	L	1,100	15-17 May 75	200	188	6	Control
E of Lucerne Valley							
Johnson Valley,	M	920	18-19 May 75	229	210	5	Control
14.5 km N & 33.8 km	N	920	18-19 May 75	203	181	7	Control
E of Lucerne Valley							
Johnson Valley,	O	975	22-23 May 75	142	59	12	Heavy Use
9.7 km N & 27.4 km	P	975	22-23 May 75	38	1	16	Pit Area
E of Lucerne Valley							

Toward this goal, we here report the results of studies conducted in 1974 and 1975 on the effects of ORV's on vertebrates inhabiting creosote shrub habitat in the California Desert.

Study Sites

Field studies were conducted in San Bernardino County, California, in typical Mojave Desert habitat. Areas that were obviously affected by grazing, power lines, mining, or major roads were avoided. We established several paired test sites representing undisturbed controls and affected sites relatively close to one another, and sampled these paired sites concurrently or on consecutive days, thereby minimizing sampling error. We selected paired sites which appeared to have the same topography, slope, soils, and vegetation type. Disturbance in ORV areas was due mainly to motorcycles.

Four study sites (two controls and two ORV-used sites) were established in each of four localities: Barstow, A-D; Stoddard Wells, E-H; Anderson Valley, I-L; and Johnson Valley, M-P (Table 1, Fig. 1). We surveyed the Barstow area in 1974 and the other three localities in 1975.

All study areas were creosote shrub association dominated by creosote, *Larrea tridentata* (*L. divaricata;* Porter 1963), but there were differences in subdominant perennials, ground cover, and substrata. All study sites were level or with a slight grade (< 3%). Paired sites always sloped in the same direction. The elevation of study sites varied from 740 to 1,100 m. Elevations of paired sites were equal except for minor differences of 10 and 30 m at the Barstow locality (Table 1).

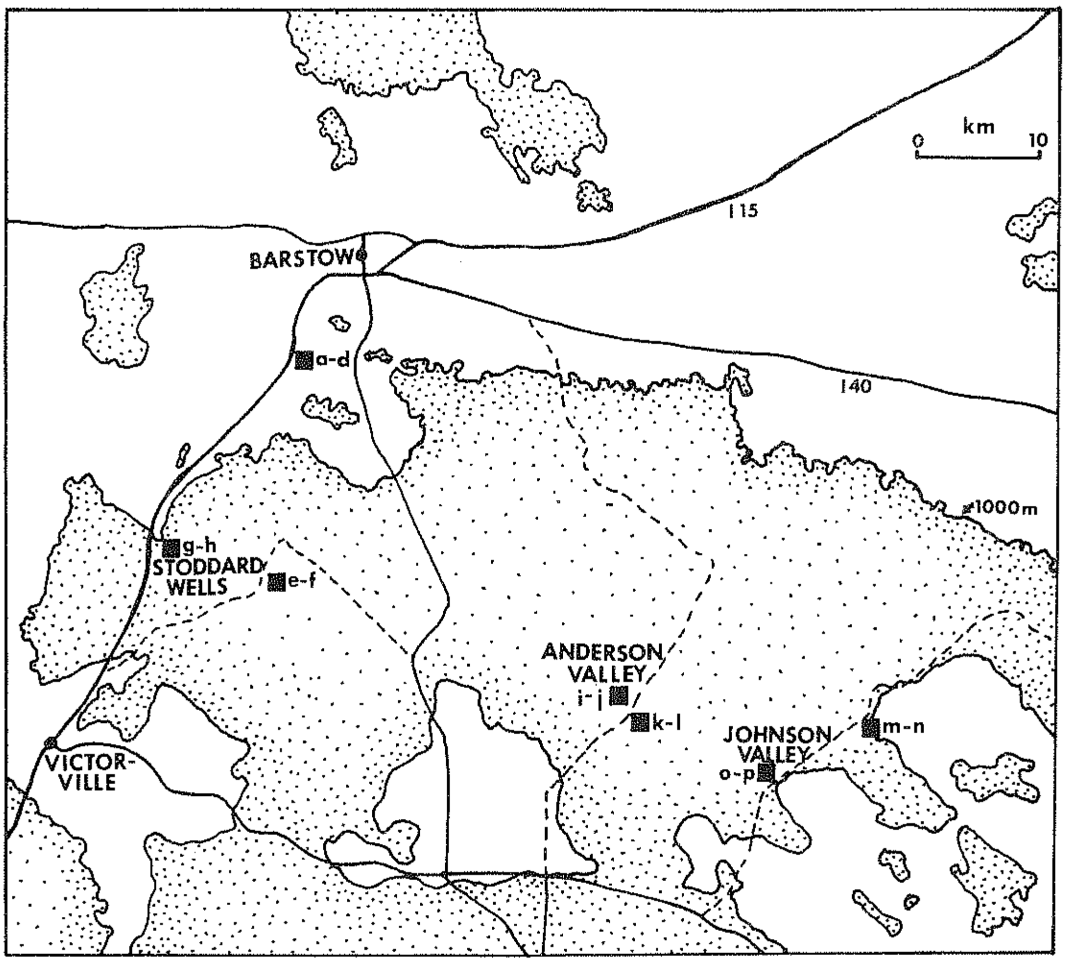

Fig. 1. Location of study sites in the western Mojave Desert, California.

Barstow

The four sites were 9 km SW of Barstow (A-D, Table 1; A-B, Fig. 2). Second to creosote the most abundant perennial at these sites was burro weed (*Ambrosia dumosa*). Other shrubs were turpentine-broom (*Thamnosma montana*), Nevada joint fir (*Ephedra nevadensis*), paper-flower (*Psilostrophe cooperi*), and indigo bush (*Dalea fremontii*). One small Mojave yucca (*Yucca schidigera*) was on the Moderate Plot (B) and two were on the bird census control site. Ground cover largely consisted of spring annuals such as yellow cups (*Oenothera brevipes*), Wallace eriophyllum (*Eriophyllum wallacei*), Venus blazing star (*Mentzelia nitens*), rigid spiny herb (*Chorizanthe rigida*), and filaree (*Erodium texanum*). The substrate was sandy with some areas of small, coarse rocks and desert pavement (i.e., rocky, firm soil).

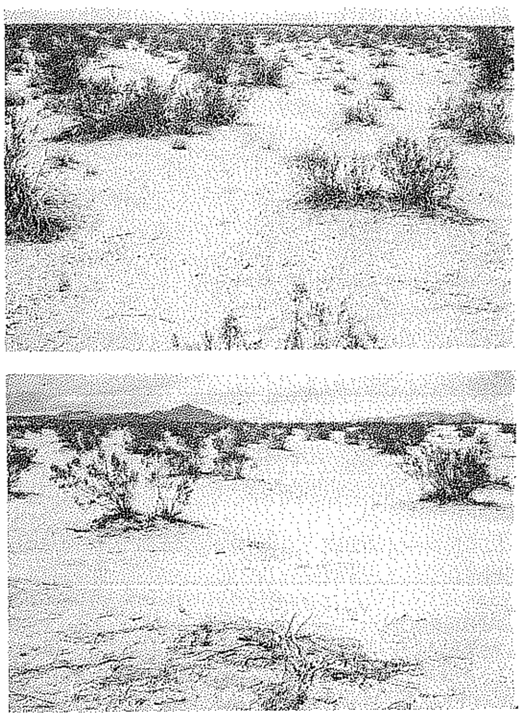

Fig. 2. Habitat at the Barstow locality. Top: Control (A); Bottom: Moderate Use (B).

Stoddard Wells

One pair of sites along Stoddard Wells Road (E and F, Fig. 3) was in a broad, sandy bajada area cut by small washes; rocky areas were located in and near the washes. Perennials included bladder-sage (*Salizaria mexicana*), Mojave yucca, Nevada joint fir, with scattered Joshua trees (*Yucca brevifolia*) and pencil cholla (*Opuntia ramosissima*). Ground cover consisted of fiddleneck (*Amsinckia tessellata*), storksbill (*Erodium cicutarium*), and pincushion flower (*Chaenactis fremontii*).

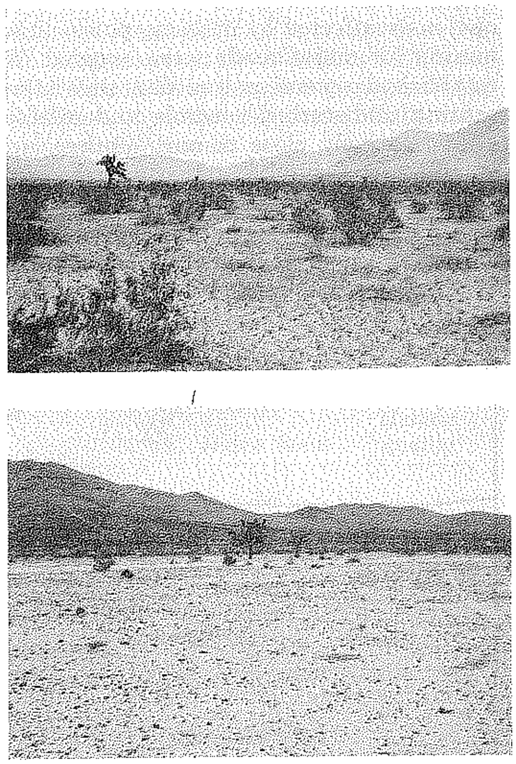

Fig. 3. Habitat at Stoddard Wells. Top: Control (E); Bottom: Heavy Use (F).

The other paired sites were along Mission Road (G and H, Fig. 4). Vegetation was almost entirely an open stand of *Larrea;* the control site had 328 shrubs per hectare but most were small-sized and sparse in foliage. Subdominant shrubs included a few grizzly bear cactus (*Opuntia erinacea* var. *ursina*) and Nevada joint fir. Sparse ground cover consisted mostly of scattered sand mat (*Euphorbia polycarpa*) and filaree; the area between shrubs appeared barren. Soil was mostly heavy limestone gravel; sandy areas occurred near the lower parts of the sites, which bordered a broad wash.

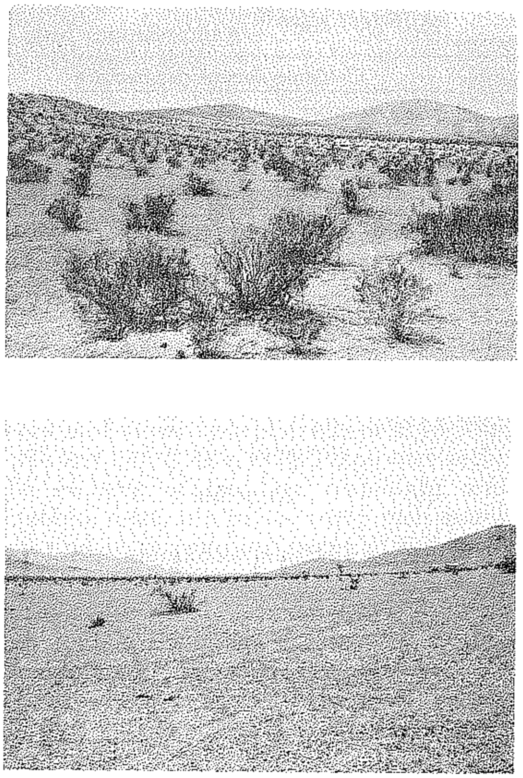

Fig. 4. Habitat at Stoddard Wells. Top: Control (G); Bottom: Pit Area (H).

Anderson Valley

The ORV-used sites at Anderson Dry Lake (J, Fig. 5) were predominantly *L. tridentata* with burro weed, Cooper boxthorn (*Lycium cooperi*), and pencil cholla. Annuals present included storksbill, pincushion flower, Venus blazing star, gilia (*Gilia latiflora*), and spotted langloisia (*Langloisia punctata*). Substrate was chiefly granitic gravel but the bird plot had sandy soils with some deflation mounds.

Control sites at Anderson Valley (L, Fig. 5) were in a similar area of *L. tridentata* with burro weed, turpentine broom, staghorn cholla (*Opuntia acanthocarpa*), pencil cholla and paper-flower. Annual herbage was pincushion flower, spotted langloisia, desert dandelion (*Malacothrix glabrata*), and galleta grass (*Hilaria rigida*). The soil was granitic pebbles and sand.

Johnson Valley

Vegetation in Johnson Valley (M-P, Table 1) was mostly a stand of *L. tridentata* with interspersed burro weed and few turpentine-broom and beavertail cactus (*Opuntia basilaris*). There were essentially no annuals sprouted or blooming, but those few present were mostly storksbill, spotted langloisia, and Mohave buckwheat (*Eriogonum mohavense*). Plant life in the disturbed sites O-P was scant. Substrate in both control and ORV-used areas was granitic pebbles and sand.

Materials and Methods

Habitat Quality

We counted creosote shrubs (number per hectare) and estimated the shrub's foliage to the nearest quartile. For example, a control

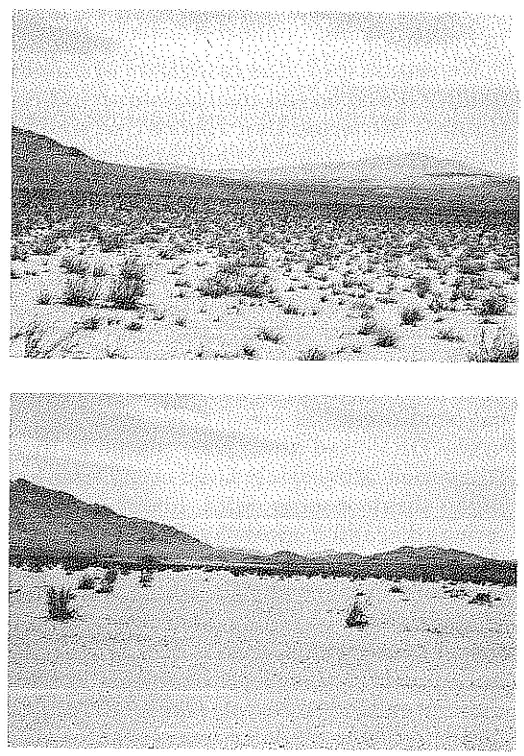

Fig. 5. Habitat at Anderson Valley. Top: Control (L); Bottom: Pit Area (J).

Table 2. *Habitat quality at 16 test sites.*

Condition	N	Rank	Creosote shrubs per hectare: Number	Creosote shrubs per hectare: Index
Control	8	1-8	240 (153-328)	216 (146-293)
Moderate	2	9-10	236 (229-242)	112 (87-137)
Heavy Use	3	11-13	145 (74-218)	56 (41-69)
Pit Area	3	14-16	84 (38-149)	10 (1-24)

test site with 200 shrubs including 20 shrubs which were half broken or dead (20 x 0.50 = 10) and the remainder fully intact (180 x 1.00 = 180) gives an index value of 190. Dead or greatly disrupted creosote shrubs often remained as mounds with a central stump; we counted these as shrubs with a value of zero.

The ORV-used sites had lower shrub counts than controls (Table 2). Many shrubs are disrupted directly by ORV activities and removal of the branches for firewood by ORV riders. The lower shrub counts on affected areas were due to the destruction of perennial vegetation, not to local variation in density.

We established four categories of habitat quality based on the creosote shrub indices: Control, Moderate Use, Heavy Use, and Pit Area (Tables 1 and 2). Only one control site (D, 153 shrubs) had less than 200 shrubs per hectare. Control sites were relatively free of ORV tracks, and we considered a few single tracks to have no, or slight, impact on the site. Pristine sites could not be located in our study because we attempted to place controls relatively close to affected areas for a minimal difference in vegetation and physical conditions.

The ORV-used areas were placed in three categories. Moderately Used study sites had high shrub counts with about half the foliage disrupted; most shrubs were intact at the base. Soil and ground vegetation were disturbed between shrubs, which is a sign of moderate use; initially, ORV's travel around rather than through shrubs. Heavy Use sites had appreciably reduced shrub numbers and indices; ground cover was essentially absent and there was obvious destruction of creosote shrubs (ORV tracks through shrubs, cut branches, crushed plants). Pit Areas were used for camping and ORV staging areas; much debris and litter were present. In pit areas, most shrubs and ground cover were absent or pulverized; the soil was compacted. Representative conditions of our selected study sites are shown in Figs. 2-5.

Reptiles

Lizard collection techniques employed throughout this study area are described by Busack and Bury (1974). Common species were shot with .22 dust or rubber bands; rare species were noosed or captured by hand. All lizards were sexed and weighed; live animals were returned to the test sites at the conclusion of each sampling period. Desert tortoises (*Gopherus agassizii*) were removed from the study areas, measured and weighed, and returned to the exact place of capture within 2 days.

In 1974, two collectors sampled 2 ha per morning by systematically patrolling a grid 2-3 m wide; the route was shifted at the end of each patrol (e.g., changing from a N-S to E-W direction). In 1975, two pairs of collectors simultaneously sampled two sites of 2 ha each (100 x 200 m). Sampling during both years was designed for a total of 8 man-hours per hectare during the same hours each day over three consecutive mornings in a ratio of 3:3:2 h. Collecting was done during periods of peak reptile activity, mostly from 0900-1200 h. For both years, collectors alternated on the sites each day to reduce sampling bias.

Almost all sampling was done during stable weather with temperature and wind conditions approximately the same for the paired study sites. Only 2 days of 3:3 h were done at sites M-N and O-P due to inclement weather which reduced sampling time. It became apparent that 2 days with 3:3 man-hours were sufficient to remove most reptiles from a site; few data were added by the 3rd day's sample (2 man-hours). The data for

8- and 6-h sampling periods are analyzed separately.

Mammals

A grid system of 150 traps was used to sample small mammals on 1 ha at each study site. Single trap stations were set at regular intervals about 8 m apart. Grids consisted of 6 rows of 12 traps and 6 rows of 13 traps set in alternating rows (12, 13, 12, etc). Museum special, rat, Sherman live traps, baited with rolled oats and peanut butter, were used on each site in a ratio of 82:18:50 in 1974 and 100:30:20 in 1975. Traps were set in the evening of the first trap-night and checked, reset, and baited early each morning and in the evening over the sampling period.

Traps were set for 3 trap-nights and the first 2 days of the sampling periods at 10 of the 16 test sites and provided 450 trap-nights per site (Table 3). Due to darkness, Sherman live traps (20/ha) were not set for the first trap-night on four occasions. One pair of sites (E-F) had 430 trap-nights per hectare (96% of the 450 value). Two other pairs of sites (M-N and O-P) were sampled only 2 nights (280 and 300 trap-nights per hectare) and data from these sites are included only with comparisons with those for other 2 trap-night samples. Trap data for the 2 trap-nights and 3 trap-nights are analyzed separately.

There were 3,240 trap-nights completed on the eight controls and 3,280 on the eight ORV-used sites.

Birds

During 1974, three bird study sites of 4 ha each (100 x 400 m) were located adjacent to the control (A) and moderate-use area (B), and included the heavy-use site (C). A total of 6 man-hours was spent on each bird census site over a 3-day period (Control, 25-27 May; Moderate, 28-30 May; Heavy Use, 22-24 May). Surveys were done from 0530 to 0800 h and during the evening from 1800 to 2030 h when bird activity was greatest.

In 1975, four surveys were completed on areas of 40 ha each (1 km x 400 m). Two sites were surveyed in Anderson Valley in the vicinity of sites K-L (Controls) and I-J (Moderate and Pit areas). The latter bird site was assessed as a moderately disturbed area. Two additional sites were located in Johnson Valley: near the control sites (M-N) and a

Table 3. *Number of traps set on each of 3 nights at various sites.*

Site	Condition	Date	Trap night 1	Trap night 2	Trap night 3	Total
A	Control	25-27 May 74	150	150	150	450
B	Moderate	28-30 May 74	150	150	150	450
C	Heavy Use	28-30 May 74	150	150	150	450
D	Control	31 May-2 June 74	150	150	150	450
E	Control	4-6 May 75	130[a]	150	150	430
F	Heavy Use	4-6 May 75	130[a]	150	150	430
G	Control	8-10 May 75	150	150	150	450
H	Pit Area	8-10 May 75	150	150	150	450
I	Moderate	12-14 May 75	150	150	150	450
J	Pit Area	12-14 May 75	150	150	150	450
K	Control	15-17 May 75	150	150	150	450
L	Control	15-17 May 75	150	150	150	450
M	Control	18-20 May 75	130[a]	150	—[b]	280
N	Control	18-20 May 75	130[a]	150	—[b]	280
O	Heavy Use	21-23 May 75	—[b]	150	150	300
P	Pit Area	21-23 May 75	—[b]	150	150	300

[a] Sherman live traps (20) not set.

[b] No traps set because of inclement weather.

moderate ORV-used area north of sites O-P (Heavy Use and Pit Area). Grids were established on the 40-ha sites and flagging was placed every 100 m. A total of 15 man-hours was spent on each bird area over a 3-week period in late May and early June. Census work was again done in the early morning and late evening.

Breeding bird densities in 1974-75 were estimated by the Williams Spot-Mapping Method (Williams 1936; Kendeigh 1944), which determines the abundance and distribution of birds on a grid. The censusing procedure included walking slowly along the edge of each plot, systematically crisscrossing the area, and then wandering until all of the site had been traversed at least three times. Positions, activities, and movements of all birds were noted on field maps of the sites. Species names and activities were abbreviated following Robbins (1970) to rapidly record data. Special effort was made to discover all nests on each site; nearly every shrub was examined for nests and careful search was made for ground nests. Additional time spent surveying areas adjacent to the sites helped determine the approximate percentage of a territory or home range of a bird that occurred in the study area.

The live weights of observed birds were estimated by averaging the recorded data from a series of 20 specimens for each species. These data are based on birds from the Mojave Desert in the collections of the Museum of Vertebrate Zoology, University of California at Berkeley.

Composition of Sampled Fauna

Species composition, abundance, and live weights for all collections and observations are provided in Appendices I (Reptiles), II (Mammals), and III (Birds).

The lizard fauna included: TEIIDAE — western whiptail (*Cnemidophorus tigris*); IGUANIDAE — zebra-tailed lizard (*Callisaurus draconoides*), desert iguana (*Dipsosaurus dorsalis*), desert horned lizard (*Phrynosoma platyrhinos*), desert spiny lizard (*Sceloporus magister*), side-blotched lizard (*Uta stansburiana*), and the leopard lizard (*Crotaphytus wislizeni*). The desert night lizard (*Xantusia vigilis*) was found once (control site L) but is not included because no special effort was made to sample this secretive species. The nocturnal banded gecko (*Coleonyx variegatus*) occurs in the range of the sampled areas but it was not recorded.

The herbivorous desert tortoise occurred on or near all localities; none was found at the Stoddard Wells sites E-H but tortoises frequented the area.

Five snakes were encountered. A spotted leaf-nosed snake (*Phyllorhynchus decurtatus*, 19 g) and one coachwhip (*Masticophis flagellum*, 16 g) were found at the two heavily used sites (C and F). A gopher snake (*Pituophis melanoleucus*, 450 g), coachwhip (250 g), and western ground snake (*Sonora semiannulata*, 8 g) were taken at three control sites (E, G and L). These are not included in the data analysis because they were scarce and most were found in the evening while checking mammal traps.

The mammalian community consisted of the following: CRICETIDAE — desert woodrat (*Neotoma lepida*), southern grasshopper mouse (*Onychomys torridus*), canyon mouse (*Peromyscus crinitus*), and deer mouse (*P. maniculatus*); HETEROMYIDAE — Panamint kangaroo rat (*Dipodomys panamintinus*), and Merriam's kangaroo rat (*D. merriami*), long-tailed pocket mouse (*Perognathus formosus*), and little pocket mouse (*P. longimembris*); and SCIURIDAE — antelope ground squirrel (*Amnospermophilus leucurus*).

We did not observe or attempt to trap carnivorous mammals (coyote, kit fox, mustelids) or large-bodied forms on the study sites. Tracks were not left at some of the sites with a gravel or granitic soil, and we thus omitted occasional signs from our analysis.

Breeding avifaunal species (nesting females or territorial males) were: FRINGILLIDAE — sage sparrow (*Amphispiza belli*) and black-throated sparrow (*A. bilineata*), house finch (*Carpodacus mexicanus*), and Brewer's sparrow (*Spizella breweri*); ALAUDIDAE — horned lark (*Eremophila alpestris*); MIMIDAE — LeConte's thrasher (*Toxostoma lecontei*); and TYRANNIDAE — ash-throated flycatcher (*Myiarchus cinerascens*).

Terrestrial Vertebrate Fauna on Paired Sites

We made comparisons of pooled data of reptiles and mammals (controls and ORV-used sites) using the Wilcoxon Matched-Pairs Signed Ranks test ($P < 0.025$; one-tailed test, Siegel 1956).

We found an average of 1.63 more species of reptiles and 1.25 more species of small mammals on control sites than on the ORV-used plots (Table 4). The ORV-used areas had significantly fewer species of both reptiles and mammals than control areas. The control sites had 270 more reptiles ($\bar{X}$ = 33.75 per 2-ha plot) and 115 more mammals ($\bar{X}$ = 14.38 per 1 ha) than the ORV-used areas. The biomass estimates were also significantly different with 23,031 g ($\bar{X}$ = 2,878.8 g/2 ha) more of reptiles and 2,388 g ($\bar{X}$ = 298.5/ha) more of mammals on the control sites than on ORV-used sites.

Of the 48 sets of paired data (Table 4), only five ORV-used sites had higher values than their controls. Moderately used ORV site I had one more reptile than the control, apparently because site I had a disproportionately high number of horned lizards (16, Appendix I) compared with any other site in Anderson Valley. One more species of mammal was found on the heavy-use area F than on its control E. These one species differences are minor compared with the magnitude of variation in individuals and biomass on control and ORV-used sites (Table 4).

The three other high values for ORV-used areas occurred at moderately used site B, which had one more species, 30 more individuals, and a biomass of 119 g of mammals greater than control A. Such high values on the ORV-used area may be due to several factors. First, site B has a higher shrub count (242) than its control (229), perhaps enabling the area to support a greater diversity and density of animals. Second, ORV activities were "moderate" and most shrubs were still intact at their bases. Third, the number of sampled mammals may be higher due to other ORV-related phenomena, such as the killing of

Table 4. *Reptiles and mammals sampled on paired test sites.*

Area and condition	Reptiles (2 ha)			Mammals (1 ha)		
	Species	Number	Weight (g)	Species	Number	Weight (g)
Barstow						
A—Control	6	75	3,618	3	39	982
B—Moderate	5	42	1,027	4	69	1,101
C—Heavy Use	5	20	279	2	25	325
D—Control	5	71	4,793	3	62	600
Stoddard Wells						
E—Control	5	65	529	4	43	874
F—Heavy Use	3	33	272	5	22	693
G—Control	5	53	562	4	31	750
H—Pit Area	5	14	178	2	8	85
Anderson Valley						
I—Moderate	5	30	513	3	11	141
K—Control	6	29	1,486	4	28	744
J—Pit Area	3	16	1,514	1	3	22
L—Control	5	41	14,318	6	29	563
Johnson Valley						
M—Control	4	46	473	4	18	223
O—Heavy Use	3	8	44	2	3	68
N—Control	6	53	1,079	2	8	125
P—Pit Area	0	0	0	1	2	39

predators (e.g., large-bodied snakes) which allows a temporary increase of small mammals. Lastly, the values may represent no more than natural variation between sites (which is corrected by sampling many sites). Moreover, the mammal fauna at site B should be considered in conjunction with the reptiles there. Site B had one less species, 33 fewer individuals, and 2,591 g less biomass of reptiles than control site A. Therefore, the control site had a much greater overall biomass (2,472 g difference) than the moderately used site.

The other moderately used site (I) is clearly depauperate compared with its paired control site (Table 4). There is no present evidence to indicate that ORV's in any way enhance the terrestrial vertebrate fauna of desert ecosystems. These comparisons of paired study sites demonstrate a statistically significant decrease in species, number of individuals, and biomass of mammals and reptiles on ORV-used areas compared with control sites.

Reptiles Per Day

Total numbers of reptiles taken on consecutive days from the same category of habitat quality (Fig. 6) clearly indicate an appreciable daily decrease in the average numbers collected at control sites: Day 1, 9.00/h; Day 2, 6.33/h; and Day 3, 4.60/h. Of 252 lizards collected over these 3-day periods, 49.6% were found on the 1st day, 32.9% on the 2nd, and 17.5% on the 3rd. Of 22 tortoises located, 77% were found on the 1st day of the survey.

There were fewer reptiles collected per hour on all of the ORV-used sites over the 3-day periods. The average daily catches on

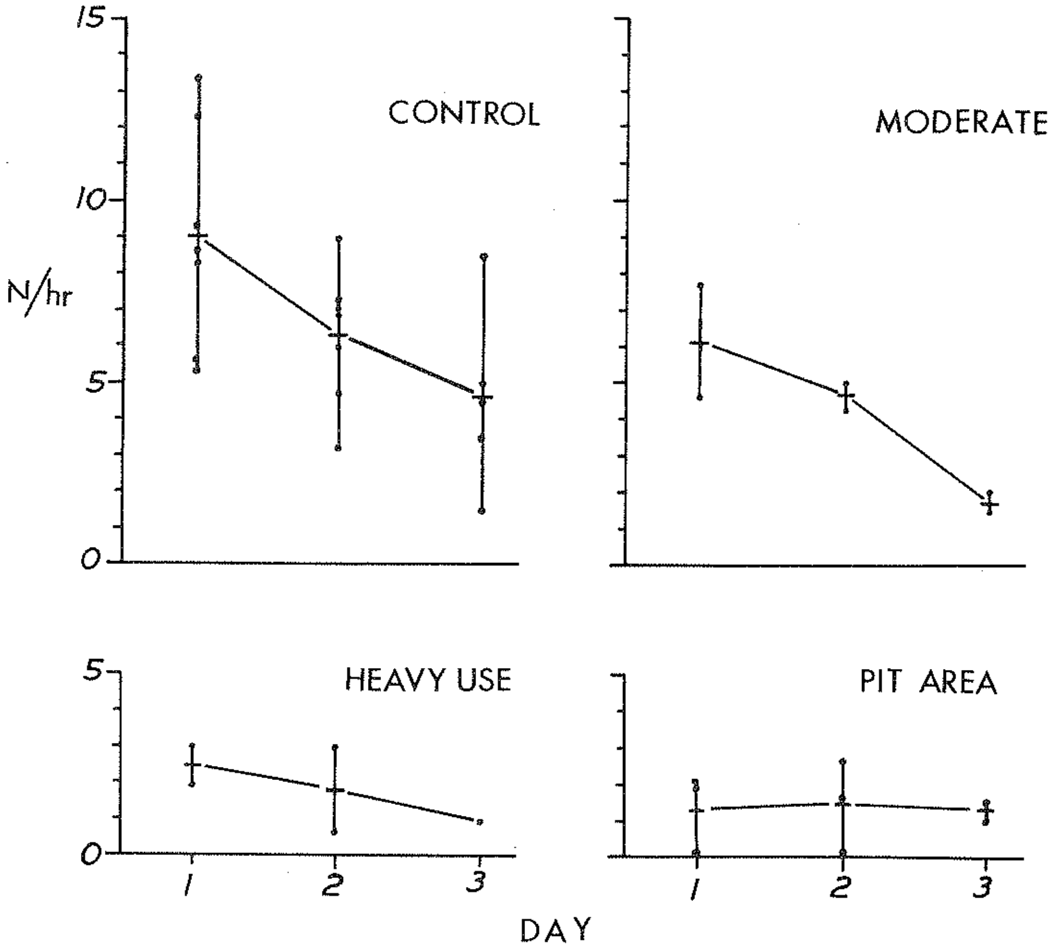

Fig. 6. Comparison of reptiles taken per hour over three consecutive days.

moderate sites were: Day 1, 6.17/h; Day 2, 4.67/h; and Day 3, 1.75/h. The 1st day on heavy-use sites yielded 2.50 reptiles per man-hour; all other efforts on heavy-use and pit areas gave an average of only 1.37/h (1.00-1.84).

The average rate of collecting reptiles on the 1st day was 31.4% less on moderate-use, 72.2% less on heavy-use, and 85.2% less on pit areas than on control sites.

Mammals Per Trap Day

The 1st trap day was the most successful for capturing small mammals in this study (Table 5). The capture of animals at one moderate site (B) in 1974 was higher for the first 2 days than the average for the control sites. The mammals taken on the 1st night were 29% and 78% fewer on heavy-use and pit areas, respectively, than on the control sites. The reductions on the 2nd day were 65% and 92%, and on the 3rd day, 64% and 91%, respectively. Small mammal populations apparently were less dense on ORV-used areas than on the control sites.

Over the 3-day trapping periods, most of the small mammals were taken on the 1st day at ORV-used sites (Fig. 7). The average decrease in mammals from Day 1 to Day 2 was 31% for the control, 43% for moderate-use sites, 67% for heavy-use, and 71% for pit areas.

For mammals trapped on 2-day sampling periods, most individuals (64.8%) were taken on the 1st day (Table 6). Except for one moderate site (B), there are lower values for mammals trapped on ORV-used areas compared with control sites. Heavy-use and pit

Table 5. *Mammals taken per night corrected for number of traps set (N/trap).*

Condition and site		Number x 100		
		1	2	3
Control				
A		12.00	5.33	4.00
D		19.33	12.67	8.00
E		7.69	7.33	12.67
G		6.00	5.33	6.67
K		6.67	4.67	6.67
L		6.00	6.67	6.00
M		10.77	2.67	—
N		5.38	0.67	—
	$\bar{X}$ =	9.23	5.67	7.34
Moderate				
B		20.00	13.33	9.33
I		4.67	0.67	2.00
	$\bar{X}$ =	12.33	7.00	5.67
Heavy Use				
C		10.67	2.00	2.67
F		7.69	4.00	2.67
O		1.33	0.00	—
	$\bar{X}$ =	6.56	2.00	2.67
Pit Area				
H		2.67	1.33	1.33
J		2.00	0.00	0.00
P		1.33	0.00	—
	$\bar{X}$ =	2.00	0.44	0.67

Table 6. *Mammals taken on 1st 2 days (2 trap-nights, 2 trap-days).*

Condition and site		Number		Average number per trap x 100	
		1	2	1	2
Control					
A		23	10	15.33	6.67
D		31	19	20.67	12.67
E		13	11	9.29	7.33
G		12	9	8.00	6.00
K		11	7	7.33	4.67
L		9	11	6.00	7.33
M		14	4	10.00	2.67
N		7	1	5.00	0.71
	$\bar{X}$ =	15	9	10.20	6.01
Moderate					
B		33	22	22.00	14.67
I		7	1	4.67	0.71
	$\bar{X}$ =	20	11.5	13.34	7.67
Heavy					
C		18	3	12.00	2.00
F		10	8	7.14	5.33
O		2	0	1.33	0.00
	$\bar{X}$ =	10	3.7	6.82	2.44
Pit Area					
H		4	2	2.67	1.33
J		3	0	2.00	0.00
P		2	0	1.33	0.00
	$\bar{X}$ =	3	0.7	2.00	0.44

areas were particularly depauperate in mammals when compared with control sites.

Total Reptile and Mammal Fauna

A comparison of the average number of species, individuals, and biomass of reptiles and mammals (Table 7) sampled for 3-day periods (Sites A-L) shows an average decrease of all these parameters with increasing use of areas by ORV's (Fig. 8). Species diversity appears to be the least affected by ORV activity, although the number of species present in an area is inversely related to the level of ORV activity. Heavy-use and pit areas had 19% and 41%, respectively, fewer species than the control sites. The biomass of terrestrial animals declined sharply with ORV use and moderately used areas had less than half the biomass of control sites.

Table 7. *Comparison of total terrestrial fauna sampled on test sites A-L.*

	Average reptiles (2 ha)			Average mammals (1 ha)			Terrestrial fauna		
							Total	Average (ha)	
Condition	Species	Number	Weight (g)	Species	Number	Weight (g)	Species	Number	Weight (g)
Control (N=6)	5.3	55.7	4217.5	4.0	38.7	752.2	9.3	66.5	2860.9
Moderate (N=2)	5.0	36.0	770.0	3.5	40.0	621.0	8.5	58.0	1006.0
Heavy Use (N=2)	4.0	26.5	275.5	3.5	23.5	509.0	7.5	36.8	646.8
Pit Area (N=2)	4.0	15.0	846.0	1.5	5.5	53.5	5.5	13.0	476.5

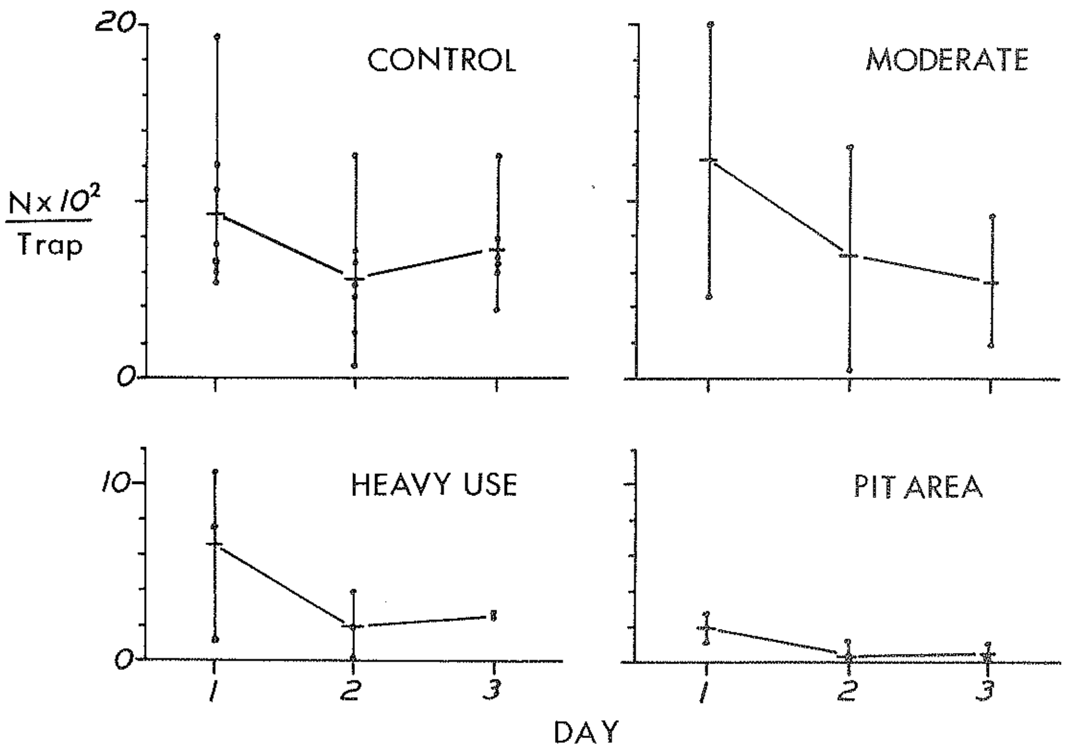

Fig. 7. Comparison of mammals taken per day over three consecutive days.

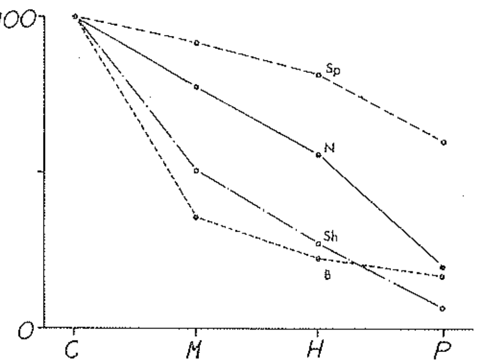

Fig. 8. Average percentage differences in species (Sp), number of individuals (N), and biomass of terrestrial vertebrates (B) and shrubs (Sh) sampled at control (C), moderately used (M), heavily used (H), and pit area (P) sites.

Bird Fauna

In 1974, censuses on three 4-ha sites (control, moderate use, heavy use) indicated a marked bird fauna decrease on ORV-used areas. The control site had four species present: singing males observed included two sage sparrows and one each of Brewer's and black-throated sparrows; a LeConte's thrasher nested in an indigo bush (*Dalea fremontii*) during the census period (25-27 May). These five breeding pairs of birds on the control site had an estimated weight of 221 g/4 ha (5.5 kg/100 ha). Mourning doves (*Zenaidura macroura*) and horned larks had finished nesting early in the spring and during our census they had already formed small flocks. Five empty nests of these birds were found on the control plot; three appeared to have been used earlier in the spring and two of these were probably mourning dove nests. No adult doves were observed breeding or with territories on the control site during our census.

The moderately used site had one male each of the house finch and black-throated sparrow, both with territories centered peripheral to the plot in an area of less disturbance. We determined that there were only two birds present and the weights were 23 g/4 ha (0.46 kg/100 ha).

No breeding birds were found on the heavily used site. The control site had 5 times the number of breeding pairs and 10 times the biomass of the moderately disturbed area (Appendix III).

Of the birds foraging or on the ground in 1974, 62 individuals were seen in the control plot: horned lark (38); Brewer's sparrow (8); vesper sparrow (*Pooecetes gramineus*) (3); 2 each of mourning dove, black-throated sparrow, sage sparrow, and Wilson's warbler (*Wilsonia pusilla*); and 1 each of LeConte's thrasher, MacGillivray's warbler (*Oporonis tolmiei*), ash-throated flycatcher, Costa's hummingbird (*Calypte costae*), and American coot (*Fulica americana*). Nineteen individuals were in the moderately used site: horned lark (17); house finch (1); and black-throated sparrow (1). Only one individual (horned lark) was observed in the heavily used area.

Differences between two pairs of control and moderately used sites were smaller in 1975 (Table 8). At Anderson Valley the breeding avifauna on the control consisted of twice the number of species and biomass, and 1.5 times the numbers of birds than on the moderately used area. The breeding avifauna at Johnson Valley was depauperate in 1975 but the control site had greater values than the ORV-used area (Table 8; Appendix III). Also, we noted that standing bird crops were less on the sampled control sites from 1974 (5.5 kg/100 ha) to 1975 (0.9 and 0.8 kg/100 ha).

The breeding avifauna of the Mojave Desert, in part, responds to the spring ephemeral wildflower bloom, and concentrates in areas that have received winter rains adequate to ensure the growth of spring annuals (Miller and Stebbins 1964). Also, breeding efforts of birds may vary greatly over large areas. Our study sites in 1974 (Barstow) had received sufficient winter rains to produce a spring wildflower bloom. In 1975, the investigated sites received almost no winter rains and the spring wildflower display over most of the Mojave Desert was greatly reduced. In 1974 *Larrea* was blooming or had already bloomed and was in seed, whereas in 1975 the *Larrea* blooming was late in the spring and sporadic; none was in seed. As a result, avian breeding densities were apparently reduced in 1975 because of weather conditions. Reptile and mammal abundance and biomass were, in general, higher in 1974 than in 1975 (Table 4), perhaps due in part to weather.

Table 8. *Breeding bird census on 40-ha sites in 1975.*

Condition	Anderson Valley			Johnson Valley		
	Species	Number	Weight (g)	Species	Number	Weight (g)
Control	4	12	364	2	19	313
Moderate	2	8	197	1	7	204

Correlations With Habitat Conditions

The number and condition (index) of creosote shrubs differed markedly within the four categories of habitat quality: control, moderate use, heavy use, and pit area sites (Tables 1 and 2). We compared the shrub index on each site and the terrestrial fauna sampled for 2-day periods using Spearman Rank Correlation Coefficients (r_S, $P < 0.05$).

Significant positive correlations existed between the shrub index and the total number of species ($r_S = 0.80$), abundance ($r_S = 0.88$), and biomass ($r_S = 0.55$) of all terrestrial vertebrates sampled for 2-day periods (sites A-P; N = 16). At the family level, there were significant correlations for the biomass of Iguanidae ($r_S = 0.69$), Teiidae (0.62), Heteromyidae (0.57), and Sciuridae (0.54). Insignificant correlations were found for Testudinidae (0.21) and Cricetidae (0.06), but sample sizes for these groups were small (25 and 11 individuals, respectively).

Correlation coefficients (r) between three measures (species, individuals, and weight) and habitat conditions (shrub index) for the first 2 days of sampling sites (A-P; N = 16) were significant ($P<0.05$) for all measures except weights of reptiles (lizards and tortoises) and of all terrestrial vertebrates combined (Table 9). These results are due to the unequal occurrence of the heavy-bodied tortoises on sites. For samples obtained on 3-day periods (A-L; N = 12), the weights of tortoises again affect the weights of reptiles and of terrestrial vertebrates combined. There were insignificant correlations between the shrub index and the number of species and individuals of mammals, which may be due to the large variability of mammals on control sites (3-6 species per hectare and 28-62 individuals per hectare).

Further, 11 of the 15 measures of vertebrates were significantly correlated to habitat conditions; excluding tortoise weights, 11 of 13 measures were correlated ($P < 0.05$).

The appropriate linear regressions for the terrestrial fauna (excluding tortoises) were

Table 9. *Relationships between the shrub index and vertebrate fauna sampled.*

Sampling period and group	Species	Number individuals	Weight
2-day sampling (N = 16)			
Lizards and tortoises	0.57*	0.73*	0.26
Lizards	0.60*	0.74*	0.65*
Mammals	0.60*	0.75*	0.57*
Terrestrial vertebrates	0.71*	0.88*	0.37
Terrestrial vertebrates[a]	0.72*	0.88*	0.61*
3-day sampling (N = 12)			
Lizards and tortoises	0.63*	0.70*	0.21
Lizards	0.62*	0.72*	0.62*
Mammals	0.52	0.49	0.70*
Terrestrial vertebrates	0.74*	0.61*	0.32
Terrestrial vertebrates[a]	0.72*	0.61*	0.74*

[a]No tortoises were collected.
*Correlation Coefficient (r: $P<0.05$).

determined for the 2-day sampling periods. Figs. 9-11 illustrate the relationship of the number of species, individuals, and weights to the shrub indices. The coefficients of determination (r^2) express the proportion of the total variation in the measures of the sampled terrestrial vertebrate fauna that is accounted for by the fitted regression.

Discussion

Local conditions of soils, slopes, exposures, and other factors affect the biotic composition of the creosote community and, consequently, there was some natural variation between localities. Species structure, abundance, and weights of animals certainly also vary in different years (drought or high rainfall periods), seasons, and habitats. We attempted to minimize these differences between localities by avoiding markedly distinct habitats, such as washes, alkali flats, or rocky terrain, and locally by establishing paired study sites (used and unused by ORV's) of similar environmental conditions. Basic community structure was generally similar on all control sites and we think our data characterize the major elements in the vertebrate fauna in the western California Desert.

Our studies on ORV's employed several comparisons and analyses of the data. Impacted areas were sampled at four localities that extended over a 60-km belt (Fig. 1). The effect on desert wildlife was negative wherever ORV's were used in creosote shrub habitat over this large area.

We also found that the removal method was useful in sampling terrestrial species because it could be done over short time periods (3 days), and we concurrently sampled most of the paired test sites, thus reducing climatic variables.

Total samples from control and ORV-used areas similarly reflect the loss of terrestrial vertebrates where ORV's operate (Tables 4 and 7; Appendices I and II). Measures of the terrestrial vertebrate fauna were inversely related to the level of ORV usage (Figs. 8-11).

Avian diversity, abundance, and biomass were markedly different on unused and ORV disturbed sites. Horned larks were the only birds that frequented ORV areas in this study. They typically prefer open and disturbed areas, exploiting the temporary availability of insects and seeds in disrupted ecosystems. But, even these birds are subject to negative effects since ORV's destroy their ground nests.

The impact of ORV activity on the desert vertebrate fauna is both direct and indirect. The ORV's have a direct impact by killing or maiming ground-dwelling animals; we have observed such effects in the field. ORV's can also destroy wildlife by crushing ground nests or breaking bushes and shrubs containing nests and cover. ORV's collapse burrows that are important retreats for tortoises and other wildlife. Harassment by ORV activity may place a considerable energy strain on individuals and may cause incubating birds to abandon nests. Noise from ORV activity probably interferes with the establishment and maintenance of territories. Indirect effects are perhaps the most significant and result from the destruction of vegetation and disturbance of soil. Vegetation is destroyed by crushing and root exposure. Mechanical disturbance upsets the water storage, penetration capacities, and thermal structure of the soils and disrupts the germination strategies of seeds (Davidson and Fox 1974; Luckenbach 1975; Vollmer et al. 1976; Wilshire and Nakata 1976). One result is a reduction in the number of spring annuals in areas of ORV use. The loss of these annuals likely means the loss of seeds and forage as well as the loss of arthropods that feed on these annuals (Luckenbach 1975).

We have heard arguments stating that light ORV use has little or no effect on the biota of desert lands. Low intensity use by ORV's results in trails that skirt the shrubs, leaving part of the surface and subsurface environment intact. The terrestrial fauna presumably is able to survive or adapt to ORV use in such areas. Although this idea may be attractive, we contend that it is erroneous. It is important to realize that the creosote shrub community is an ancient, diverse assemblage of plants and animals. The shrubs themselves may require decades to mature and even partial damage to the plants, particularly the root systems, may subject them to stress in dry years or droughts. ORV's cause loss of top soil and compaction. Traffic around shrubs decreases food for birds and small mammals by dispersing and burying seeds and disrupting

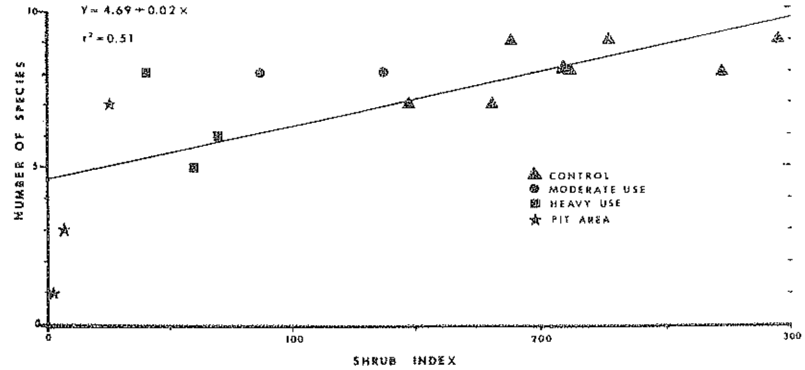

Fig. 9. Relationship of the number of species of terrestrial vertebrates and the shrub index at sampled sites (N = 16).

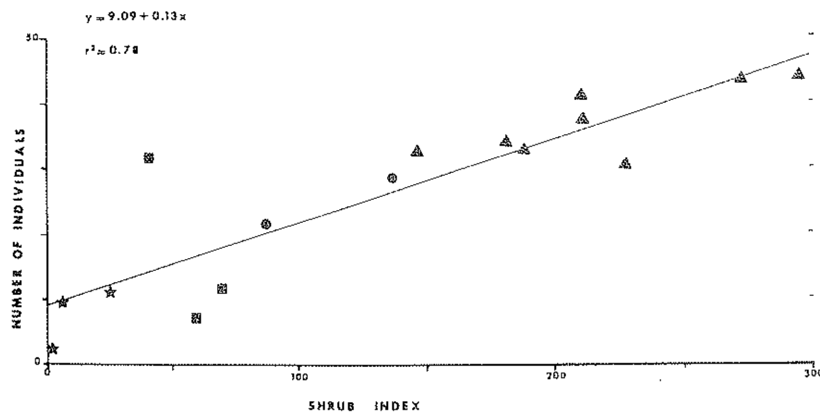

Fig. 10. Relationship of the number of individuals of terrestrial vertebrates and the shrub index at sampled sites (N = 16). Symbols are the same as for Fig. 9.

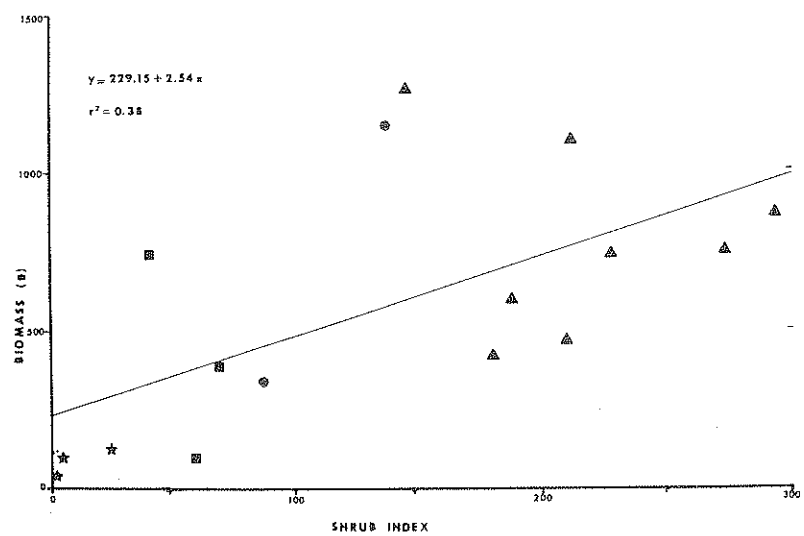

Fig. 11. Relationship of the biomass of terrestrial vertebrates and the shrub index at sampled sites (N = 16). Symbols are the same as for Fig. 9.

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the soil mantle. The resultant loss of seeds and herbaceous grasses decreases food sources over time. Repeated travel over trails causes mortality to the resident vertebrates by crushing, wounding, or harassing animals.

Continual use of areas, even at low intensity, reduces recruitment into the vertebrate populations. Moreover, the problem is compounded by the direct mortality of animals which naturally have a low recruitment rate or a long maturation time. There are several examples of this situation among desert animals. The desert tortoise may require 15 to 20 years to reach sexual maturity in the field (Woodbury and Hardy 1948). Turner et al. (1969a, 1969b) reported that the leopard lizard had a life span of at least 7-8 years and the western whiptail lizard of at least 7 years; females of both species usually do not reproduce until 1.5-2 years of age. Death or removal of these long-lived animals will result in a loss not only of these individuals but also their reproductive potential for a relatively long time. Recovery of desert communities would be slow, even where there are no further ORV activities.

Intensive ORV use, together with related camping and staging activities, results in obvious heavy damage to desert ecosystems. The vegetation and wildlife are depauperate, if not obliterated, in these areas.

No estimate of the present overall impact of ORV's on the biota of the California Desert is available, but some indication of the widespread effects can be illustrated by extrapolation of the average values of our data taken from 1 to 2 ha sites (N = 16). Using the figures for the species for which we have adequate data, we have estimated that a square kilometer of comparable creosote shrub habitat would contain about 6,650 terrestrial vertebrates weighing about 285 kg. According to our study, heavy ORV use over 1 km^2 would destroy about 3,000 individuals and 220 kg of animals. In moderately used areas, there would be a decline of 830 individuals and 185 kg/km^2. Such estimates are not unrealistic in that ORV's have already heavily disrupted large areas in

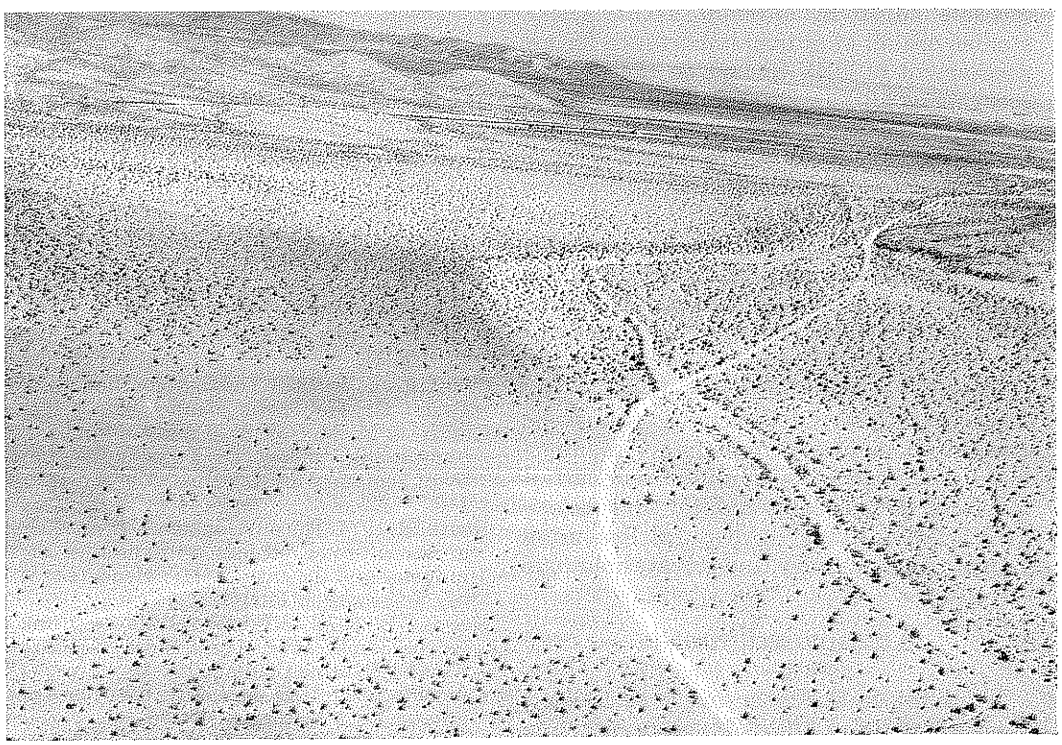

Fig. 12. Off-road vehicle disruption of a desert shrub community at Stoddard Wells (G and H). The clearing in the middle is a result of intensive ORV activities that create a "pit area."

Johnson Valley, Anderson Valley, Stoddard Wells (Fig. 12), and the Algodones Dunes, among others.

Impact on these large areas also includes depletion of other groups we did not assess. For example, we suspect that there is a major effect on the rich snake fauna of the region, but nocturnal surveys would be needed to determine the occurrence and diversity of most snakes. The California Desert is seasonally visited by migratory birds, and habitat disruption may affect bird populations along the entire flyway. Predatory birds are also abundant in part of desert systems, and decline of prey will certainly cause decline in predator populations. Depletion of large mammals (coyote, kit fox, badger, bighorn sheep) and game species (e.g., quail) has not yet been studied. We urge further field research to assess the impact of ORV's on these larger-bodied, game, or migratory species, and also the vast invertebrate fauna of the California Desert.

We also need evaluation of ORV effects on other arid land habitats, such as Joshua Tree woodland, sand dunes, playas, and creosote shrub in different areas. These studies are all of critical importance for an assessment of ORV impact on the diverse ecosystems of the California Desert.

The present study provides evidence that ORV's detrimentally affect desert wildlife and creosote shrub habitat. The ORV's have been extensively used for less than a decade in the Mojave Desert, but already there has been widespread negative impact on desert communities. The available data indicate that continued intensive ORV activities will be increasingly detrimental to the wildlife resources of the California Desert. The impact of these ORV activities must be recognized in present and future management programs so as to minimize or curtail losses of irreplaceable habitat and associated wildlife living on Natural Resources Lands, State, military, and private holdings.

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APPENDIX I. *Reptiles collected on 2-ha test sites.*

Site and species	N (♂:♀:J)	Wt (g)	N (♂:♀:J)	Wt (g)	N (♂:♀:J)	Wt (g)	N (♂:♀:J)	Wt (g)
BARSTOW[a]	CONTROL — A		MODERATE —B		HEAVY USE — C		CONTROL — D	
Cnemidophorus tigris	33 (12:12:9)	444	12 (8:2:2)	216	3 (1:2:0)	59	23 (11:7:5)	463
Callisaurus draconoides	8 (2:1:5)	77	16 (5:1:10)	174	7 (2:2:3)	88	32 (7:8:17)	342
Uta stansburiana	21 (13:8:0)	67	8 (2:6:0)	23	8 (4:4:0)	22	8 (3:5:0)	23
Phrynosoma platyrhinos	7 (3:2:2)	145	4 (1:1:2)	70	1 (1:0:0)	17		
Crotaphytus wislizeni	1 (0:1:0)	75					3 (0:1:2)	104
Gopherus agassizii	5 (1:0:4)	2,810	2 (0:0:2)	543	1 (0:0:1)	93	5 (1:1:3)	3,860
Total	75 (31:24:20)	3,618	42 (16:10:16)	1,026	20 (8:8:4)	279	71 (22:22:27)	4,792
STODDARD WELLS[a]	CONTROL — E		HEAVY USE — F		CONTROL — G		PIT AREA — H	
Cnemidophorus tigris	20 (10:4:6)	225	14 (5:4:5)	171	8 (7:1:0)	162	2 (0:0:2)	12
Callisaurus draconoides	1 (1:0:0)	21			11 (4:2:5)	116	1 (0:0:1)	4
Uta stansburiana	27 (11:16:0)	76	9 (2:7:0)	25	19 (7:12:0)	64	4 (3:1:0)	16
Phrynosoma platyrhinos	15 (2:1:12)	127	10 (1:1:8)	75	13 (2:3:8)	158	6 (3:2:1)	121
Sceloporus magister	2 (1:1:0)	80						
Crotaphytus wislizeni					2 (0:1:1)	62	1 (0:0:1)	25
Total	65 (25:22:18)	529	33 (8:12:13)	271	53 (20:19:14)	562	14 (6:3:5)	178
ANDERSON VALLEY[a]	MODERATE — I		PIT AREA — J		CONTROL — K		CONTROL — L	
Cnemidophorus tigris	7 (4:3:0)	172			9 (6:3:0)	236	9 (6:3:0)	220
Callisaurus draconoides	2 (1:1:0)	24	6 (0:1:5)	32	7 (2:4:1)	104	9 (6:1:2)	109
Uta stansburiana	3 (0:3:0)	7			7 (2:5:0)	19	15 (4:11:0)	45
Phrynosoma platyrhinos	16 (6:5:5)	258	9 (3:1:5)	132	2 (2:0:0)	51		
Dipsosaurus dorsalis	2 (0:1:1)	52						
Crotaphytus wislizeni					3 (2:0:1)	76	2 (2:0:0)	69
Gopherus agassizii			1 (1:0:0)	1,350	1 (0:1:0)	1,000	6 (2:3:1)	13,875
Total	30 (11:13:6)	513	16 (4:2:10)	1,514	29 (14:13:2)	1,486	41 (20:18:3)	14,318
JOHNSON VALLEY[b]	CONTROL — M		CONTROL — N		HEAVY USE — O		PIT AREA — P	
Cnemidophorus tigris	9 (6:1:2)	159	8 (6:1:1)	139				
Callisaurus draconoides	31 (11:9:11)	276	33 (15:7:11)	301	3 (1:0:2)	16		
Uta stansburiana	3 (0:3:0)	7	8 (5:3:0)	23	3 (2:1:0)	8		
Phrynosoma platyrhinos	3 (1:0:2)	32	2 (0:2:0)	36	2 (1:0:1)	19		
Dipsosaurus dorsalis			1 (1:0:0)	80				
Gopherus agassizii			1 (0:0:1)	500				
Total	46 (18:13:15)	474	53 (27:13:13)	1,079	8 (4:1:3)	43		

[a]Sites A-L for 3-day periods (3:3:2h). [b]Sites M-P for 2-day periods (3:3h).

APPENDIX II. *Mammals trapped on 1-ha sites.*

Gopherus agassizii			1 (0:0:1)	500		
Total	46 (18:13:15)	474	53 (27:13:13)	1,079	8 (4:1:3)	43

[a]Sites A-L for 3-day periods (3:3:2h). [b]Sites M-P for 2-day periods (3:3h).

APPENDIX II. *Mammals trapped on 1-ha sites.*

Site and species	N (♂:♀:J)	Wt (g)	N (♂:♀:J)	Wt (g)	N (♂:♀:J)	Wt (g)	N (♂:♀:J)	Wt (g)
BARSTOW[a]	CONTROL — A		MODERATE — B		HEAVY USE — C		CONTROL — D	
Perognathus longimembris	28 (6:20:0)	229	61 (28:33:0)	419	23 (8:15:0)	162	59 (31:27:1)	444
Dipodomys merriami	4 (2:2:0)	132						
Peromyscus maniculatus			1 (1:0:0)	11			1 (0:1:0)	13
Neotoma lepida			2 (2:0:0)	188				
Amnospermophilus leucurus	7 (3:4:0)	600	5 (3:2:0)	483	2 (1:1:0)	163	2 (1:1:0)	143
Total	39 (11:28:0)	961	69 (34:35:0)	1,101	25 (9:16:0)	325	62 (32:29:1)	600
STODDARD WELLS[a]	CONTROL — E		HEAVY USE — F		CONTROL — G		PIT AREA — H	
Perognathus longimembris	31 (11:20:0)	244	11 (5:6:0)	85	12 (5:7:0)	93	6 (5:1:0)	47
P. formosus					13 (7:6:0)	214	2 (1:1:0)	38
Dipodomys merriami	8 (5:3:0)	325	5 (4:1:0)	213	2 (2:0:0)	76		
D. panamintinus			3 (1:2:0)	216				
Onychomys torridus	1 (0:1:0)	12						
Peromyscus crinitus			1 (0:1:0)	13				
Amnospermophilus leucurus	3 (3:0:0)	293	2 (0:2:0)	166	4 (3:1:0)	367		
Total	43 (19:24:0)	874	22 (10:12:0)	693	31 (17:14:0)	750	8 (6:2:0)	85
ANDERSON VALLEY[a]	MODERATE — I		PIT AREA — J		CONTROL — K		CONTROL — L	
Perognathus longimembris	7 (3:4:0)	49	3 (2:1:0)	22	11 (4:7:0)	87	20 (10:10:0)	168
P. formosus	3 (1:2:0)	54			4 (0:4:0)	71	2 (2:0:0)	37
Dipodomys merriami	1 (1:0:0)	38			12 (7:5:0)	491	4 (3:1:0)	139
Onychomys torridus							1 (0:1:0)	23
Neotoma lepida							1 (1:0:0)	86
Amnospermophilus leucurus					1 (1:0:0)	95	1 (1:0:0)	110
Total	11 (5:6:0)	141	3 (2:1:0)	22	28 (12:16:0)	744	29 (17:12:0)	563
JOHNSON VALLEY[b]	CONTROL — M		CONTROL — N		HEAVY USE — O		PIT AREA — P	
Perognathus longimembris	14 (7:7:0)	110	6 (1:5:0)	44	2 (2:0:0)	19		
P. formosus	1 (1:0:0)	13						
Dipodomys merriami	2 (1:1:0)	84	2 (2:0:0)	81	1 (1:0:0)	49		
Peromyscus crinitus	1 (0:1:0)	16					2 (1:1:0)	39
Total	18 (9:9:0)	223	8 (3:5:0)	125	3 (3:0:0)	68	2 (1:1:0)	39

[a]Sites A-L for 3-day periods (3 trap-nights). [b]Sites M-P for 2-day periods (2 trap-nights).

APPENDIX III. *Comparison of breeding bird fauna.*

Site, plot size, and species	Condition	Number pairs of birds		Estimated weight (g)		
		Per plot	Per 100 ha	Per bird[a]	Per plot	Per 100 ha
BARSTOW, 4 ha						
Amphispiza belli	Control	2	50	14	56	1,400
Spizella breweri	Control	1	25	10	20	500
Taxostoma lecontei	Control	1[b]	25	62.4	125	3,120
Amphispiza bilineata	Control	0.75	18.8	13.3	20	499
Total			119			5,519
Amphispiza bilineata	Moderate Use	0.5	12.5	13.3	13.3	332.5
Carpodacus mexicanus	Moderate Use	0.3	6.3	19	9.5	237.5
Total			18.8			570.0
No birds	Pit Area	0	0	0	0	0
ANDERSON VALLEY, 40 ha						
Eremophila alpestris	Control	3	7.5	28.4	170.4	426
Myiarchus cinerascens	Control	1.5	3.8	28.4	85.2	213
Amphispiza bilineata	Control	1	2.5	13.3	26.6	66.5
Taxostoma lecontei	Control	0.7	1.7	62.4	82.4	205.9
Total			15.5			911.4
Eremophila alpestris	Moderate	3	7.5	28.4	170.4	426
Amphispiza bilineata	Moderate	1	2.5	13.3	26.6	66.5
Total			10.0			492.5
JOHNSON VALLEY, 40 ha						
Amphispiza bilineata	Control	7.5[b]	18.8	13.3	199.5	498.8
Eremophila alpestris	Control	2	5	28.4	113.6	284.0
Total			23.8			782.8
Eremophila alpestris	Moderate	3.6	9	28.4	204.5	511.2

[a]Weights estimated from a series of 20 specimens from the Mojave Desert.
[b]Does not include fledglings.

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