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WHEN DESERT TORTOISES ARE RARE: TESTING A NEW PROTOCOL FOR ASSESSING STATUS

KEVIN KEITH AND KRISTIN H. BERRY

U.S. Geological Survey
Western Ecological Research Center
22835 Calle San Juan de Los Lagos
Moreno Valley, CA 92553
E-mail: kristin_berry@usgs.gov

JAMES F. WEIGAND
U.S. Bureau of Land Management
California State Office
2800 Cottage Way, Room 1928
Sacramento, CA 95825

We developed and tested a new protocol for sampling populations of the desert tortoise, *Gopherus agassizii*, a state- and federally listed species, in areas where population densities are very low, historical data are sparse, and anthropogenic uses may threaten the well-being of tortoise populations and habitat. We conducted a 3-year (2002–2004) survey in Jawbone-Butterbredt Area of Critical Environmental Concern and Red Rock Canyon State Park in the western Mojave Desert of California where the status was previously unknown. We stratified the study area and used 751, 1-ha plots to evaluate 187.7 km^2 of habitat, a 4% sample. Tortoise sign was found on 31 of the 751 plots (4.1%) in two limited areas: ~14 km^2 on the Kiavah Apron and ~40 km^2 in the Red Rock Canyon watershed. Density estimates for adults were <9 tortoises/km^2 for each of the two areas and were lower (0.4 tortoises/km^2) elsewhere in the study area. An estimated 72 adult tortoises (95% CI = 15-210) live in the entire study area. Five live and nine dead tortoises were found, as well as 62 cover sites, 136 scats, and other sign. The data were insufficient for establishing a baseline for future population monitoring, but the protocol was suitable for locating clusters of tortoise sign, which could be the focus of future surveys. We coupled the data for tortoises with data on historical and current anthropogenic uses to interpret potential population trends and existing risks. The study area has been an important transportation corridor for people and grazed by livestock since the mid-1800s. Tortoise sign was found in areas with significantly lower impacts from livestock or off-highway vehicles than elsewhere. Land managers must often make decisions about threatened and endangered species based on limited data. Our protocol and synthesis of current population status, historical land uses, and current impacts offer a new approach that may be useful for other species.

INTRODUCTION

The desert tortoise, *Gopherus agassizii*, has been a species of concern in the Mojave Desert since 1980, when the Bureau of Land Management (BLM) first published the *California Desert Conservation Area Plan, 1980* (BLM 1980). By 1989–1990, the tortoise was listed as a threatened species by the State of California (California Code of Regulations) and the U.S. Fish and Wildlife Service (FWS, 1990). Although distribution and relative abundance of desert tortoise populations have been documented for many parts of the geographic range (Germano et al. 1994, FWS 1994, Berry and Medica 1995, Berry et al. 2002a), data on this topic are sparse to non-existent for some regions, especially for areas thought to have low densities in the 1970s and 1980s.

Biologists have sampled desert tortoise populations for distribution, density, and other population attributes using several methods. They used strip transects to delineate distribution and relative abundance for much of the geographic range in the United States during the 1970s and early 1980s (Burge 1978, Luckenbach 1982, Berry and Nicholson[1] 1984). For assessing population attributes, biologists have surveyed study plots at intervals to determine changes (Berry and Medica 1995, Averill-Murray et al. 2002). In tortoise critical habitat, line-distance sampling technique has been the method of choice for estimating densities of large immature and adult desert tortoises at landscape scales (Anderson et al. 2001, McLuckie et al. 2002, Swann et al. 2002). This technique is likely to be successful when population densities are moderate to high than if densities are very low. Other combinations of methods also have been tested (Krzysik 2002), but none have focused on both low tortoise densities and anthropogenic effects to habitat.

Status and trends in desert tortoise populations have been well-documented in parts of the western Mojave Desert but not within our study area in the Jawbone-Butterbredt Area of Critical Environmental Concern (ACEC) and Red Rock Canyon State Park (the Park) (FWS 1994, Berry and Medica 1995, Brown et al. 1999). Our study area is at the western edge of the geographic range and is outside federally designated critical habitat (FWS 1994). Previous data from the late 1970s consist of a list of observations from the Park (Berry et al. 2008) and six transects, which indicated densities of <8 tortoises/km^2 (Berry and Nicholson[1] 1984).

For the Jawbone-Butterbredt ACEC and Park, we faced two challenges: assessing the status of a population with almost no historic data, and a study area where individuals appeared to be rare. Our objectives were to: 1) develop and test a protocol for monitoring desert tortoises in areas with low population densities; 2) establish baseline population and health data for the current population of desert tortoises in the ACEC and the western part of the Park for future long-term monitoring; 3) evaluate historical and current anthropogenic uses of the study area; 4) identify significant

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[1] Berry, K.H., and L.L. Nicholson. 1984. The distribution and density of desert tortoise populations in the 1970s. Chapter 2 *in:* K.H. Berry, editor. The Status of the Desert Tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report to U.S. Fish and Wildlife Service, Sacramento, California, USA. Order No. 11310-0083-81.

correlations between tortoise populations and different types of anthropogenic uses; and 5) provide a basis for future management decisions.

THE STUDY AREA

The 759-km^2 study area is in Kern County, California, at the southern end of the Sierra Nevada and on the western edge of the Mojave Desert. It is bordered by State Highways 178 and 14 on the north and east, respectively (Fig. 1). Elevations range from 650 m at the southeast border to >1800 m on peaks in the Scodie Mountains, which extend on a north-south axis through the western half of the ACEC. The wide range

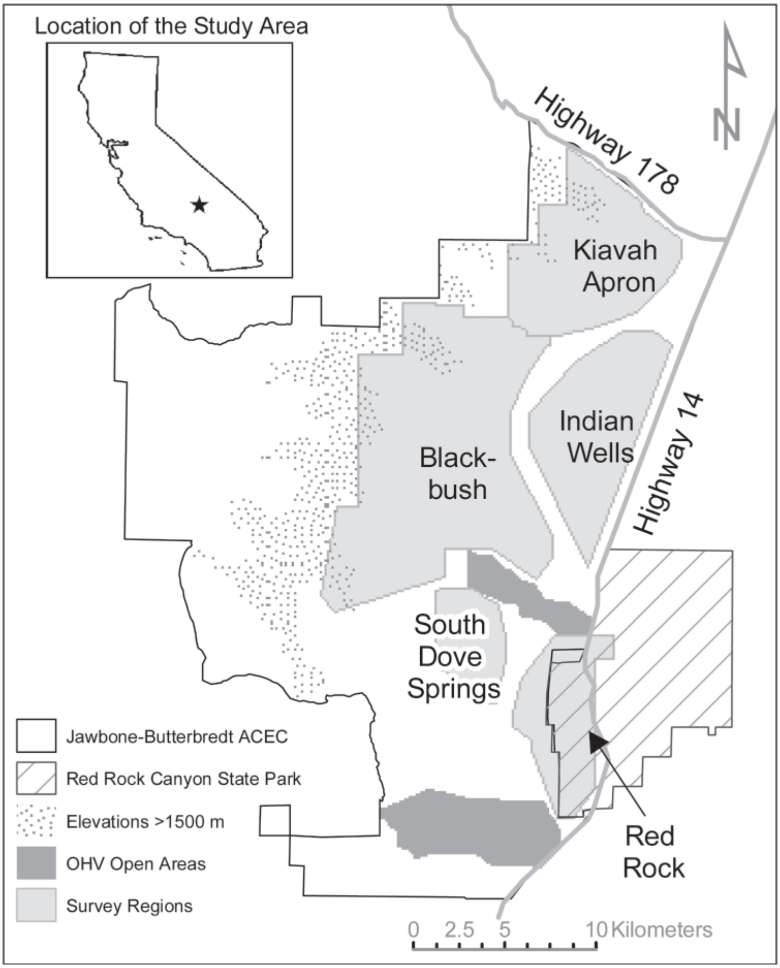

Figure 1: The study area: the Jawbone-Butterbredt Area of Critical Environmental Concern and Red Rock Canyon State Park, the five survey regions, and two OHV Open areas (Dove Springs, top; Jawbone Canyon, bottom).

of elevations contributes to diversity of vegetation. Piñon-juniper woodlands, *Pinus monophylla* and *Juniperus occidentalis,* are found at the higher elevations. At mid-elevations, plant communities include Joshua tree woodlands, *Yucca brevifolia*; shrublands dominated by blackbush, *Coleogyne ramosissima*; and mixed scrub communities with hop-sage, *Grayia spinosa*, California buckwheat, *Eriogonum fasciculatum*, Mojave aster, *Xylorhiza tortifolia*, and Anderson's box thorn, *Lycium andersonii*. The valleys and alluvial fans at lower elevations are generally dominated by creosote bush, *Larrea tridentata*, and burro-weed, *Ambrosia dumosa*. Distribution of the different communities is affected by topography, slope, aspect, surficial geology, and soil types.

The study area is managed separately by two agencies, the BLM and the California State Department of Parks and Recreation (CDPR). The BLM designated the public lands as an ACEC in 1980 as part of the *California Desert Conservation Area Plan* (BLM 1980) and followed by developing a habitat management plan with goals of changing livestock grazing practices, protecting water sources, and protecting, stabilizing and/or enhancing wildlife resource values (BLM 1982). The BLM manages most of the ACEC as a "limited use" off-highway vehicle (OHV) area, where the management prescription is to "allow vehicle use on approved routes only". Within the ACEC are two "open riding" areas for off-highway motor vehicles, the Dove Springs and Jawbone Canyon OHV Open Areas, where OHV recreationists are permitted to drive, park, and camp without restrictions (BLM 1982, 1999; Fig. 1). The CDPR administers Park lands, which border the southeastern ACEC. The CDPR first established a small group of parcels as a State Recreation Area in 1973, designated the lands as a State Park in 1980, and then enlarged the Park in 1989 and 1994 through the incorporation of public lands from the BLM.

METHODS

Design of Surveys for the Desert Tortoise

We divided the study area into five regions (Indian Wells, Kiavah Apron, Blackbush, South [S.] Dove Springs, and Red Rock) that reflect differences in geomorphology, topography, and vegetation (Fig. 1). The Indian Wells region (950–1000 m) is a flat, broad alluvial slope at the base of the Scodie Mountains, formed by the coalescence of alluvial fans and dominated by creosote bush scrub. The Kiavah Apron region (1050–1500 m) consists primarily of sloping foothills and canyons of the Scodie Mountains with mixed desert vegetation. The Blackbush region (1050–1500 m) includes both mountains and wide valleys and is generally dominated by blackbush. The S. Dove Springs region (1000–1300 m) has complex topography with many small, steep-sided drainages with mixed desert scrub. The Red Rock region (750–1000 m) lies within the Red Rock Canyon watershed and includes land that is managed both by the BLM and the Park.

We used a systematic random sampling design to select survey plots (100 m x 100 m, or 1 ha). We divided the ACEC and Park into 500 m x 500 m quadrats, the boundaries of which were oriented north-south and east-west. Within each quadrat, we randomly selected one 100 m x 100 m plot. We eliminated plots when: 1) the plot was <500 m from a paved road, aqueduct, utility transmission line, or accompanying utility access road; 2) the entire plot was not managed by BLM or the Park; 3) any part of the plot was inside a designated OHV Open Area; 4) any part of the plot was >1500 m in elevation; 5) the maximum slope of the plot was >45°; 6) the plot was west of the crest of the Sierra Nevada; or 7) the plot was in the checkerboard land ownership area, where square mile sections of public land alternate with square mile sections of private land. We applied criteria 1, 3, 4, 5, and 6 to focus the survey on areas with a greater likelihood of finding tortoises, because recent information indicated numbers were very low (e.g., Berry and Nicholson[1] 1984). We applied criteria 2 and 7 for legal and logistical reasons. Additionally, we eliminated (and did not replace) a plot if field biologists decided that rough terrain made surveys unsafe. Total excluded land was 578 km^2 or 76.2% of the ACEC and Park. Of the 181 km^2 in the non-excluded areas, 4% were sampled with 751, 1-ha plots.

Collection of Data on the Tortoises

Field teams located each plot with a Trimble GeoExplorer3 Global Positioning System, and marked the four corners of the plot with 2.5-m flagged poles. They worked in summer of 2002 (5 June–15 October), fall of 2003 (9 July–18 September), and during spring and summer of 2004 (12 April–14 September). They primarily conducted surveys in summer to maximize collection of data on tortoise sign. Two field biologists simultaneously searched each plot using 10-m wide transects: one person walked north-south, and another person walked east-west. Both field biologists searched for live tortoises, signs (scats, tracks, cover sites, and other sign), and shell-skeletal remains. Work began at sunrise and continued until noon, a time of day when tortoises are more likely to be active (Zimmerman et al. 1994). At the end of each plot survey, field biologists compared notes to check findings. The two surveys were not entirely independent of each other, particularly for counting anthropogenic impacts (see livestock scat below).

Field teams followed a standard protocol for live tortoises (Berry and Christopher 2001), noting whether observed on or off plots. They marked the tortoise with a unique number, weighed it, measured carapace length at the midline, determined sex, noted behaviors, and recorded habitat type. They recorded clinical signs of health and disease, such as starvation and dehydration, upper respiratory tract disease (URTD) caused by *Mycoplasma agassizii* or other *Mycoplasma species*, herpes virus, and shell diseases (Jacobson et al. 1991, 1994, Brown et al. 1994, Homer et al. 1998, Berry et al. 2002b).

Field teams photographed shell-skeletal remains and collected them following a standard protocol (Berry and Woodman[2] 1984). They also checked scats of tortoise

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[2] Berry, K.H., and A.P. Woodman. 1984. Methods used in analyzing mortality data for most tortoise populations in California, Nevada, Arizona, and Utah. Appendix 7 *in*: K.H. Berry, editor. The Status of the Desert Tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report To U.S. Fish and Wildlife Service, Sacramento, California, USA. Order No. 11310-0083-81.

predators (e.g., coyotes, *Canis latrans* and kit foxes, *Vulpes macrotis)*, for remains of tortoises. They determined size and sex of the tortoise (when possible), estimated the time since death using two categories ($\leq$4 years and >4 years), and made a preliminary assessment of the potential cause(s) of or contributor(s) to death. Causes of death were based, where possible, on published and unpublished data for vehicle trauma, shell diseases (Jacobson et al. 1994, Homer et al. 1998), avian predators (Boarman 1993), and gunshot (Berry 1986).

Field teams measured and photographed tortoise cover sites, defined as burrows, caves, pallets, and rock shelters (Burge 1978). They assigned cover sites to one of five classes: 1) excellent condition, currently used and active—fresh tracks or plastron marks evident; 2) excellent condition, probably used within last year, and clean—tortoise can walk into and use cover site without excavation; 3) good condition—plant debris or drifted sand present, tortoise could walk or plow into it and use it immediately; 4) disused or fair condition—some excavation necessary, signs of structural degradation occurring at corners of burrow opening and at mouth; and 5) poor condition—abandoned, collapsed, major excavation necessary for use.

Tortoise scats were measured, and the age of each was recorded using three age classes: 1) within this season—slick, coated with a dried and shiny substance, dark brown or black in color; 2) within last year—dull surface, no longer shiny or smooth, lightened in color to straw, greenish, yellow or light brown, often with pieces of vegetation protruding; and 3) >1, probably >2 years old—surface rough with vegetation protruding (pale yellow, beige, or whitened or grayish in color).

Collection of Data on Current and Historical Uses of the Area

Field biologists surveyed each plot for old and recent evidence of human-related uses including roads, trails, vehicle tracks, fences, trash, livestock scat, signs of shooting (firearm casings or targets), and evidence of mining. With the exception of livestock scat, both field biologists tallied these disturbances separately and compared results when they finished the plot. One person on each team tallied livestock scat, because it was ubiquitous and often in high concentrations. Livestock scat also deteriorates and breaks into pieces over time, making determination of the number of original scats difficult or impossible. Therefore we defined a single scat as all pieces of scat within a 0.3 m radius. All anthropogenic disturbances were recorded on standard data sheets. To determine the history of land use, data were collected from BLM cadastral survey records, master title plats, books, newspaper and magazine articles, and personal interviews.

Analysis of Data

We mapped distribution and relative abundance of live tortoises and other tortoise sign, as well as the most common anthropogenic disturbances, in Geographic Information System (GIS) layers. We calculated densities of live adult and subadult tortoises/km^2 for the study areas as a whole and for those subregions where tortoise sign was found.

We used 20,000 iterations of the bootstrap method and calculated 95% CIs using the bias corrected accelerated (BC_a) method for all densities of live tortoises (Efron and Tibshirani 1993). Since no more than one live tortoise was found per plot, we also calculated 95% CIs of the proportion of the plots occupied by a tortoise by using exact binomial statistics, and extrapolated these values into density estimates (tortoises/km^2). All of the exact binomial CIs were very similar to the bootstrap CIs and generally slightly more conservative (larger intervals). We present just the exact binomial CIs. These analyses were conducted with SAS® software using the %jackboot macro and FREQ procedure (SAS Institute 2004). We compared our results with studies of populations with low densities elsewhere in the Mojave Desert.

Since tortoise sign (burrows, scats) is correlated with tortoise densities (Krzysik 2002), we used tortoise sign as a surrogate for tortoise abundance to test for relationships between sign and anthropogenic impacts. We used logistic regressions (LogReg) to test whether the presence of tortoise sign on plots was related to the amount of OHV tracks, livestock scat, trash, and evidence of shooting (SPSS Inc. 1998). We also analyzed differences in amounts of anthropogenic impacts in different regions using analysis of variance (ANOVA) with the Tukey pairwise comparison post hoc test (TPC). Because the distribution of the anthropogenic impact variables was skewed, we used a square-root transformation of the data to perform the statistical tests.

RESULTS

The Desert Tortoise

Definitive tortoise sign was found on 31 of 751 (4.1%) plots. An additional four plots had old sign that may have belonged to tortoises or to another burrowing species (Tables 1, 2; Fig. 2). The plots with tortoise sign were primarily clustered in two parts of the study area: 1) the Red Rock watershed (10 plots), both inside the Park and on the BLM-managed land directly west of the Park; and 2) the Kiavah Apron (19 plots), primarily within a ~14 km^2 area in the sloping foothills of the Scodie Mountains (Table 1). At Red Rock, the extent of the area with tortoise sign has not been fully delineated

Table 1. Numbers of plots with tortoises and tortoise sign, displayed by region.

Plots	Blackbush	Indian Wells	Kiavah Apron	Red Rock	S. Dove Springs	Grand total
Total	392	137	154	37	31	751
No. with sign, %	4, 1.0	2, 1.5	19, 12.3	10, 27.0	-,0	35, 4.7
No. with cover sites	4	1	11	8	-	24
No. with scat	-	1	18	3	-	22
No. with footprints	-	-	2	-	-	2
No. with live tortoises	-	-	2	1	-	3
No. with remains	-	-	-	-	-	-

Table 2. Summary of tortoises and tortoise sign found on and off plots, by region.

	Total sign observed in each region and for all regions																	
Sign type	Blackbush			Indian Wells			Kiavah Apron			Red Rock			S. Dove Springs			Grand total		
	On	off	total	on	off	total	on	off	total	on	off	total.	on	off	total	on	off	total
Live tortoises	-	-	-	-	-	-	2	2	4	1	-	1	-	-	-	3	2	5
Tortoise remains	-	-	-	-	-	-	-	-	-	-	9	9	-	-	-	-	9	9
Cover sites	4	-	4	2	-	2	17	21	38	10	7	17	-	-	-	33	28	61
Tortoise scats	-	-	-	1	-	1	63	46	109	10	16	26	-	-	-	74	62	136
Footprints	-	-	-	-	-	-	3	3	6	-	1	1	-	-	-	3	4	7
Totals	4	-	4	3	-	3	85	72	157	21	33	54	-	-	-	113	105	218

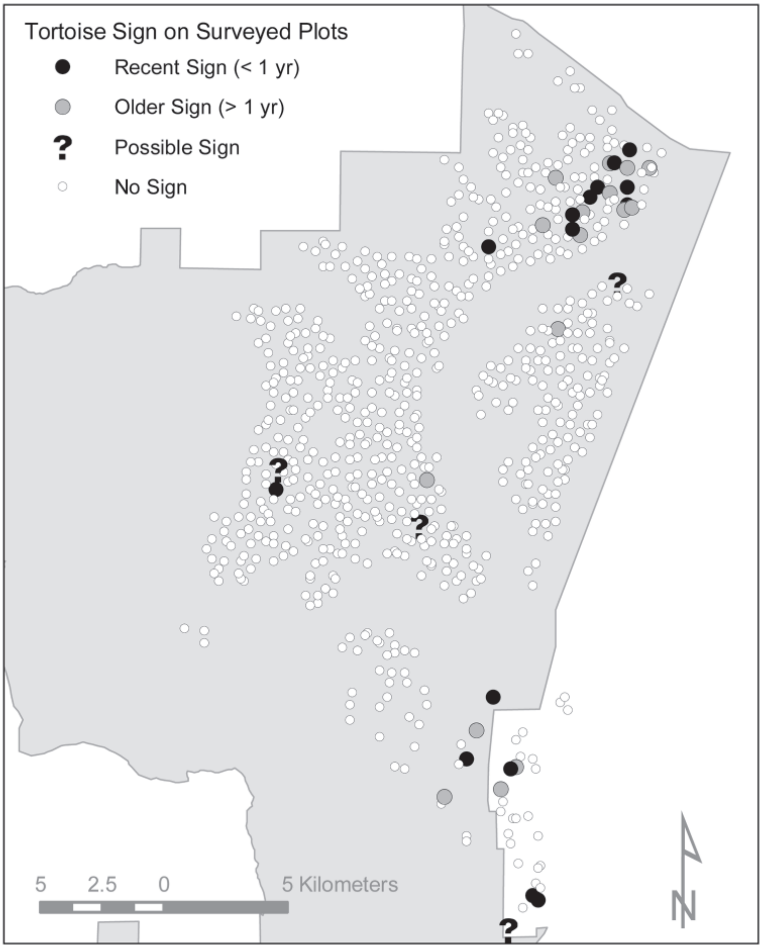

Figure 2: Results of the search for desert tortoise sign on the plots.

because of private lands to the west, steep topography that prevented systematic searches, and the low-density of the sampling design. However, ~40 km^2 are currently in the area with elevated levels of sign. Walking between plots, field biologists noted additional and similar amounts of tortoise sign, which was found exclusively within the Kiavah Apron and Red Rock regions (Table 2). Two plots in the Indian Wells region and four plots in the Blackbush region also had tortoise sign or possible tortoise sign.

Four live tortoises were encountered in the Kiavah Apron region, three adult females and one adult male. All four tortoises were old adults and exhibited an advanced stage of shell-wear or aging. Their shells had few remaining growth rings. On the carapace, smooth, worn areas made up large portions (>50%) of some scutes and depressions were present on up to 8 of the 13 vertebral and costal scutes. Three of the tortoises had clinical signs of URTD, i.e., edema of the palpebra and periocular area.

The nares, however, were unobstructed and there was no evidence of wet or dried mucus on the face or forelimbs. The eyes and face of the fourth tortoise were not visible during the health evaluation, and thus the assessment was incomplete. A fifth tortoise was identified inside of its burrow in the Red Rock region but was not evaluated because of high ambient temperatures.

Nine shell-skeletal remains were discovered, all within the Red Rock region. Six shells were of adult tortoises: one male, one female, and four of unknown sex. Five of the adults had been dead >4 years, and evidence was insufficient to assign a cause of death. The other adult had been dead ~4 years and had chew and puncture marks typical of a carnivore, indicting that the tortoise may have been killed or scavenged. The three juveniles had been dead <4 years, and one showed signs of avian predation.

Tortoise cover sites and scats were found almost exclusively in the Kiavah Apron and Red Rock regions (Table 2). Of the 61 cover sites that were observed, most (50) were in good or excellent condition (classes 1-3). Tortoises had probably deposited 73% and 41% of the observed scat within the last year and last 6 months, respectively.

We estimated densities of 3.6 ±2.32 SD adult tortoises/km^2 (95% CI = 0.44–12.31 tortoises/km^2) for the area within the Kiavah Apron region and 2.7 ±2.63 SD adult tortoises/km^2 (95% CI = 0.07–14.61 tortoises/km^2) for the Red Rock area. Tortoise sign in the Kiavah Apron area was in a concentrated area, and we estimated that 50 adult tortoises (3.6 tortoises/km^2 x 14 km^2) may live in the local area (95% CI = 6–172). Tortoise sign in the Red Rock area occurred over a larger area, ~40 km^2, and using the same method, we estimated that 108 adult tortoises may be present (95% CI = 3–566). Because both of these population estimates are based on highly skewed data (only three plots had live tortoises), the CIs are quite large. For Kiavah and Red Rock combined, the density is estimated at 3.2 (95% CI = 0.67–9.14 tortoises/km^2) and the population is 174 (95% CI = 36–493). For the entire Jawbone-Butterbredt study area, where large numbers of plots were found without tortoises, we are more certain that the overall population is small (density = 0.4, 95% CI = 0.08–1.16 tortoises/km^2; population size = 72, 95% CI = 15-210).

Current Uses

Surveys for signs of human-related disturbances revealed widespread activities throughout the study area (Table 3). The most prevalent sign was livestock scat, found on 97% (N = 726) of the plots. It was only absent on plots in and around the Park, three plots in S. Dove Springs and one plot with steep terrain in the Scodie foothills. Trash, often tin or aluminum cans, occurred on 58% (N=436) of plots. Fifty-two percent (N=388) of plots had vehicle tracks, either 4-wheel drive or motorcycle or both. Few tracks were on designated OHV routes; most tracks (92%) stemmed from cross-country travel and provided documentation of unauthorized use. Shooting was also a widespread: 37% of plots (N=278) had bullet casings.

Each of the four more common anthropogenic impacts was significantly higher in some regions and lower in others (Fig. 3). Cattle scat was lower in the Red Rock region than in each of the other regions (ANOVA, F=69.9; df=4, 746, P=0.001; TPC, P = 0.001),

Table 3. Most common evidence of current anthropogenic uses found on plots in the study area, by region.

Human-related impacts	Blackbush (N=392)	Indian Wells (N=137)	Kiavah Apron (N=154)	Red Rock (N=37)	S. Dove Springs (N=31)	All regions (N=751)
	Percentage of plots in each region with the indicated disturbance					
4-wheel drive tracks	25	13	25	22	45	23
Motorcycle tracks	39	48	30	32	52	39
Garbage (general)	50	75	55	84	71	58
Bullet casings	37	31	38	54	35	37
Shooting targets	7	1	7	16	3	6
Livestock scat	>99	100	100	43	90	97
Balloons	26	31	23	41	29	27

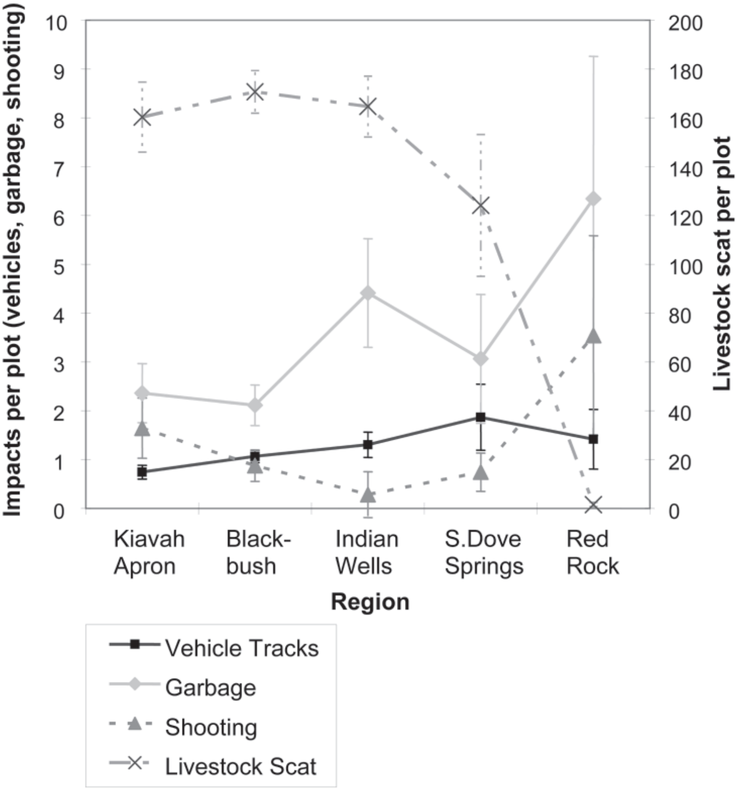

Figure 3: Average number of human-related impacts per plot by region. Error bars show 90% CIs for the mean.

and it was lower in the S. Dove Springs region than in both the Blackbush and Indian Wells regions (ANOVA, F=69.9; df=4, 746; TPC, *P*= 0.003–0.014). The amount of trash was higher in the Red Rock and Indian Wells regions and lower in the Blackbush and Kiavah Apron regions (ANOVA, F=8.9; df=4, 746; *P*=0.001; TPC, *P*= 0.001–0.043). The number of vehicle tracks was higher in the S. Dove Springs than in the Kiavah Apron and Blackbush regions (ANOVA, F=4.2, df=4, 746; *P*=0.002; TPC, *P* = 0.002–0.029). Another important pattern of OHV use was the high amount of unauthorized OHV use adjacent to and outside of the Dove Springs Open Area: three times as many tracks were on the 42 plots within 3 km of the northern edge of the Open Area compared with other plots in the Blackbush region (ANOVA, *P*<0.0005, F=42.5, df=1, 390). Finally, evidence of shooting was significantly higher in the Red Rock region than in the Indian Wells region (ANOVA, F=2.6; df=4, 746; *P*=0.035; TPC, *P*=0.033).

The pattern of impacts is thus different for each region. The Indian Wells region tends to have more anthropogenic impacts (with the exception of shooting) than other regions. At the other end of the spectrum are the Blackbush and Kiavah Apron regions with generally lower amounts of impacts. The Red Rock region stands out because of the lower amount of livestock scat, but has higher amounts of shooting debris and trash. The S. Dove Springs region had the greatest number of vehicle tracks but was moderate in terms of the other impacts.

Relationships between Current Uses and Tortoise Sign

Plots with tortoise sign had significantly fewer livestock scats than plots without tortoise sign. Specifically, there were almost 100% more livestock scats on the plots without tortoise sign than on plots with tortoise sign (Table 4). The presence of tortoise sign appeared to be dependent on and inversely related to the amount of livestock scat for all the plots in the study area (LogReg, t ratio = -5.1; df=746; *P*<0.0005) as well as for plots only within the Kiavah Apron region (LogReg, t ratio = -2.5; df= 153; *P*=0.011).

Historic Use

The ACEC and Park have been an arena for human activity since the mid-1800s (Fig. 4). Early maps showed routes of travel along the boundaries (Gibbes 1852, Bancroft 1868). The routes were used for mining, agriculture, movement of livestock, freight, exploration, and general travel. By the 1870s, routes were well-established from the South Fork of the Kern River and Kern River Valley south through Kelso Creek and Kelso Valley to Jawbone and Red Rock canyons (Wheeler 1879, Nadeau 1964, Faull and Hangan 2004). Stage and freight stations such as Red Rock, Dixie, Coyote Holes/ Freeman, and Indian Wells were on main travel routes along the eastern edge of the study area and were place names on Army maps (Wheeler 1879, Pracchia 1995). Routes crossed the ACEC west to east from the Kelso Creek area through Bird Spring to Dixie Station, and northwest to southeast from Kelso Valley and Kelso Creek areas to what is now Dove Spring Canyon and Butterbredt and Hoffman springs (Wheeler 1879, Nadeau 1964). The ACEC was bordered or crossed by routes that connected the

Table 4. Comparison of the average amounts of different types of anthropogenic impacts on plots with tortoise sign to the amounts on plots without tortoise sign. Four plots with possible tortoise sign were excluded.

Type of disturbance	Plots with tortoise sign (N=31)	Plots without tortoise sign (N= 716)	*P*-value (LogReg)
Livestock scat	74	165	<0.0005
Trash	2.3	4.0	0.60
Shooting	1.1	2.7	0.75
Vehicle tracks	1.7	1.2	0.40

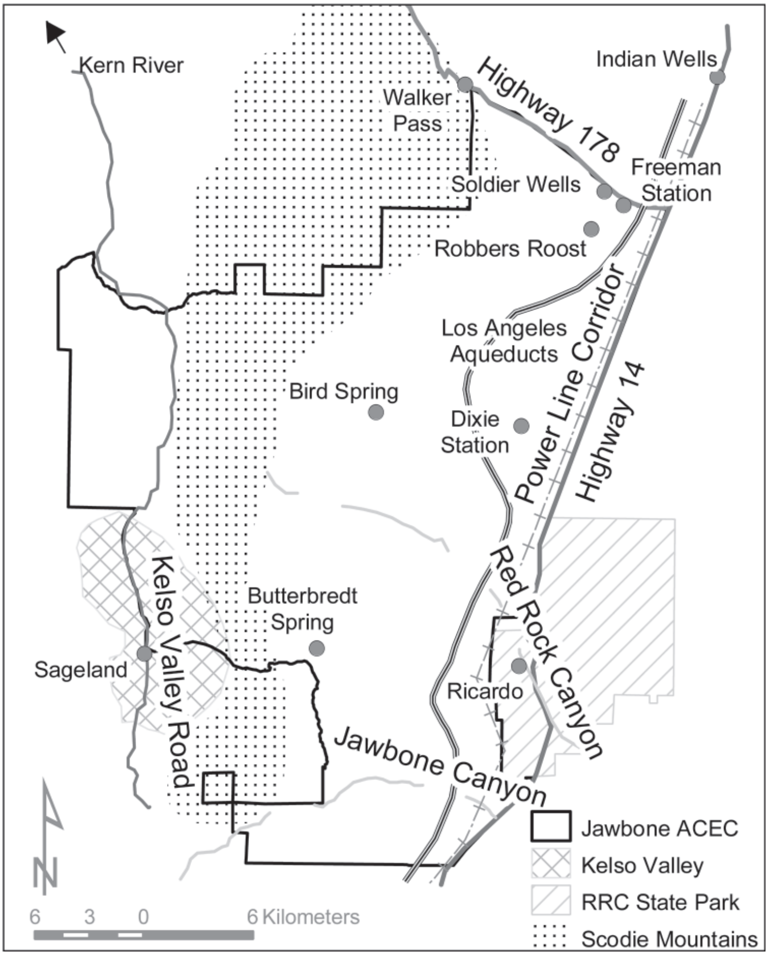

Figure 4: Results of the research into historic uses of the study area. This map shows the locations of some important human impacts.

southern California basins and San Joaquin Valley with Owens Valley and mining centers in the desert mountain ranges (Inyo Mountains; Coso, Argus, and Slate ranges) and Death Valley. Some of the same routes were used to move livestock through the desert (Wentworth 1948; Powers 1988, 2000).

Subsistence farming, ranching, livestock grazing and mining contributed to the development of South Fork, Kern River, and Kelso valleys, as well as Sageland, on the north and west edges of the study area in the 1850s and 1860s (Boyd 1952; Starry 1974; Powers 1988, 2000). Livestock grazing was and continues to be an important part of the landscape adjacent to and throughout the ACEC. Sheep and cattle driveways historically crossed the ACEC at Walker Pass, Jawbone Canyon, and in an approximately north-south direction through Red Rock Canyon along the eastern face of the Scodie Mountains and Sierra Nevada (Wentworth 1948, Fulwider[3] 1963). In the county and state, sheep business revolved around annual drives to a succession of forage grounds (Wentworth 1948). Two principal sheep driveways passed through the ACEC from the San Joaquin Valley to the Mojave Desert and included watering stops at Red Rock Canyon, Soldier Wells, Indian Wells and other sites (Wentworth 1948). In 1933, the Department of the Interior created a stock driveway from Mojave north to Owens Lake, which included the Dove Springs area, Kelso Valley, and Isabella/Walker Pass and Freeman Junction areas (Fulwider[3] 1963).

Other north-south surface disturbances included the two pipelines of the Los Angeles aqueduct, power towers, associated transmission lines, and a major state highway. The first Los Angeles aqueduct was constructed between 1905 and 1913 (Nadeau 1997), and was followed by an almost parallel disturbance with the second aqueduct between 1965 and 1970. The Red Rock Railroad, built through Red Rock Canyon to the Dove Springs aqueduct camp and used for 22 months from 1908 to 1910 (Faull[4] 1991), supported aqueduct construction. The first paved highway was completed in 1931 (Highway 6, subsequently Highway 14) and was adjacent to early stage routes. Power towers and transmission lines lie to the west of the paved highway. In the last 40 years, OHV recreation added another layer of disturbance. The OHV use, concentrated in the Jawbone and Dove Springs canyons (BLM 1980), also had networks expanding out from the aqueducts and into the canyons of the Scodie Mountains.

DISCUSSION

Establishing Baseline Data for Monitoring Desert Tortoise Populations in the Future

Our study provides the first systematic survey of the Jawbone-Butterbredt ACEC and the Park for desert tortoises (see also Berry et al. 2008). The sampling technique

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[3] Fulwider, D.S. 1963. Realignment of Stock Driveway. Memorandum to the Files – Cantil Unit Stock Driveway dated January 15, 1963. U. S. Department of the Interior, Bureau of Land Management, Bakersfield, California. 12 pages with 46 Exhibits.

[4] Faull, M. 1991. The Red Rock Railroad: The history and remnants of a short-lived, early Twentieth-Century supply spur. Unpublished manuscript. 9 pp.

has advantages and limitations for rare species. By recording all sign observed, whether on or off plots, we were able to better define the areas where tortoises occur. The combined data on different sign types also provided a more robust sample than counts and distribution of live tortoises alone. Counts of tortoises, burrows and scats are strongly correlated (Krzysik 2002) and thus are a good measure of tortoise presence and use of habitat.

Our survey protocol produced density estimates similar to the historical data and to other sites in the Mojave Desert with low densities. Density estimates on the Kiavah Apron and in the Red Rock area are similar to estimates of <8 tortoises/km^2 obtained from strip transects in the late 1970s and early 1980s (Berry and Nicholson[1] 1984). When the ACEC data are compared with data sets from other, larger study plots with low densities at the Park and at Goldstone Deep Space Communication Center (Table 5, Berry et al. 2006, 2008), the findings are similar for counts of live tortoises/km^2, tortoise cover sites/km^2, and tortoise scats/km^2. The low sign counts and limited evidence of tortoise occupation in Blackbush are also similar to other research results for this vegetation type (Weinstein[5] 1989).

Table 5. Comparisons of data from the plots in the Kiavah Apron tortoise population and plots in the Red Rock tortoise population to data from larger areas with very low tortoise densities. Goldstone is located on Fort Irwin in San Bernardino County, California; the data are from the spring of 1998 (Berry et al. 2006). The data from the Red Rock Demographic Plot were collected from the State Park in the spring of 2004 (Berry et al. In Press).

Live tortoises and tortoise sign	Plots in Kiavah Apron area (56)	Plots in Red Rock area (37)	Goldstone Plot#7	Goldstone Plot#12	Red Rock Demographic Plot
Total area sampled (km^2)	0.56	0.37	1.0	1.0	4.1
Live tortoises (N)	2	1	2	6	9
Live tortoise counts/km^2	3.6	2.7	2.0	6.0	2.2
Cover sites (N)	18	10	30	25	74
Cover site counts/km^2	32.1	27.0	30.0	25.0	18.1
Scat locations (N)	63	10	>25	>75	39
Scat locations/km^2	112.5	27.0	>25.0	>75.0	9.5

The FWS (1994) noted that desert tortoise populations at minimum densities of 3.86 adult tortoises/km^2 require at least 518–1295 km^2 of habitat for genetic viability. The populations and habitat in the ACEC and Park do not meet that criterion and are not connected to areas that meet that criterion.

The population estimates have three limitations. First, while we are confident that the density is <9 adult tortoises/km^2 (upper limit of 95% CI for both areas combined),

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[5] Weinstein, M.N. 1989. Modeling desert tortoise habitat: Can a useful management tool be developed from existing transect data? Ph.D. dissertation. University of California, Los Angeles. 121 pp.

we do not know the exact density nor how many tortoises are present. The technique did not generate sufficient data for establishing a baseline for future monitoring of status and trends. Second, while two areas with clusters of tortoise sign were identified, other areas with tortoises and sign may have been missed. Third, most fieldwork was conducted in the summer when tortoises may spend less time above ground because of the heat, lack of water and scarce forage (Henen et al. 1998; Duda et al. 1999). However summer is also the season for courting and mating when adults are active (Lance and Rostal 2002). The small sizes of juvenile and immature tortoises make them more difficult to detect at any time of year, and these size classes were likely under-sampled (Morafka 1994, but see Berry and Turner 1986). While sample sizes of live tortoises might be increased by more intensive sampling, use of adaptive or cluster sampling (Thompson 2004), or numerous distance sampling transects (Krzysik 2002), the bottom line is that tortoise densities are very low.

Historic Densities of Tortoises

We do not know if tortoises were more abundant in the study area prior to the time of the first surveys with strip transects (Berry and Nicholson[1] 1984). We can infer that the ACEC and Park may have supported higher densities prior to the advent of the many layers of anthropogenic activities between the 1860s and 2002 from three nearby studies in similar habitats. First, population densities in the Desert Tortoise Research Natural Area, located in Fremont Valley 16 km from the southeastern edge of the study area were 150/km^2 between 1979 and 1982, but had declined >90% by the early 1990s (Berry and Medica 1995, Brown et al. 1999). Second, about 20 km east of the study area in Indian Wells Valley, local residents reported seeing high numbers of tortoises (densities estimated at >100 /km^2) between the 1940s and 1960s (Berry[6] 1984). The time period coincided with the growth and development of the Department of Defense's facilities and the concomitant rise in human populations in the Valley to 20,000 people. In the southern end of the Park, recent data from a study plot indicated that densities were about three times higher in 2000 (Berry et al. 2008). An alternative explanation is that tortoise populations in the Park and the ACEC were historically low.

Current Land Uses: Correlations of Tortoise Sign with Anthropogenic Impact Variables

Many different human uses are known to negatively affect desert tortoise populations and habitats. Since we cannot parse the effects of historic and current uses on the tortoise populations here, we are limited to evaluating current correlations of sign with the impact variables. The evidence of recent livestock use was widespread

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[6] Berry, K.H. 1984. The distribution and abundance of the desert tortoise in California from the 1920s to the 1960s and a comparison with the current situation. Chapter 4 *in*: K. H. Berry, editor. The status of the desert tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Rept. to U.S. Fish and Wildlife Service, Sacramento, California, USA. Order No. 11310-0083-81.

throughout the ACEC except in the Park. Tortoise sign was significantly lower on plots with high livestock scat counts. Livestock grazing affects tortoises through loss of shrub cover, trampled cover sites, competition for forage plants, and the degraded nutritional quality of forage (Avery and Neibergs 1997, Avery[7] 1998, Jennings 2002, Oftedal et al. 2002). Throughout much of the Mojave and Sonoran deserts, livestock grazing and other surface disturbances have altered the composition and biomass of critical forage for the tortoise: herbaceous perennial plants and winter annual herbs. Alien annual plants now compose ~65% of the biomass of the annual flora in the western Mojave Desert (Brooks and Berry 2006). Plant cover of alien annuals is also higher in the piospheres of disturbance around livestock watering sites (Brooks et al. 2006), which were common throughout the area historically and are prevalent today outside of the Park.

Off-highway vehicle use contributes to mortality of tortoises as well as deterioration and loss of habitat (Bury and Luckenbach 2002). The comparisons of plots with tortoise sign versus those without sign showed no significant differences for vehicle tracks. However, tortoise sign was absent from the S. Dove Springs region, where vehicle track counts were significantly higher than elsewhere, and the number of vehicle tracks was significantly higher in S. Dove Springs than in the Kiavah Apron and Blackbush regions. The total length of OHV routes inside the Dove Springs OHV Open Area increased from 49 km to 576 km between 1965 and 2001 (Matchett et al.[8] 2004). The growth in OHV use levels is further supported by our finding of a high concentration of unauthorized use outside of OHV Open Areas. Recreation in general adds to pressure on tortoise populations from shooting and vandalism (Berry 1986), and tortoise remains found in the Red Rock Canyon State Park and surrounding areas showed signs of gunshot wounds (Berry et al. 2008). One factor contributing to the presence of tortoises in the Kiavah Apron may be lower OHV use.

Other variables contributing to low numbers of tortoises in the ACEC are the highways and roads, disease, and predation of juveniles by ravens. Highways and roads are known to have impacts on tortoises for a substantial distance from the pavement edge (e.g. von Seckendorff Hoff and Marlow 2002, Boarman and Sazaki 2006). Newly emerging diseases, such as URTD, caused by one or more species of *Mycoplasma*, have contributed to population declines in the DTRNA (Jacobson et al. 1991; Brown et al. 1994, 1999) and are more likely to affect tortoises within or in close proximity to urban areas than in remote parts of the desert (Jacobson et al. 1995, Berry et al. 2006, Johnson et al. 2006). The combination of clinical signs in ACEC and Park tortoises and the close proximity to the urban areas of Ridgecrest and Inyokern, both of which have households with ill captive tortoises (Berry, unpublished data), suggest that one or

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[7] Avery, H.W. 1998. Nutritional ecology of the desert tortoise (*Gopherus agassizii*) in relation to cattle grazing in the Mojave Desert. Ph.D. Dissertation, University of California at Los Angeles, Los Angeles, California.

[8] Matchett, J.R., L. Gass, M.L. Brooks, A.M. Mathie, R.D. Vitales, M.W. Campagna, D.M. Miller, and J.F. Weigand. 2004. Spatial and temporal patterns of off-highway vehicle use at the Dove Springs OHV Open Area, California. Report prepared for the Bureau of Land Management – California State Office by the U.S. Geological Survey. 17 pp.

more of the tortoises in our study is likely to have URTD. Raven populations have increased 1000% since the late 1960s with a consequent increase of predation on juvenile tortoises (Boarman and Berry 1995). Ravens have the potential for causing local declines and extinctions of tortoise populations through hyperpredation (Kristan and Boarman 2003). Although we do not know the extent of tortoise mortality due to vehicles, disease, and ravens in the ACEC, the numerous variables affecting populations and habitat are probably interacting synergistically to the detriment of the tortoise.

Data on Historic and Current Land Uses Provide Potential Explanations

Our findings of low density and patchy tortoise populations may be best understood in the context of the historic and current land use and human-related impacts. Many factors have contributed to State and Federal listings of the desert tortoise, and a significant number of the factors are anthropogenic in nature (California Code of Regulations, FWS 1990, 1994; Berry and Medica 1995). Historic records indicate that land use in the ACEC and the Park has been both diverse and continuous since the 1860s. Virtually no areas below 1500 m in elevation, where tortoises are most likely to occur, remain unaffected by multiple human activities. Although some areas >1150 m are in wilderness designated by Congress (e.g., Kiavah Wilderness), the designation did not occur until Congress passed the California Desert Protection Act in 1994. Cattle still graze these wilderness lands as a pre-existing land use. Below 1150 m, ~1.5 centuries of livestock grazing have been accompanied by the stock driveways; travel routes for stage coaches, freight lines, and modern-day vehicles; north-south utility lines and two aqueducts; and intensive motorized recreation use in Jawbone and Dove Springs canyons and the Park. Activities at different spatial and temporal scales have fragmented desert habitats and created cumulative impacts on the landscape, with effects on vegetation, and to some extent, topography. The pattern of impacts in the ACEC and Park are similar to that occurring in the southern California deserts in general (Lovich and Bainbridge 1999), but is higher overall because of the close proximity to urbanized lands in the Indian Wells Valley, San Joaquin Valley, and metropolitan southern California.

SUMMARY

The new protocol and field surveys for desert tortoises, as well as the review of current and historic land uses, met four of our five objectives. We determined that densities throughout the area are very low and that populations appear to be patchy. The two clusters of tortoise sign in the Kiavah Apron and Red Rock regions may be remnants of formerly more abundant populations in the Indian Wells and Fremont valleys. Unfortunately the existing data set is insufficient to serve as baseline for long-term monitoring of status and trends. The two clusters of tortoise sign that we identified provide information for the next phase of surveys, which can be designed to acquire a more robust baseline sample for the future.

We were able to accomplish the broader objectives of determining how land uses and management may affect desert tortoises and their habitats by combining the current biological data on tortoises and their sign with studies of historic and current land use histories. The presence of tortoises and sign in areas with lower levels of livestock or OHV use indicates that these activities may have significant impacts on tortoises. By considering this finding in combination with the results of our historical survey, we can offer several recommendations. Livestock (both cattle and sheep) have been using the area for forage for over 150 years. If land managers wish to protect tortoises and tortoise habitat in the ACEC, they can use fencing to restrict or eliminate livestock from specific areas such as the Kiavah Apron. By hastening the recovery of perennial shrubs and annual plants (Brooks 1995), fencing results in more forage for tortoises, more protection from predators and less trampling of cover sites and tortoises by livestock. Off-highway vehicle use is a more recent activity, but its intensity is increasing. Increased patrols and stricter enforcement of the designated route system would reduce much of the risk to tortoises from OHV activity.

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