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STATUS OF THE DESERT TORTOISE IN RED ROCK CANYON STATE PARK

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We surveyed for desert tortoises, *Gopherus agassizii*, in the western part of Red Rock Canyon State Park and watershed in eastern Kern County, California, between 2002 and 2004. We used two techniques: a single demographic plot (~4 km^2) and 37 landscape plots (1-ha each). We estimated population densities of tortoises to be between 2.7 and 3.57/km^2 and the population in the Park to be 108 tortoises. We estimated the death rate at 67% for subadults and adults during the last 4 yrs. Mortality was high for several reasons: gunshot deaths, avian predation, mammalian predation, and probably disease. Historic and recent anthropogenic impacts from State Highway 14, secondary roads, trash, cross-country vehicle tracks, and livestock have contributed to elevated death rates and degradation of habitat. We propose conservation actions to reduce mortality.

INTRODUCTION

The desert tortoise (*Gopherus agassizii*), a Federally- and State-listed threatened species (Fish and Wildlife Service [FWS] 1990, California Code of Regulations 2004) occurs in the western Mojave Desert in Red Rock Canyon State Park (Park), Kern County, California. The Park was first established as a State Recreation Area in 1973 with ~7.81 km^2 of land, most of which was west of State Highway 14. It was re-designated as a State Park in 1980 and enlarged in 1989 and 1994 through the addition of public lands from the Bureau of Land Management (BLM) (Mark Faull, Park Ranger and Ecologist, personal communication). The exact size of the State-managed area is in flux, because of frequent new additions of private holdings. In 2005, the size was ~104.44 km^2, ~20% of which is west of State Highway 14.

The Park is ~5 km northwest and outside of the federally designated critical habitat for the tortoise in Fremont Valley, the Fremont-Kramer Desert Wildlife Management Area, and Western Mojave Recovery Unit (FWS 1994). It is also within 7 km of the Desert Tortoise Research Natural Area (DTRNA). Both Fremont Valley and the DTRNA had high density populations in the 1970s and 1980s (FWS 1994, Berry and

Medica 1995, Brown et al. 1999). In the 1970s, when surveys were first conducted for tortoises in the Park and vicinity[1], densities were estimated at <8 tortoises/km^2. Thus, when the BLM published a 20-year land use plan for the California deserts in 1980, the lands encompassing the Park were not included in tortoise "crucial" habitat (BLM 1980). Nevertheless, Park personnel observed and kept records of tortoise sightings, but did not determine distribution, status and trends. Therefore, no baseline data were available.

The design of effective surveys for rare or elusive species continues to be a challenge (Thompson 2004). Desert tortoises spend much of their lives underground (Nagy and Medica 1986) and are inactive during drought (Henen et al. 1998, Duda et al. 1999). In addition, juvenile and immature tortoises can be difficult to find because of their small size and cryptic coloration (Berry and Turner 1986, Morafka 1994). Several different methods have been used to gather data on population attributes, including study plots, strip transects, tortoise sign, and line-distance sampling (Berry and Medica 1995, Buckland et al. 2001, Anderson et al. 2001, Krzysik 2002, Swann et al. 2002). Each method provides advantages and disadvantages. Data on tortoise sign from strip transects were useful in mapping distribution and relative abundance, whereas mark-recapture data from study plots formed the basis for long-term monitoring of status and trends in populations using such variables as size-age class structure, sex ratios, density, mortality rates, and causes of death. In critical habitat, line-distance sampling is the current method of choice for measuring changes in densities of the large immature and adult tortoises at a landscape scale (Anderson et al. 2001, McLuckie et al. 2002) but does not provide data on other population attributes.

We reviewed land use history and conducted two different types of surveys for tortoises in and adjacent to the Park between 2002 and 2004. We focused efforts on the older, western part of the Park, west of State Highway 14. The first type of survey was an intensive, demographic survey on a 4-km^2 study plot in the southwest portion of the Park. The second type consisted of 37 1-ha plots, which were part of a landscape-level survey in the Jawbone-Butterbredt Area of Critical Environmental Concern (ACEC) (Keith et al. 2008). The ACEC borders the Park to the west and is managed by the BLM. Our objectives included: (1) providing an historical background of land uses for interpreting tortoise population data, (2) creating baseline data for long-term monitoring of status and recent trends in a low density desert tortoise population, (3) comparing survey methods in areas with low density of tortoises, (4) identifying significant correlations between tortoise counts and anthropogenic impacts; and (5) proposing management options for enhancing protection and recovery of the desert tortoise. For the Park, an important objective was to maximize the amount of data and information on distribution and demographic attributes within a limited budget.

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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.

METHODS

Historical Data on Land Uses and Desert Tortoises

We examined old maps, journals, newspaper accounts, master title plats, and other records to compile a history of land uses within and adjacent to the Park. We reviewed records of tortoise observations kept by the Park (Mark Faull, Park Ranger and Ecologist, personal communication), BLM, and U. S. Geological Survey for locations, whether the tortoise was live or dead, and for notes that might be important for management purposes.

Red Rock Demographic Plot (4 km^2)

The study area (4.096 km^2) was selected by Park personnel and is in the southwest portion of the State Park at elevations of 700–800 m (Fig. 1). State Highway 14, which is elevated and blocks the natural flow of water draining into the mouth of Red Rock Canyon, borders the east edge of the plot. Only the northern part of the plot was in

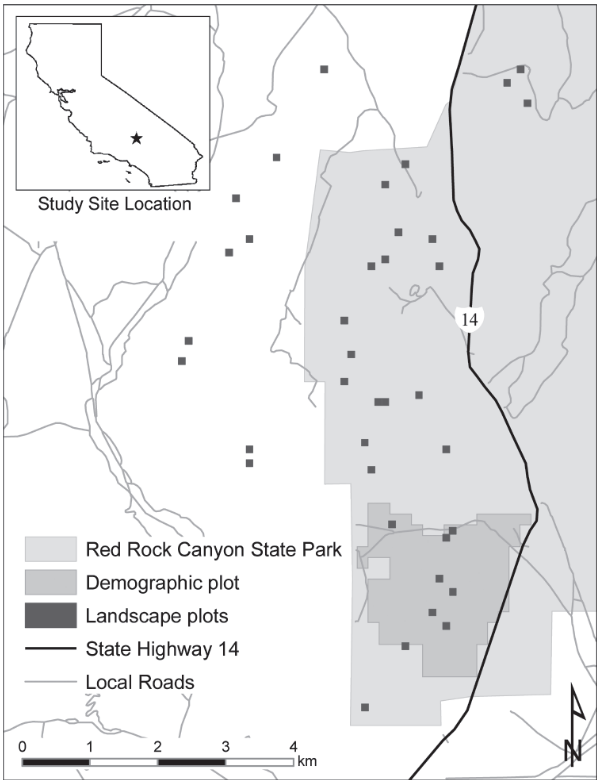

Fig. 1. Distribution of the demographic and landscape plots for desert tortoises in Red Rock Canyon State Park and watershed, eastern Kern County, California.

the originally designated Red Rock State Recreation Area boundaries in 1973. The remaining portions were added in 1989 with transfer of public land under the jurisdiction of the BLM to the State. The habitat is predominantly creosote bush scrub, *Larrea tridentata*. Associated shrub species are burro-weed, *Ambrosia dumosa*, goldenhead *Acamptopappus sphaerocephalus*, spiny senna, *Senna armata,* and cheesebush, *Hymenoclea salsola*. We established a grid of 160 quadrats, each measuring 160 x 160 m, by locating the corner of each quadrat with a global positioning system. Field biologists surveyed the quadrats at 10-m intervals, recording data on all live tortoises, signs (scats, cover sites, egg-shell fragments), and shell-skeletal remains (Berry and Christopher 2001). The plot was surveyed once between 29 March and 19 May 2004. A total of 351 person hours was spent in surveys, 318 of which were consumed in searching and 33 in processing tortoises and tortoise sign.

Live tortoises were processed using a standard protocol, which included photographs, permanently marking the tortoise with a unique number, a health assessment, measuring carapace length at the midline (MCL, mm) and taking weights (g), and determining sex and relative age (Berry and Christopher 2001). Tortoises were assigned to one of five size-age classes based on MCL: juvenile (<100 mm), immature (100–179 mm), subadult (180–207 mm), adult (208–239 mm), and large adult (≥240 mm). Observations were also made about habitat use and behavior.

For the health assessment, we compared data on weight-length relationships to healthy or control tortoises from other studies (Berry et al. 2002, Christopher et al. 2003). We recorded clinical signs of diseases, e.g., starvation and dehydration (Berry et al. 2002), an infectious upper respiratory tract disease (URTD) caused by the pathogens *Mycoplasma agassizii* and *M. testudineum* (Jacobson et al. 1991; Brown et al. 1994, 1995, 2004), and shell diseases (cutaneous dyskeratosis, shell necrosis) (Jacobson et al. 1994; Homer et al. 1998).

We evaluated all cover sites which are defined as shelters used by tortoises. Cover sites include burrows, caves, rock shelters, and pallets (Burge 1978). Each cover site was measured and photographed, and a condition class was assigned using an ordinal scale: (1) active now—fresh tracks or plastron marks evident; (2) active, free of debris—tortoise can walk into and use cover site, probably used within the past year; (3) good condition—plant debris or drifted sand, tortoise could walk into it or plow into it and use it immediately; (4) unused recently/fair condition—some excavation necessary, signs of structural degradation occurring at corners of burrow opening and at mouth; and (5) abandoned, collapsed—a major construction effort would be necessary for re-use.

We recorded numbers and locations of tortoise scats and scored each scat or group of scats for recency using an ordinal scale: (1) within this season—slick, coated with 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.

We evaluated shell-skeletal remains *in situ* using a standard data sheet which included date, unique identification number, location, and evidence for the cause of death. We then photographed and collected the remains. In addition, scats of tortoise predators, e.g., coyotes, *Canis latrans*, and kit foxes, *Vulpes macrotis*, were examined for remains of tortoises. In the laboratory, we determined, when possible, the size and sex of the tortoise, relative age of adult tortoises, and time since death[2,3,4]. The time since death was estimated in four categories (<1 year, 1–2 years, 2–4 years, and >4 years). Causes of death were assigned where possible, drawing on published and unpublished criteria for vehicle damage, shell diseases (Jacobson et al. 1994; Homer et al. 1998), avian predators (Boarman 1993), mammalian predators (chew, gnaw marks, broken scutes and bones), gunshot (Berry 1986), and trauma from dogs[5]. We estimated a death rate for adults and subadults during the past 4 years by dividing the number of subadult and adult tortoises that had died during the past 4 years by the sum of live and dead subadult and adult tortoises.

We quantified evidence of human use and recorded locations for trash and cattle scat; signs of shooting (shells, clay pigeons, casings); lengths of fences and locations of road barriers (rocks, boulders); and vehicle tracks, motorcycle trails and dirt roads. For trash and signs of shooting, each site was counted as one, whether or not multiple items were present.

Red Rock Landscape Plots (1 ha each)

The survey for desert tortoises at a landscape scale occurred between the summer of 2002 and summer of 2004 in the Jawbone-Butterbredt ACEC and the western part of the State Park (Keith et al. 2008). We stratified the entire area of 759 km^2 by habitat, topography, surficial geology, and elevation and then divided it into a 500 x 500 m grid of cells. From each of these cells, we randomly selected a single 1 ha (100 x 100 m) plot for a complete survey. We eliminated plots if (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 and was on private land; (3) any part of the

[2]Berry, K.H., and A.P. Woodman. 1984a. Preliminary investigations of shell wear in determining adult age groups in desert tortoises. Appendix 4 *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.

[3]Berry, K.H., and A.P. Woodman. 1984b. 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.

[4]Woodman, A. P., and K. H. Berry. 1984. A description of carcass deterioration for the desert tortoise and a preliminary analysis of disintegration rates at two sites in the Mojave Desert, California. Appendix 6 *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.

[5]Demmon, A., and K. H. Berry. 2005. Evaluating trauma in live desert tortoises: Wild vs. domestic canids. A Progress Report. Presentation and Abstract. 30th Annual Meeting and Symposium of the Desert Tortoise Council, Tucson, Arizona. February 18-21, 2005.

plot was inside a designated off-highway vehicle (OHV) open area; (4) any part of the plot was >1500 m in elevation; (5) the maximum slope of the plot was >45°; or (6) the plot was in an area where square mile sections of public land alternate with square mile sections of private land, thus creating access problems. We applied these criteria for legal (2,6), logistical (6), and safety reasons (5), and to focus on areas with greater likelihood of finding tortoises (1, 3, 4, 5).

Of the 751 plots in the landscape survey, 37 plots were within the Red Rock Canyon watershed (the watershed included lands that drained into the State Park from the west, were within the ACEC east of the Los Angeles aqueducts, but did not include Dove Springs Canyon). Of the 37 plots, 28 were within and 9 were outside of State Park boundaries. Eight of the 28 plots inside the Park were within the demographic plot. Vegetation in the Red Rock Canyon watershed is diverse, reflecting the heterogeneity of the topography, but primarily consists of creosote bush scrub or mixed desert scrub with Joshua trees, *Yucca brevifolia*. Field biologists sampled the 37 plots during 10 days of fieldwork from June to October 2002 and on one day in June of 2004, comprising 129 person hours of fieldwork.

We used survey methods similar to those described for the demographic plot, with the exceptions that each plot was covered twice (coverages were not entirely independent), the survey season was summer and fall, and human impact data were quantified using standard data sheets. Field biologists also recorded all signs of tortoises that they observed while walking to and from the plots.

The distributions of live tortoises, shell-skeletal remains, other tortoises sign, and the different types of anthropogenic impacts were mapped in Geographic Information System (GIS) layers. Because no more than one live tortoise was found per plot, we calculated 95% CIs of the proportion of plots occupied by a tortoise using exact binomial statistics and extrapolated these values into density estimates (tortoises/km^2). We used SAS® software, the %jackboot macro and FREQ procedure for these analyses (SAS Institute 2004). We compared findings on human disturbances from the study inside the Park with findings from two comparison groups outside the Park: (1) in the adjacent Red Rock Canyon watershed, and (2) in the surrounding Jawbone-Butterbredt ACEC (Keith et al. 2008). For each of the five more common types of human disturbances, we conducted a separate analysis of variance (ANOVA) (SPSS Inc. 1998). Because the distribution of human impact variables was skewed, we used a square-root transformation of the data to perform statistical tests.

RESULTS

Land Use History

Beginning in the mid-1800s, explorers, miners, and livestock operators visited this region of the Mojave Desert, and many settlements developed (Gibbes 1852, Goddard 1857, Bancroft 1868, Wheeler 1879, Coville 1893, Faull and Hangan 2004). During the 1860s, Red Rock Canyon became a major route for travelers going to mines in the eastern half of the Park in the El Paso Mining District, the nearby Rand Mining District, and the northern part of California and Nevada (Boyd 1952, Troxel and Morton 1962, Nadeau 1964, Pracchia 1995, Faull and Hangan 2004). About this same time, livestock operators moved sheep and cattle north and south through Red Rock Canyon, relying on local springs and waters (Wentworth 1948, Boyd 1952). Use as a stock driveway continued for about 100 years. At the turn of the 20th Century, between 1901 and 1913, the Red Rock Canyon watershed became part of a major north-south utility corridor with construction of the first Los Angeles aqueduct (Nadeau 1997). The second Los Angeles aqueduct, built between 1965 and 1970, paralleled the first aqueduct. Both linear disturbances lie from 1.6 to 2.6 km west of Park boundaries. Transmission lines (230 kv, 800 dc), power towers, and associated dirt roads are within or on the western boundary. The rights-of-way were established in 1949 and 1989, and the utility corridor is 3.2 km wide (BLM 1980). State Highway 14, which runs through Red Rock Canyon and the Park, was paved in the early 1930s and has continued to be the major travel route connecting the southern California valleys and coasts to the Mojave Desert and to eastern and northern California. The beautiful landscape and unusual rock formations in Red Rock Canyon attracted early tourists 80 to 90 years ago, and tourism remains an important use (Faull 2000, Faull and Hangan 2004).

Red Rock Canyon first received some degree of protection in May, 1970 with the arrival of rangers, who initiated major clean up campaigns to remove large volumes of trash (Faull, Park Ranger and Ecologist, personal communication). The area achieved increasing levels of protective status as a State Recreation Area in 1973 and as a State Park in 1980. In the 32 years between the designation as a State Recreation Area and 2005, the lands managed by Park staff have increased 13-fold. Livestock grazing has been excluded and boundary fences protect parts of the western portion of the Park from unauthorized vehicle use and livestock.

Evaluation of Park Records of Tortoises

Park staff compiled 158 observations of tortoises and tortoise sign between March 1979 and May 2003 (Faull, Park Ranger and Ecologist, personal communication). Of the 158 observations, 154 were of live tortoises, 1 was of a crushed tortoise (roadkill), 1 was of tortoise dens, and 2 were of tortoise scat. Most sightings (34%) occurred at the Ricardo Campground or nearby, the popular hiking area in Hagen Canyon (23%), and along roads (16%). Visitors reported seeing a tortoise with fiber-glass repairs to the shell in the Ricardo Campground six times between 1990 and 1992.

Red Rock Demographic Plot (4 km^2)

Nine live tortoises were found: 4 were immature (110–157 mm MCL), 1 was a subadult (205 mm MCL), and 4 were adults (267–296 mm MCL). Of the 4 adults, 3 were male and 1 was female. All adults were considered to be middle- to old-aged adults. The subadult male was a young individual. Tortoises were not evenly distributed throughout the plot (Fig. 2). Two large males (11, 14) and one female (21) were clustered together in the northeast part of the plot with two young, immature tortoises nearby. For adults,

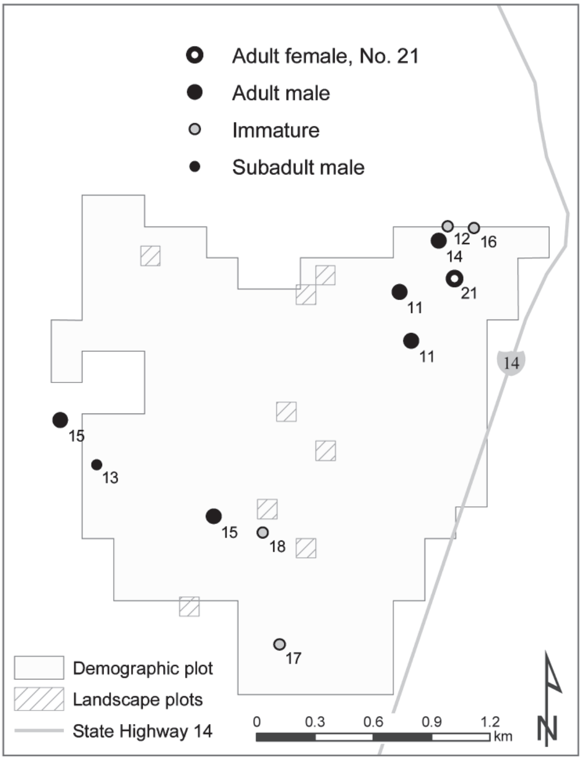

Fig. 2. The distribution of live desert tortoises on the demographic plot and landscape plots within the demographic plot, Red Rock Canyon State Park, Kern County, California, in spring of 2004.

the live tortoise count/km^2 was 0.98. For all sizes of tortoises, the count/km^2 was 2.2. In terms of search effort, ~36 hours were required to find a new tortoise. Only one female adult was found, and she was located within ~0.5 km of State Highway 14 and ~100 m of a road to a scenic area. The presence of the immature tortoises indicates that eggs have been produced, hatched, and young tortoises have survived an estimated 7–15 years.

All nine tortoises showed one or more mild to moderate clinical signs associated with URTD or other respiratory tract diseases: mild swelling of the eyelids (edema of palpebrae), wet lids, discharge from the eyes, deposits of dried mucus or discoloration of the lids or periocular area or both, dirt on the beak, and occluded nares. One middle-aged adult male tortoise had more co-occurring clinical signs of URTD than other tortoises: discoloration of the palpebrae, discharge from the eyes, wet lids, and indications of potential nasal discharge (dirt on beak, occluded nare). One old adult male tortoise had active lesions typical of cutaneous dyskeratosis on <10% of the plastron, and an immature tortoise had vermiculations under the carapacial scutes, advanced wear on scute laminae and depressions in several scutes. Five tortoises showed signs of old, healed trauma to the shell such as old chews and chips on the marginal scutes, damage to the gular scutes, puncture wounds, and a depression fracture from a possible puncture wound. Lesions were evident on the posterior plastron and/or anal scutes for three adult tortoises (2 males, 1 female). The adult female had substantial abnormalities and lesions on humeral and anal scutes, unlike any previously observed. No tortoises showed clinical signs of dehydration or starvation. Weight-length relationships were within normal limits (95% CI) for spring, and five tortoises had green stains from fresh plants on their beaks, indicating that they had recently eaten.

During the demographic survey, 55 sets of shell-skeletal remains were collected. Three additional sets of remains were collected previously from the demographic plot during the landscape level survey. The 58 remains included 2 juvenile, 8 immature, 14 subadult, and 34 adult tortoises (Fig. 3). Most remains (76%, N = 44) were from tortoises that had been dead >4 years but probably <20 years (1984-2000). Four of the tortoises had died within the past 2 years, and 10 had died 2 to 4 years previously. The composition of these recently dead tortoises included: 1 juvenile, 3 immatures, 2

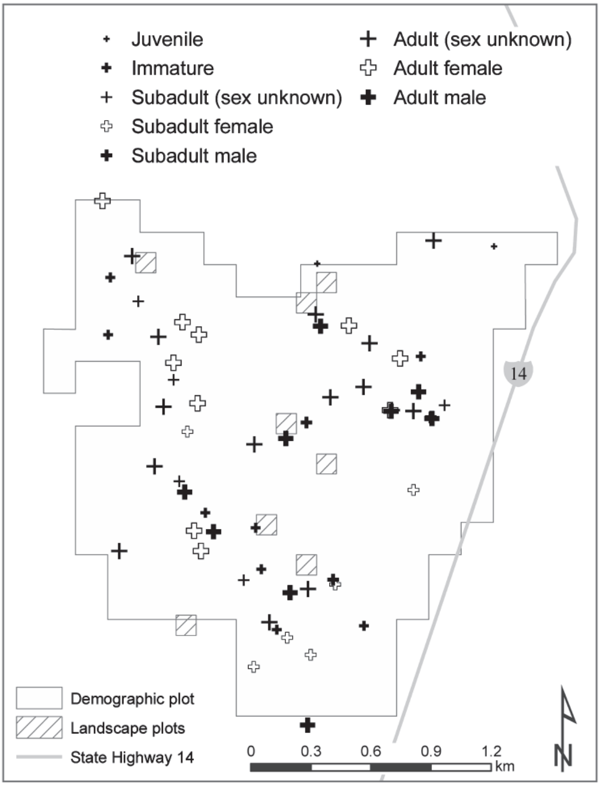

Fig. 3. The distribution of desert tortoise shell-skeletal remains on the demographic plot and landscape plots within the demographic plot at Red Rock Canyon State Park, Kern County, California, in 2002-2004.

subadult females, 3 adult females, 4 adult males, and 1 adult of unknown sex. The group of 44 tortoises that died >4 years ago included 40 individuals with entire and partial shells and 4 represented in sets of fragments. At least one tortoise was killed by gunshot, and 4 others showed evidence of death by gunshot (Berry 1986). As many as 19 tortoises may have been killed by mammalian predators; however, only 1 of these could be confirmed with a high level of certainty.

The death rate for subadult and adult tortoises between 2000 and 2004 was estimated at 67% (=10/[10 + 5]). If the 10 subadult and adult tortoises had not died, we might have seen 15 subadults and adults on the plot instead of 5 in 2004. The sex ratio also may have been more balanced: among the dead subadult and adults were 5 females, 4 males, and 1 of undetermined sex. Thus, instead of the ratio of 1 female to 4 males recorded in 2004, the sex ratio might have been 3 females to 4 males.

We identified 74 cover sites, and most were active (classes 1 and 2: 28%) or in good condition (class 3: 35%). Three burrows had tortoise scat at the opening or on the mound, and one of them had egg-shell fragments. In addition, 36 other scat locations and one egg-shell fragment were recorded. All scat appeared to be from adult or subadult tortoises, and 38% of scat was ≤1 year old (classes 1 and 2).

Evidence of human use was present throughout the plot. The numbers of sites totaled 1068 for trash, 349 for shooting, 78 for balloons, and 44 for cattle scat. In addition, at least 54 motorcycle trails, 7 old dirt roads, and 3 actively used dirt roads were observed. The dirt roads in use (~0.7 linear km) were on the northern end of the plot. Several fences or fence fragments (3.2 linear km) occurred throughout the plot. Rock barriers to inhibit unauthorized vehicle use were evident in several places.

Red Rock Landscape Plots (1 ha each) within the State Park

A single live and probably immature tortoise was found on 1 of the 28 plots but was not processed because ambient temperatures exceeded permit limitations**.** Because the tortoise occurred on a landscape plot within the demographic plot, it may have been one of the tortoises located during the demographic survey. No tortoise remains were found on the plots, but six remains were collected while walking between plots. Three of the six remains were within the demographic plot and are included with the demographic plot data. The other three remains consisted of two juveniles, both of which had died <4 years ago, and one adult which had died >4 years previously. One of the juveniles had been killed by a raven.

Four cover sites and 10 scat locations were found on the 28 plots, and almost as many (3 cover sites, 8 scat locations) were observed between the plots (Fig. 4). One set of tortoise footprints was identified. Among the 28 plots, 3 had recent tortoise sign (<1 year) and 3 had sign >1 year in age (Fig. 5).

Red Rock Landscape Plots (1 ha each) Outside the State Park

No live tortoises were observed on the nine plots, but remains of three tortoises were collected while walking between plots. One was a juvenile that had died within the past

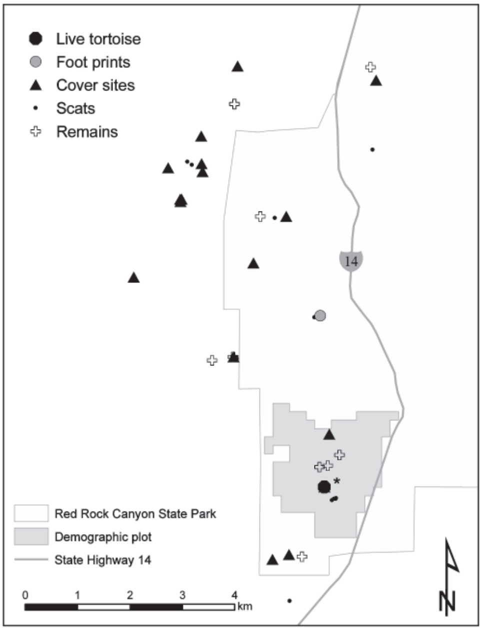

Fig. 4. The distribution of tortoise sign on and off landscape plots at Red Rock Canyon State Park and watershed, Kern County, California, in 2002-2004.

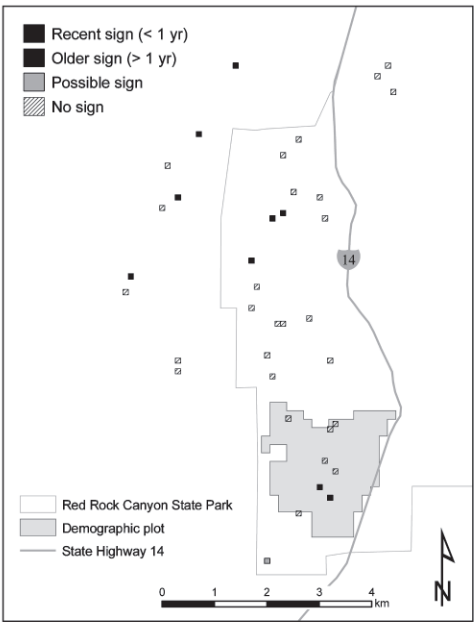

Fig. 5. The presence and age of desert tortoise sign on landscape plots in Red Rock Canyon State Park and watershed, Kern County, California, in 2002-2004.

year, and two were adults, both of which had died >4 years previously. Six cover sites (no scat locations) were found on plots, whereas four cover sites and nine scat locations were located between the plots (Figs. 4, 5). Of the nine plots, two had recent tortoise sign (<1year) and two had older sign (>1 year).

The 28 landscape plots inside the Park tended to have more human impacts than the nine landscape plots outside of the Park (Table 1). On average, the amount of trash, shooting (bullet casings and targets), and cattle scat was more than two times higher inside the Park. The exception to this trend was OHV tracks: plots outside the Park had more than five times as many tracks as plots inside the Park. The differences in OHV tracks (ANOVA, P = 0.04) and shooting (ANOVA, P = 0.01) were statistically significant, and the difference in trash (ANOVA, P=0.09) also indicates a potential trend. If we compare the plots in the Park (N = 28) with all of the Jawbone-Butterbredt ACEC plots that occur outside the Park (N = 723), then trash is significantly higher inside the Park (ANOVA, P<0.0005), as is shooting (P = 0.001), while cattle scat is significantly higher outside the Park (ANOVA, P<0.0005) (Table 1; see also Keith et al. 2008). We wish to point out that while we used square-root transformations for these data sets, the resulting data were still not normally distributed. Nevertheless, the low P-values indicate that we can place some confidence in the results.

Table 1. A comparison of the mean numbers (and standard errors) of human disturbances found between 2002 and 2004 on landscape plots inside Red Rock Canyon State Park with plots outside the Park (1) in the Red Rock Canyon watershed and (2) in the Jawbone-Butterbredt ACEC, California. The means and standard errors have been back-transformed.

Types of human disturbance	Plots inside the park (n=28)	Plots outside the Park in the Red Rock Canyon watershed (n=9)	P-value (ANOVA)	Plots outside the Park in the Jawbone-Butterbredt ACEC (n=723)	P-value (ANOVA)
OHV tracks	0.366 ± 0.223	1.98 ± 0.948	0.04	0.557 ± 0.046	0.38
Trash	6.760 ± 2.127	1.525 ± 1.373	0.09	1.274 ± 0.129	≤0.0005
Balloons	0.188 ± 0.093	0.277 ± 0.232	0.69	0.091 ± 0.012	0.19
Signs of shooting	2.471 ± 0.883	0.025 ± 0.049	0.01	0.454 ± 0.072	0.001
Cattle scat	0.701 ± 0.352	0.172 ± 0.182	0.29	146.941 ± 4.066	<0.0005

Comparisons of Tortoise Data from the Demographic and Landscape Plots

Based on all observations of tortoises, shell-skeletal remains, and other sign, tortoises occur throughout the western part of the Park and Red Rock Canyon watershed (Figs. 2, 3, 4, 5). Densities of tortoises in the western part of the Park and watershed are probably ≤ 18 /km^2, the upper limit of one CI estimate. The counts of live tortoises/km^2 were similar regardless of the survey method: 2.2 for the demographic plot, 3.57 (95% CI = 0.09–18.35) for the landscape plots within in the Park, and 2.7 (95%CI = 0.07–14.16) for the Red Rock Canyon watershed. The estimates may be higher than the actual density for the western part of the Park, because the sampling design eliminated plots near the highway and heavily disturbed areas.

The presence of sign was similar between the demographic and landscape plots. For example, of the eight landscape plots that were partly or entirely in the demographic plot, two of them (25%) had tortoise sign (Fig. 4). Almost the same percentage of plots outside of the demographic plot (24%) had tortoise sign. Counts of cover sites and scat varied between the demographic and landscape plots (Table 2); when scat locations and cover site data are combined, landscape plots had almost twice as many scat locations and cover site counts/km^2 as the demographic plot (54 vs. 27.6).

Table 2. Comparisons of desert tortoise data gathered between 2002 and 2004 from the demographic plot in the Park, landscape plots in Red Rock Canyon State Park and watershed, landscape plots inside the Park only, and landscape plots outside the Park only.

Live tortoises and tortoise sign	Demographic plot (1)	All landscape plots (37)	Landscape plots inside Park only (28)	Landscape plots outside Park only (9)
Total area (km^2)	4.096	0.37	0.28	0.09
Live tortoises (n)	9	1	1	0
Live tortoises /km^2	2.2	2.7	3.57	0
(95% CI)		(0.0684–14.1603)	(0.0904–18.3478)	
Cover sites (n)	74	10	4	6
Cover sites /km^2)	18.1	27.0 ±17.1 SE	14.3 ± 6.7	66.7 ± 33.3
Scat locations (n)	39	10	10	0
Scat locations/km^2	9.5	27.0 ±10.0 SE	35.7 ± 22.5	0

DISCUSSION

Sampling Strategies in Low Density Populations

We found live tortoises, shell-skeletal remains, and other sign using both demographic plots and landscape-level sampling techniques. Both techniques provided valuable but different information. The demographic plot yielded substantially more details on population structure and sex ratios, health status, death rates and causes of death, whereas the landscape-level plots revealed that tortoise sign was widespread throughout the Park. The data gathered while walking to and from plots was an important adjunct on distribution of tortoises within the Park, their use of habitats, and vulnerability to mortality. When tortoise densities are anticipated to be low (<18/km^2), we recommend use of both techniques and that all data on sign be recorded; robust correlations exist between presence of tortoises and sign (Krzysik 2002).

Survey techniques can be improved to provide more valuable information to managers. Demographic plots should have two complete, independent surveys in spring, thereby providing opportunities to calculate density using mark-recapture techniques or occupancy estimation (e.g., MacKenzie et al. 2006). Replication of plots in different habitat types with various levels of anthropogenic impacts also would be useful. For landscape-level plots, the number could be increased, and where appropriate, the sampling could be adapted for clustered populations (Thompson 2004). More intensive or extensive sampling is unlikely to alter the finding of low densities in the western part of the Park, however. Additional and more frequent sampling will provide a more substantial and robust baseline for future tracking of status and trends in the tortoise populations and will offer Park managers opportunities to focus on reducing specific anthropogenic sources of mortality.

The Park as a Small Preserve

Red Rock Canyon State Park is small, particularly the part west of State Highway 14 where we surveyed. Here it is ~11.2 km in length and varies from 1.5 to 2.5 km in width (total area is ~20.5 km^2). Both the shape and historical land uses provide an important background for understanding the low and declining tortoise population in 2004. The lands within and adjacent to Park boundaries have experienced numerous and often concurrent human uses since the 1860s, similar to those described for many parts of the California deserts (Lovich and Bainbridge 1999). The parallel linear disturbances from the highway, transmission lines and nearby aqueducts, when coupled with the numerous roads to campgrounds and scenic views, have fragmented tortoise habitat into small pieces. Additional pressures in the form of intensive OHV recreation exist on both the northern and southern boundaries with the Dove Springs and Jawbone Canyon Open Areas, where recreation vehicle use is unrestricted (BLM 1980). These two OHV areas probably have served and continue to serve as sinks for tortoises. Some spillover of OHV use, including unauthorized travel off of designated routes, occurs in the Park and on the boundaries (Keith et al. 2008).

The Status of Tortoises in the Western Part of the Park

Tortoises were documented in high density populations in adjacent Indian Wells and Fremont valleys from the 1950s[6] to the1980s (Berry and Medica 1995, Brown et al. 1999). Their presence at the Park has been noted since 1979, shortly after the Park was established. Our findings indicate that tortoises are present or have been present within the last ~ 20 years throughout the western part of the Park and watershed. As of spring 2004, we estimate that current densities are low: 3.57 tortoises/km^2 in suitable habitat

[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 Park and on the demographic plot (upper limit of 95% CI is ≤18/km^2). The low densities are not surprising given the long history of intensive human use. However, data from the shell-skeletal remains of subadult and adult tortoises on the demographic plot suggest that numbers of subadults and adults were almost three times higher in 2000, and that the deaths in this size-age class exceed recruitment. Significant declines in tortoise populations have been recorded in nearby areas at the DTRNA and in Fremont Valley (FWS 1994, Berry and Medica 1995, Brown et al. 1999). The existing density is close to or has declined below the minimum density of adults recommended by the Fish and Wildlife Service in the *Desert Tortoise (Mojave Population) Recovery Plan* for a genetically viable population: ≥3.86 adult tortoises/km^2 (FWS 1994).

Three major factors contribute to the status of the existing population in the western part of the Park and may be operating synergistically: disease, anthropogenic impacts, and deteriorated habitat. We believe that one or more tortoises is likely to have URTD caused by one or more species of *Mycoplasma*, because of the combination of clinical signs and close proximity to populations documented as having mycoplasmosis (Jacobson et al. 1991; Berry and Christopher 2001; Brown et al. 1994, 1995,1999, 2004). Two tortoises also have clinical signs of a shell disease, cutaneous dyskeratosis (Jacobson et al. 1994, Homer et al. 1998). Although clinical signs of cutaneous dyskeratosis are currently mild in these tortoises, the disease may progress to more severe forms seen in tortoises from other parts of the desert where population declines have occurred (Jacobson et al. 1994, Homer et al. 1998, Christopher et al. 2003). The release of captive tortoises (e.g., the tortoise with a repaired shell that was observed between 1990 and 1992) may contribute to the spread of infectious diseases (Jacobson et al. 1995). Parks and Natural Areas are often viewed as appropriate places for release of captive tortoises by the public and by some government personnel.

Anthropogenic impacts contribute to the threatened status of the tortoise (FWS 1994) on both a range-wide and local basis. Human use was and is widespread in the Park, based on the distribution and amounts of trash and in spite of the clean up efforts described by Faull (Park Ranger and Ecologist, personal communication). Trash is a potential threat to tortoises, a group of animals that is curious and tends to eat inappropriate materials (e.g., Burge 1989, Boyer and Boyer 2006). Consumption of foreign objects contributes to gastrointestinal compaction (Donoghue 2006) and many turtle deaths in the wild and in captivity (Wyneken et al. 2006). In a recent research project on the status of the desert tortoise in the El Mirage Off-highway Vehicle Recreation Area, tortoise sign counts were significantly lower on plots with high counts of trash.[7]

The presence of State Highway 14 within the Park poses a threat to tortoises, e.g., Tortoise 14 is near both the highway and a road to popular recreation site. Road kills are a source of losses (von Seckendorff Hoff and Marlow 2002, Boarman and Sazaki

[7]Keith, K, and K.H. Berry. 2005. Surveys for desert tortoises in the El Mirage Off-Highway Vehicle Recreation Area, San Bernardino County, California. U.S. Geological Survey, Moreno Valley, California. Final Report.

2006). Roads also provide access to vandals and collectors. Remains of tortoises with gunshot wounds indicate that shooting is a contributor to mortality. Gunshot deaths are more frequent in areas with high densities of recreationists than in remote areas (Berry 1986). Although we did not witness illegal collecting of tortoises, collecting is likely to have occurred in the past and is still a threat to tortoises.

Common ravens, *Corvus corax*, predators on juvenile tortoises, increased 10-fold in the Mojave Desert in the 24-year period between 1968 and 1992 and may still be increasing in numbers (Boarman and Berry 1995). Ravens are attracted to highways, roadside rests, campgrounds, trash, and visitors—all of which are present in the Park (Boarman and Coe 2002, Kristan et al. 2004). They have the potential to reduce juvenile recruitment and contribute to population declines and local extinctions (Kristan and Boarman 2003).

Off-highway vehicle use contributes to deterioration of tortoise habitat, loss of shrub cover and forage, and crushing of tortoises and their burrows. Tortoise numbers are lower in areas disturbed by OHV users than in undisturbed areas (Bury and Luckenbach 2002), and tortoise sign was significantly lower in the parts of recreation area in the western Mojave Desert (the El Mirage OHV Recreation Area) where OHV use was high.[7] Prior to the 1989 transfer to the State, OHV recreationists heavily used the demographic plot and continue to drive on roads, washes, and trails in parts of the Park.

Decades of the numerous types of human activities described above have degraded tortoise habitat. While we did not sample perennial and annual vegetation, we noted that surface disturbances have contributed to a high biomass of alien annual plants such as the forb *Erodium cicutarium,* the annual grasses *Schismus* sp. and *Bromus* sp., and forbs and herbaceous perennials in the family Brassicaceae (Bossard et al. 2000). In the western Mojave Desert, aliens (*Erodium cicutarium*, *Schismus* sp., and *Bromus* sp.) compose about 65% of the biomass of annual forbs and grasses (Brooks and Berry 2006). In addition, aliens are not among the favored forage plants of desert tortoises in the western Mojave (Jennings 2002, Oftedal et al. 2002). With establishment of the Park, livestock grazing has been excluded; fewer livestock scat were found on Park landscape plots than in the adjacent Jawbone-Butterbredt ACEC (Keith et al. 2008). If other surface disturbances are limited or removed, we can anticipate the same types of gradual recovery observed at the DTRNA for shrubs (Brooks 1995, 1999), and possibly a reduction in the biomass of the alien annual plants.

POTENTIAL CONSERVATION MEASURES TO ENHANCE TORTOISE POPULATIONS AND HABITAT

Conservation and management actions that have potential for reducing mortality include preparation of a management plan for conservation of tortoises; removal of all old and recent trash throughout the Park; construction of tortoise-proof fencing along Highway 14; construction of tortoise-proof fences along selected secondary roads and washes; and implementation of temporary or seasonal closures (February 15-November 1) of secondary roads and washes. Construction of fences along secondary roads and washes are likely to fragment habitat however (Fig. 1), and in the latter case, restrict tortoises from some potentially critical foraging areas in washes (Jennings, 1997). Such exclusions may be preferable to the high risk of injury and death to the tortoises. Informational kiosks, signs, and brochures that describe the prohibitions on handling, harassment, collecting of tortoises, and release of captives would be valuable. The release of captives may be circumvented by offering alternatives for visitors to transfer ownership of unwanted captive tortoises to California Department of Fish and Game-approved adoption services.

Our research on status and trends in the Park was limited to the western part. The lands east of State Highway 14 in the El Paso Mountains, the vast majority of the Park, have not been surveyed since the late 1970s[1]. They may support pockets of higher density tortoise populations than observed in the western part of the Park, especially at distances >2 km from the State Highway. We recommend that surveys be conducted here, because Park files indicate presence of tortoises.

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