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MOJAVE DESERT TORTOISE POPULATION MONITORING WITHIN THE RED CLIFFS NATIONAL CONSERVATION AREA, 2023

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by

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INTRODUCTION

The Mojave desert tortoise (*Gopherus agassizii*) is a burrowing reptile in the family Testudinidae that occurs in the Mojave and western Sonoran or Colorado deserts of California, Nevada, Arizona, and southwestern Utah (Berry et al. 2021, USFWS 1990, 1994). The tortoise was listed as threatened under the Endangered Species Act in 1990 (USFWS 1990). Declines in desert tortoise populations are primarily attributed to habitat degradation and loss, disease, predation, and stochastic events including drought and wildfires (USFWS 1994, 2011). A recent range-wide population assessment of the desert tortoise has demonstrated continued adult population and density declines in four of the five USFWS designated recovery units (Alison and McLuckie 2018; Kissel et al. 2023; Zylstra et al. 2023). There are two recovery units in Washington County, Utah: the Upper Virgin River Recovery Unit (UVRRU) which occurs mostly east of the Beaver Dam Mountains, and the Northeastern Mojave Recovery Unit (NEMRU) located on the west side of the Beaver Dam Mountains. Portions of the UVRRU and NEMRU are found within the Red Cliffs and Beaver Dam Wash National Conservation Areas, respectively. Due to its proximity to urban growth and small size, the UVRRU is considered highly threatened and the most at-risk (USFWS 1994).

The habitat conservation planning process was initiated in Washington County, Utah, in 1991, to resolve conflicts between urban development and desert tortoise conservation. Washington County completed a Habitat Conservation Plan (HCP) in 1996 and the Restated and Amended HCP in 2020 (WCC 1995, WCC 2020). The HCP identified measures to minimize and mitigate incidental take by establishing the Red Cliffs Desert Reserve (Reserve; USFWS 1996; WCC 1995). In 1995, the Reserve included approximately 38,000 acres of Mojave desert tortoise habitat for the long-term protection of tortoise populations. Federal land within the Reserve was designated as a National Conservation Area (NCA) under the Omnibus Public Land Management Act of 2009 (Pub.L. 111-11, H.R. 146). The Red Cliffs NCA is comprised of approximately 45,000 acres of BLM-administered lands in southcentral Washington County (BLM 2016). In 2020, Management Zone 6, in southwest of St. George, was included in the Reserve and added an additional 6,813 acres for tortoise conservation (WCC 2020).

Long term population monitoring is a critical component of the USFWS Mojave Desert Tortoise Recovery Plan and is an integral part of the delisting criteria. For example, rate of population change should be increasing for at least one tortoise generation (e.g., 25 years) in all recovery units to warrant delisting (USFWS 1994, 2011). The primary goal of this project is to determine the current tortoise density, and long-term demographic and population trends for desert tortoises within the Red Cliffs NCA, the primary conservation area in the UVRRU. Obtaining population estimates in calendar year 2023, exactly 25 years since full scale implementation of the monitoring program, will allow for trend evaluation of one tortoise generation, an important recovery criterion. A secondary goal of the project is to evaluate the effectiveness of the recovery program and implement appropriate adaptive management strategies to recover desert tortoises in the UVRRU.

In 1996, the Management Oversight Group, an interagency desert tortoise management group, recommended distance sampling to assess regional densities across the entire range of the desert tortoise. In response, the Utah Division of Wildlife Resources (UDWR) implemented distance sampling methodology within conservation areas in southwest Utah to monitor desert tortoise densities at large spatial scales. A pilot study was conducted in 1997 to standardize field techniques, provide preliminary estimates of encounter rates, and determine the field effort necessary to achieve regional density estimates (McLuckie et al. 1998). Total line length and sample size required to achieve a 15% precision level, as well as allocation of effort, were determined using methods described in Buckland et al. (2001). In 1998, full scale monitoring was implemented with surveys continued annually for the first four years (1998-2001) and in alternate years thereafter (2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, and 2019) generating 13 seasons of population monitoring data over 22 years. Under the 1995 HCP, the County provided substantial funding to support baseline monitoring that demonstrated the efficacy of the conservation program and provided an understanding of population trends within the UVRRU (Allison and McLuckie 2018; McLuckie et al. 2020). In 2023, the Bureau of Land Management funded population monitoring, focusing on resurveying permanent transects within the Red Cliffs NCA.

Specific objectives of this project include the following: (1) complete effectiveness monitoring by sampling long term desert tortoise monitoring plots in Management Zones 2, 3, 4, and 5; (2) hire, supervise, train, and coordinate field crew; (3) track radiotelemetered tortoises to quantify above ground activity during surveys; (4) evaluate and assess size class distribution, sex ratios, recapture analysis on marked animals, and health; (5) collect presence data on other species observed on transects and in the field; (6) analyze monitoring data (1998 to 2023) and assess adult population density, abundance and long term trends; (7) evaluate population status and assess effectiveness of management actions (e.g., fencing, habitat rehabilitation, translocation, etc.); (8) provide an assessment of plant community status across the landscape (e.g., species present, % cover); and (8) analyze data and prepare annual and final reports for BLM and agency partners.

MATERIALS AND METHODS

Study Area – The NCA and Reserve are located in southwestern Utah, Washington County, within the Upper Virgin River Valley. The study area is directly north of St. George and extends west from Ivins and east to Hurricane. Populations in Utah represent the northeastern extent of the desert tortoise's geographic distribution.

Although the Reserve is divided into six management zones, Zones 1 through 6, we focused our monitoring effort within the Red Cliffs NCA, in Management Zones 2 through 5 (Fig. 1). Zone 1, approximately 3,449 acres (13.96 km^2), contains a narrow strip of tortoise habitat at the base of the Red Mountains that could provide an area for movement and genetic exchange between neighboring tortoise populations within the Reserve and Shivwits Indian Reservation to the west. Monitoring is not conducted Zone 1 due to high elevation areas in the north, where tortoises are not expected to occur, and a low-density housing development in the south which prevents sampling (WCC 1995). Zone 2, approximately 10,274 acres (41.58 km^2), extends north of the City of Ivins and east to State Highway 18, including Snow Canyon State Park and Paradise Canyon, areas with medium to high relative tortoise densities. Zone 3, approximately 38,659 acres (156.45 km^2), comprises the area between State Highway 18 and Interstate 15 in St. George, Utah. It contains the largest contiguous block of tortoise habitat, and historically included some of the highest tortoise densities in the Reserve (Bury et al. 1994, Fridell et al. 1995a, Fridell et al. 1995b). Zone 4, approximately 5,318 acres (21.52 km^2) is a translocation site for displaced incidental take tortoises associated with the HCP. Zone 5, approximately 684 acres (2.77 km^2), contains areas with moderate to high relative tortoise densities and is adjacent to the City of Hurricane. Zone 6, approximately 6,813 acres (27.57 km^2), is located in southwest St. George. In this Zone, tortoise densities were monitored mainly using drones, through a separate effort under the Washington County HCP (Bandy 2022).

Desert tortoises occupy a mosaic of Navajo sandstone outcrops, rugged rocky canyons, creosote-bursage flats, and basalt-capped ridges interspersed with sandy valleys within the NCA (Bury et al. 1994). A combination of habitat types is utilized for winter and summer dens, egg laying, and foraging (Esque 1994). Overwintering tortoises are found in caves, deep fissures, rocky overhangs, and deep sandy burrows (Bury et al. 1994).

Vegetation within the NCA is diverse and includes representative species from the Mojave and Great Basin desert scrub biomes (Turner 1982a, Turner 1982b). Major vegetation types consist of a transitional mix of creosote bush, blackbrush and sagebrush scrub along with desert psammophyte (USFWS 1994). Predominant vegetation within these groups includes creosote bush (*Larrea tridentata*), blackbrush (*Coleogyne ramosissima*), snakeweed (*Gutierrezia sarothrae*), ephedra (*Ephedra nevadensis*), sand sage (*Artemisia filifolia*), and white bursage (*Ambrosia dumosa*).

Low precipitation, humidity, and a wide annual temperature range characterize the NCA and surrounding areas. Average annual precipitation, from 1965 to 2019, was 213.73 mm ± 10.24 (range = 80.77 - 454.41), with the majority of precipitation typically occurring from November to March (WRCC, 2019). Winter storms are typically widespread, with low intensity storms bringing moisture from the North Pacific. Summer thunderstorms, which bring moist tropical air northward from the Gulf of California, are usually intense, local, and of fairly short duration (Pope and Brough 1996).

Field Methods – The sampling methodology was consistent with the desert tortoise long-term monitoring programs implemented range wide across the Mojave desert (Allison and McLuckie 2018) and described by Anderson and Burnham (1996). The monitoring program consisted of two independent teams of observers, one surveying permanent transects and the other estimating above ground activity using telemetered tortoises. Population monitoring efforts were concentrated on federal lands within Management Zones 2, 3, 4, and 5 in the Red Cliffs NCA; additional surveys were conducted in surrounding areas on State Trust Institutional Lands Administration (STILA) and Utah Department of Natural Resources (UDNR) lands (Fig. 1).

Long term permanent random transects, established in 1998, were resurveyed within the NCA to assess population trends. Each transect is 2 km in length, and either shaped in a square, with 500 m sides, or linear. Due to the small and irregular size of Zone 5 linear transects were placed laterally, perpendicular to high concentrations of tortoises. Transects are within tortoise habitat, defined as areas below 1,200 m (4000 ft). Portions of transects with greater than 45° slopes were excluded during sampling due to safety concerns. Transect start points and corners were permanently marked, beginning in 1998, with 16" rebar, and painted red with enamel exterior spray paint to facilitate relocation. Each transect start point or corner was permanently labeled using double-faced aluminum tags identifying the transect number and directional orientation of each corner (i.e., NE, SE, NW, SW).

Transects were surveyed by a two person crew using a three-pass survey technique to search on and near the transect centerline. Using a compass to check directional alignment, a 50 m surveyor tape was pulled along the transect line by the first observer. Then, both observers walked in a sinusoidal pattern on opposite sides of the transect line, crossing over the surveyor tape, to ensure that all tortoises were detected. Finally, the first observer walked directly back along the transect line to ensure that all tortoises on the line were detected. Search efforts extended 12 m from the transect line, with particular focus near the center, 3 to 5 m from the line. This procedure was repeated in 50 m increments, with the roles of the surveyors reversing each time, until the entire 2 km transect was completed.

The tortoise location relative to the three pass search pattern was noted to quantify any tortoises missed on the transect line and evaluate crew performance. Snake sticks and signal mirrors were used to search under bushes and within deep shelters, particularly along the transect line. The surveyed length of each transect was calculated as the straight-line distance between GPS coordinates at start and end points, excluding areas that could not be surveyed.

When tortoises were detected, we measured the perpendicular distance from the line using a 30 m open reel fiberglass tape. In addition, we also recorded distance along the transect line, UTM coordinates, dominant vegetation, environmental variables (ambient/surface temperatures, percent humidity, cloud cover, wind speed), and time detected. Standard tortoise carapace measurements were taken using a caliper and ruler including carapace length (CL), width at the third and fourth marginal seam (post M3), and width at the seventh and eighth marginal seam (M7/M8). Additional data collected included sex (determined for tortoises with a CL ≥ 180 mm), time found, behavior, health observations (Berry and Christopher 2001), parasites observed (e.g., ticks, mites), injuries, shell wear (Berry and Woodman 1984) and shell anomalies. When a tortoise could not be removed from a burrow, it was visually estimated as either reproductive (CL ≥180 mm) or nonreproductive (CL < 180 mm). Nonreproductive tortoises were further identified as juveniles (CL < 100 mm) or immatures (CL=100 m to 179 mm). For future identification, each tortoise (CL > 100 mm) was given a unique number by notching marginal scutes with a triangular file. The carapace of each tortoise was photographed for future reference. We used latex gloves while handling each tortoise and disinfected equipment with a diluted bleach solution (1:10 dilution of 5.25% bleach) after use (Brown et al. 2003). Once processing was complete, tortoises were released at the point of detection.

For each shell remain found, CL, sex, UTM coordinates, signs of predator or scavenger, percent scutes and bones present, position of shell, estimated time since death, and perpendicular distance from the transect line was recorded. The CL of deteriorated or fragmented shell remains was estimated using regressions based on scute size (Berry and Woodman 1984). Time since death was estimated using deterioration rates of tortoise shell and skeletal remains (Berry and Woodman 1984). All processed shell remains were photographed.

We estimated the proportion of tortoises visible (g_o) during the monitoring period by simultaneously tracking a subset of radioed adult tortoises. Tortoises seen on the surface or in burrows with only the aid of mirrors were identified as "visible" while tortoises deep in burrows or hidden in dense vegetation were considered undetectable and therefore "not visible" (Anderson and Burnham 1996). In addition to assessing visibility, UTM locations were collected, along with activity, habitat, and a temperature profile at the start and end of each day. Telemetered tortoises were monitored two times daily, two to three times per week at the telemetry site in Management Zone 3, located in the central portion of the NCA.

Adult tortoises (CL ≥ 180 mm) were fitted with radio transmitters (Holohil RI-2B) affixed to the anterior of the carapace using quick-drying gel epoxy. Transmitters were attached below the highest point of the carapace to reduce interference in shelters. Antennas were attached to marginal scutes and masking tape was placed directly onto scute seams, to prevent epoxy from soaking into seams. Radioed tortoises were located using a Telonics receiver (Model TR-2E) and directional antenna.

During the first week, field crews were intensively trained on distance sampling theory, field protocols and search patterns. We placed polystyrene desert tortoise models of two sizes (adults and juveniles) on a training course in Management Zone 5 to teach crews on the search technique, improve the detection function, maintain detection shoulders, measure the perpendicular distance of each model to the transect line accurately, and use of orientation equipment (e.g., compass, GPS). Data was checked daily for quality and analyzed weekly to assess the detection histogram and improve search efforts. Field crews were regularly rotated between distance sampling and radio telemetry to allow training in the overall survey method and to improve technicians' tortoise search image.

To assess overall habitat condition, we surveyed vegetation cover at one transect corner (e.g., NE, NW, SE, SW) for each selected transect. Within a flagged 6 m radius circle at the designated transect corner, we assigned a cover class category for each perennial and annual species based on its % cover as follows: 1=trace, 2=0-1%, 3=1-2%, 4=2-5%, 5=5-10%, 6=10-25%, 7=25-50%, 8=50-75%, 9=75-95%, and 10=>95%. For simplicity, we combined cover class for *Bromus tectorum* and *Bromus madritensis*, previously known as *Bromus rubens*, but only after confirming that both species were present. We summarized overall vegetation composition and percent ground cover for both unburned and fire disturbed habitat. Plant nomenclature was consistent with U.S. Department of Agriculture, National Resources Conservation Service (https://plants.usda.gov).

Statistical Analyses – Processed tortoises were categorized into three class sizes based on carapace length (CL): juvenile (CL < 100 mm), immature (CL= 100-179), and reproductive adult (CL ≥ 180 mm). Descriptive statistics (i.e., means, standard errors and range) are presented for each size class observed (Excel 2016). Data from tortoises recaptured a second time within the monitoring year (n=4; i.e., 2023) were not included in the descriptive statistics. Means are presented ± one standard error (SE). Annualized mortality rate $[(n/(N+n))*100]$ was calculated where n is the number of adult shell remains found on the transect line and recently dead (i.e., time since death estimated to be less than one year) and N is the estimated abundance of live adults observed on the transect line (Berry 2016).

Density estimates included all reproductive adult tortoises (CL ≥ 180 mm). Anderson et al. (2001) recommend excluding juveniles and immatures from analyses because they are often undetected along the transect line. To avoid violating the main assumption of distance sampling, that all animals are detected on the transect line, we have confined estimates to include only adult tortoises.

Estimates that included immatures and juveniles would underestimate the true population density particularly if survey methods did not incorporate specific search protocols for small tortoises (e.g., g_o for nonreproductive animals, etc.; Thompson et al. 1998, Buckland et al. 2001).

We used Program DISTANCE 7.5 Release 2 (Thomas et al. 2010) to estimate adult density and abundance within Management Zone 3 and across the NCA (Zones 2, 3, 4 & 5). Management Zone 3 contains the largest contiguous block of tortoise habitat within the NCA and as such, is intensively sampled. A second analysis, included Zones 2 and 5 to allow comparisons to previous monitoring years (1999 to 2019). Finally, we estimated density across the Reserve including Zone 4, a designated translocation site. In addition, we report 2023 density and abundance for Management Zone 2, within Snow Canyon State Park and the Red Cliffs NCA. Data collected from previous monitoring years (1998-2023) were included in the analysis to assess population trends. Three components that account for the variance in the estimates include:

1) $\hat{P}_a$, the probability of detecting a tortoise within transect width w,

2) $\hat{g}_o$, the proportion of tortoises "visible" or detected during the survey period, and

3) n/l, the spatial variance or encounter rate, tortoises observed per km searched.

Due to small sample sizes, these variance components were pooled across years (e.g., 1998-2023) thereby increasing the coefficient of variation and, in turn, precision of estimates.

Density was estimated using the following formula: $\hat{D} = n/(2wL \cdot \hat{P}a \cdot \hat{g}_0)$ where n is the number of tortoises observed, w is the width of truncated observations, and L is the total line length. The variable $\hat{D}$ is an estimate of the average density across the survey area and includes those tortoises "visible" and "not visible" during the survey period. Population abundance (N) is estimated by $\hat{N} = A \cdot \hat{D}$ where A is the total area sampled. To account for tortoises not visible or detected during sampling, including those deep in burrows or hidden in dense vegetation, we used the correction factor, $\hat{g}_0$. A weighted mean for $\hat{g}_0$ was computed from weekly averages by using the following formula: $\hat{g}_0 = \sum(\hat{g}_J) \div \sum N_J$, where $\hat{g}_J$ equals the number of locations where the tortoise was above ground and visible while N_J equals the total number of tortoise observations.

Four standard detection models were examined (uniform + cosine, uniform + simple polynomial, half-normal + cosine, half-normal + hermite polynomial) to analyze the data. The minimum Akaike Information Criterion (AIC) value was used to select the detection model that best fit the perpendicular distance data (Buckland et al. 2001). Outliers were truncated as they provide little information for estimating the detection function at $x=0$, are difficult to model, and may increase the sampling variance of the density estimate (Buckland et al. 2001). To determine potential truncation points, w, we fit a preliminary model to the data and computed w based on $g(w) \simeq 0.15$ (Buckland et al. 2001).

The sampling area for Zone 3 was reconfigured to remove upper Cottonwood, a 6.23 km^2 rugged terrain dominated by scrub oak (*Quercus gambelii*), cliff rose (*Purshia stansburiana*), and Apache plume (*Fallugia pardoxa*) from long term sampling; this resulted in the removal of up to six permanent transects that contained no tortoise sign (i.e., scat, burrows, remains, live animals) since monitoring was implemented in 1998. Total area sampled within each zone, determined using ESRI ArcMap (v. 10.8.1), is as follows: Zone 2=18.68 sq km^2, Zone 3=95.86 sq km^2, Zone

4=18.11 sq km^2, and Zone 5=2.40 sq km^2. Using a Gaussian distribution to assign concentric contours, a heat map was generated from a point Kernal density calculation (ESRI ArcMap (v. 10.8.1). Natural break points were designated for seven relative density classes.

Encounter rates, density and abundance estimates, and their associated 95% confidence intervals were calculated using program DISTANCE (Thomas et al. 2010). The precision of density and abundance estimates were computed by program DISTANCE as coefficients of variation (Thomas et al. 2010). Two Goodness of Fit tests were performed to measure the fit of the selected model to the data, including Chi-square and Kolmogorov-Smirnov tests (D_n). The linear trend of adult tortoise densities (1998 to 2023) was calculated from the $\log_e$-transformed density estimates (Excel v. 6.0). We assessed population trends by comparing current estimates with UDWR's long term monitoring data collected from 1998 to 2019. We calculated the piecewise linear regression model for densities across the NCA and Reserve (Management Zones 2, 3, 4, and 5) using the Segmented package in Program R (Muggeo 2008, R Core Team 2023). We constrained the segments to be continuous and tested the assumption of one break-point (pscore.test; Muggeo 2017).

RESULTS

Field Effort –Eight field technicians surveyed long term monitoring plots within the NCA and surrounding areas. Intensive training, conducted from April 3 to 7, 2023, focused on search methodology at mock transects in Hurricane and radio tracking tortoises to assess surface activity and hone tortoise searching skills. From April 10 to June 13, 2023, we completed 161 transects and surveyed 314.64 km within Management Zones 2, 3, 4, and 5 of the Reserve (Table 1, Fig. 2). Transect lengths ranged from 1.42 to 2.00 km. Depending on the number of survey teams and the topography, we completed an average of 3.6 transects and surveyed 6.99 km per day. Approximately 2,687 field hours were spent monitoring desert tortoises over 50 workdays including training.

Size Class Distribution and Recaptures – We encountered 178 tortoises (i.e., 69 males, 70 females, 39 unknown) during population monitoring either on or adjacent to transects or at the telemetry site in Management Zones 2, 3, 4, and 5 (Table 2, Fig. 3). Of those, sex was undetermined for twelve adult tortoises because they were in deep burrows and could not be removed. In addition, we observed 27 juvenile and immature tortoises, including one hatchling. All tortoises encountered including the date found, zone, file number, status, sex, carapace length, shell wear, presence of Upper Respiratory Tract Disease (URTD) clinical signs, presence of shell disease, presence of burn injuries, and perpendicular distances are summarized in Appendix 1. Carapace length of tortoises ranged from 51 to 312 mm. Processed tortoises included 11 juveniles (mean CL = 73 ± 5.37 mm; range 51-97), 16 immatures (mean CL = 142 ± 6.14 mm; range 100-176), and 135 adults (mean CL = 248 ± 2.48 mm; range 188-312). Non-reproductive tortoises composed 15% of the total tortoises observed in 2023 (Fig. 4).

We observed 163 tortoises on transects including 139 adults. Tortoises were observed up to 51 m from the transect line, with the majority of tortoises observed within 8 m of the line (54%; Fig. 5). A visual analysis of the cumulative perpendicular distances show that the data follows the recommended shape criterion with detection highest near the line, a shoulder of detection and a gradual decrease in observations with distance to the transect line.

Fifty processed tortoises (30%) were previously marked including four recaptures within the same monitoring year (i.e., 2023, Table 3). Only one recaptured tortoise was an immature (CL=176 mm); all others were adults. The average time since original capture was 14 ± 1.6 years (range 0.1 – 50.8 yrs). Four tortoises were found with drill holes in the center of select marginals, an old permanent marking system that was implemented prior to 1985 in the Paradise Canyon and Red Cliffs Recreation Area (Pers. comm, Eric Coombs). Four tortoises were translocated into Management Zone 4, between 6.06 and 19.65 years prior to their capture. Recaptured tortoises were relatively close to their previous capture location with an average distance of 228 ± 42 m (range 3-1,538 m). The majority of recaptured tortoises (56%; 28 of 50 tortoises) were found on the same transect as a previous capture. The mean annual growth rate for recaptured female tortoises was 1.92 ± 0.57 mm/year (n=20; range=0.04-9.06) while the mean annual growth rate for males was 2.47 ± 0.70 mm/year (n=28; range=0-17.56)

Health Observations and Mortality – In general, the majority of tortoises appeared healthy with green around their mouths, indicating recent foraging (Fig. 6 and 7). Clinical signs similar to those reported for Upper Respiratory Tract Disease (URTD) were observed in 9% (n=15) of the processed adult tortoises (i.e., 6 males, 9 females). Tortoises with URTD clinical signs were found in relatively high density areas including City Creek (2), Cottonwood Wash, Industrial Wash, Middleton Wash (2), Mill Creek, Padre Canyon (2), Paradise Canyon, Pioneer Park (2), Red Cliffs (2) and Red Hills Parkway (Fig. 8). Health could not be assessed for tortoises that were deep in soil burrows or tucked deeply in their shells (n=17). Tortoises that were identified with URTD clinical signs had one or more of the following: swollen or sunken eyes with discharge, nares that were moist (i.e., damp or wet) with exudate present (i.e., clear, cloudy or thick, with bubbles), mild to severe discharge, or one or both nares completely impacted, in addition to labored breathing (i.e., wheezing; Fig. 9). One tortoise in the Red Cliffs Recreation Area had clear mucus on its front limbs, likely from using the foreleg to wipe its nares. Two processed tortoises were observed with *Bromus tectorum* and *B. rubens* seeds in either the mouth, nare or eye causing swelling, discharge or an abscess in the cheek region.

We observed eight tortoises with shell disease covering a portion of their carapace scutes in Babylon, City Creek, Industrial Wash, Padre Canyon, Paradise Canyon, Red Cliffs Recreation Area, Snow Canyon State Park and the telemetry site (Fig. 10). We observed thirty-two tortoises with marginal (i.e., 10/10, 10/11, 11/10, 11/12, 12/11, 12/12, 13/12), costal (i.e., 4/5) or vertebral anomalies (Fig. 11). Six burned tortoises were observed with deformed and peeling scute laminae, sloughed scutes, scarring on forelimbs and bone exposed covering up to 20% of their carapace in Middleton, Mill Creek (2), Twist Hollow and the telemetry site (2; Fig. 7, 12 and 13). We attribute these burn injuries to the Plateau, Mill Creek, and Turkey Farm Road wildfires in the summer of 2005 and 2020.

A total of 12 shell remains were observed during population monitoring in several stages of decay (Table 4). The majority of shell remains were observed within Zone 3; one shell remain was found in Zone 4 and one in Zone 5. Sex was determined for five adult tortoise shell remains (2 M: 3 F). We estimated four of the remains to have died within the year and cause of death was unknown for the majority of remains observed. One adult male shell was wedged in a deep sandstone fissure at Twist Hollow; likely the tortoise fell in the crack, was unable to get out, and ultimately died

(Fig. 14). We observed one juvenile shell in a deep sandstone burrow adjacent to Red Hills Parkway with advanced shell fungus on the carapace. We observed a heavily scavenged adult male shell at the entrance of an active coyote den in the City Creek area; time since death was estimated at greater than four years. Finally, one fresh juvenile shell remain was observed at City Creek; cause of death was attributed to predation (e.g., coyote, fox) due to the fully severed shell with canine puncture mark on the right rear costal. Shells were located in Babylon, City Creek (2), East Valley, Hurricane Cinder Knolls, Middleton (2), Pioneer Park, Red Cliffs Recreation Area, Red Hills Parkway, Twist Hollow and the telemetry site. The annualized adult mortality across the NCA and surrounding areas was relatively low at 1.4% (Table 5).

Other Species Observed and Plant Transects Completed – We recorded fifty-eight observations of other reptile species during tortoise population monitoring (Appx. 2). Of the fifteen unique reptile species observed, six are included on the BLM State Directors sensitive species list for BLM-administered lands (IM 2011-037) and two are identified as imperiled or vulnerable (e.g., rare) in Utah (Table 6; UWAP 2015). In addition, we observed four mammals including kit fox, coyote, black-tailed jackrabbit and desert cottontail and observed active kit fox and coyote dens within the NCA.

From April 10 to May 30, we completed fifteen plant transects in both burned (n=5) and unburned (n=10) habitat (Fig. 2). We observed 56 species of plants on transects (Appx. 3). The most common native species found was snakeweed (*Gutierrezia sarothrae*), present on ten transects with an average cover class of 5 (range 3-7). Invasive weeds were present on all transects and included cheatgrass (*Bromus tectorum*), red brome (*Bromus madritensis*, previously known as *Bromus rubens*), London rocket (*Sisymbrium irio*), Common storksbill (*Erodium cicutarium*), Mediterranean grass (*Schismus barbatus*), and tumbleweed (*Salsola tragus*). Bromus sp. were ubiquitous and found at every plant transect, with the highest average cover class rating of all other species (x=7; range 5 to 8). Although detected in the NCA, Sahara mustard (*Brassica tournefortii*) was not found on any plant transects. When comparing burned and unburned plots, there were no differences detected in number of species present however unburned plots had twice the native shrub species present and a higher percent shrub cover than burned plots (Appx. 3).

Above Ground Activity – We assessed surface activity for thirteen telemetered adult tortoises during spring monitoring, April 10 to June 13, 2023. Over a ten week period, UDWR personnel spent 27 field days documenting 629 encounters, with telemetered tortoises tracked up to two times each field day. The majority of tortoise activity observations were identified as either stationary (271) or unknown (190) followed by basking (53), walking or moving (45), foraging (37), at rest but active (16), digging (8), at rest but inactive (4), fighting (3) or mating (2). Average carapace length of telemetered tortoises was 260 mm ± 8.61 (n=13; range = 217-327). The proportion of time a telemetered tortoise spent above ground during the monitoring period and the weekly number of tortoises observed on transects were generally consistent, with the peak of surface activity and tortoise encounters both occurring in early May (Fig. 15). The weekly mean g_o during 2023 tortoise monitoring was 0.71 ± 0.04 (n=10; range 0.46 to 0.94; Table 7; Fig. 16). When calculated across all years of the study (i.e., 1998 to 2023), g_o was 0.75 ± 0.01 (n=14; range 0.57 to 0.87).

At the telemetry site, temperatures were markedly cool in the beginning of the season and increased gradually by the end of the season. Air temperatures ranging from 10.0 to 35.5°C (50.0 to 95.9°F) and surface temperatures ranged from 10.3 to 41.4°C (50.5 to 106.5°C). Several low pressure storms brought significant precipitation to the area throughout the spring. Cloud cover varied from 0-95% while humidity ranged from 7.3 to 79.1%.

Detection Histogram, Probability Plots and Encounter Rates – To reduce the effects of extreme observations or 'outliers', data were truncated at 22 m for Zone 3 and 24 m for NCA wide analysis. We selected the uniform + cosine model (Zone 3) and half-normal + cosine (across the NCA) when data were analyzed (Fig. 17a and 17b). The detection histograms revealed field data that fit the selected model well for Zone 3 (X^2 = 14.84, P = 0.79, df = 20; K-S: D_n = 0.02, P = 0.76) and across the NCA (X^2 = 15.03, P = 0.92, df = 24; K-S: D_n = 0.02, P = 0.62); further, the data followed the shape criterion, including detectability certain near the line and the presence of a detection "shoulder" up to 5 meters from the line (Buckland et al. 2001). The effective strip width (ESW), the transect width where all animals are observed, was calculated at 12.51 m for Zone 3 (95% CI:11.71-13.37; CV: 3.39%) and 13.24 m for NCA wide analysis (95% CI: 12.72-13.78; CV: 2.04%). The proportion of tortoises detected within a defined width, *p*, was 0.57 (95% CI: 0.53-0.61; CV: 3.39%) in Zone 3 and 0.55 (95% CI: 0.53-0.57; CV: 2.04%) across the NCA. Summary of encounter rates (*n/L*) and surface activity (g_0) are reported in Table 7. For Management Zone 2, ESW was calculated at 14.68 m (95% CI:13.69-15.74; CV: 3.54%) and *p* was 0.73 (95% CI: 0.68-0.79; CV: 3.54%).

Density and Abundance Estimates – We report density and abundance for Management Zone 3 (Table 8; Fig. 18a) and across the NCA (Zones 2, 3, and 5; Table 9; Fig. 18b) for all years of the study (i.e., 1998 to 2023). We estimated density in Management Zones 2, 3, 4, and 5 at 20.6 adult tortoises per km^2 (95% CI: 16.4-26.0 tortoises per km^2; CV: 11.78%) and abundance at 2,784 adult tortoises (2,208-3,510 animals). Similar to previous years, in 2023 the largest variance component was the spatial variation in the encounter rate (96.0), followed by the detection probability (2.8), and above ground activity (1.2). The variance associated with secondary estimates (i.e., proportion of tortoises detected within a defined width, w, and surface activity) decreased by pooling multiple years of data, resulting in increased precision of density and abundance estimates. Using piecewise linear regression and one breakpoint at year 2009 (pscore.test value=2.95, p-value=0.01), we calculated a negative slope in tortoise densities (y = -0.08x + 3.70) from 1998 to 2009 and a slight positive slope from 2009 to 2023 (y=0.01x + 2.60; Fig. 18a) in Management Zone 3. We estimated density in Management Zone 2 at 34.22 adult tortoises per km^2 (95% CI: 21.57-54.30 tortoises per km^2; CV: 22.72%) and abundance at 639 adult tortoises (403-1,014 animals).

DISCUSSION

We observed extensive plant growth and high annual plant diversity throughout the spring, a result of above average winter precipitation. Temperatures were cool during the training week (April 4 to April 10) with above ground tortoise activity relatively low (10%). Weekly tortoise surface activity increased by mid-April as temperatures warmed. As in previous years, tortoise activity peaked in early May, steadily decreasing by the end of the season. The number of tortoises encountered followed a similar pattern with the majority of tortoises observed in early to mid-May, and encounters decreasing weekly through the remainder of the season. When compared to previous monitoring years (1998 to 2019), surface activity for radioed tortoises was below average likely due to cooler spring temperatures, particularly in early April (Fig. 15). Across the NCA, tortoise encounter rates (tortoises observed per km walked) during the 2023 spring monitoring season were within the range of previous monitoring years (1998-2019; Table 7).

During the first week of May, thunder storms brought significant precipitation and limited, local storms were present from mid to late May. Relative to previous monitoring years, spring ambient temperatures (e.g., May, April, June) were below average and, surprisingly, ambient temperatures did not exceed 36.9°C (98.4°F) the entire season. Frequent winter precipitation produced abundant growth of annual and perennial plants that was subsequently choked in some areas by aggressive growth of exotic mustards (e.g., Sahara mustard, London rocket), cheatgrass, red brome, Mediterranean grass, and Russian thistle.

In general, the majority of tortoises appeared healthy with appropriate muscle mass and weight. We observed numerous tortoises actively foraging with green around their mouths. In addition, we observed a high number of recaptures relative to previous years. Interestingly, we recaptured seven tortoises that were originally marked 26 to 51 years prior. Four of those tortoises were marked with a distinctive permanent marking system (e.g., drill holes in marginals) that was implemented prior to 1985 in the Paradise Canyon and Red Cliffs Recreation Area. Further, a majority of recaptured tortoises were found previously on the same transect, indicating high site fidelity and the importance of burrows on the landscape. We found one tortoise in a burrow just 3 meters from its previous location in 2017.

Since 2009, tortoise populations across the NCA appear to have stabilized and there is no evidence of recent declines in tortoise densities (see Fig. 18a). We estimate there are 2,425 adult tortoises across Management Zones 2, 3, and 5, and an additional 359 adult tortoises estimated in Management Zone 4, the translocation site for displaced tortoises. Our abundance estimate of 2,784 adult tortoises in Zones 2-5 is similar to abundance estimates from a 2023 drone survey which estimated 2,609 animals (Bandy 2023). The majority of tortoises were found in Management Zone 3, the largest contiguous bock of tortoise habitat within the NCA (i.e., 1,681 adult tortoises). These estimates are also similar to the 2023 drone surveys, although drone estimates were slightly lower (1,221 adult tortoises; Bandy 2023). Our 2023 abundance estimate of 2,245 across the NCA (Zones 2, 3, and 5) is the highest recorded since 2005, in part, influenced by the high densities in Zone 2, within Snow Canyon State Park and Paradise Canyon (34.22 adults per km^2). Further, translocating displaced tortoises helped establish a robust population within Management Zone 4 (McLuckie et al. 2019). The addition of Zone 6 in 2020 provides additional protection for 772 tortoises, estimated using drones, and protects an additional 6,813 acres of habitat in the Reserve that has not been impacted by fires in the recent past (Bandy 2022). Densities within the NCA are currently higher than many other Mojave desert tortoise populations range wide (2.2 to 7.2 tortoises per km^2; USFWS 2021). Recovery actions implemented as part of the Washington County Habitat Conservation Plan, including protection of existing habitat, restoration of degraded habitat (e.g., disturbed, burned), tortoise fencing on the perimeter of the NCA, community education programs, translocation of displaced animals, addition of Management Zone 6, and law enforcement presence, are important to maintain stable populations. In addition, the NCA designation in 2009 offers additional regulations and oversight to protect tortoises and their habitat (Pub.L. 111-11, H.R. 146).

We observed an increase in abundance of adult animals within Zone 3 and across the Reserve although the difference was not significant and may reflect variation in environmental conditions (Figures 18a and 18b). A high number of tortoise encounters were observed within Paradise Canyon, Snow Canyon State Park and west of Cottonwood Springs Road, primarily in unburned habitat, with as many as 5-8 tortoises observed per transect in each of these locations (Fig. 8). These areas contained high native shrub and annual plant diversity offering tortoises a variety of forage and shelter sites.

The Mojave desert tortoise has experienced population declines throughout its range, with adult tortoises decreasing in most recovery units (Kissel et al. 2023). Declines of desert tortoises have been attributed to multiple, simultaneous threats including but not limited to habitat degradation and loss, wildfires, disease, drought, recreation, illegal collection, and predation. Within the NCA, tortoise populations have experienced an annual decline of 3.2% lower than other tortoise populations across the range including Colorado Desert (4.5%), Eastern Mojave (11.2%), and Western Mojave (7.1%; Allison and McLuckie 2018). During the first several years of monitoring (1998 to 2001), tortoise densities were consistently high; however, following two stochastic events, drought (i.e., 2002) and wildfire (i.e., 2005, 2012, 2020), tortoise densities within Management Zone 3 decreased from an estimated 3,409 adult tortoises in 2001 to 1,681 adults by 2023.

In 2002, the most severe drought on record was recorded with annual precipitation (81.99 mm) significantly less than the 52 year average (209.22 mm; WRCC 2019). No perennial or annual plant growth was observed in the spring and fall of 2002 with some desert perennial communities, such as blackbrush, noticeably stressed. Tortoises have evolved in arid environments for millions of years and have numerous adaptations for living in areas where drought is a relatively common periodic event (Nagy and Medica 1986, Peterson 1996, Berry et al. 2002). However, if droughts are severe, as in 2002, tortoises will eventually succumb from lack of food and water (Berry et al. 2002; Longshore et al. 2003). In fall 2002, field personnel began observing abnormal behavior (e.g., failure to hibernate), emaciated tortoises, as well as increased clinical signs of URTD (e.g., occluded nares, bubbles from nares, etc.). In 2003, one year following the severe drought, we observed a dramatic increase in the number of shell remains observed and a corresponding decrease in the percent of tortoises with clinical signs of URTD, likely due to sick tortoises unable to survive the extreme drought. Reflective of these losses, we observed a marked increase in annualized mortality in 2003, following the drought (Table 5).

Wildfire frequency, extent, and intensity within the NCA has increased as a result of widespread nonnative invasive annual brome grasses. Plant surveys in 2023 revealed the presence of invasive grasses on all transects, with the highest percent cover relative to other species. Impacts to desert tortoises from wildfires include direct burning fatalities or injuries, dehydration, exposure to high temperatures, or smoke inhalation, as well as indirect impacts resulting from a loss of forage, change in plant composition and hydrology, and damage to soil and burrows (Drake et al. 2016; Esque et al. 2003). In the summer of 2005, wildfires burned significant portions of the NCA. Consequently, tortoise populations declined in some areas due primarily to direct mortality and habitat degradation, resulting in high mortality (McLuckie et al. 2007). During the summer of 2020, five human-caused wildfires burned approximately 12,439 acres within the Red Cliffs NCA and Reserve, including the 1,414-acre Cottonwood Trail Fire, negatively impacting local tortoise populations (Kellam et al. 2022). Annualized mortality following the 2020 wildfires reflect the high number of shell remains observed relative to previous years (11%) but declined to the lowest recorded in 2023 (1%; Table 5). During 2023 monitoring, tortoises with burn scars in addition to shell disease or, cutaneous dyskeratosis, were observed. Shell disease has been associated with population declines in some tortoise populations, a result of habitat degradation (Jacobson 1994, Homer et al. 1998). Post wildfire vegetation changes may significantly alter the long-term quality of habitat for tortoises by reducing plant forage diversity, promote non-native plants, and increase the threat and spread of additional fires (Esque et al. 2003). Effective restoration in burned areas is critical to restore degraded habitat and ultimately recover the desert tortoise. Further, providing multiple protected populations within a recovery area (i.e., Management Zones 1-6) offers additional protection from future wildfires that could theoretically burn across multiple zones.

During 2023 population monitoring, several demographic parameters including growth, shell remains, and health assessments were observed. Similar to previous monitoring reports, exact cause of death was unknown for the majority of remains. In 2023, the adult annualized mortality was 1%, the lowest ever recorded in the Reserve and lower than many other populations in the Mojave Desert (Berry et al. 2016). Although tortoises with URTD clinical signs were observed in relatively high density areas (e.g., City Creek, Padre Canyon, Paradise Canyon, Red Cliffs Recreation Area, Red Hills Parkway), the percent of processed tortoises with URTD clinical signs was 9%, below the threshold that could trigger a mortality event (25%; Homer et al. 1998). Brown et al. (1999) reported that clinical expression of the disease may be cyclical with clinical signs of the disease more likely to be observed at the time of emergence from hibernation in late winter and less likely to be seen in late spring or summer. Because evidence of the disease is present throughout the NCA, albeit at a chronic phase, the tortoise population may be vulnerable to future disease outbreaks triggered by stochastic events (e.g., drought, wildfires, etc.).

Notably, juvenile and immature tortoises exhibit low capture rates in populations, are more difficult to observe than adults, and therefore often under-represented in most studies (Wilbur 1975, Bourn and Coe 1978, Berry and Turner 1986; Wilson et al. 1994). The majority of tortoises encountered during 2023 monitoring were reproductive adults (85%); 15% of the tortoises observed had a carapace length of less than 180 mm. The percentage of juvenile and immature tortoises observed in 2023 was below average from previous years (19%; 1998-2019), which varied from 13% in monitoring year 2000 to 26% in 1998. Allison and McLuckie (2018) determined that the odds of encountering a juvenile from 1999 to 2014, not only in the Reserve but in all recovery units across the tortoises range, have declined since 2007. This may be a reflection of reduced reproduction and increased mortality across the range of the desert tortoise, a result primarily of drought, predation and habitat degradation (Darst et al. 2013).

The cumulative and interactive nature of multiple threats to desert tortoise populations has been acknowledged and described (Tracy et al. 2004, USFWS 2011). Although tortoise declines are primarily attributed to a combination of drought, disease, and wildfires, other threats such as habitat degradation and fragmentation, direct take of animals, and predation (e.g., domestic dogs, ravens) likely play a role. Tortoise habitat bordering the NCA is rapidly changing; areas that were once accessible to tortoises are now developed and fenced, preventing immigration from adjacent tortoise populations. Human activities can also have adverse effects on tortoise populations, particularly if they result in cumulative impacts (Peterson 1994). Illegal collection and intentional killing, although difficult to quantify, may be a significant factor contributing to tortoise declines (Grandmaison 2012). Although many human related threats have been removed or minimized within the NCA (e.g., grazing, off-road vehicles, dumping/littering) recreational impacts, habitat fragmentation, habitat degradation, and utility development and maintenance are continued cumulative threats to tortoise populations. The protection of additional habitat within the UVRRU (e.g, Management Zone 6) increases the viability of desert tortoises by increasing the number of tortoises living within protected habitat and providing increased resiliency and redundancy against the cumulative threats they face (USFWS 2021).

Due to the number of potential threats within the NCA and its proximity to rapidly growing communities, long-term monitoring is critical to understand and assess the status of tortoise populations (USFWS 2011a). Life history traits associated with desert tortoises include a low reproductive rate, high juvenile mortality, and delayed sexual maturity (Congdon and Gibbons 1990). These attributes make tortoise populations highly sensitive to human induced perturbations (USFWS 2011a). As pressures from human populations increase, intensive management is essential to ensure the continued existence of tortoises within the NCA and surrounding areas.

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Table 1. Tortoises encountered, shell remains observed, and kilometers completed during desert tortoise monitoring, Spring 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah.

Sampling Period	Tortoises Observed				Shell Remains	Weekly Total (km)	Total (km)
	Adult ♂	Adult ♀	Unknown sex	< 180 mm			
Week 1 (4/10-4/14)	7	3		2	1	24.34	24.34
Week 2 (4/17-4/21)	3	2	2			30.95	55.29
Week 3 (4/24-4/28)	4	7	3	3	2	25.06	80.35
Week 4 (5/1-5/5)	12	13	1	4		38.00	118.35
Week 5 (5/8-5/12)	17	12	1	7	3	41.98	160.33
Week 6 (5/15-5/19)	11	10	2	5	3	39.25	199.58
Week 7 (5/22-5/26)	5	8	1	2		39.13	238.71
Week 8 (5/29-6/2)	7	10		3	1	31.48	270.19
Week 9 (6/5-6/9)	3	3	1	1	1	34.94	305.13
Week 10 (6/12-6/13)		2	1		1	9.51	314.64
Total	69	70	12	27	12		314.64

Table 2. Size and sex structure of live desert tortoises (n=178) encountered during population monitoring, April 10 to June 13, 2023, Management Zones 2, 3, 4, and 5, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah.

Age Class	CL Range (mm)	Male	Female	Unknown	Total Tortoises
Juvenile	<100			11	11
Immature	100-179			16	16
Adult	≥ 180	69	70	12[A]	152
Total		69	70	39	178

[A] Tortoises were not processed because they could not be removed from deep burrows.

Table 3. Recaptured tortoises encountered (n=50) including date found, management zone, file number, status, sex, recapture carapace length (mm), original capture carapace length (mm), original capture date, time since original capture (years), and average distance moved (m/yr), April 10 to June 13, 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah. Status of tortoises includes: N=native and T=translocated. Sex includes M=male, F=female and U=unknown. We were unable to calculate average distance moved for two historical captures due to incomplete original capture data.

Date Found	Zone	File No.	Status	Sex	CL (mm)	Org Capture CL (mm)	Original Capture Date	Time Since Org Capture (yrs)	Dist Moved (m/yr)
04/10/23	3	94	N	M	259	223	05/12/03	19.91	94
04/11/23	3	4477	N	M	298	296	04/15/19	3.99	355
04/12/23	3	4042	N	F	193	140	06/06/17	5.85	119
04/12/23	3	4471	N	F	252	245	06/06/17	5.85	135
04/13/23	3	4473	N	M	280	279	04/25/19	3.97	9
04/18/23	3	4113	N	M	249	174	04/13/15	8.01	244
04/18/23	3	6044	N	F	245	243	04/26/21	1.98	171
04/26/23	3	4214	N	F	259	247	04/05/13	10.06	6
04/27/23	3	4238	N	M	271	270	05/09/13	9.97	183
04/27/23	3	216 [A]	N	F	252	243	05/22/13	9.93	47
04/27/23	3	4152	N	F	255	245	05/14/15	7.95	237
04/27/23	3	112 [A]	N	F	226	223	05/23/13	9.93	134
05/01/23	2	213	N	F	257	216	06/25/82	40.85	
05/01/23	2	132	N	M	263	212	05/04/15	7.99	141
05/01/23	2	4232	N	M	240	216	05/06/13	9.99	47
05/01/23	2	4482	N	F	291	293	05/06/19	3.99	53
05/02/23	2	860	N	M	263	245	04/14/83	40.05	359
05/02/23	3	2913[B]	N	M	263	222	05/27/05	17.93	214
05/03/23	2	39	N	M	299	299	05/11/09	13.98	101
05/03/23	2	3	N	M	262	255	07/22/72	50.78	
05/03/23	2	3153	N	F	238	235	05/11/11	11.98	53
05/08/23	3	113	N	F	231	185	08/21/97	25.71	520
05/08/23	3	2836	N	F	230	221	05/16/05	17.98	204
05/09/23	3	3025[B]	N	M	270	261	09/28/12	10.61	143
05/10/23	3	3178	N	M	249	245	05/27/11	11.95	461
05/11/23	3	151	N	M	248	223	05/27/15	7.96	368
05/11/23	3	4116	N	F	246	245	04/17/17	6.07	18
05/11/23	3	4409	N	M	295	296	05/15/17	5.99	129
05/11/23	3	6040	N	M	201	165	04/23/21	2.05	640
05/11/23	3	1123[B]	N	M	241	197	05/12/04	19.00	403
05/11/23	3	1325[B]	N	F	238	237	05/18/00	22.98	179
05/15/23	5	156	N	M	260	256	05/15/17	6.00	3
05/15/23	5	1331	N	M	269	218	05/30/00	22.96	202
05/16/23	5	443	N	M	259	235	06/04/03	19.95	165
05/17/23	3	912[A]	N	M	298	298	06/07/85	37.94	48
05/18/23	2	3051	N	F	247	233	05/26/09	13.98	91
05/19/23	3	4182	N	M	266	208	06/01/15	7.97	88
05/19/23	3	2813	N	F	232	221	05/05/05	18.04	87

Date Found	Zone	File No.	Status	Sex	CL (mm)	Org Capture CL (mm)	Original Capture Date	Time Since Org Capture (yrs)	Dist Moved (m/yr)
05/19/23	3	3053	N	F	245	228	06/02/11	11.96	85
05/23/23	3	217	N	M	294	287	05/17/19	4.02	75
05/31/23	4	4242	T	M	281	237	10/08/09	13.65	227
05/31/23	4	4762	T	F	240	233	10/08/09	13.65	224
05/31/23	4	3471	T	U	176	123	05/09/17	6.06	1293
06/01/23	4	6132	T	F	274	153	10/07/03	19.65	6
06/02/23	3	440	N	M	250	225	04/22/05	18.11	235
06/02/23	3	211	N	M	285	250	04/18/94	29.12	145
06/05/23	3	6036	N	F	237	230	05/12/20	3.06	1538
06/09/23	3	370	N	M	246	202	05/05/88	35.09	327
06/09/23	3	6094 [A,B]	N	F	180	173	05/11/23	0.08	59
06/13/23	2	211	N	F	239	192	05/12/17	6.09	269

[A] Recaptured multiple times during the 2023 monitoring season.
[B] Incidental and not found on a transect.

Table 4. Shell remains (n=12) encountered including date found, management zone, carapace length (mm), measurement type, sex of adult remains and estimated time since death, April 10 to June 13, 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah. Measurement type includes 1=carapace length estimated using scute regression formula and 2= carapace length measured directly (Berry and Woodman 1984).

Date Found	Zone	CL (mm)	Measurement Type	Sex	Time Since Death (yrs)	Cause of Death/Notes
4/10	3	123	1	U	1-2	Unknown
4/24	3	246	1	M	>4	Fell in rock crevice
4/26	3	233	1	F	>4	Unknown
5/9	3	253	1	M	>4	Scavenged, found at coyote den entrance
5/10	3	229	2	F	<1	Unknown
5/12	3	U		U	>4	Unknown, bone fragments
5/16	5	223	1	U	2-4	Unknown
5/19	3	194	1	U	2-4	Unknown, deep cracks in shell
6/1	4	226	2	F	<1	Unknown, shell intact, File number #3100
6/2	3	90	2	U	<1	Unknown, fungus on plastron
6/8	3	122	1	U	<1	Predator, puncture wounds
6/13	3	U		U	2-4	Unknown, bone fragments; no scutes found

Table 5. Summary of adult shell remains observed on transects with time since death (TSD) estimated at less than 1 year, total line length (km), encounter rate (*n/l*), live adult tortoises observed on transects and annualized mortality rate during population monitoring, Red Cliffs National Conservation Area and surrounding areas, 1998 to 2023, Washington County, Utah. Annualized mortality rate [(*n*/(N+*n*))*100] was calculated where *n* is the number of shells observed on transects (TSD < 1 yr) and N is the estimated abundance of live adults observed on transects during the monitoring season. Population surveys in 2006 and 2021 were conducted only in burned habitat within the perimeter of the 2005 and 2020 wildfires respectively. Mortality rate could not be calculated in 2006 as transects were completed in fall and winter, immediately following the 2005 wildfires (McLuckie et al. 2007).

Year	Shells Remains TSD < 1 yr	Line Length (km)	Encounter Rate (*n/l*)	Live Adult Encounters	Annualized Mortality Rate (%)
1998	5	193.4	0.03	138	3.5
1999	9	296.0	0.03	192	4.5
2000	13	289.0	0.04	191	6.4
2001	9	302.0	0.03	181	4.7
2003	52	298.8	0.19	100	34.2
2005	25	293.7	0.09	167	13.0
2006	38	90.3	0.63		
2007	14	296.4	0.05	106	11.7
2009	16	298.5	0.06	88	15.4
2011	18	298.9	0.06	124	12.7
2013	9	302.6	0.03	108	7.7
2015	4	300.2	0.01	94	4.1
2017	3	266.2	0.02	112	2.6
2019	7	262.0	0.04	100	6.5
2021	4	88.3	0.17	33	10.8
2023	2	314.6	0.01	139	1.4

Table 6. Species observed during desert tortoise population monitoring and their status, April 4, 2023 to June 13, 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah. A detailed list of observations is found in Appendix 2.

Common Name	Latin Name	S Rank[1]	N Rank[2]	BLM Status[3]
California Common Kingsnake	*Lampropeltis getula*			
Coachwhip	*Masticophis flagellum*			
Common Chuckwalla	*Sauromalus ater obesus*			SS
Desert Horned Lizard	*Phrynosoma platyrhinos*			
Gila Monster	*Heloderma suspectum*	S2	N4	SS
Gopher Snake	*Pituophis catenifer*			
Great Basin Collared Lizard	*Crotaphytus bicinctores*			
Great Basin Rattlesnake	*Crotalus oreganus lutosus*			SS
Long-nosed Leopard Lizard	*Gambelia wislizenii*			
Long-nosed Snake	*Rhinocheilus lecontei*			
Sidewinder	*Crotalus cerastes*			SS
Western Banded Gecko	*Coleonyx variegatus*	S3	N4	SS
Western Ground Snake	*Sonora semiannulata*			
Western Patch-nosed Snake	*Salvadora hexalepis*			
Yellow-backed Spiny Lizard	*Sceloporus uniformis*			
Zebra-tailed Lizard	*Callisaurus draconoides*			SS

[1]S Rank: S2=Identified as imperiled on the subnational or state level. S3= Identified as Vulnerable (rare) on the subnational or state level (UWAP, 2015).
[2]N Rank: N4=Identified as "apparently secure", uncommon but not rare but with some cause for concern on the national level (UWAP, 2015).
[3]From the BLM State Directors sensitive species (SS) list for BLM-administered lands (IM 2011-037, https://www.blm.gov/programs/fish-and-wildlife/threatened-and-endangered/state-te-data/utah).

Table 7. Encounter rate (*n/L*), associated coefficient of variation (%) of adult desert tortoises (≥ 180 mm), number of radiotelemetered tortoises (*n*), proportion of tortoises above ground (g_0) and standard error (*SE*) during distance sampling monitoring within Zone 3 and across the NCA (Zones 2, 3, and 5), 1998 to 2023, Red Cliffs National Conservation Area, Washington County, Utah. Note that Reserve wide monitoring was not conducted in 1998.

Yr	**Zone 3**		**Zones 2, 3, and 5**		***n***	**g_0 ± SE**
	***n*/L**	**CV (%)**	***n*/L**	**CV(%)**		
1998	0.63 (0.47-0.84)	14.78			30	0.79 ± 0.06
1999	0.61 (0.44-0.85)	16.77	0.59 (0.44-0.79)	14.48	30	0.64 ± 0.06
2000	0.65 (0.47-0.89)	16.15	0.61 (0.47-0.80)	13.36	15	0.83 ± 0.04
2001	0.67 (0.51-0.88)	14.06	0.58 (0.45-0.74)	12.35	12	0.81 ± 0.06
2003	0.34 (0.26-0.45)	13.89	0.32 (0.26-0.41)	12.16	8	0.87 ± 0.03
2005	0.49 (0.39-0.63)	12.58	0.54 (0.43-0.68)	11.85	8	0.85 ± 0.05
2007	0.31 (0.23-0.41)	14.37	0.33 (0.26-0.43)	12.85	11	0.57 ± 0.05
2009	0.22 (0.16-0.31)	17.00	0.28 (0.22-0.38)	14.29	11	0.68 ± 0.03
2011	0.35 (0.27-0.45)	12.65	0.39 (0.31-0.48)	11.27	9	0.74 ± 0.02
2013	0.30 (0.23-0.39)	13.62	0.34 (0.27-0.44)	12.97	11	0.69 ± 0.04
2015	0.26 (0.19-0.36)	15.67	0.31 (0.23-0.40)	13.65	11	0.74 ± 0.02
2017	0.36 (0.27-0.47)	13.83	0.41 (0.33-0.51)	11.50	13	0.75 ± 0.05
2019	0.24 (0.17-0.33)	16.86	0.37 (0.27-0.50)	16.21	13	0.79 ± 0.04
2023	0.33 (0.25-0.43)	13.61	0.41 (0.33-0.52)	11.93	13	0.71 ± 0.04

Table 8. Sample size of truncated data (*n*), total line length (*L*), number of transects (*k*), density (D; tortoises per km^2) and abundance (N; total animals per area sampled) estimates with associated 95% confidence interval, and coefficient of variation (%) for adult desert tortoises (≥180 mm) encountered within Management Zone 3, 1998 to 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah.

Year	n	L	K	D (95%CI)	N (95%CI)	CV(%)
1998	121	193.4	99	33.3 (24.7-45.0)	3195 (2367-4312)	15.22
1999	132	215.5	110	32.6 (23.3-45.7)	3129 (2233-4384)	17.16
2000	136	209.3	106	34.6 (25.0-48.0)	3319 (2397-4597)	16.55
2001	146	218.9	111	35.5 (26.7-47.3)	3406 (2559-4534)	14.52
2003	73	215.6	109	18.0 (13.6-23.9)	1729 (1303-2295)	14.36
2005	114	230.7	117	26.3 (20.3-34.1)	2524 (1950-3366)	13.10
2007	74	239.8	122	16.4 (12.3-22.0)	1576 (1178-2110)	14.83
2009	54	241.5	123	11.9 (8.5-16.8)	1142 (812-1607)	17.39
2011	84	239.0	122	18.7 (14.5-24.3)	1795 (1385-2326)	13.16
2013	72	241.0	123	15.9 (12.1-21.0)	1526 (1156-2013)	14.09
2015	63	238.7	123	14.1 (10.3-19.3)	1348 (983-1849)	16.08
2017	74	207.2	105	19.0 (14.4-25.2)	1824 (1376-2418)	14.30
2019	50	211.2	107	12.6 (9.0-17.7)	1209 (861-1697)	17.25
2023	80	243.0	124	17.5 (13.3-23.1)	1681 (1274-2218)	14.09

Table 9. Sample size of truncated data (*n*), total line length (*L*), number of transects (*k*), density (D; tortoises per km^2) and abundance (N; total animals per area sampled) estimates with associated 95% confidence interval, and coefficient of variation (%) for adult desert tortoises (≥180 mm) encountered within Management Zone 2, 3, and 5, 1999 to 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah.

Year	n	L	K	D (95%CI)	N (95%CI)	CV(%)
1999	175	296.0	152	29.7 (22.3-39.7)	3482 (2610-4646)	14.48
2000	178	289.9	147	30.9 (23.7-40.4)	3616 (2769-4723)	13.36
2001	175	302.0	153	29.2 (22.8-37.4)	3413 (2664-4372)	12.35
2003	97	298.8	151	16.4 (12.8-20.9)	1912 (1498-2440)	12.16
2005	158	293.7	149	27.1 (21.4-34.4)	3169 (2497-4020)	11.85
2007	98	296.4	151	16.7 (12.9-21.5)	1947 (1506-2519)	12.85
2009	85	298.5	152	14.3 (10.8-19.1)	1677 (1262-2230)	14.29
2011	116	298.9	153	19.5 (15.6-24.5)	2286 (1822-2868)	11.27
2013	104	302.6	155	17.3 (13.4-22.4)	2025 (1562-2624)	12.97
2015	92	300.2	155	15.4 (11.7-20.3)	1805 (1375-2370)	13.65
2017	109	266.2	136	20.6 (16.4-26.0)	2412 (1913-3040)	11.50
2019	96	262.0	133	18.5 (13.4-25.5)	2159 (1564-2978)	16.21
2023	123	298.8	153	20.7 (16.3-26.3)	2425 (1908-3081)	11.93

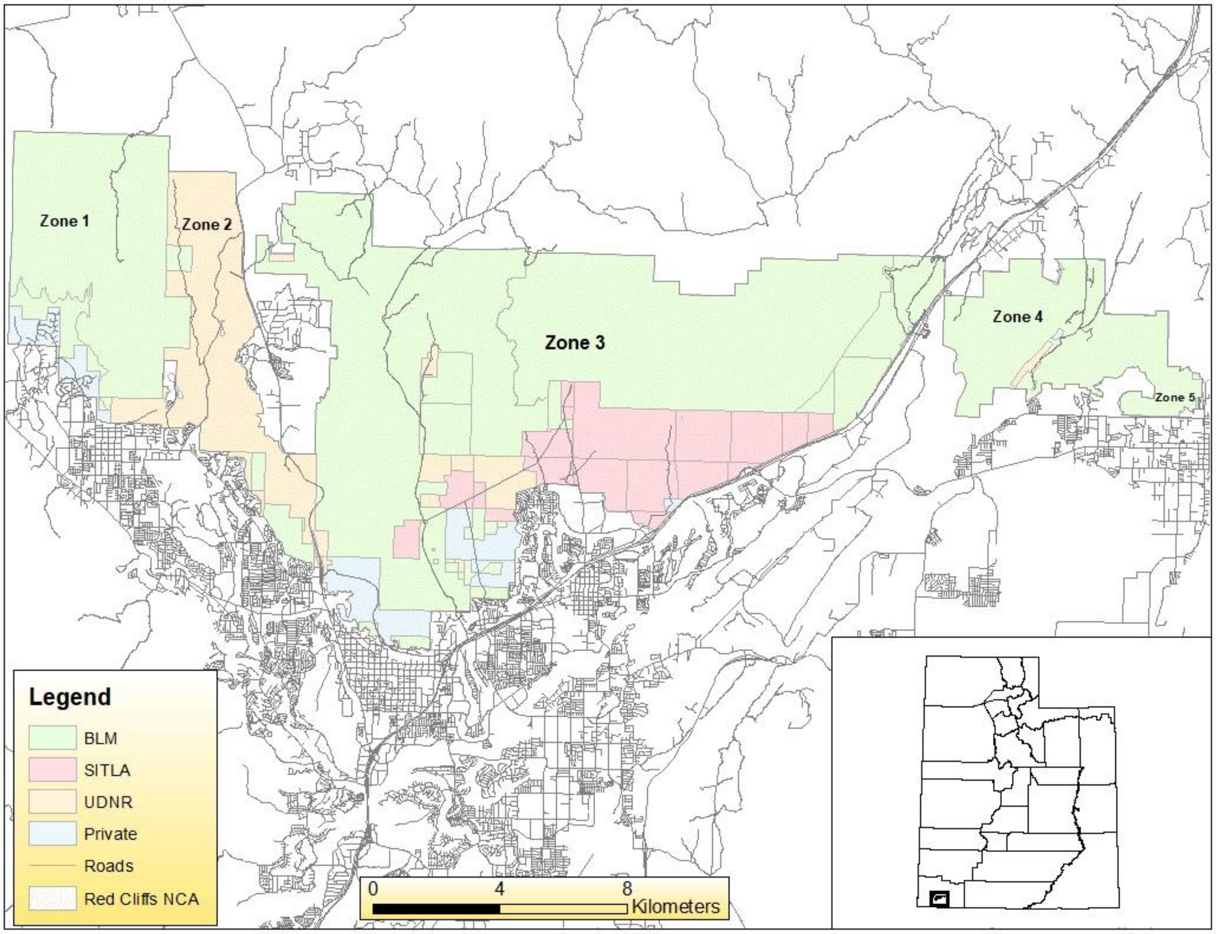

Figure 1. Location of desert tortoise long term monitoring, Management Zones 1-5, and land ownership, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah.

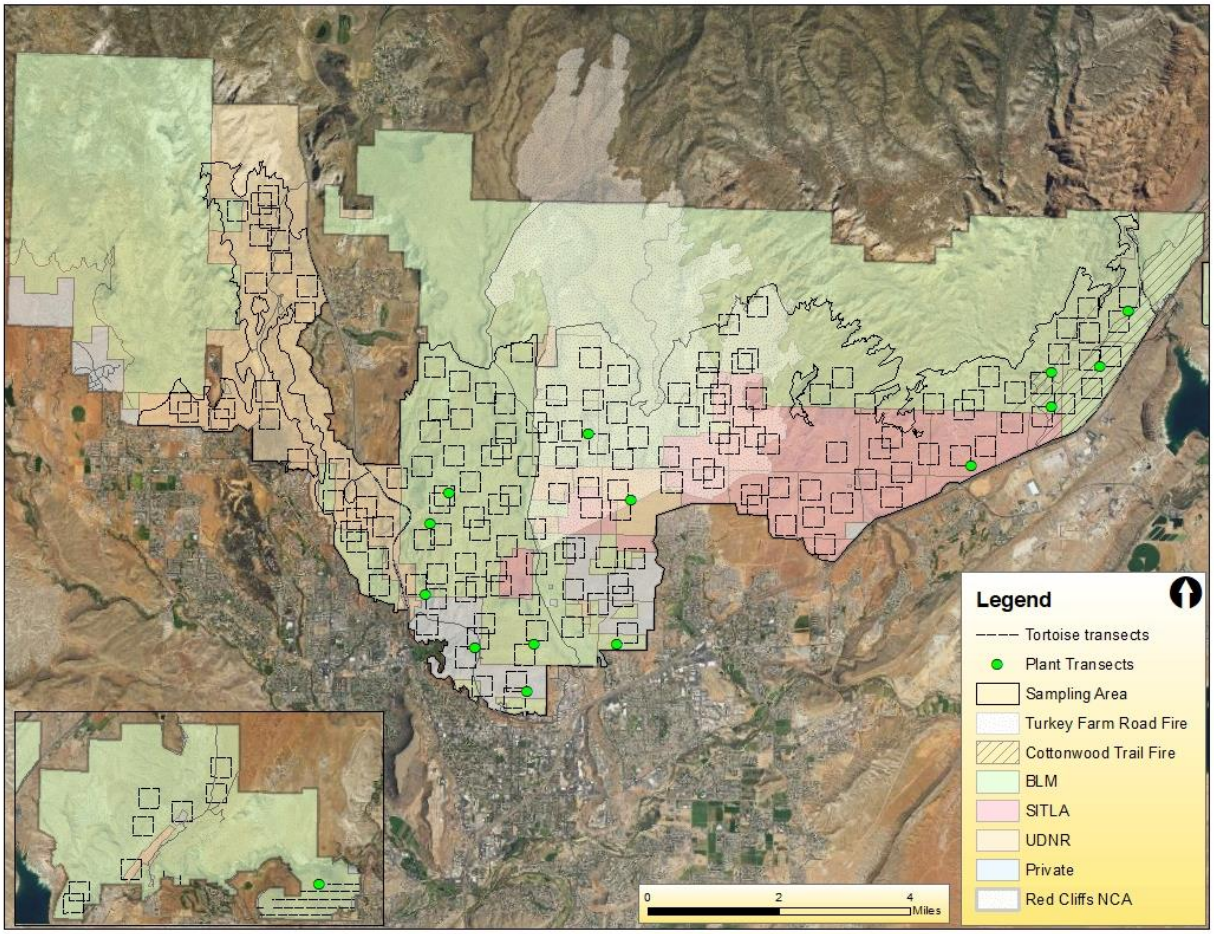

Figure 2. Desert tortoise long-term monitoring and plant transects overlaid onto land ownership, Red Cliffs National Conservation Area, Snow Canyon State Park, and surrounding areas, 1998 to 2023, Washington County, Utah.

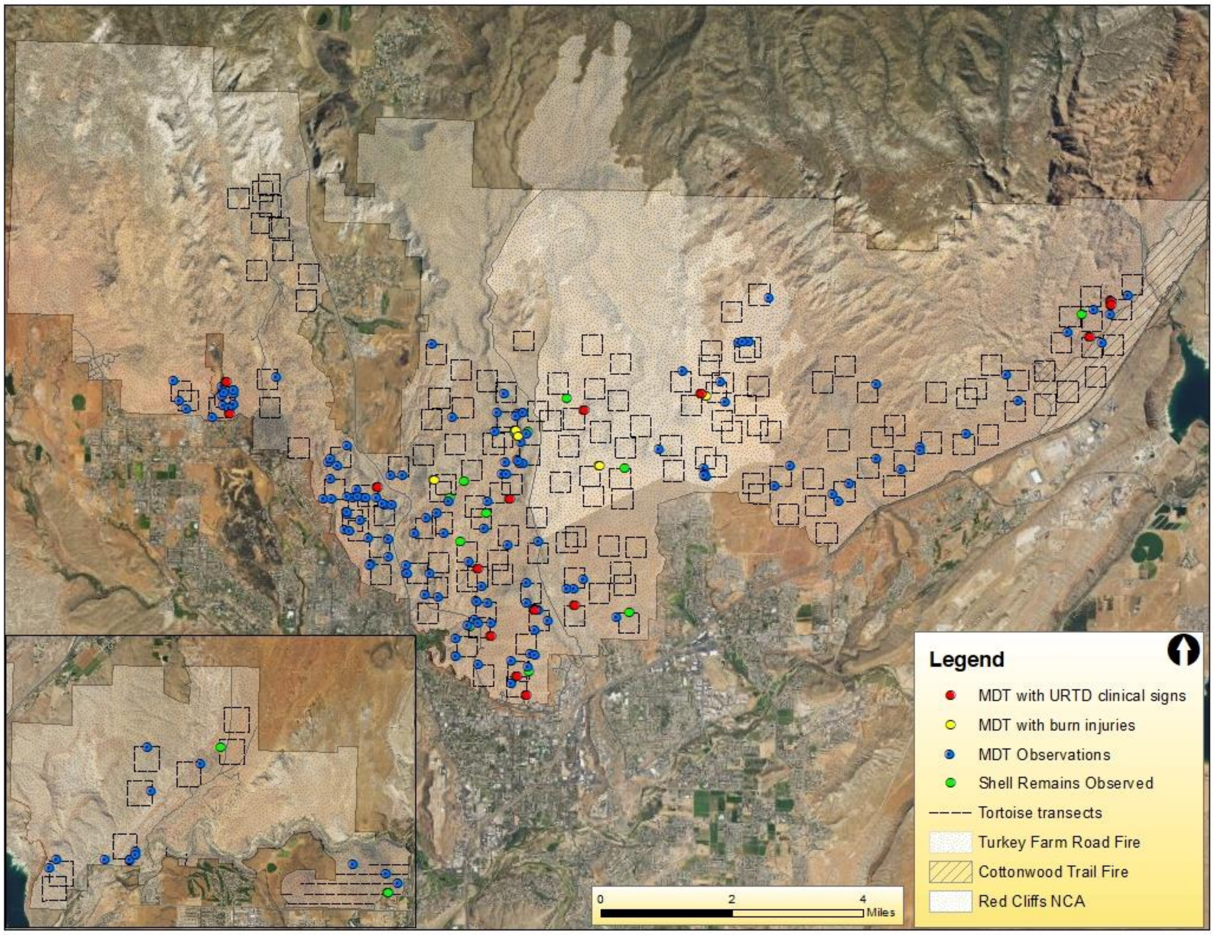

Figure 3. Locations of live desert tortoises and shell remains during population monitoring, April 10 to June 13, 2023, Red Cliffs National Conservation Area, Snow Canyon State Park, and surrounding areas, Washington County, Utah. Locations include incidental and transect observations.

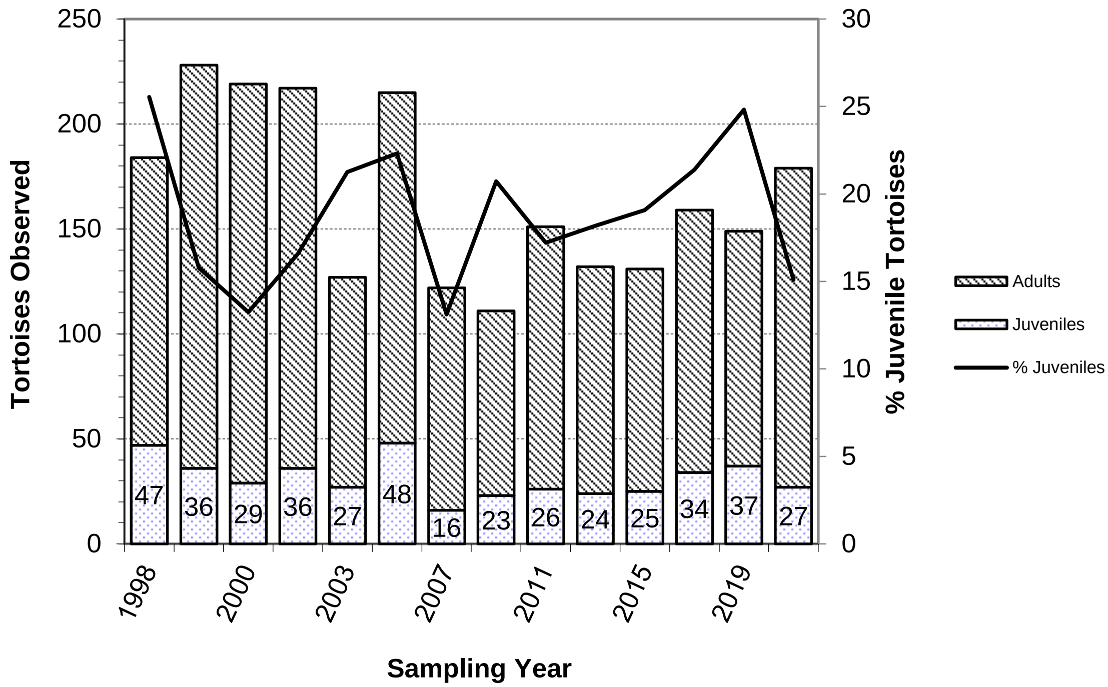

Figure 4. Comparison of adult (CL ≥ 180 mm) and juvenile (CL < 180 mm) desert tortoises, including percent juveniles, encountered annually during population monitoring, 1998 to 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah.

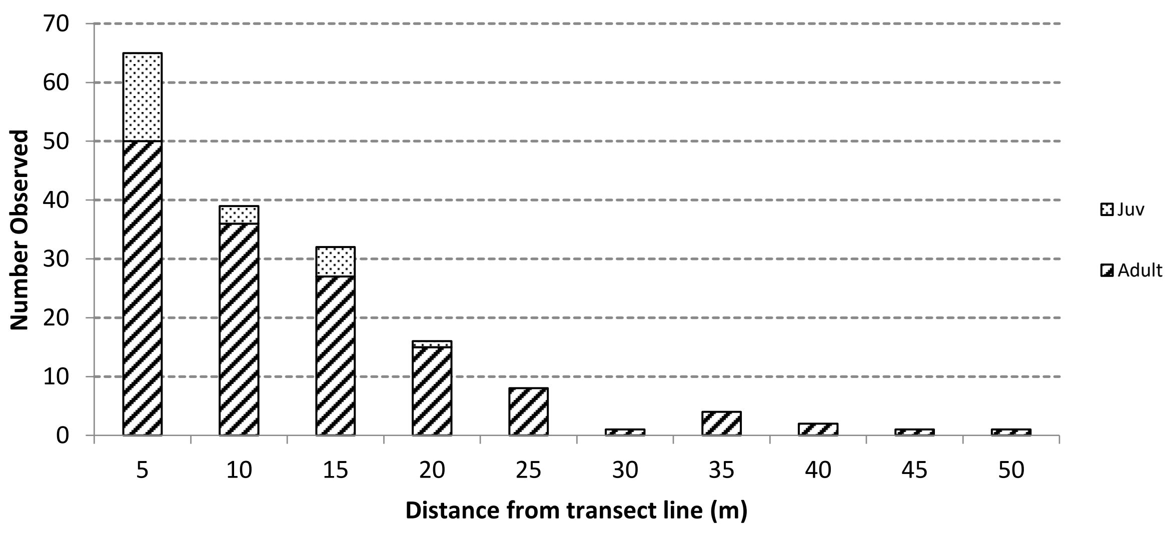

Figure 5. Perpendicular distances for adult (CL ≥ 180 mm) and nonreproductive (CL < 180 mm) tortoises encountered during distance sampling monitoring, April 10 to June 13, 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah.

Figure 6. Male desert tortoise (File number 6191) with green on mouth indicating recent and active foraging, May 25, 2023, Red Cliffs National Conservation Area, Washington County, Utah.

Figure 7. Female desert tortoise (File number 6044) with green on mouth and scarring on forelegs from wildfire exposure. Tortoise found within the Mill Creek (2005) and Turkey Farm Rd fire (2020) perimeter, April 18, 2023, Red Cliffs National Conservation Area, Washington County, Utah.

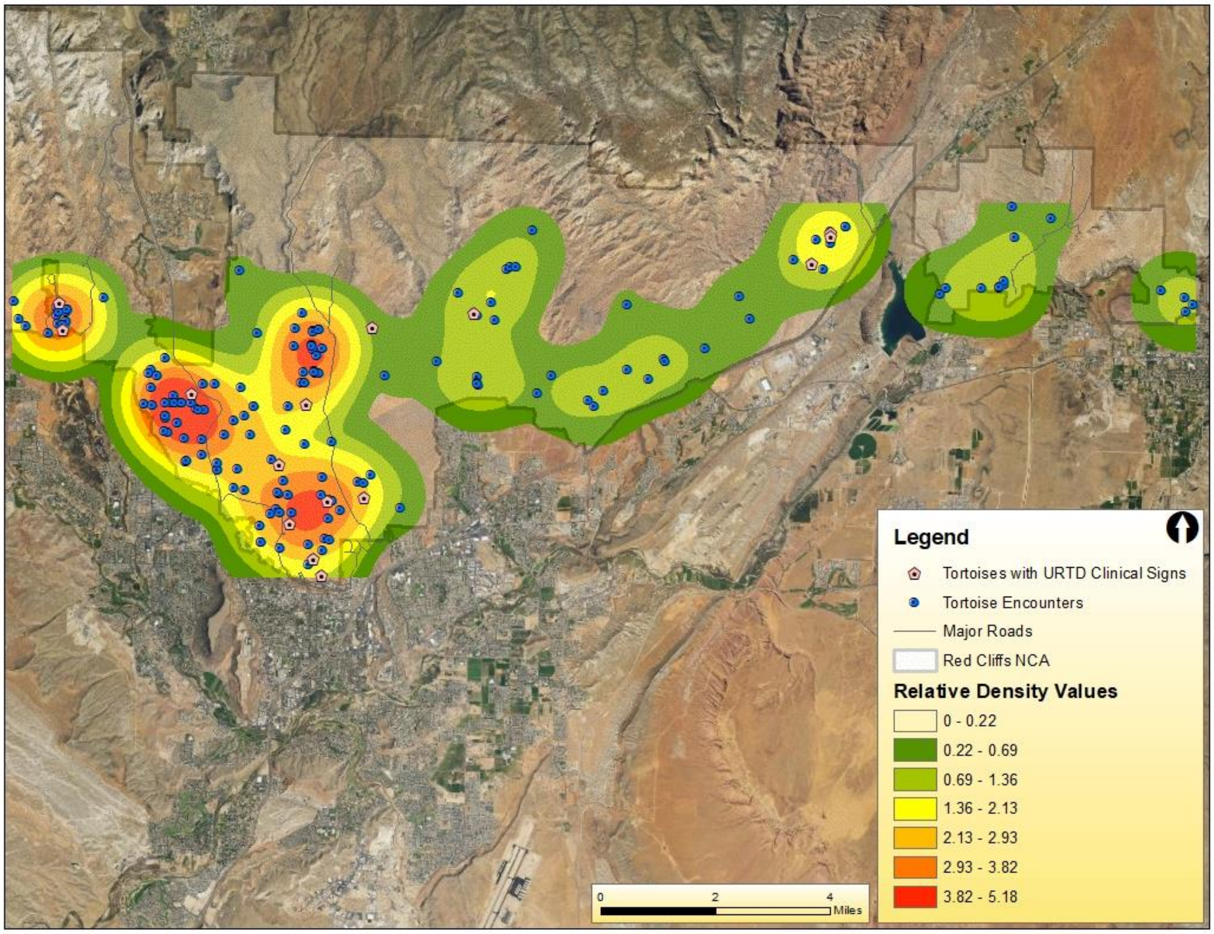

Figure 8. Tortoise encounters, including those with clinical signs of Upper Respiratory Tract Disease (URTD), overlaid onto a density heat map, April 10 to June 13, 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah. Locations include incidental and transect observations. Concentric circles indicate relatively low (green), medium (yellow) and high tortoise densities (red).


Figure 9. Male desert tortoise (File number 211) with URTD clinical signs, June 2, 2023, Red Cliffs National Conservation Area, Washington County, Utah.


Figure 10. Immature desert tortoise (File number 6094) with shell disease on right anterior of carapace, May 11, 2023, Red Cliffs National Conservation Area, Washington County, Utah.

Figure 11. Male desert tortoise (File number 6205) with vertebral scute anomaly, May 23, 2023, Red Cliffs National Conservation Area, Washington County, Utah.

Figure 12. Female tortoise (File number 6107) in Mill Creek with burned and deformed scutes, April 18, 2023, Red Cliffs National Conservation Area, Washington County, Utah.

Figure 13. Male desert tortoise (File number 6180) in Twist Hollow, within the Plateau fire (2005) perimeter, with burned and deformed scutes, May 2, 2023, Red Cliffs National Conservation Area, Washington County, Utah.

Figure 14. Adult male shell remain found in sandstone fissure, April 24, 2023, Twist Hollow, Red Cliffs National Conservation Area, Washington County, Utah.

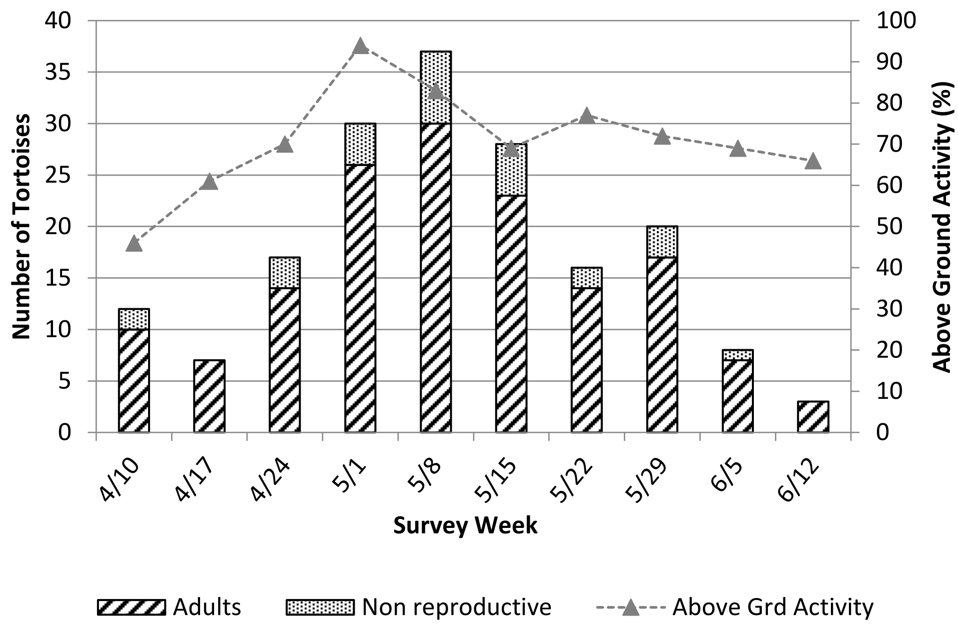

Figure 15. Number of tortoises detected during long term monitoring and percent of tortoises visible by sampling week (i.e., surface activity), April 10 to June 13, 2023, Red Cliffs National Conservation Area, Washington County, Utah. Survey week is the start date of each sampling week (see Table 1).

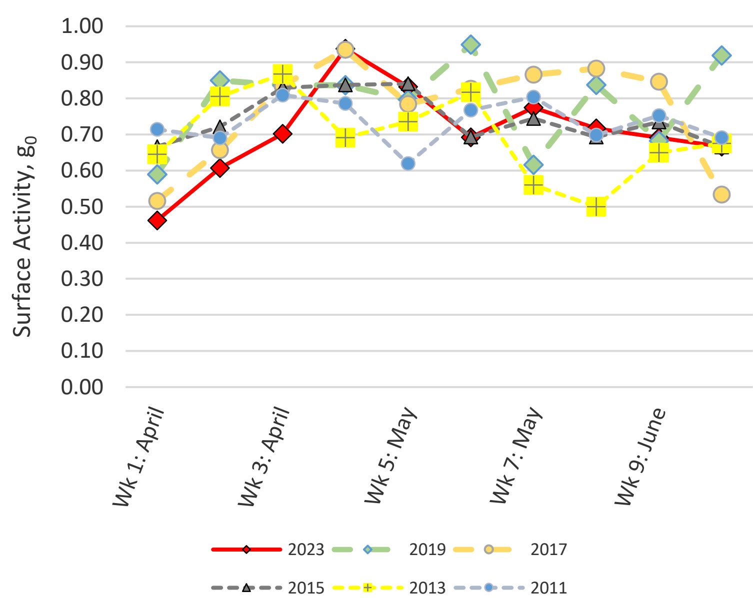

Figure 16. Comparison of weekly surface activity (g_0) for telemetered adult desert tortoises during distance sampling monitoring, 2011-2023, Red Cliffs National Conservation Area, Washington County, Utah.

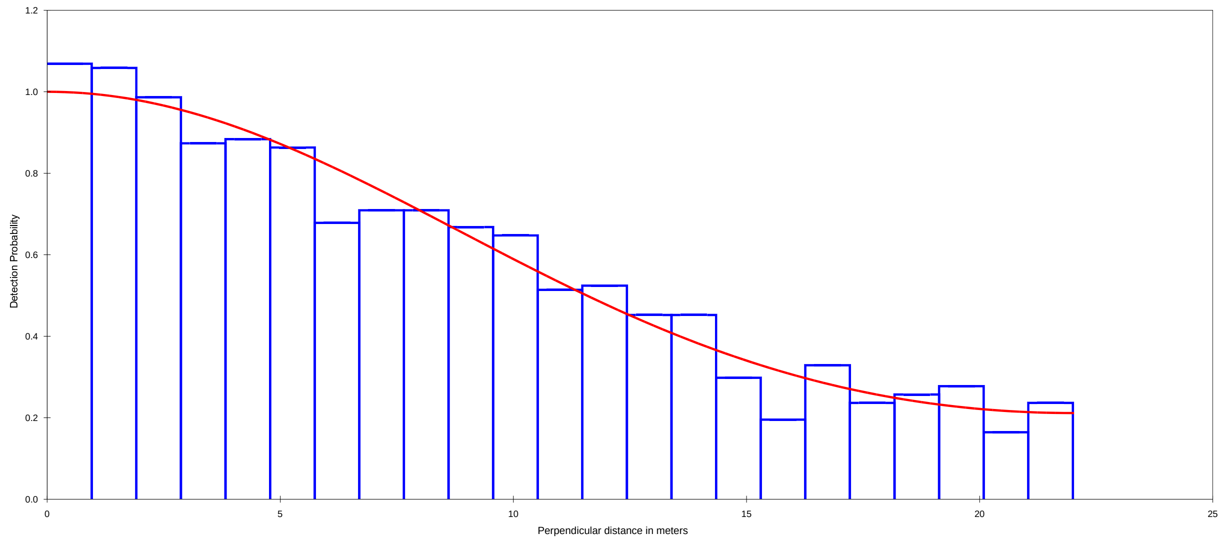

Figure 17a. Detection histogram of truncated perpendicular distances (n=1273) and the detection probability plot (uniform + cosine model) for reproductive desert tortoises (≥180 mm) encountered within Management Zone 3 of the Red Cliffs National Conservation Area and surrounding areas, 1998 to 2023, Washington County, Utah. Data was truncated at 22 m to reduce the effects of outliers (Buckland et al. 2001).

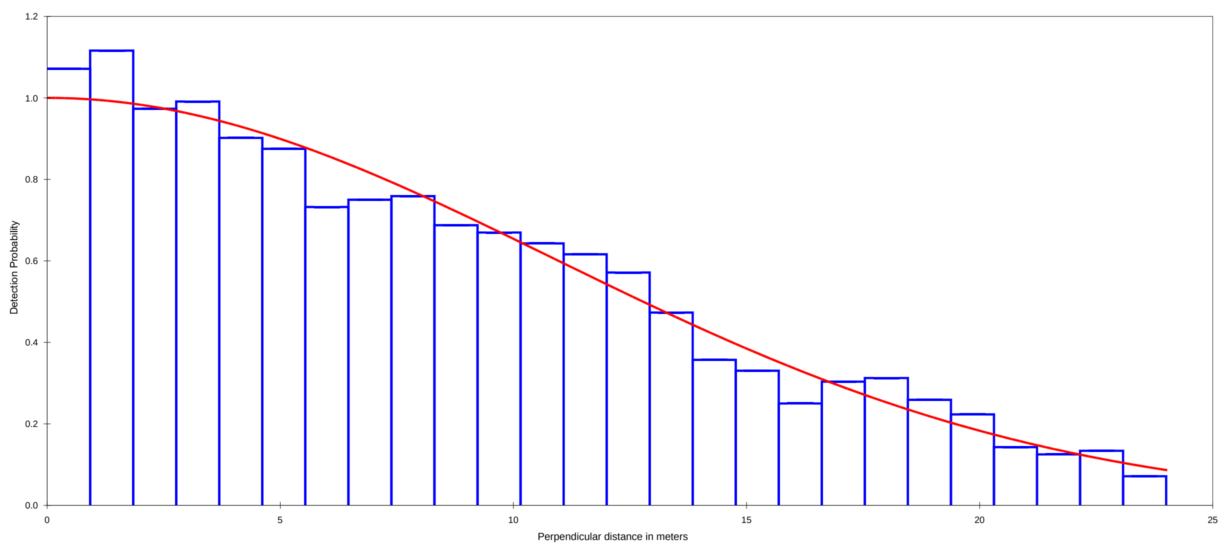

Figure 17b. Detection histogram of truncated perpendicular distances (n=1606) and the detection probability plot (half-normal + cosine model) for reproductive desert tortoises (≥180 mm) encountered within Management Zones 2, 3, and 5 of the Red Cliffs National Conservation Area and surrounding areas, 1999 to 2023, Washington County, Utah. Data was truncated at 24 m to reduce the effects of outliers (Buckland et al. 2001).

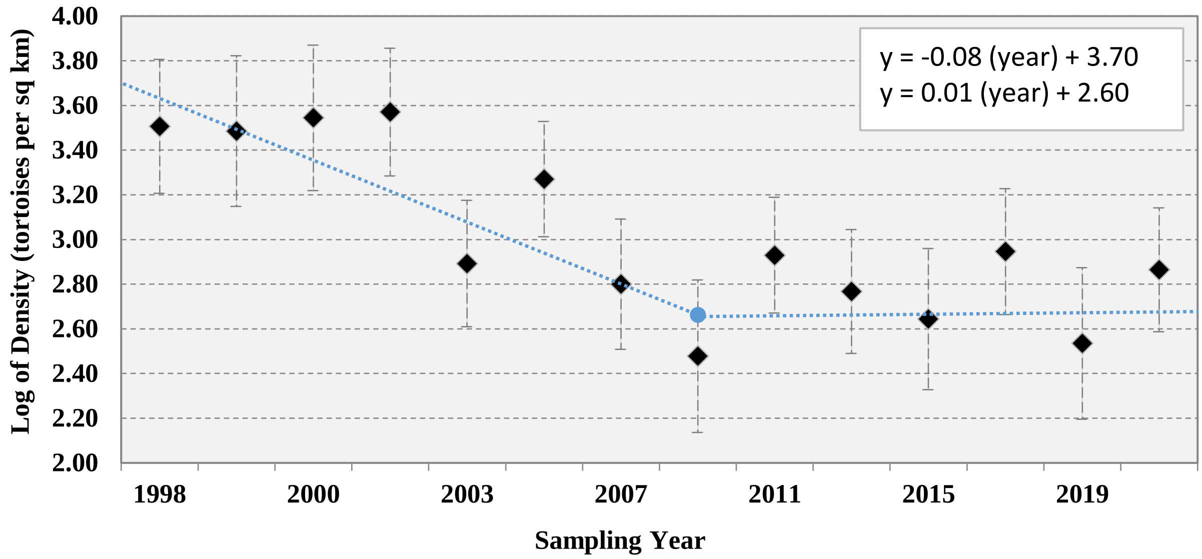

Figure 18a. Log density estimates and the piecewise linear regression model for desert tortoise populations in Management Zone 3, 1998 to 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah. Vertical lines represent the 95% confidence interval. Breakpoint at year 2009 with regression equation 1, y=-0.08 (year) + 3.70, and regression equation 2, y = 0.01 (year) + 2.60.

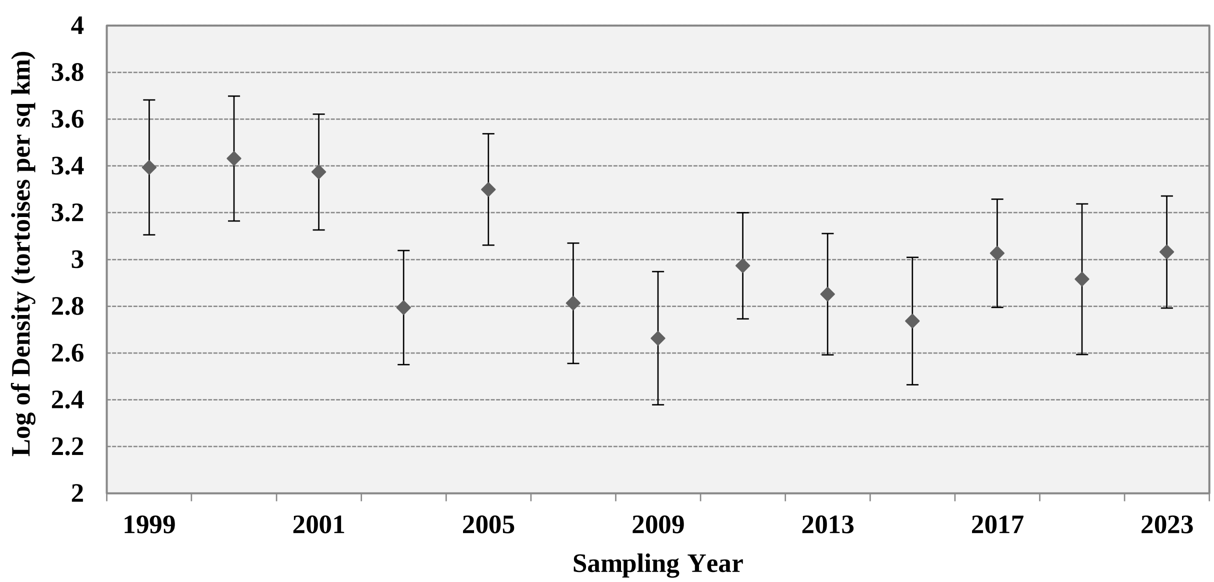

Figure 18b. Log density estimates for desert tortoise populations across the NCA (Management Zones 2, 3, and 5), 1999 to 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah. Vertical lines represent the 95% confidence interval.

Appendix 1. Date found, management zone, file number, status, sex, carapace length, shell wear, presence of Upper Respiratory Tract Disease (URTD) clinical signs, presence of shell disease, presence of burn injuries, and perpendicular distances of live desert tortoises observed during distance sampling monitoring, April 5 to June 13, 2023, Red Cliffs National Conservation Area and surrounding areas, Washington County, Utah. Status categories include: O=original capture, R=recapture, and X=recapture within same monitoring year (i.e., 2023). Sex includes: F=female, M=male, and U=Unknown. Shell wear includes the following categories: Class 1: no growth rings (hatchlings); Class 2: 6 or less growth rings; Class 3: > 6 growth rings, growth rings distinct; Class 4: hatchling plates beginning to wear smooth, < 50% of any line on width or length of scute overlies smoothly worn areas; Class 5: worn areas are expanding on scutes, 2 or more scutes with > 50% of any line on width or length of scute overlies smoothly worn areas; Class 6: ≤ 8 scutes and bone are sunken and depressed; Class 7: Most growth rings worn smooth, > 8 scutes and bone partially or completely sunken and depressed. For all categories: N=no, Y=yes, and U=unknown.

Date Found	Zone	File Number	Status	Sex	CL (mm)	Shell Wear	URTD Symptoms	Shell Disease	Burned	Perpendicular Distance (m)
4/10/23	3	6116	O	M	303	6	Y	N	N	7.89
4/10/23	3	6178	O	F	228	7	Y	N	N	0.15
4/10/23	3	94	R	M	259	7	N	N	N	2.45
4/10/23	3	6167	O	M	270	7	N	N	N	4.05
4/10/23	3	U	O	U	55	1	N	N	N	
4/11/23	3	4477	R	M	298	7	N	N	N	9.43
4/12/23	3	4042	R	F	193	5	N	N	N	11.52
4/12/23	3	4471	R	M	252	6	N	N	N	1.37
4/12/23	3	6166	O	F	252	5	N	N	N	6.50
4/12/23	3	6115	O	M	279	7	N	N	N	
4/12/23	3	U	O	U	119	3	N	N	N	
4/13/23	3	4473	R	M	280	7	N	N	N	9.87
4/18/23	3	4113	R	M	249	6	N	N	N	7.62
4/18/23	3	6107	O	F	254	7	Y	N	Y	13.28
4/18/23	3	6044	R	F	245	6	N	N	Y	
4/18/23	3	6113	O	M	312	6	N	N	N	9.66
4/19/23	3	U	O	U	>180	U	U	U	U	
4/20/23	3	6176	O	M	258	6	N	N	N	6.09
4/20/23	3	U	O	U	>180	U	U	U	U	9.14
4/24/23	3	6101	O	U	162	3	N	N	N	2.01
4/24/23	3	6114	O	M	290	7	N	N	N	0.64
4/24/23	3	U	O	U	>180	U	U	U	U	8.13
4/24/23	3	U	X	U	>180	U	U	U	U	5.18
4/26/23	3	U	O	U	>180	U	U	U	U	25.90
4/26/23	3	4214	R	F	259	7	N	N	N	4.77
4/26/23	3	912	R	M	299	7	Y	N	N	
4/27/23	3	4238	R	M	271	7	N	N	N	17.89
4/27/23	3	216	R	F	252	6	N	N	N	14.05
4/27/23	3	216	X	F	252	6	N	N	N	5.44
4/27/23	3	4152	R	F	255	6	N	N	N	4.97
4/27/23	3	112	R	F	226	7	N	N	N	2.27
4/27/23	3	112	X	F	226	7	N	N	N	10.33
4/27/23	3	6111	O	M	188	5	N	N	N	7.66

Date Found	Zone	File Number	Status	Sex	CL (mm)	Shell Wear	URTD Symptoms	Shell Disease	Burned	Perpendicular Distance (m)
4/27/23	3	6112	O	F	231	7	N	N	N	23.63
4/27/23	3	U	O	U	82	2	N	N	N	2.17
4/27/23	3	U	O	U	136	4	N	N	N	10.39
5/1/23	2	213	R	F	257	7	N	N	N	7.47
5/1/23	2	6165	O	M	305	7	N	N	N	0.71
5/1/23	2	U	O	U	97	2	N	N	N	0.67
5/1/23	2	132	R	M	263	5	N	N	N	18.38
5/1/23	2	4232	R	M	240	6	N	N	N	1.61
5/1/23	2	6098	O	F	231	4	N	N	N	12.39
5/1/23	2	4482	R	F	291	7	N	N	N	1.41
5/1/23	2	6175	O	F	219	6	N	N	N	15.19
5/2/23	2	6174	O	F	213	5	N	N	N	3.86
5/2/23	2	860	R	M	263	7	N	Y	N	4.41
5/2/23	2	4125	O	F	219	6	Y	N	N	5.95
5/2/23	2	6124	O	F	240	6	N	N	N	6.21
5/2/23	3	6180	O	F	231	6	N	N	Y	12.45
5/2/23	3	2913	R	M	263	6	N	N	N	
5/3/23	2	6158	O	M	233	4	N	N	N	39.83
5/3/23	2	6163	O	M	211	4	N	N	N	7.22
5/3/23	2	6164	O	M	279	6	N	N	N	33.28
5/3/23	2	39	R	M	299	7	N	N	N	4.66
5/3/23	2	6173	O	M	211	4	U	N	N	11.69
5/3/23	2	U	O	U	90	2	N	N	N	2.34
5/3/23	2	3	R	M	262	7	N	N	N	11.71
5/3/23	2	3153	R	F	238	6	N	N	N	11.61
5/3/23	2	6091	O	F	251	5	N	N	N	7.28
5/3/23	2	6102	O	U	157	3	N	N	N	8.83
5/3/23	2	6122	O	F	225	4	N	N	N	18.73
5/3/23	2	6123	O	F	239	6	N	N	N	8.48
5/3/23	2	U	O	U	75	2	N	N	N	4.75
5/3/23	2	U	O	U	>180	U	U	U	U	5.67
5/3/23	3	6108	O	M	284	4	N	N	N	0.57
5/4/23	2	6155	O	F	265	7	N	N	N	9.12
5/8/23	3	113	R	F	231	6	N	N	N	17.11
5/8/23	3	6151	O	F	194	3	N	N	N	5.81
5/8/23	3	6152	O	M	209	3	N	N	N	3.35
5/8/23	3	6153	O	M	241	4	N	N	N	40.62
5/8/23	3	6154	O	M	265	4	N	N	N	3.86
5/8/23	3	6156	O	M	273	4	N	N	N	33.76
5/8/23	3	6157	O	M	311	7	Y	N	N	7.94
5/8/23	3	U	O	U	96	3	N	N	N	10.39
5/8/23	3	6136	O	M	214	4	N	N	N	6.01
5/8/23	3	U	O	U	59	2	N	N	N	14.31
5/8/23	3	6162	O	F	224	4	Y	N	N	1.48
5/8/23	3	2836	R	F	230	7	N	N	N	5.45
5/8/23	3	6146	O	U	162	3	N	N	N	2.36
5/9/23	3	6168	O	M	281	7	N	N	N	15.20

Date Found	Zone	File Number	Status	Sex	CL (mm)	Shell Wear	URTD Symptoms	Shell Disease	Burned	Perpendicular Distance (m)
5/9/23	3	6134	O	F	223	6	N	N	N	1.15
5/9/23	3	3025	R	M	270	6	N	N	N	
5/9/23	3	6145	O	M	273	6	Y	N	N	
5/9/23	3	6150	O	F	239	6	N	N	N	
5/10/23	3	6050	O	F	193	4	N	Y	N	1.35
5/10/23	3	6143	O	F	226	6	Y	Y	N	14.28
5/10/23	3	6144	O	F	250	5	N	N	N	34.73
5/10/23	3	3178	R	M	249	6	N	N	N	0.59
5/10/23	3	6093	O	M	260	6	N	N	N	
5/11/23	3	6161	O	M	204	5	N	N	N	15.82
5/11/23	3	U	O	U	87	3	N	N	N	4.65
5/11/23	3	6142	O	U	129	3	N	N	N	0.78
5/11/23	3	U	O	U	>180	U	U	U	U	5.67
5/11/23	3	151	R	M	248	5	N	N	N	16.52
5/11/23	3	6121	O	F	228	6	N	N	N	13.15
5/11/23	3	U	O	U	63	2	N	N	N	2.92
5/11/23	3	1123	R	M	240	6	N	N	Y	19.43
5/11/23	3	1325	R	F	238	6	N	N	Y	20.21
5/11/23	3	4116	R	F	246	6	N	N	N	22.96
5/11/23	3	4409	R	M	295	6	N	N	N	1.37
5/11/23	3	6040	R	M	201	3	N	N	N	2.20
5/11/23	3	6094	O	U	173	3	N	Y	N	10.67
5/11/23	3	6096	O	M	218	3	N	N	N	21.13
5/15/23	3	6422	O	F	280	6	N	N	N	18.73
5/15/23	5	156	R	M	260	7	N	N	N	1.49
5/15/23	5	1331	R	M	269	6	N	N	N	6.13
5/16/23	5	6110	O	U	144	4	N	N	N	2.37
5/16/23	5	443	R	M	259	6	N	N	N	11.10
5/17/23	3	912	X	M	298	7	N	N	N	3.32
5/17/23	3	6137	O	F	233	5	Y	N	N	6.50
5/17/23	3	6423	O	M	252	5	U	Y	N	12.42
5/17/23	3	U	O	U	>180	U	U	U	U	3.23
5/17/23	3	U	O	U	>180	U	U	U	U	3.23
5/17/23	3	6117	O	M	263	4	N	N	N	8.19
5/17/23	3	6118	O	F	224	3	N	N	N	0.92
5/17/23	3	6133	O	M	274	7	N	N	N	11.72
5/17/23	3	6135	O	M	300	6	N	N	N	19.64
5/18/23	2	3051	R	F	247	6	N	N	N	10.83
5/18/23	2	4235	O	M	272	7	N	N	N	5.51
5/18/23	2	6095	O	F	244	4	N	N	N	11.41
5/18/23	2	6260	O	F	254	5	N	N	N	12.36
5/18/23	2	U	O	U	51	2	N	N	N	15.33
5/18/23	2	U	O	U	106	2	N	Y	N	1.67
5/18/23	2	U	O	U	112	3	N	N	N	1.57
5/18/23	2	6203	O	M	231	4	N	N	N	15.71
5/18/23	3	6099	O	F	220	6	N	N	N	
5/19/23	3	4182	R	M	266	6	N	N	N	23.24

Date Found	Zone	File Number	Status	Sex	CL (mm)	Shell Wear	URTD Symptoms	Shell Disease	Burned	Perpendicular Distance (m)
5/19/23	3	2813	R	F	232	6	N	N	N	8.52
5/19/23	3	3053	R	F	245	7	N	N	N	4.82
5/19/23	3	6206	O	F	224	6	N	N	N	1.43
5/19/23	3	6210	O	U	140	4	N	N	N	2.36
5/23/23	2	6188	O	F	233	7	N	N	N	4.94
5/23/23	2	U	O	U	>180	U	U	U	U	2.85
5/23/23	3	217	R	M	294	6	N	N	N	2.45
5/23/23	3	6211	O	M	262	5	N	N	N	8.14
5/23/23	3	6205	O	F	239	6	N	N	N	0.77
5/24/23	2	6149	O	F	211	3	N	N	N	17.30
5/24/23	2	6207	O	U	166	4	N	N	N	3.79
5/24/23	2	6209	O	F	256	6	N	N	N	13.98
5/24/23	3	6187	O	F	210	5	Y	N	N	0.80
5/25/23	2	6185	O	M	231	4	N	N	N	2.84
5/25/23	2	6010	O	F	199	4	N	Y	N	1.49
5/25/23	2	6184	O	F	239	5	N	N	N	1.78
5/25/23	2	6186	O	M	206	4	N	N	N	23.51
5/25/23	2	6190	O	F	240	5	Y	N	N	4.45
5/25/23	3	6191	O	M	301	6	N	N	N	11.62
5/25/23	3	6240	O	U	165	4	N	N	N	10.61
5/30/23	3	6172	O	F	188	4	N	N	N	2.56
5/30/23	3	U	O	U	53	2	N	N	N	4.13
5/30/23	3	6160	O	M	292	7	N	N	N	17.95
5/30/23	3	6140	O	U	132	3	N	N	N	9.08
5/30/23	4	6181	O	M	292	7	U	N	N	21.77
5/31/23	2	4242	R	M	281	6	N	N	N	2.80
5/31/23	4	6182	O	F	213	6	N	Y	N	12.15
5/31/23	4	4762	R	F	240	5	N	N	N	51.00
5/31/23	4	6199	O	M	195	3	N	N	N	2.79
5/31/23	4	6221	O	M	247	7	N	N	N	31.00
5/31/23	4	6223	O	F	232	4	N	N	N	38.00
5/31/23	4	3471	R	U	176	4	N	N	N	6.29
6/1/23	4	6224	O	F	240	7	U	N	N	12.71
6/1/23	4	6132	O	F	274	7	N	N	N	14.78
6/2/23	3	440	R	F	250	6	N	N	N	9.13
6/2/23	3	6148	O	F	269	7	N	N	N	1.59
6/2/23	3	6922	O	F	237	5	N	N	N	9.93
6/2/23	3	211	R	M	285	7	Y	N	N	23.00
6/2/23	3	6131	O	F	241	6	N	N	N	6.98
6/2/23	3	6086	O	M	203	4	U	N	N	
6/5/23	3	6036	R	F	237	6	N	N	N	2.23
6/5/23	3	U	O	U	>180	U	U	U	U	4.94
6/7/23	3	6226	O	M	260	6	N	N	Y	3.84
6/7/23	3	6216	O	M	252	6	Y	N	N	4.35
6/9/23	3	370	R	M	246	7	N	N	N	5.68
6/9/23	3	6084	O	F	212	5	N	N	N	2.75
6/9/23	3	6094	X	F	180	3	N	N	N	

Date Found	Zone	File Number	Status	Sex	CL (mm)	Shell Wear	URTD Symptoms	Shell Disease	Burned	Perpendicular Distance (m)
6/9/23	3	U	O	U	100	2	N	N	N	
6/13/23	2	211	R	F	239	5	N	N	N	5.35
6/13/23	2	U	O	F	225	5	Y	N	N	2.13
6/13/23	3	U	O	U	>180	U	U	U	U	16.35

Appendix 2. Other reptile species observed including date, common name, scientific name, age class (A=adult, J=juvenile), number observed, substrate, and general comments. Habitat and substrate includes BLAC= blackbrush dominant, BROM= Cheatgrass or red brome dominant, DEPA= desert pavement, MOTE=Mormon tea, and SNAK=snakeweed dominant.

Date	Common Name	Latin Name	Age	#	Substrate	Comments
4/4/23	Western Ground Snake	*Sonora semiannulata*	A	1	ROCK	Under basalt rock
4/5/23	Common Chuckwalla	*Sauromalus ater obesus*	A	1	ROCK	In crack
4/5/23	Great Basin Rattlesnake	*Crotalus oreganus lutosus*	A	1	ROCK	Coiled on basalt rock basking
4/11/23	Great Basin Collared Lizard	*Crotaphytus bicinctores*	A	1	MOTE, ROCK	Running away
4/12/23	Yellow-backed Spiny Lizard	*Sceloporus uniformis*	A	1	ROCK, SAND	Under desert almond in shade
4/17/23	Great Basin Rattlesnake	*Crotalus oreganus lutosus*	A	1	CLIFF	Basking on sandstone cliff
4/18/23	Long-nosed Leopard Lizard	*Gambelia wislizenii*	A	1	WASH	Mill Creek
4/18/23	Great Basin Rattlesnake	*Crotalus oreganus lutosus*	J	1	WASH	Coiled inside burrow
4/18/23	Great Basin Collared Lizard	*Crotaphytus bicinctores*	A	1	ROCK, BROM	Running under rock
4/20/23	Western Banded Gecko	*Coleonyx variegatus*	A	2	ROCK	Under rock
4/20/23	Yellow-backed Spiny Lizard	*Sceloporus uniformis*	A	1	ROCK	Crawling on boulder
4/20/23	Yellow-backed Spiny Lizard	*Sceloporus uniformis*	A	1	WASH	Hurricane, by Virgin River, on Cottonwood tree
4/24/23	Great Basin Rattlesnake	*Crotalus oreganus lutosus*	A	1	SAND	Coiled
4/24/23	Great Basin Rattlesnake	*Crotalus oreganus lutosus*	A	1	MOTE	Coiled up
4/24/23	Long-nosed Leopard Lizard	*Gambelia wislizenii*	A	1	ROCK, WASH	Basking on sandstone
4/24/23	Western Banded Gecko	*Coleonyx variegatus*	A	1	ROCK	Under rock
4/24/23	Great Basin Rattlesnake	*Crotalus oreganus lutosus*	A	1	ROCK	Coiled
4/25/23	Western Banded Gecko	*Coleonyx variegatus*	A	1	ROCK	Under rock
4/25/23	Western Banded Gecko	*Coleonyx variegatus*	A	1	ROCK	Under sandstone rock
4/25/23	Great Basin Rattlesnake	*Crotalus oreganus lutosus*	A	1	ROCK	moving away/rattling
4/25/23	Zebra-tailed Lizard	*Callisaurus draconoides*	A	2	SAND	Basking
4/27/23	Gila Monster	*Heloderma suspectum*	A	1	SAND	Digging
4/27/23	Common Chuckwalla	*Sauromalus ater obesus*	A	2	ROCK	Basking
4/28/23	Gopher Snake	*Pituophis catenifer*	A	1	ROAD	Moving across Babylon road to east side
5/2/23	Great Basin Collared Lizard	*Crotaphytus bicinctores*	A	1	ROCK	Under rock
5/3/23	Coachwhip	*Masticophis flagellum*	A	1	BLAC	Hiding under bush
5/3/23	Gila Monster	*Heloderma suspectum*	A	1	BLAC, ROCK	Stationary, on sandstone
5/3/23	Gila Monster	*Heloderma suspectum*	A	1	WASH, SAND	Walking

Date	Common Name	Latin Name	Age	#	Substrate	Comments
5/4/23	Great Basin Rattlesnake	*Crotalus oreganus lutosus*	A	1	SAND	Coiled basking
5/8/23	Great Basin Collared Lizard	*Crotaphytus bicinctores*	A	1	ROCK	Basking on basalt boulder
5/8/23	Western Patch-nosed Snake	*Salvadora hexalepis*	A	1	SAND, BLAC	Out in open, under blackbrush
5/8/23	Yellow-backed Spiny Lizard	*Sceloporus uniformis*	A	1	ROCK	Basking on basalt boulder
5/8/23	Coachwhip	*Masticophis flagellum*	A	1	DEPA	In open
5/9/23	Gopher Snake	*Pituophis catenifer*	J	1	BROM	Basking
5/9/23	Long-nosed Leopard Lizard	*Gambelia wislizenii*	A	1	ROCK	Ran under rock
5/9/23	Western Patch-nosed Snake	*Salvadora hexalepis*	A	1	ROCK, CREO	Out in open, moving fast
5/10/23	Gopher Snake	*Pituophis catenifer*	A	1	DEPA, ROAD	Industrial Wash, in old road/trail
5/10/23	Gopher Snake	*Pituophis catenifer*	A	1	ROCK	Basking
5/10/23	Coachwhip	*Masticophis flagellum*	A	1	DEPA, ROAD	In shoulder of the road
5/11/23	Great Basin Rattlesnake	*Crotalus oreganus lutosus*	A	1	SAND	In sand coiled in the open
5/11/23	Great Basin Rattlesnake	*Crotalus oreganus lutosus*	J	1	ROCK	At telemetry site, in burrow with radioed tortoise
5/11/23	Great Basin Rattlesnake	*Crotalus oreganus lutosus*	A	2	DEPA, CREO	Under EPNE, coiled/resting in burrow
5/11/23	Great Basin Collared Lizard	*Crotaphytus bicinctores*	A	1	ROCK	Basking on rock
5/15/23	Common Chuckwalla	*Sauromalus ater obesus*	A	1	ROCK	Basking
5/15/23	Common Chuckwalla	*Sauromalus ater obesus*	A	1	ROCK	Basking
5/15/23	Desert Horned Lizard	*Phrynosoma platyrhinos*	A	1	SAND	Stationary in open
5/15/23	Desert Horned Lizard	*Phrynosoma platyrhinos*	A	1	DEPA	Out in open, on basalt cobble, dark colored
5/17/23	Sidewinder	*Crotalus cerastes*	A	1	SAND	Very fresh tracks, on steep dune
5/17/23	Zebra-tailed Lizard	*Callisaurus draconoides*	A	1	WASH	Running across wash
5/19/23	Long-nosed Leopard Lizard	*Gambelia wislizenii*	A	1	SNAK, SAGE	On sandstone
5/19/23	Great Basin Collared Lizard	*Crotaphytus bicinctores*	J	1	SAGE	On sandstone, by Indigo bush
5/22/23	Long-nosed Snake	*Rhinocheilus lecontei*	A	1	CREO, BLAC	Basking
5/22/23	Great Basin Collared Lizard	*Crotaphytus bicinctores*	A	1	ROCK	Basking
5/22/23	Great Basin Collared Lizard	*Crotaphytus bicinctores*	A	1	ROCK	Basking
5/22/23	Great Basin Collared Lizard	*Crotaphytus bicinctores*	A	1	DEPA	Basking
5/24/23	California Common Kingsnake	*Lampropeltis getula*	A	1	ROCK	Moving, on the crawl
5/24/23	Zebra-tailed Lizard	*Callisaurus draconoides*	A	1	SAGE, SAND	Running into sand sage
5/25/23	Gopher Snake	*Pituophis catenifer*	A	1	SAND	Moving, on the crawl

Appendix 3. Plant species observed on transects including date surveyed, transect number, % cover class, total number of transects present and percent cover class average per species, in both burned and unburned habitat, April 10 to May 30, 2023, Red Cliffs National Conservation Area, Washington County, Utah. Cover class category for each perennial and annual species is as follows: 1=trace, 2=0-1%, 3=1-2%, 4=2-5%, 5=5-10%, 6=10-25%, 7=25-50%, 8=50-75%, 9=75-95%, and 10=>95%.

Common Name	**Latin Name**	**Date Surveyed and Transect Number**															**Total Transects**	**% Cover Class Avg**
		Burned					**Unburned**											
		3-52	**3-33**	**3-49**	**3-26**	**3-79**	**3-11**	**3-38**	**3-55**	**3-50**	**3-14**	**3-36**	**5-4**	**3-133**	**3-142**	**3-114**		
		4/20	4/21	4/24	5/5	5/22	4/10	4/19	4/27	5/8	5/10	5/11	5/15	5/17	5/19	5/30		
Bromus species	*Bromus tectorum, B. madritensis*	7	6	7	5	7	6	5	8	6	7	7	5	8	8	6	15	7
Common stork's bill	*Erodium cicutarium*	7	8	2	6	4	4		8	4	5	4	5	7	5	6	14	5
Snakeweed	*Gutierrezia sarothrae*	3		5	6			6	4	4	3		5	7		5	10	5
Mormon tea	*Ephedra sp.*						2	6	6	6	4	5	5	5			8	5
Small-flowered milkvetch	*Astragulus nuttallianus*	4	3	2	3							3	2	2		2	8	3
Mediterranean grass	*Schismus barbatus*		5		8	6	4	5			8					7	7	6
Range ratany	*Krameria erecta*			4						4	4	3	4	4	5		7	4
Blackbrush	*Coleogyne ramosissima*						4	6	6	6		5		7			6	6
Brittlebush	*Encelia farinosa*			7	4				5	6		6			5		6	6
London rocket	*Sisymbrium irio*	6	6		5						4			3		2	6	4
Wolfberry	*Lycium andersonii*				4		1		6		4		4	1			6	3
Desert marigold	*Baileya multiradiata*	2	2	3	4	5									2		6	3
Shaggyfruit pepperweed	*Lepidium lasiocarpum*			5	2	2				2		2			5		6	3
Creosote	*Larrea tridentata*						6				7			6	5	6	5	6
Desert trumpet	*Eriogonum inflatum*			3	3	5									4	4	5	4
Mariposa lily	*Calochortus flexuosus*		3		3	2				4		2					5	3
Pricklypear	*Opuntia phaeacantha*					2				4				4	5		4	4
Desert four o'clock	*Mirabilis multiflora*		2		3	5									4		4	4
Western tansymustard	*Descurainia pinnata*						2				4	2				4	4	3
White bursage	*Ambrosia dumosa*			5								5			7		3	6

Mormon tea	*Ephedra nevadensis*			4		4									7		3	5
Indigo bush	*Psorothamnus fremontii*	*4*													5	5	3	5
Desert almond	*Prunus fasciculata*					2		5				5					3	4
E. Mojave buckwheat	*Eriogonum fasciculatum*					6								4		2	3	4
Desert primrose	*Oenothera deltoides*	*2*									2					4	3	3
Plantain	*Plantago species*							4		2		2					3	3
Woolly daisy	*Antheropeas wallacei*	*1*						4				2					3	2
Lily (Bluedick/Mariposa)	*Dichelostemma or Calochortus sp*	*1*					2								2		3	2
Rattlesnake spurge	*Euphorbia albomarginata*	*4*												6			2	5
Sand sagebrush	*Artemisia filifolia*							4								6	2	5
Globemallow	*Sphaeralcea ambigua*			4		6											2	5
Whitestem paperflower	*Psilostrophe cooperi*				5										2		2	4
Bluedick lily	*Dichelostemma capitatum*		*2*						4								2	3
Big galleta	*Pleuraphis rigida*					2									4		2	3
Crypthantha sp.	*Cryptantha sp.*			3									2				2	3
Desert sage	*Salvia dorrii*												7				1	7
Singleleaf ash	*Fraxinus anomala*							6									1	6
Bush muhly	*Muhlenbergia porteri*					6											1	6
Spiny hopsage	*Grayia spinosa*								5								1	5
Mojave aster	*Xylorhiza tortifolia*							5									1	5
Desert alyssum	*Lepidium fremontii*								4								1	4
Bluedick lily	*Dichelostemma capitatum*			4													1	4
Scrub oak	*Quercus turbinella*							4									1	4
Cleftleaf wildheliotrope	*Phacelia crenulata*			4													1	4
Purple threeawn	*Aristida purpurea*									4							1	4
Wirelettuce	*Stephanomeria species*														4		1	4
Tumbleweed	*Salsola tragus*				3												1	3
Winterfat	*Krascheninnikovia lanata*											3					1	3
Longspine horsebrush	*Tetradymia axillaris*							2									1	2
Phacelia species	*Phacelia sp.*												2				1	2
Lacepod mustard	*Thysanocarpus curvipes*			2													1	2

Desert chicory	*Rafinesquia neomexicana*			2	1	2
Fluff grass	*Dasyochloa pulchella*	2			1	2
Spectaclepod mustard	*Dimorphocarpa wislizeni*		2		1	2
Funnel lily	*Androstephium breviflorum*		1		1	1