DISTRIBUTION AND DENSITY OF DESERT TORTOISES AT IRONWOOD FOREST NATIONAL MONUMENT, WITH NOTES ON OTHER VERTEBRATES

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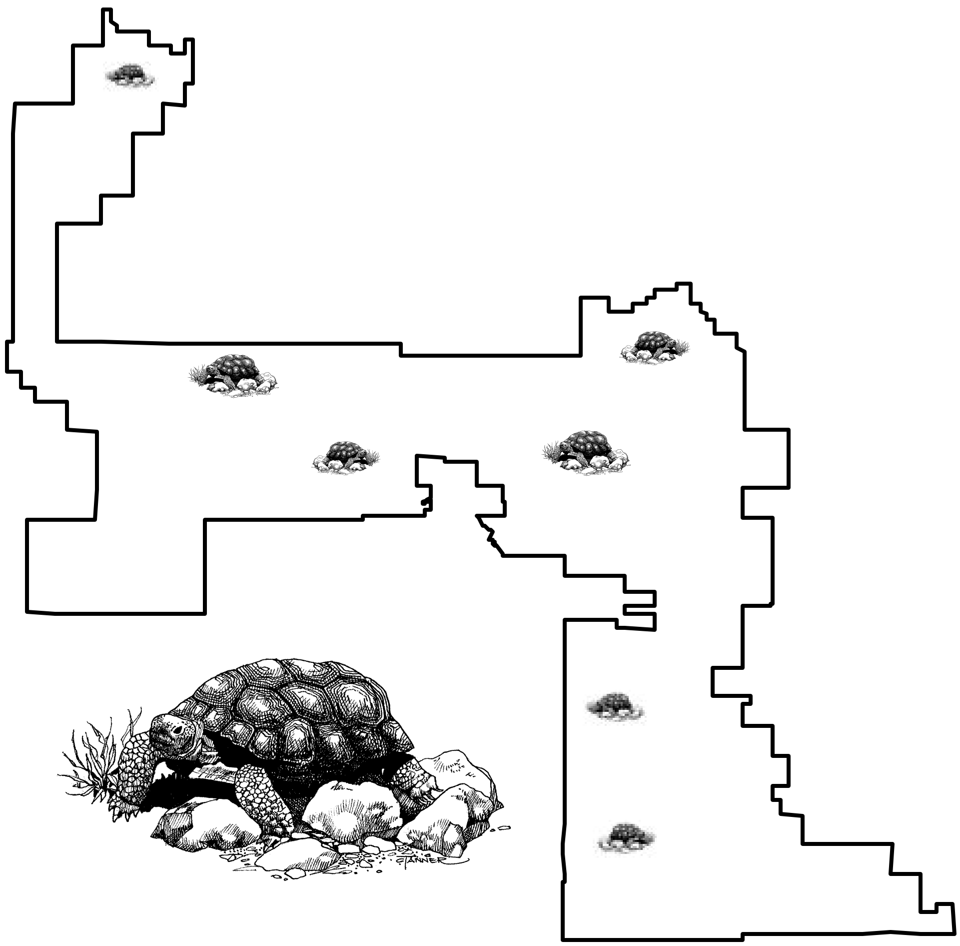

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DISTRIBUTION AND DENSITY OF DESERT TORTOISES AT IRONWOOD FOREST NATIONAL MONUMENT, WITH NOTES ON OTHER VERTEBRATES

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CHAPTER 1: INTRODUCTION

Ironwood Forest National Monument (IFNM), located northwest of Tucson, Pima and Pinal counties, Arizona, was created on 9 June 2000 by presidential proclamation to protect an area with one of the highest densities of ironwood *Olneya tesota* trees in the Sonoran Desert (Clinton 2000). Designation of this area as a National Monument evolved from Pima County's Sonoran Desert Conservation Plan and efforts to balance continued urban development and the habitat requirements of sensitive species.

The U.S. Bureau of Land Management (BLM) Tucson Field Office is responsible for administration of IFNM and preparation of an IFNM management plan by 2004 (Tersey and others 2001). BLM manages the area for recreation (hunting, off-highway vehicle use, and hiking), grazing, and mining (pre-existing claims only), as well as protection of archeological and natural resources. Due to its proximity to Tucson, the monument offers highly accessible recreation opportunities but is vulnerable to the impacts of urban growth. Therefore, BLM must determine how to manage the land and resources under increasing recreation and urban pressure. A pre-IFNM management plan analysis by Tersey and others (2001) addressed the need for monument-wide surveys to determine the distribution and status of certain wildlife species, including the desert tortoise. A 1.6-km^2-tortoise plot in the West Silverbell Mountains has been monitored approximately every 5 years since 1991 (Averill-Murray and Klug 2000), but there is a lack of baseline data on tortoise distribution, density, and habitat use for the entire area that is now IFNM. BLM needs this information in order to make effective management decisions regarding tortoises on the monument. Additionally, a 1996 die-off of tortoises on Ragged Top Mountain in the Silverbell Mountain Range, an area known for its high concentration of desert tortoises, has raised additional concerns about tortoise viability on the monument.

OBJECTIVES

The objectives of this study were several-fold. Primarily, we sought to 1) estimate density and abundance of desert tortoises across IFNM and 2) determine distribution of tortoises across IFNM. In addition to these objectives and due to the intensity and scope of the project, we developed secondary objectives that should provide useful information for management of the monument: 3) determine the extent of the population decline observed at Ragged Top, while searching for signs of disease; 4) record the distribution and density of litter at IFNM, such as wind-blown trash (balloons) and rubbish discarded by undocumented immigrants; and 5) list and record distribution information of other diurnal vertebrates.

SITE DESCRIPTION

IFNM encompasses approximately 76,800 ha, including federal lands (52,232 ha), State Trust lands (22,135 ha), and small private in-holdings (2,433 ha; Tersey and others 2001). The monument encompasses 5 major mountain ranges (Sawtooth, West Silverbell, Silverbell, Waterman, and Roskruge mountains), as well as intervening desert valleys and several smaller ranges (Pan Quemado, Samaniego Hills; Figure 1). The monument is bordered by private land and farmland to the east and north and the Tohono O'odham Nation to the west and south. Additionally, the ASARCO Silver Bell Mine abuts the monument along the south-central edge.

The predominant vegetation is that typical of the Arizona Upland subdivision of the Sonoran Desert, including ironwood, foothill paloverde *Cercidium microphyllum*, white-thorn acacia *Acacia constricta*, velvet mesquite *Prosopis velutina*, saguaro, triangleleaf bursage *Ambrosia deltoidea*, and many *Opuntia* species (Wiens 2000). The intervening desert valleys have vegetation more characteristic of the Lower Colorado River Valley subdivision of the Sonoran Desert, such as creosotebush *Larrea tridentata* and white bursage *Ambrosia deltoidea* (Wiens 2000). Within the Arizona Upland subdivision are desert arroyos characterized by ephemeral water and denser vegetation. Some plant species, such as blue paloverde *Cercidium floridum* are found almost entirely, if not exclusively, in these washes (Wiens 2000).

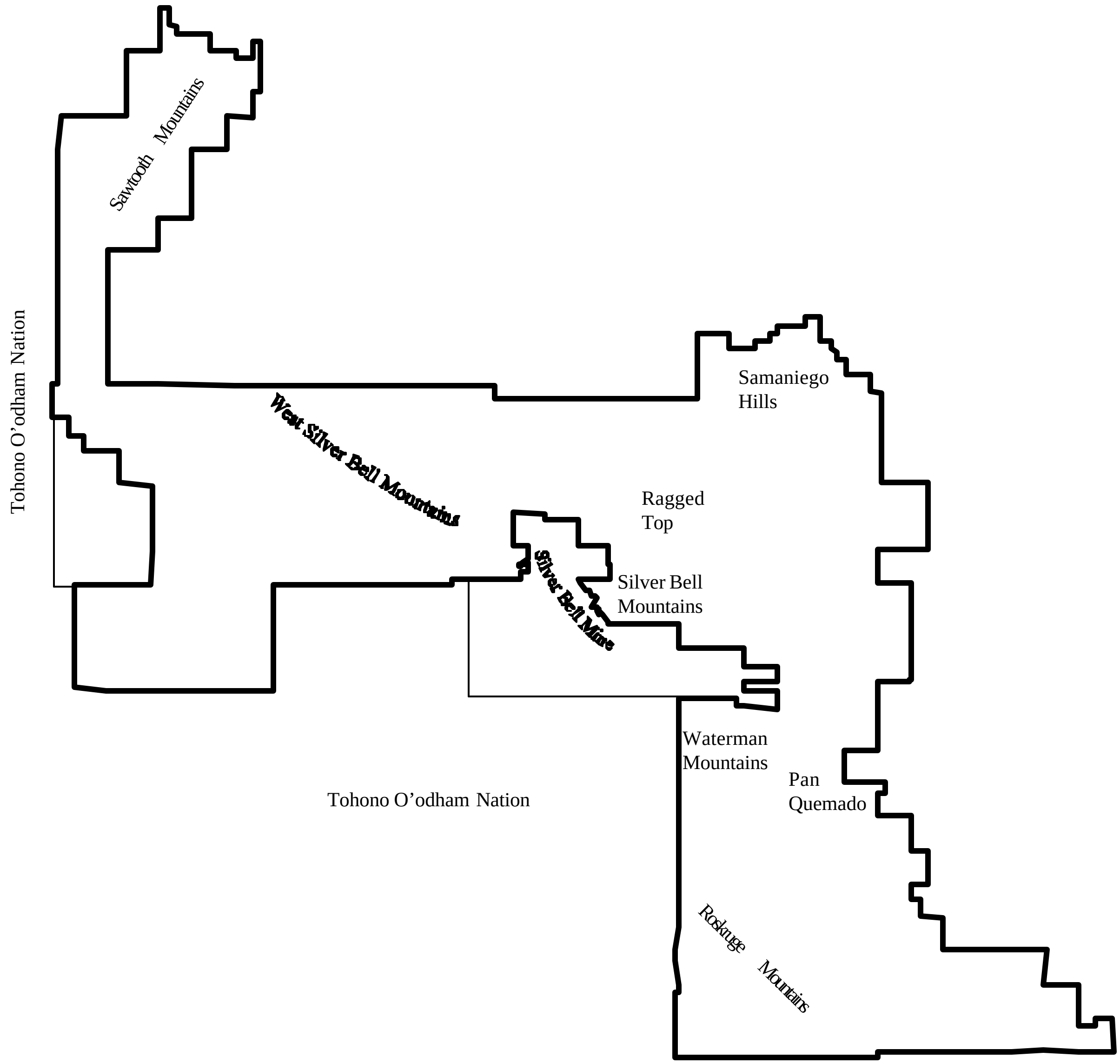

Figure 1. Mountain ranges on Ironwood Forest National Monument.

CHAPTER 2: DISTRIBUTION AND DENSITY OF DESERT TORTOISES

BLM has categorized the habitat on and around IFNM for desert tortoises based on transects conducted from 1978 to 1991 (T. Cordery, personal communication 2002; Figure 2). These habitat categories are based on 4 criteria: 1) importance of the habitat to maintaining viable populations, 2) resolvability of management conflicts, 3) perceived desert tortoise density, and 4) population status (Table 1; BLM 1988). These previously-surveyed transects resulted in counts of tortoises and tortoise sign, but they did not yield quantified estimates of tortoise density. The primary objectives of our study were to 1) estimate density and abundance of desert tortoises across IFNM and 2) further determine distribution of tortoises across IFNM. In accomplishing these objectives, we also sought to 3) document recent mortality and signs of disease across the monument.

Table 1. Goals and criteria for BLM's desert tortoise habitat categorization (BLM 1988).

Item	Category 1	Category 2	Category 3
Category Goals	Maintain stable, viable populations and protect existing tortoise habitat values; increase populations, where possible	Maintain stable, viable populations and halt further declines in tortoise habitat values	Limit tortoise habitat and population declines to the extent possible by mitigating impacts
Criterion 1	Habitat area essential to maintenance of large, viable populations	Habitat area may be essential to maintenance of viable populations	Habitat area not essential to maintenance of viable populations
Criterion 2	Conflicts resolvable	Most conflicts resolvable	Most conflicts not resolvable
Criterion 3	Medium to high density or low density contiguous with medium or high density	Medium to high density or low density contiguous with medium or high density	Low to medium density not contiguous with medium or high density
Criterion 4	Increasing, stable, or decreasing populations	Stable or decreasing populations	Stable or decreasing populations
Area on IFNM (uncategorized: 23,127 ha)	6,970 ha	17,673 ha	29,016 ha

We accomplished our first objective by surveying for tortoises using distance sampling (Burnham and others 1980; Buckland and others 2001). This method uses measured distances between sampled objects and a central point or line (that is, transect), and a set of assumptions regarding detectability to estimate population density. Measured distances allow for the creation of a detection function, a curve with object detectability decreasing with increasing distance from the centerline. This function allows for the estimation of the number of objects that remained undetected during the surveys.

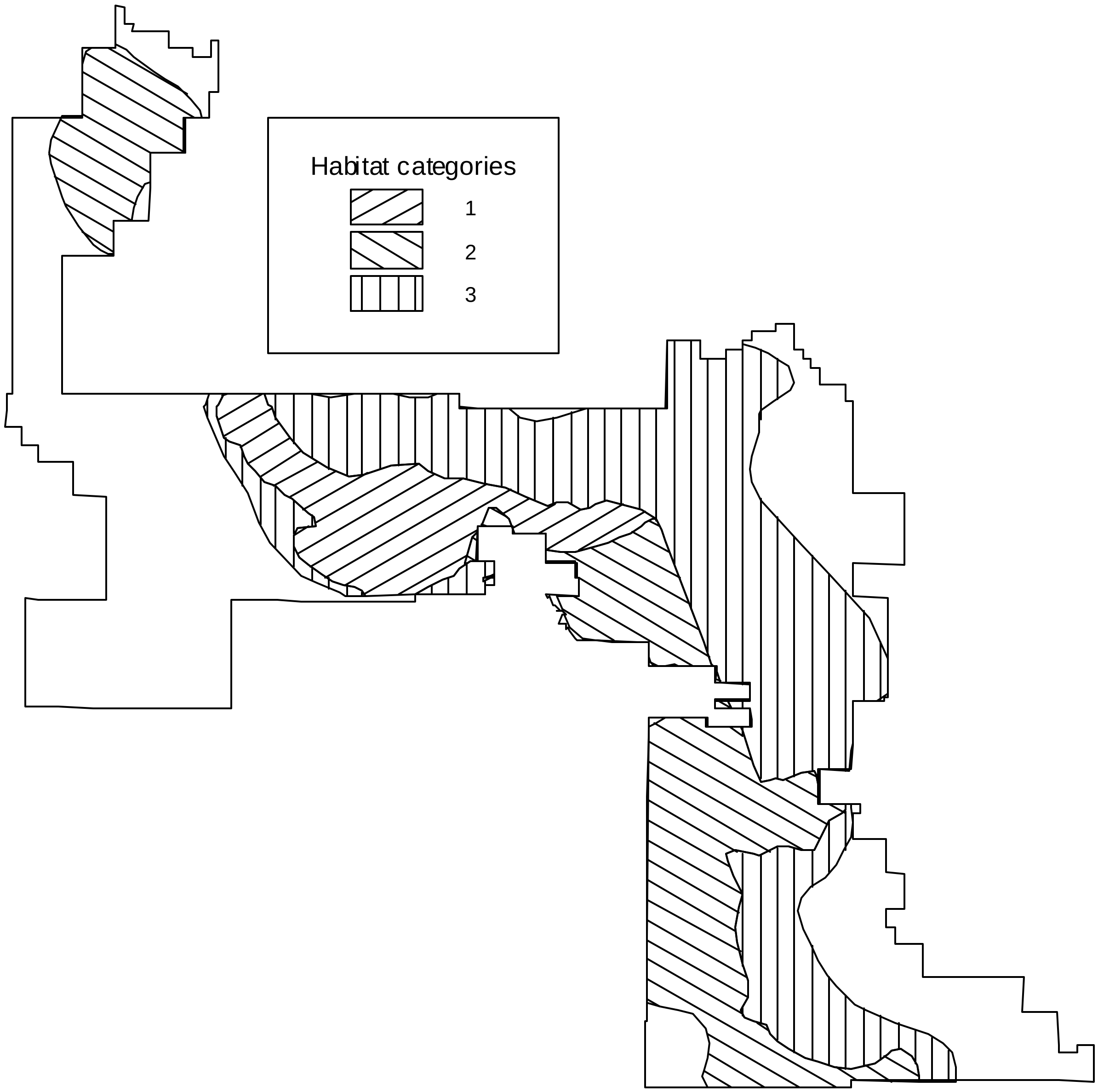

Figure 2. BLM desert tortoise habitat categories on Ironwood Forest National Monument.

We determined tortoise distribution across IFNM from the distance-sampling results, as well as from observations of tortoises and sign we made incidental to the transect surveys, from third-party observations, and from historical data. We also took note of tortoise carcasses, and we examined all live tortoises for symptoms of disease.

METHODS

SAMPLING DESIGN

We established 120 one-km transects across IFNM, randomly located but stratified according to BLM's desert tortoise habitat categorization (Figure 2). Each transect was a square measuring 250 m (map distance) on each side. We randomly located 69 (57.5%) transects in combined categories 1 and 2 (hereafter, Category 1-2), 38 (31.7%) in Category 3, and 13 (10.8%) in uncategorized (Category 0) habitat (Appendix 1). We had to shift or move the location of 14 transects because they either fell partially off monument land or across a sheer cliff face.

We surveyed for desert tortoises on 53 days between 16 July and 11 October 2001, which coincides with the Sonoran Desert monsoon season and the period of greatest tortoise activity (Averill-Murray and others 2002). We tried to visit each transect once during this period, but fell slightly short of the goal (108.25 km surveyed). Because our study site was large and some areas were not easily accessible, we did not randomly select the order in which to survey transects. We did, however, select transects such that each major area of the monument (for example, mountain range) was surveyed periodically throughout the study.

DENSITY AND ABUNDANCE

Distance Sampling Survey Protocol

We surveyed for tortoises in the morning (74.95 km) and evening (33.3 km). The majority of morning surveys were conducted between 0630 hr and 1200 hr, and the majority of evening surveys were conducted between 1630 hr and 1830 hr, with exact times depending on weather conditions, sunrise/sunset, and travel distance from camp. Transects were primarily surveyed by 3 people with experience in herpetology or wildlife biology and with previous training in the survey methodology. Twenty-five other biologists either worked or volunteered for one or more days on the project.

Field technicians worked in pairs, surveying 50-m stretches of transect at a time. Technicians navigated to a corner point of the square (that is, transect) using a Global Positioning System (GPS) receiver (Garmin GPS 12) and marked the spot with flagging. One field technician dragged a 50-m fiberglass tape along one edge of the square, following a straight north-south or east-west line using the GPS receiver as a guide. After stretching out the tape, the technician walked back toward the origin in a sinusoidal pattern on his or her right side of the tape while searching for tortoises. Meanwhile, a second field technician walked in a similar sinusoidal pattern on the opposite side of the tape, heading toward the end of the tape. Anderson and others (2001) recommended expending more search effort near the centerline in areas with dense vegetation and uneven topography, so we instructed technicians to concentrate their searches within 5 m of the centerline. However, surveyors routinely searched beyond 5 m as they navigated around dense vegetation and scanned outward for tortoises or potential burrows. Upon reaching their respective ends of the 50-m tape, one field technician stretched the tape another 50 m while the other technician walked directly along the tape, ensuring that no tortoises on the centerline were missed. Technicians repeated this process 20 times, 5 times for each side of the square. Because of drift in GPS coordinates, topography, and obstacles such as rock outcrops and vegetation, it was frequently difficult to maintain a straight line and reach the corner with 5 pulls of the 50-m tape. We used the GPS receiver to determine the location of the mapped corner, measured the distance from the end of the tape to the mapped corner, and surveyed any remaining area if we fell short.

We searched visually for tortoises, scanning open ground and looking under vegetation and in rocky crevices and underground holes. We used supplemental light (flashlight, reflected sunlight) as needed, but did not probe burrows for tortoises that were out of sight due to variability in tortoise response to "tapping" (Medica and others 1986). We measured the perpendicular distance to the nearest centimeter between the tortoise and the survey tape and recorded location (UTM coordinates) using a GPS receiver. We extracted tortoises found inside shelter sites by hand or by using a snake hook. We measured midline carapace length (MCL) of each tortoise using calipers and a ruler, identified sex (juvenile if MCL <180 mm), and gave each tortoise a unique mark by notching the marginal scutes (Appendix 2). Lastly, we assessed health by visually inspecting for signs of upper respiratory tract disease (URTD; Jacobson and others 1991) and shell abnormalities. We wore latex gloves while handling tortoises and washed equipment with the veterinary disinfectant chlorhexidine diacetate (Nolvasan, American Home Products Corporation, Madison, NJ) after processing each tortoise. If we were unable to extract a tortoise from a burrow, we estimated whether its MCL was greater or less than 150 mm. Tortoises with a MCL <150 mm are more easily overlooked, so they were not included in data analysis.

Distance Sampling Assumptions

Unbiased density estimation using distance sampling rests on 3 major assumptions: 1) objects on the centerline are always detected; 2) objects are detected at their initial location, prior to movement in response to the observer; and 3) perpendicular distances are measured accurately (Buckland and others 2001). In using the distance sampling approach for desert tortoises, the latter 2 assumptions are relatively easy to meet. Desert tortoises generally do not move in response to approaching observers, and perpendicular distances can be accurately measured if the centerline is clearly marked (Anderson and others 2001). However, field protocols must address the first assumption.

Because desert tortoises spend a significant amount of time underground, it may be impossible to detect all tortoises on the centerline regardless of how thoroughly the area is searched. Therefore, the proportion of the population visible must be independently estimated to meet the first assumption. To determine tortoise detectability (g_0) at IFNM- that is, the proportion of time that a tortoise would be visible to an observer during distance sampling, with or without supplemental light- we affixed radio transmitters to 10 individuals and tracked them concurrently with transect surveys.

We chose Ragged Top as the radio-telemetry site due to its central location on the monument (Chapter 1, Figure 1) and known concentration of tortoises. On 30 June and 1 July 2001, volunteers located 7 tortoises large enough (>150 mm MCL) for transmitters. We found an additional tortoise the following week and the remaining 2 tortoises by mid-August. Of these tortoises, 5 were female and 5 were male; MCL ranged from 185 to 256 mm. We affixed transmitters (AVM Instrument Company, Colfax, CA; Advanced Telemetry Solutions, Isanti, MN) to the right front (for females and some males) or rear (for males only) of the carapace with quick-drying epoxy.

We tracked tortoises using a directional antenna and receiver (Telonics Model TR-2, Mesa, AZ) on 30 of the 50 mornings (60%) and 21 of the 38 evenings (55%) that we also conducted distance sampling. We did not track all tortoises during each session and only counted sessions in which more than 4 tortoises were found (morning average = 8.3 $\pm$ 1.46 SD, n = 28; evening average 6.0 $\pm$ 1.88, n = 18). Tortoises not found during a morning session were located that evening, and tortoises not found one evening were located the following evening when possible. When we located a tortoise, we recorded whether it was visible with the naked eye, supplemental light, or not at all. We also recorded tortoise activity and the location of all tortoises and carcasses using a GPS receiver.

We calculated tortoise detectability (g_0) as the mean daily proportion of tortoises visible with the naked eye or supplemental light during morning surveys, evening surveys, and overall. We estimated the standard error of g_0 as the mean of the daily binomial standard errors of the proportion visible (Zar 1984). We used g_0 as a correction factor in estimating the detection probability curve, from which density is computed (see below).

<u>Computation</u>

We used Program DISTANCE 3.5 (Thomas and others 1998) to estimate density of tortoises ≥150 mm MCL. We used the detection-function models (key function/series expansion) recommended by Buckland and others (2001): uniform/cosine, uniform/simple polynomial, half-normal/cosine, half-normal/hermite polynomial, hazard-rate/cosine, and hazard-rate/simple polynomial. We first applied the uniform/cosine model to the complete data set. We truncated 5% of the largest observations (n = 2; Buckland and others 2001) to eliminate spikes on the tail of the curve and improve model fit. We ran preliminary analyses with the data grouped into intervals (6, 8, and 10 m) in an effort to smooth the curve. At best, these groupings only slightly improved the fit of the model; therefore, we used the ungrouped data after truncation for our final analysis. We analyzed the data 3 ways: without stratification, stratified by BLM habitat categories (pre-stratified), and stratified by natural habitat categories based on landscape features beneficial to tortoises (post-stratified; see below). We chose the best-fitting model as that with the lowest Akaike Information Criterion (AIC; Buckland and others 2001). Density variance was computed by Program DISTANCE with 999 bootstrap samples; upper and lower confidence intervals (CIs) were taken as the 2.5% and 97.5% quantiles of the bootstrap estimates. Program DISTANCE converted density estimates to estimates of absolute abundance based on the study area of 767.9 km^2 (76,790 ha). Abundance estimates were given by stratum and overall.

Post-stratification of Transects by Landscape Features

During surveys, we noticed a high level of heterogeneity in vegetation composition, landscape structure, and tortoise encounter rates *within* BLM tortoise habitat categories and we recognized that this could potentially nullify our pre-stratification efforts. Because it might be beneficial to stratify based on topography, we noted landscape features beneficial to desert tortoises on each transect, such as the presence of boulders or incised washes. At the end of the field season, we post-stratified the transects into 3 categories based on these features: Category B, characterized by steep topography with boulders; Category W, characterized by incised washes and few to no boulders (with or without topographic relief); and Category X, characterized by the absence of incised washes and boulders (Figure 3; Appendix 1). A transect was considered type B or W if any portion of the transect met the above criteria; therefore, these landscape features were not necessarily the primary component of a transect.

DESCRIBING TORTOISE DISTRIBUTION WITHIN IFNM

Tortoise Carcasses and Sign

We noted all tortoise carcasses found on IFNM, including partial skeletons and isolated scutes, and recorded UTM coordinates using a GPS receiver. If a plastron was present, we tried to determine sex of the deceased tortoise. Additionally, we noted any sign of tortoises on transects surveyed for density estimation, including scat, tracks, pallets, and burrows likely excavated by tortoises. If there were no tortoises or tortoise sign on a survey, we noted any sign seen nearby.

Incidental and Third-Party Sightings

We recorded the location (UTM coordinates) of all tortoises found off density-estimation transects, which consisted primarily of those found in transit to transects or while conducting telemetry on Ragged Top. We measured MCL, determined sex, marked each tortoise with a unique number, and performed a brief health assessment. Additionally, we recorded the location of tortoise carcasses found off transects. Other biologists (M. Fredlake, BLM; T. Van Devender, Arizona-Sonora Desert Museum [ASDM]) also supplied us with records of tortoises and tortoise sign observed on IFNM in 2001. We used both the incidental and third-party sightings to supplement our data on the distribution of tortoises on IFNM.

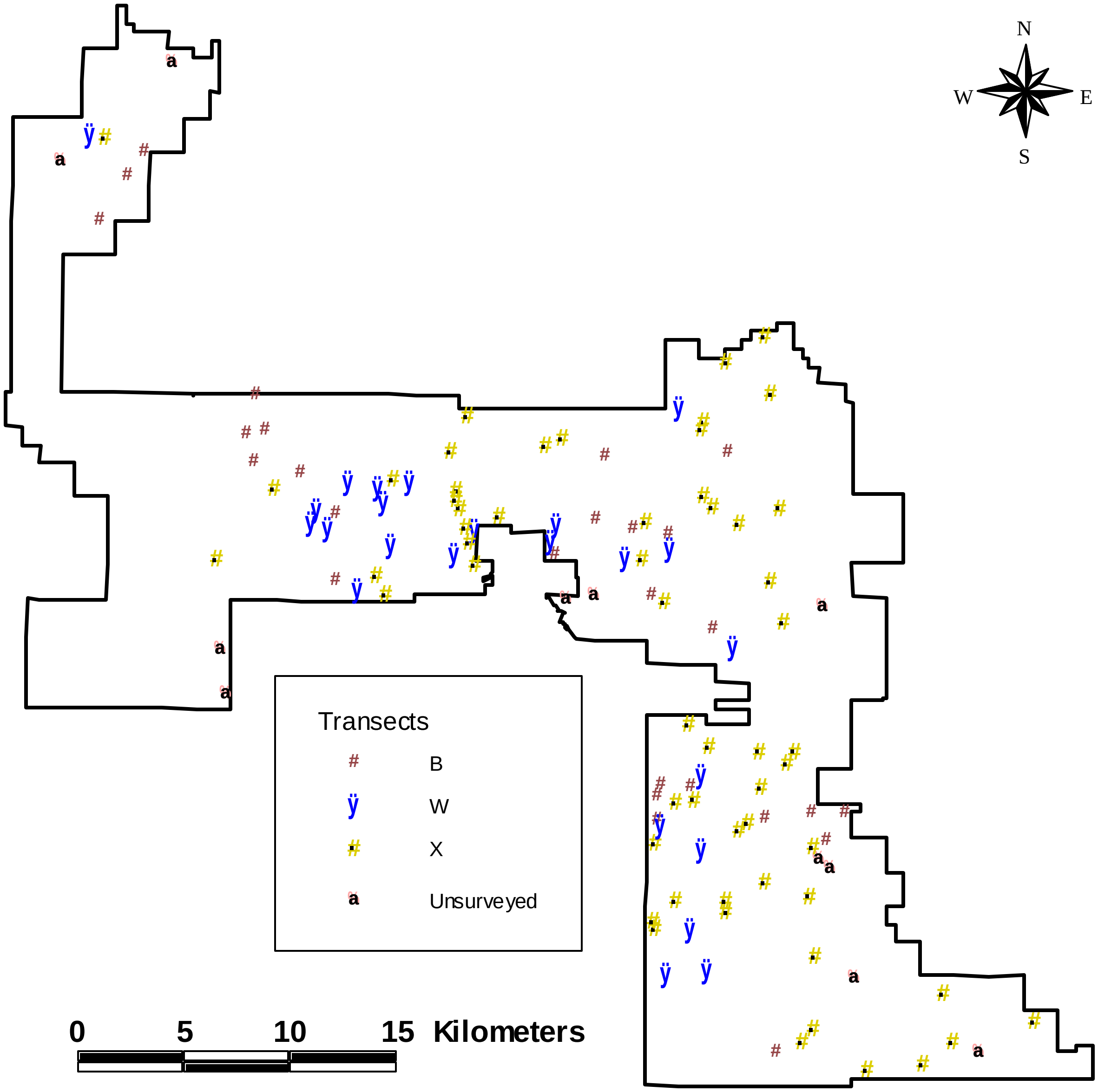

Figure 3. Distance-sampling transects on Ironwood Forest National Monument. Category B - steep topography with boulders; Category W - incised washes, few to no boulders (with or without topographic relief); Category X - absence of incised washes and boulders.

RESULTS

We surveyed 66 transects in combined BLM habitat categories 1-2, 35 in Category 3, and 8 in uncategorized habitat (Category 0; Appendix 1). When we post-stratified these transects according to landscape features, over half of them (n = 59; 54%) randomly fell in Category X, characterized by a lack of boulders and incised washes. The remaining transects were relatively evenly split between categories B (n = 26) and W (n = 24). Transects in Category X made up the highest proportion within BLM categories 1-2 (40%), 3 (71%), and 0 (100%) (Table 2).

Table 2. Comparison of survey effort by stratum and of tortoises and tortoise sign observed by pre- and post-stratified habitat categories on Ironwood Forest National Monument, 2001.

Natural Habitat Category[1]	Tortoises[2]	Tortoise Sign[3]
BLM 1-2[4]		
B: 20.00 km (30%)	10 (50%)	18 (90%)
W: 20.00 km (30%)	8 (40%)	13 (65%)
X: 26.00 km (40%)	1 (4%)	7 (27%)
Overall: 66.00 km	19 (29%)	38 (58%)
BLM 3[4]		
B: 6.00 km (17%)	1 (14%)	6 (100%)
W: 4.00 km (12%)	2 (50%)	4 (100%)
X: 24.75 km (71%)	0 (0%)	7 (28%)
Overall: 34.75 km	3 (9%)	17 (49%)
BLM 0[4]		
B: 0.00 km	-----	-----
W: 0.00 km	-----	-----
X: 7.5 km (100%)	1 (13%)	1 (13%)
Overall: 7.50 km	1 (13%)	1 (13%)
Overall		
B: 26.00 km (24%)	11 (42%)	24 (92%)
W: 24.00 km (22%)	10 (42%)	17 (71%)
X: 58.25 km (54%)	2 (3%)	15 (25%)

[1]Kilometers surveyed (% of total) per habitat category. Category B - steep topography with boulders; Category W - incised washes, few to no boulders (with or without topographic relief); Category X - absence of incised washes and boulders. Proportion within each BLM category given in parentheses.
[2]The number and percent of transects per category on which we found desert tortoises.
[3]The number and percent of transects per category on which we found tortoise sign (includes live tortoises).
[4]Pre-stratified categories are defined by BLM (1988), with BLM 0 as uncategorized.

TORTOISE DENSITY AND ABUNDANCE

We observed 36 subadult-adult ($\geq$180 mm MCL) and 6 juvenile (<180 mm MCL) tortoises on 23 transects on IFNM (Appendix 3; Figure 4). We found 31 tortoises during morning surveys (39% of transects surveyed) and 12 tortoises during evening surveys (30% of transects surveyed). We found one tortoise (Female 532) on each of two visits to transect 35 (Appendix 3). We observed 19 males and 15 females, excluding juveniles and 2 individuals that we could not extract from burrows. Carapace length ranged from 115 to 265 mm; 39 tortoises had a MCL >150 mm and were subsequently used in DISTANCE analysis (see below). We found tortoise sign on 31 transects on which we did not find live tortoises (Appendix 1; Figure 4).

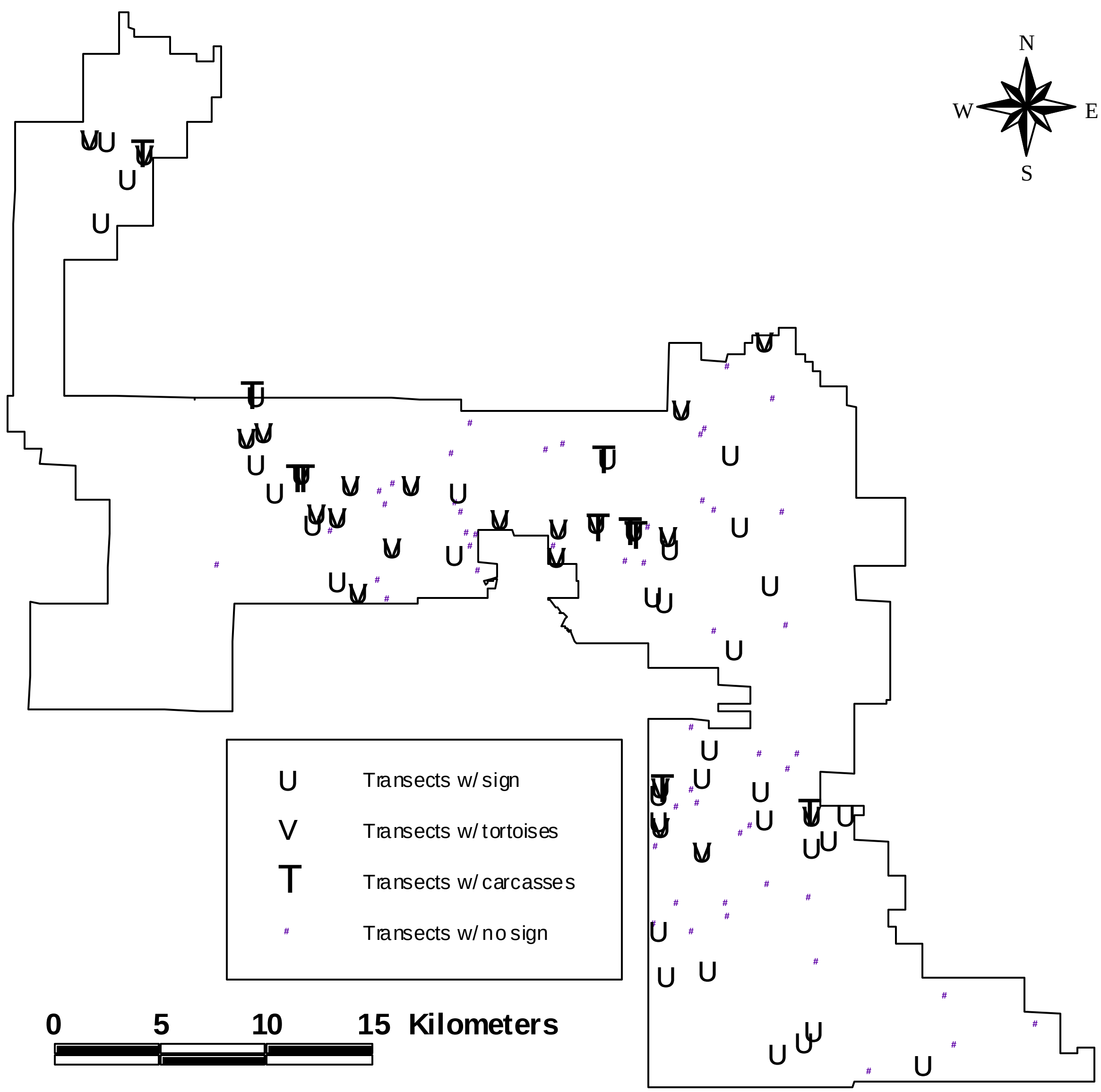

Figure 4. Desert tortoises and tortoise sign recorded during distance sampling at Ironwood Forest National Monument, 2001.

The mean overall proportion of tortoises visible during radio telemetry throughout the study was 0.83 ± 0.119 SE. The mean proportion visible was higher and less variable for evening surveys (0.92 ± 0.068) than morning surveys (0.78 ± 0.152). We used the overall proportion in DISTANCE as a correction factor (g_0), because sample sizes were too small to run separate analyses for morning and evening surveys.

The uniform/cosine model resulted in the best fit for the data (AIC = 190.68; Figure 5). The hazard rate and half-normal models followed with AIC = 191.10; DISTANCE determined that the series expansions were not required for either key function. The uniform/simple polynomial model provided the worst fit (AIC = 192.65). The effective strip width (the distance from the centerline beyond which the number of tortoises detected equals the number undetected toward the centerline) was 8.8 m (CV = 10.9%, 95% CI = 7.0-11.0). In the unstratified analysis, the estimated encounter rate for tortoises was 0.34 tortoises/km (Table 3). In the pre-stratified analysis, Category 1-2 had the highest encounter rate with 0.47 tortoises/km over 66 km. Categories 3 and 0 had encounter rates of 0.14 and 0.13 tortoises/km, respectively; however, search effort was much different (34.75 km versus 7.50 km). Post-stratification resulted in fairly similar estimated encounter rates for natural habitat categories B (0.77 tortoises/km) and W (0.62 tortoises/km), which had similar effort (26 km versus 24 km), compared to the much lower 0.03 tortoises/km in category X (58.25 km).

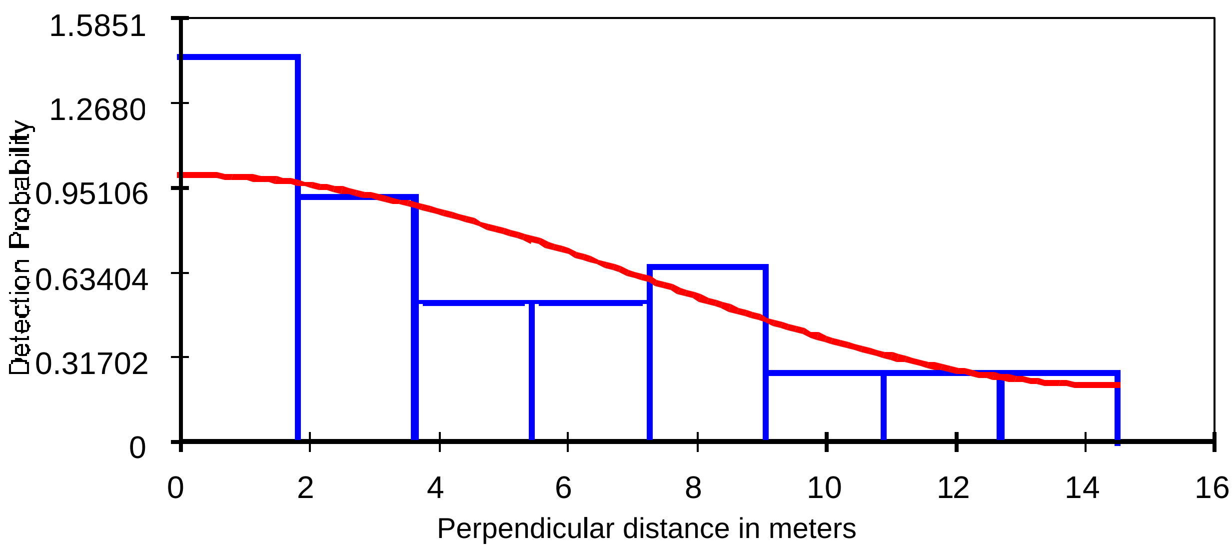

Figure 5. Detection probability plot for the uniform-cosine model for desert tortoises at Ironwood Forest National Monument, 2001 (P = 0.7720).

Table 3. Distance sampling results for desert tortoises on Ironwood Forest National Monument, 2001. Estimates are followed by %CV and 95% confidence intervals (2.5% and 97.5% quantiles for D and N).

Stratum[1]	n/L[2]	D[3]	N[4]
Unstratified			
Overall 108.25 km	0.34 26.4% 0.20-0.57	0.23 41.6% 0.13-0.50	17,997 41.5% 9616-38,757
Pre-stratified			
BLM 1-2 66.00 km	0.47 25.7% 0.28-0.78	0.32 41.4% 0.16-0.67	7937 41.4% 3836-16,474
BLM 3 34.75 km	0.14 64.8% 0.04-0.48	0.10 75.9% 0.00-0.29	2863 75.9% 0-8426
BLM 0 7.50 km	0.13 96.4% 0.02-0.91	0.09 109.6% 0.00-0.35	2114 109.7% 0-8063
Pooled Categories 108.25 km	---	0.17 43.9% 0.08-0.35	12,914 43.9% 5783-27,024
Post-stratified			
B 26.00 km	0.77 35.8% 0.38-1.56	0.53 47.3% 0.23-1.22	40,503 47.3% 17,654-93,717
W 24.00 km	0.62 31.8% 0.33-1.18	0.43 42.8% 0.15-0.84	32,909 42.8% 11,590-64,379
X 58.25 km	0.03 67.9% 0.01-0.12	0.02 94.1% 0.00-0.08	1808 94.1% 0-6449
Pooled Categories 108.25 km	---	0.23 37.2% 0.12-0.46	17,997 37.2% 9394-35,414

[1]Total transect lengths per stratum are indicated. Pre-stratified categories are defined by BLM (1988), with BLM 0 as uncategorized. Post-stratified categories: B, steep topography with boulders; W, incised washes and few to no boulders (with or without topographic relief); and X, absence of incised washes and boulders.
[2]Encounter rate, tortoises/km.
[3]Bootstrapped density estimates of tortoises ≥150 mm MCL per hectare.
[4]Bootstrapped abundance estimates of tortoises ≥150 mm MCL, based on the area of IFNM (76,790 ha).

Unstratified analysis resulted in a density estimate of 0.23 tortoises/ha with poor precision (CV = 41.6%) and an estimate of 17,997 tortoises (CV = 41.5%) across the monument (Table 3). The overall estimates from the pre-stratified analysis were lower (0.17 tortoises/ha; 12,914 tortoises overall) and slightly less precise (CV = 43.9%). Estimates ranged from 0.09 tortoises/ha (2114 tortoises) in Category 0 to 0.32 tortoises/ha (7937 tortoises) in Category 1-2. Categories 3 and 0 had very similar density estimates, and both categories had extremely high variability (CV > 75%; Table 3). The pooled density estimate in the post-stratified analysis was based on weighting by search effort in each stratum, because stratum areas were not available. Therefore, the pooled, post-stratified estimate was equal to that from the unstratified analysis (0.23 tortoises/ha), but precision was improved (CV = 37.2%). The variance was extremely high for estimates from each of the habitat categories (CV > 42%; Table 3), but density is much greater where tortoises have boulders or incised washes for shelter. Abundance estimates for each natural habitat category should be viewed with caution, since they are based on effort instead of actual habitat area.

In the unstratified analysis, component percentages of density variance were 68.2% for encounter rate, 20.1% for g_0, and 11.7% for detection probability (that is, the fit of the detection function) (Table 4). Encounter rate also contributed the most to density variances when we analyzed the data by stratum: 67.0-96.6% in the pre-stratified analysis and 75.7-93.4% in the post-stratified analysis. Detection probability contributed least in all cases ($\leq$12.1%), indicating that our curve fit well relative to other sources of variation.

Table 4. Component percentages of variation in desert tortoise density estimates.

Stratum[1]	Detection probability	Encounter rate	*g0*
Unstratified			
Overall	11.7	68.2	20.1
Pre-stratified			
BLM 1-2	12.1	67.0	20.9
BLM 3	2.6	92.8	4.5
BLM 0	1.2	96.6	2.1
Post-stratified			
B	7.4	79.7	12.8
W	9.0	75.7	15.4
X	2.4	93.4	4.2

[1]Pre-stratified categories are defined by BLM (1988), with BLM 0 as uncategorized. Post-stratified categories: B, steep topography with boulders; W, incised washes and few to no boulders (with or without topographic relief); and X, absence of incised washes and boulders.

TORTOISE DISTRIBUTION

Although the majority of tortoises and tortoise sign found on transects occurred in BLM Category 1-2 (Appendix 1), these were almost entirely found in areas with boulders or incised washes (Table 2). We found tortoises or tortoise sign on only 58% of transects in BLM Category 1-2 and 49% of Category 3, due to the high proportion of transects falling in areas without boulders or incised washes. We found tortoises and sign on only 13% of transects in BLM

Category 0. Overall, we found tortoises or sign on 92% of the transects with boulders, 71% with incised washes, and 25% with neither of these habitat features (Table 2).

We found tortoises on all major mountain ranges and hill complexes on the monument with the exception of Malpais Hill and the Roskruge Mountains, although we did find tortoise sign on 7 transects in the Roskruges (Table 5). We encountered tortoises with greater frequency in the Sawtooth, West Silverbell, and Silverbell mountains and less often in the Samaniego Hills, Waterman Mountains, and Pan Quemado (Table 5).

Table 5. Tortoises and tortoise sign by mountain range on Ironwood Forest National Monument, 16 July – 11 October 2001.

Mountain Range[1]	Transect With: Tortoises (n)	Transect With: Tortoise Sign	Encounter Rate[2]	Incidentals[3]
West Silverbell Mountains 29.50 km	10 (20)	17	0.68	6
Sawtooth Mountains 5.00 km	2 (3)	5	0.60	1
Silverbell Mountains 18.75 km	5 (10)	10	0.53	7 (45)*
Samaniego Hills 11.00 km	2 (4)	4	0.36	1
Waterman Mountains 17.00 km	3 (5)	9	0.29	0
Pan Quemado 6.00 km	1 (1)	4	0.17	2
Roskruge Mountains 19.00 km	0	6	0.00	2
Malpais Hill 2.00 km	0	0	0.00	0
Total	23 (43)	55	-----	-----

[1]Including surrounding valleys.
[2]Number of tortoises per transect km. One individual tortoise in the West Silverbells was encountered twice.
[3]Number of times tortoises were seen incidental to transect surveys. The same tortoise may have been seen on more than one occasion. *In the Silverbell Mountains, the number in parentheses represents encounters of tortoises incidental to radio telemetry at Ragged Top.

University of Arizona and Arizona Game and Fish Department (AGFD) personnel marked 9 tortoises at Ragged Top in 2000 during genetics and health sampling. In 2001 we marked 39 tortoises at Ragged Top during telemetry and transect surveys, and we recaptured 4 of those marked in 2000. A total of 48 tortoises (17 males, 14 females, 17 unsexed), ranging in MCL from 95 to 267 mm, have been marked at Ragged Top through 2001 (Figure 6; Appendix 3). Outside of Ragged Top, we found 18 tortoises incidental to transect surveys across IFNM in 2001 (Figure 7), including 12 males, 2 females, 2 juveniles, and 2 of unknown sex and/or age

(Appendix 3). MCL ranged from 139 to 284 mm. We found incidental tortoises in several areas of the monument with few tortoises on transects: Roskruge Mountains, Pan Quemado, and in the flats east of the Silverbell Mountains (Table 5; Figure 7).

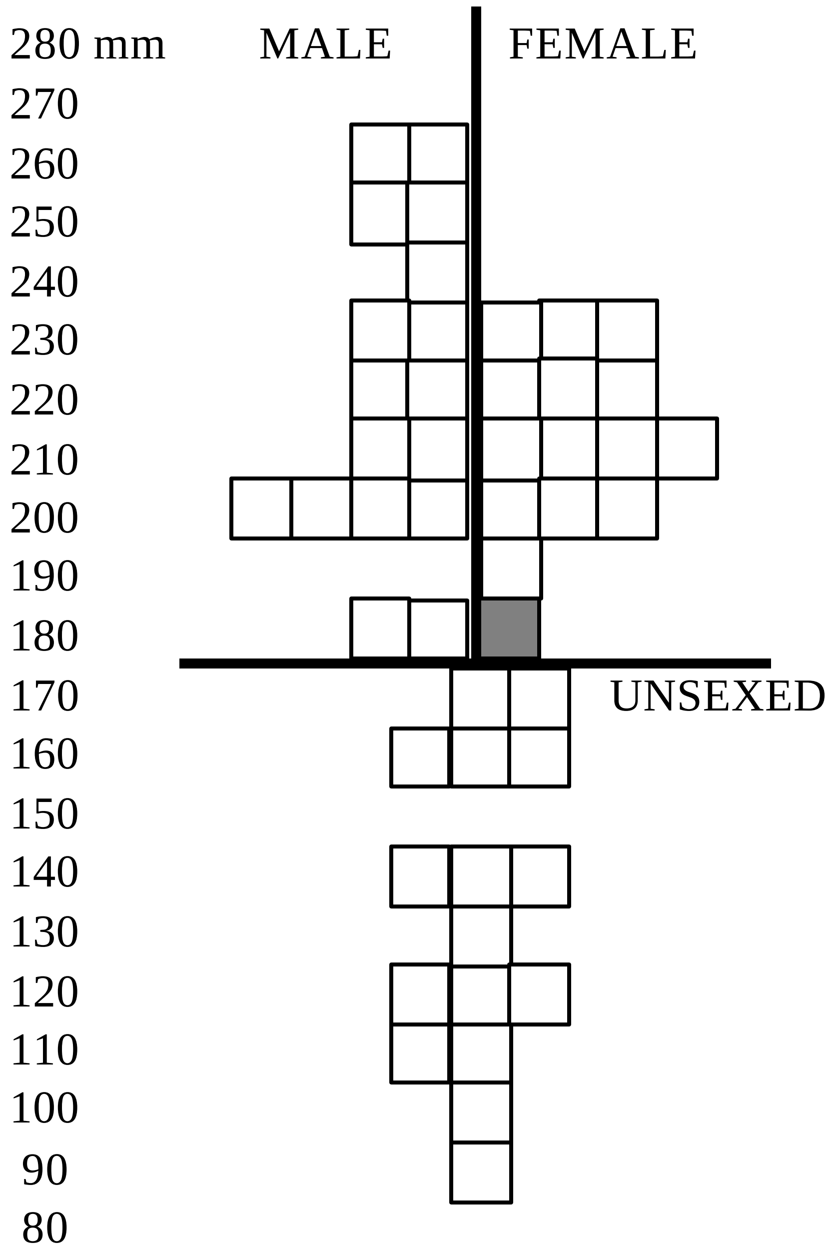

Figure 6. Size histogram for desert tortoises marked at Ragged Top, 2000-2001. The shaded box is an unsexed individual with MCL = 180 mm.

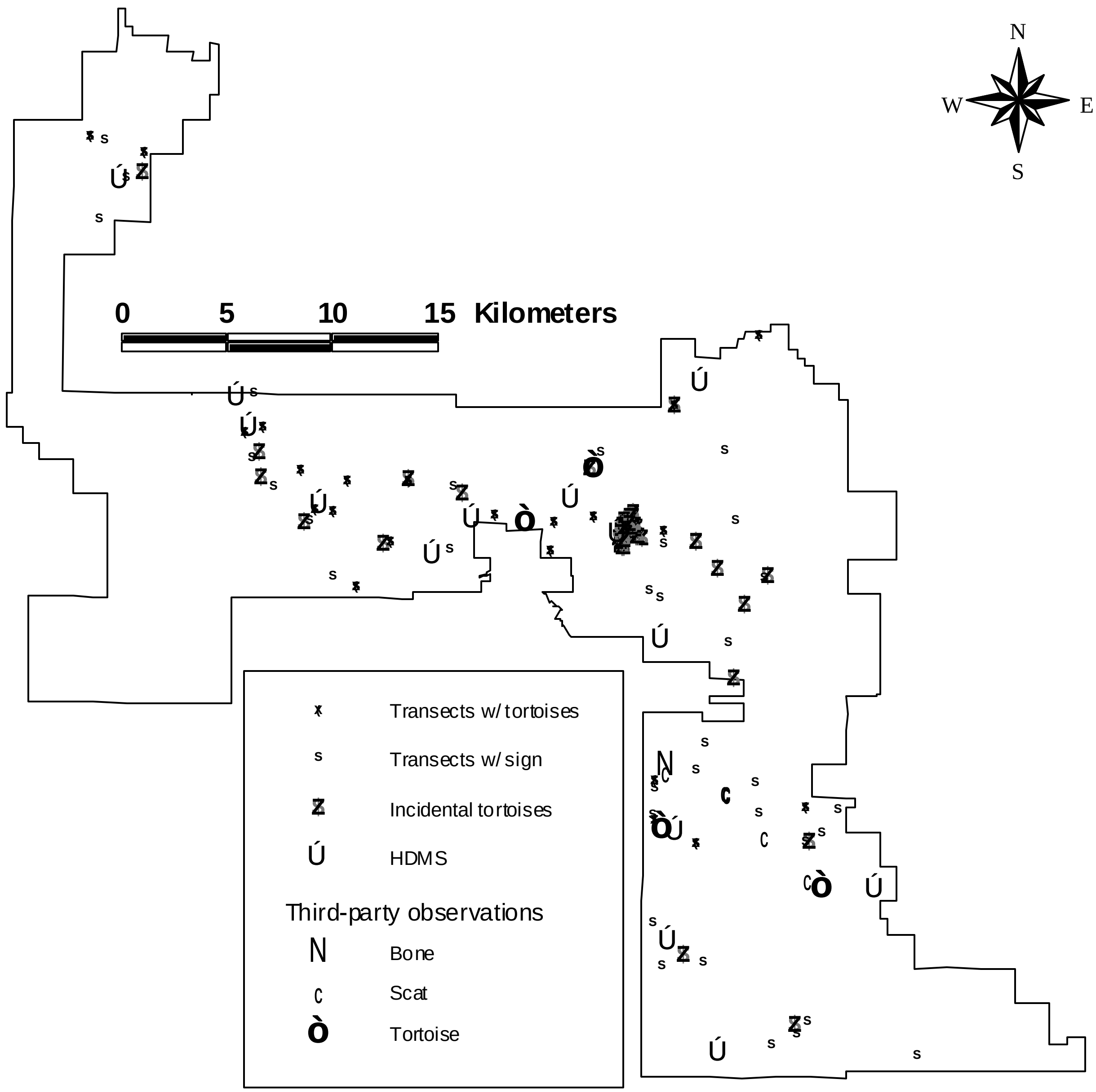

Figure 7. Incidental and third-party observations of tortoises and sign on Ironwood Forest National Monument.

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BLM and ASDM staff reported 4 records of tortoises and 7 records of tortoise sign on IFNM for 2000-2001 (Table 6). These data are especially useful, as they add more records to the southern part of the monument where we found few tortoises: the southern-most end of the Waterman Mountains and the Pan Quemado area (Figure 7). Additionally, Arizona’s Heritage Database, managed by AGFD, has 29 tortoise records from 1978-1990 for the area that is now IFNM. These records add 5 observations of live tortoises to the southern end of the monument, including 2 in the Roskruge Mountains and 2 in Avra Valley northeast of the Roskruge Mountains (Figure 7). The latter records are of a medium-sized female and a large unsexed adult in an area described as overgrazed desert pavement (predominantly creosote bush with mesquite stringers). The Heritage Database also has 5 tortoise records and a carcass record for the Samaniego Hills, an area with apparent low tortoise density, and 6 tortoise records and a carcass record for the Sawtooth Mountains (Table 6).

HEALTH AND MORTALITY

None of the live tortoises we examined showed clinical signs of URTD. We found 12 full or partial tortoise carcasses on 8 transects scattered throughout IFNM: Ragged Top in the Silverbell Mountains, West Silverbell Mountains, Sawtooth Mountains, Waterman Mountains, and Pan Quemado (Figure 4; Appendix 1; Appendix 4). Six of these transects also had live tortoises. Additionally, we found 22 carcasses off transects, with the majority (73%) of these on Ragged Top (Appendix 4). We also added another carcass to the southeastern edge of IFNM near the Roskruge Mountains and the northwestern edge near the Sawtooth Mountains. No third-party observations were made of recent mortalities.

Table 6. Third-party Desert Tortoise Observations on Ironwood Forest National Monument.

Observation	Date	Locality[1]	Source[2]
2000 & 2001 Observations			
Tortoise (male)	01 Jun 00	Silverbell Mountains	BLM
Tortoise leg bone	05 Dec 01	North of Silverbell Mine Rd.	ASDM
Scat	05 Dec 01	South of Silverbell Mine	ASDM
Tortoise (male)	30 Aug 01	West of Ragged Top	BLM
Scat	20 Nov 01	Pan Quemado	ASDM
Scat	28 Nov 01	Waterman Mountains- *3 locations*	ASDM
Tortoise (unk sex)	30 Nov 01	Waterman Mountain	ASDM
Scat	14 Nov 01	Southwest of Agua Dulce Ranch	ASDM
Tortoise (female)	09 Nov 01	El Cerrito de Represso	ASDM
Heritage Data Management System Records			
Tortoises (2 males, 2 females, 2 unk sex), 1 female carcass, tortoise sign[3]	02 Aug 89	Sawtooth Mountains	HDMS
Tortoise (unk sex), scat	18 May 89	West Silverbell Mountains	HDMS
Scat	14 Jun 89	West Silverbell Mountains	HDMS
Tortoise (unk sex) , scat, burrows, eggshell	04 Nov 89	West Silverbell Mountains-4 locations	HDMS
Juvenile carcass, scat	07 Dec 89	West Silverbell Mountains	HDMS
Scat	08 Dec 89	West Silverbell Mountains-6 locations	HDMS
Tortoise (unk sex), carcass, scat, burrows	20 Dec 89	West Silverbell Mountains-2 locations	HDMS
Tortoise sign (mostly scat)	02 Jan 90	West Silverbell Mountains-3 locations	HDMS
Tortoise sign	11 Jan 90	West Silverbell Mountains	HDMS
Tortoises (5 females), carcass	03 Aug 83	Samaniego Hills -4 locations	HDMS
Tortoise (male)	30 Jun 83	Silverbell Mountains	HDMS
Tortoise (female)	26 Oct 83	Silverbell Mountains	HDMS
Tortoise (male?)	27 Feb 86	Silverbell Mountains	HDMS
Tortoise sign	11 Jan 90	Silverbell Mountains- 3 locations	HDMS
Tortoise sign	08 Mar 90	Silverbell Mountains	HDMS
Carcass	23 Feb 78	Ragged Top	HDMS
Tortoises (7)	1980	Ragged Top	HDMS
Scat	23 Mar 90	Ragged Top- 4 locations	HDMS
Tortoise (male), tortoise sign	19 Mar 90	Waterman Mountains	HDMS
Tortoise sign	27 Mar 90	Waterman Mountains	HDMS
Tortoise (unk sex)	21 Mar 83	Roskruge Mountains	HDMS
Scat	11 Apr 90	Roskruge Mountains	HDMS
Scat, burrows	17 Apr 90	Roskruge Mountains- 2 locations	HDMS
Tortoise, (unk sex)	19 Apr 90	Roskruge Mountains	HDMS
Tortoise sign	08 May 90	Roskruge Mountains	HDMS
Tortoise sign	15 May 90	Roskruge Mountains	HDMS
Tortoise (female)	28 Aug 90	Northeast of Roskruge Mountains	HDMS
Tortoise (unk sex)	06 Sep 93	Northeast of Roskruge Mountains	HDMS

[1]Observations organized by mountain range. Multiple locations are observations within the same Township/Range/Section for HDMS data, but are distinct UTM locations for 2000-2001 observations.
[2]ASDM, Arizona-Sonora Desert Museum; BLM, Bureau of Land Management; HDMS, Heritage Data Management System. HDMS records are primarily records reported to the Arizona Game and Fish Department by BLM.
[3]Scat, carcasses or burrows.

SOCIAL INTERACTIONS

We found tortoises sharing burrows on 23 occasions or 15 of the 53 days we conducted surveys on IFNM (Table 7). At least 52% of the observations were of a male and female tortoise sharing a burrow, including one instance of 2 males and a female in a burrow, and at least 22% of the observations were 2 male tortoises in a burrow together. Additionally, we found tortoises within a few meters of each other on 8 occasions. On 28 August we observed Male 147 and Male 417 fighting with each other on Ragged Top. Male 147 pushed Male 417 onto his side and in between 2 rocks. Tortoise 417 eventually righted himself with some effort. On 19 September we found Male 417 on his back, perhaps after having a similar encounter. He turned himself over after trying for at least 30 minutes.

DISCUSSION

TORTOISE DISTRIBUTION AND RELATIVE DENSITY

Where boulders are present on IFNM (including all the major hills and mountain ranges; Figure 1), there is a good chance that tortoises occur at least at low density, depending on the degree of soil development conducive to burrow construction. While we did not conduct sampling at a level to quantify within-range density, tortoise density appears to be highest in the West Silverbell Mountains and at Ragged Top. A 1.6-km^2 monitoring plot has been surveyed in the West Silverbells 3 times since 1991, with abundance estimates reaching 147 tortoises $\geq$180 mm MCL (Hart and others 1992; Woodman and others 1996, 2001). Only 7 tortoises were found during 27 days of surveys at Ragged Top in the spring of 1980 (Schneider 1981), but this location has long been known to contain a relatively dense population (R. Repp, personal communication 2001). Forty-eight tortoises were marked at Ragged Top in 2000 and 2001.

Sonoran Desert tortoises are not limited exclusively to rock-pile habitat; they also construct burrows in the banks of washes (Germano and others 1994). Tortoise density at IFNM in areas containing incised washes was similar to bouldery habitat (Table 3). Tortoises also occur at very low density – but are not absent – in the valley floor, outside of areas with boulders or washes (Table 3). Desert tortoises at the Florence Military Reservation, Pinal County, extend well away from rocky hillsides into the lower bajada and valley floor, where they also appear to be most concentrated near incised washes and caliche caves (Averill-Murray and Klug 2001). In the initial year of study at that site, tortoise activity was centered around washes with caliche caves, but individuals also spent substantial time in the bursage-dominated flats. Tortoises have also been observed making long-distance movements across non-typical tortoise habitat (Averill-Murray and Klug 2000). Tortoises making such movements or occupying valley-floor habitat may provide connections between adjacent, otherwise disjunct, rock-pile populations.

Table 7. Social interactions between tortoises on Ironwood Forest National Monument, 2001.

Date	Locality[1]	Tortoise Sex and ID[2]	Interaction
07/16	RT	M417 and unk J	Sharing burrow
07/17	RT	M417, J438, & J410	Sharing burrow
08/01	RT	M413 and M421	Sharing burrow, M421 blocking entrance
08/01	RT	F402 and J411	Approx. 2 m from each other
08/07	N end of WSB	F75 and F146b	One meter from each other in open
08/07	N end of WSB	M180 and F181	Sharing burrow
08/08	RT	M421 and M413	Sharing burrow, M421 blocking entrance
08/08	RT	J407 and J418	Approx. 5 m from each other in open
08/20	RT	J410 and J430	Sharing burrow
08/20	RT	M432 and F431	Sharing burrow
08/21	RT	M489 and F487	Approx. 8 m from each other in open
08/22	RT	M421 and M491	Sharing burrow
08/28	RT	F409 and unk tortoise	Sharing burrow
08/28	RT	M147 and M417	Fighting; M147 pushed M417 onto his carapace, M417 eventually righted himself with much effort
08/28	RT	M420 and M508	Sharing burrow
08/29	RT	F409 and unk tortoise	Sharing burrow
08/29	RT	M420 and M508	Sharing burrow
08/29	RT	M421 and F423	Sharing burrow
09/04	SH	Unk M and F530	Sharing burrow
09/04	RT	M417 and F148	In open approx. 1.5 m from each other
09/05	S end of PQ	M533 and M537	Facing each other, approx ½ m apart
09/06	S of WM	M540 and F539	Sharing burrow, M540 blocking entrance
09/11	RT	M417 and F402	Sharing burrow
09/11	RT	M403 and at least 1 other tortoise	Sharing burrow
09/12	RT	M417 and F402	Sharing burrow, F402 blocking entrance
09/12	On pipeline road, at end of hills E of WP	M502a and M571	Within 2m of each other in open
09/19	RT	M513 and F402	Sharing burrow, M513 at entrance
09/19	RT	M517 and F408	Sharing burrow
09/24	RT	M417 and F148	Sharing burrow, M417 at entrance
09/24	RT	M521, M492, & F522	Sharing burrow
09/24	SBM	M577 and F578	Probably in same burrow complex

[1]PQ = Pan Quemado, RT = Ragged Top, SBM = Silverbell Mountains, SH = Samaniego Hills, WM = Waterman Mountains, WP = Wolcott Peak, WSB = West Silverbell Mountains.
[2]M = Male, F = Female, J = Juvenile.

DISTANCE SAMPLING

Distance sampling has been used extensively for desert tortoise surveys in the Mojave Desert since 1996, but until recently has been untested in the Sonoran Desert (Anderson and others 2001). A recent study conducted near Saguaro National Park East, Pima County, Arizona, demonstrated that distance sampling could be an effective means of estimating tortoise density in the Sonoran Desert, despite denser vegetation and more complex topography (Swann and others 2002). Examination of the detection probability plot (Figure 5) for desert tortoise surveys on IFNM indicates that our distance-sampling protocol worked well on this site as well: the model fit the raw data despite a narrow shoulder to the data. Additionally, detection probability contributed least to our density variance, indicating that we were likely finding visible tortoises at and near the centerline with the detection probability decreasing with increasing distance from the centerline.

Density and Abundance Estimation

Our results indicate tortoise densities of 0.23 tortoises per hectare and approximately 18,000 tortoises across the monument. However, our precision was low (overall %CV ranged from 37.2% to 43.9%; Table 3). Pre-stratification by geographic region or environmental conditions is recommended to minimize heterogeneity in the data, improve precision, and reduce bias of density estimates (Buckland and others 2001). We expected that pre-stratifying by BLM tortoise habitat categories would increase the precision of our density estimates, but in fact, the precision was lowered. BLM's tortoise habitat categories are coarsely delineated, with Category 1-2 including not only prime desert tortoise habitat (that is, steep slopes with boulders and friable soil/rock or incised washes), but also intervening desert valleys and hard volcanic rock slopes with an absence of boulders. Forty percent of our randomly placed transects in Category 1-2 fell in areas with a lack of boulders or incised washes (Natural Habitat Category X; Table 2). The high level of landscape heterogeneity within BLM categories, and the high variability in desert tortoise densities within these categories, led to high variability in encounter rates and low precision of density estimates within habitat categories. This essentially nullified our pre-stratification efforts.

Post-stratifying the data by landscape features increased the precision of our overall density estimate only slightly. Again, the precision is low within each post-stratified habitat category. This is because the majority of our randomly placed transects fell in Natural Habitat Category X, where there were few tortoises (Table 2).

Survey Effort

It would be difficult to discern population trends and detect anything but large population declines with the level of precision we achieved in our study. The total line length that must be surveyed to achieve a specified precision can be calculated using the following formula from Buckland and others (2001):

$$L = [b/\{CV_t(D)\}^2]/(n/L),$$

where L = total line length, b = dispersion parameter or variance inflation factor, $CV_t(D)$ = target value for coefficient of variation, and n/L = encounter rate of objects of interest. We calculated the total line length needed to achieve various levels of precision (Table 8) using encounter rates for desert tortoises based on our surveys at IFNM in 2001. We used a dispersion parameter (b) of 4; while this value typically falls between 1.5 and 3, Buckland and others (2001) recommend using a value greater than 3 for surveys where the detection function has a narrow shoulder, such as we have with our data. This value appears to be reasonably close, as our 2001 effort (108.25 km) and precision values fall between the 30% and 50% levels shown in Table 8.

Table 8. Survey effort (km) needed to achieve specified precision (%CV) of desert tortoise density estimates at Ironwood Forest National Monument.

Stratum[1] (encounter rate)	Precision			
	20% CV	25% CV	30% CV	50% CV
Unstratified				
Overall (0.34)	294	188	131	47
BLM Categories[2]				
BLM 1-2 (0.47)	213	136	94	34
BLM 3 (0.14)	714	457	317	114
BLM 0 (0.13)	769	492	342	123
Natural Habitat Categories[3]				
B (0.77)	130	83	58	21
W (0.62)	161	103	72	26
X (0.03)	3333	2133	1480	533

[1]Encounter rate of desert tortoises by stratum based on desert tortoise surveys at IFNM in 2001 (Table 3).
[2]Pre-stratified categories are defined by BLM (1988), with BLM 0 as uncategorized.
[3]Category B = steep topography with boulders; Category W = incised washes, few to no boulders (with or without topographic relief); Category X = absence of incised washes and boulders.

To achieve a 20% CV, we would need to survey almost 300 km with an unstratified sampling design, or 2.7 times what we surveyed in 2001 (Table 8). To obtain density estimates by BLM category, 213 km of transect lines needs to be surveyed in Category 1-2 and >700 km in both Category 3 and Category 0, a prohibitive amount of effort. On the other hand, a total of 291 km of transect line needs to be surveyed to obtain a 20% CV in each of natural habitat categories B and W, which is similar to the overall effort needed with an unstratified design (Table 8), or about 144 km to obtain a 20% CV for a density estimate combined across these 2 habitat types. Because tortoise density is very low in Natural Habitat Category X, and the effort needed to survey this habitat type is prohibitive, this category could be ignored without losing much in terms of accuracy in the density estimate. Therefore and not surprisingly, pre-stratification by a combination of topography and the presence or absence of boulders and incised washes is the best strategy for desert tortoise surveys over large geographic areas at IFNM and perhaps throughout the Sonoran Desert. Note also that if the shoulder of the detection function is broadened in the process of increasing the total number of encounters, a given level of precision will be met after a shorter total line length is surveyed.

HEALTH AND MORTALITY

Observations prior to this survey of numerous tortoise carcasses raised concern that the tortoise population at IFNM may be in decline. Many carcasses had been noted at Ragged Top beginning in 1996 (R. Repp, personal communication 2001), and another observer reported several others in the Sawtooth Mountains in 2001 (K. Simms, personal communication 2001). We documented 20 carcasses at Ragged Top during our transect and telemetry surveys, but we only found 8 carcasses on 106.25 km of transects outside of Ragged Top (Appendix 4). We only found 6 carcasses across IFNM incidental to transect surveys outside of Ragged Top. Most of the carcasses we found were not particularly recent deaths.

While a relatively quick (R. Repp, personal communication 2001) decline did seem to occur at Ragged Top, the population at the West Silverbell plot appears to be stable. Only 13 carcasses, including juveniles (<60 mm MCL) and adults, were found on the entire 1.6-km^2 plot during the 2000 survey (Woodman and others 2001). Six of these probably died within the prior year, 3 within 1-2 years, and the remaining 4 within 2-4 years (Woodman and others 2001). It appears that any significant decline of tortoises at IFNM has been limited to Ragged Top, but more intensive within-range surveys would be necessary to state this conclusively.

A localized drought has been suggested as a possible cause for the decline in tortoises at Ragged Top. Scant rain fell from 1995 through 1996, and dead tortoises began appearing in numbers in 1996 (R. Repp, personal communication 2002). A tortoise population in the Maricopa Mountains also declined precipitously in the late 1980s (Wirt 1988; Shields and others 1990) simultaneous with a prolonged drought (Wirt and Holm 1997). Larger tortoises appeared to suffer higher mortality than smaller ones in the Maricopas, suggesting that smaller tortoises may have been better able to buffer themselves from the severe drought conditions, perhaps by being able to retreat deeper underground (Wirt and Holm 1997). Similarly, the tortoise population at Ragged Top is significantly skewed toward smaller individuals, compared to the population at the West Silverbell monitoring plot, only 18 km away. Twenty-six percent of the marked Ragged Top population is less than 180 mm MCL compared to only 7% from the 2000 West Silverbell survey, and tortoises ≥220 mm make up only 30% of the Ragged Top population compared to 74% at the West Silverbells (Figure 8). Unfortunately, we do not have local rainfall data specific to each site.

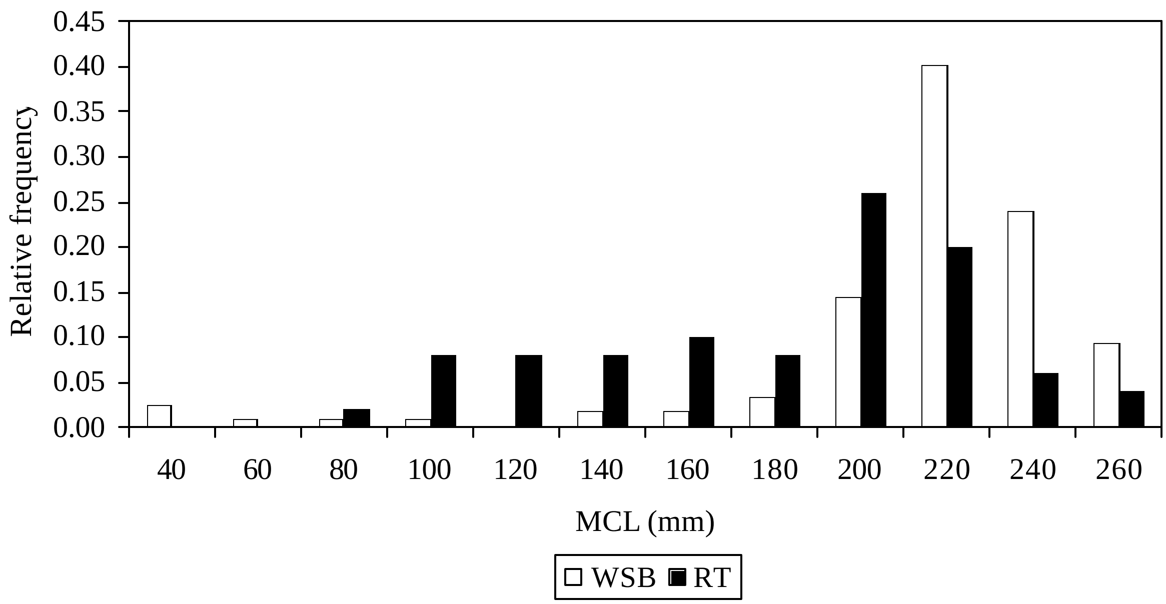

Figure 8. Size histograms for desert tortoises marked at the West Silverbell Mountains (WSB) monitoring plot in 2000 and at Ragged Top (RT) in 2000-2001. The 2 distributions differ significantly when compared with the Kolmogorov-Smirnov test ($D = 0.4756$, $D_{0.05,50} = 0.1884$, $P < 0.001$; Zar 1984).

Another cause of concern at Ragged Top is the discovery of disease in the population. Health sampling conducted independently of this project in 2000-2001 revealed that 2 out of 11 (18%) tortoises sampled tested positive for *Mycoplasma* antibodies, the causative agent of URTD (AGFD, unpublished data). We do not know whether URTD played a role in the decline. The only other Sonoran Desert population known to have a significant proportion of tortoises testing positive for *Mycoplasma* antibodies occurs at Saguaro National Park (AGFD, unpublished data), where people have been stopped when attempting to release captives (D. Swann, personal communication 2001). The release of pet tortoises has been implicated as a potential vector for the introduction of URTD into multiple sites in the Mojave Desert (Jacobson 1993). A Heritage-funded genetics study currently in progress may provide evidence of captive releases at both Ragged Top and Saguaro National Park.

CHAPTER 3: LITTER

The tortoise survey was an intensive effort, taking place over 53 calendar days and greater than twice that number of person days within a 3-month period (Chapter 2, Methods). The intensity of the survey provided the opportunity to collect a variety of additional data with little extra effort. Among these data were observations of trash and balloons, reported here, and an extensive list of other vertebrate species on the monument (Chapter 4).

The recovery plan for the Mojave population of the desert tortoise lists garbage, trash, and balloons as a threat to those tortoises (U.S. Fish and Wildlife Service [FWS] 1994). Turtles and tortoises are known to eat balloons, plastic, and other garbage (J. Behler and K. Bjorndahl, personal communications cited in FWS 1994), which can cause death by becoming lodged in the gastrointestinal tract or entangling heads and legs. The recovery plan lists several such anecdotes specifically for desert tortoises.

METHODS

We recorded UTM coordinates and the perpendicular distance from the centerline of tortoise transects to balloons and grocery bags as a potential indicator of the extent of wind-blown trash on the monument. Undocumented Mexican immigrants apparently discarded most of the bags that we found, because they were associated with discarded bedrolls, water jugs, backpacks, and clothing. Several of the bags also had Spanish print. Approximately 2 weeks into the project, we began recording this evidence of undocumented immigrants and “hotspots” of activity. We linked this evidence to the nearest individual transects, but we did not record each observation with the GPS receiver.

We estimated the density of balloons on IFNM as described in Chapter 2 for tortoises, with the following exceptions. Since neither our pre-stratified nor post-stratified habitat categories should influence balloon density, we analyzed the data without stratification. In order to eliminate a spike at the end of the tail, we truncated the largest 8% of the observations (n = 3).

RESULTS

We found 36 balloons on 27 transects scattered throughout IFNM (Appendix 1; Figure 9). The highest concentration of balloons was in or near the Silverbell Mountains east to Red Hill and north to the Samaniego Hills. Balloons consisted of rubber and mylar party balloons, as well as one U.S. Government weather balloon (not included in DISTANCE analysis).

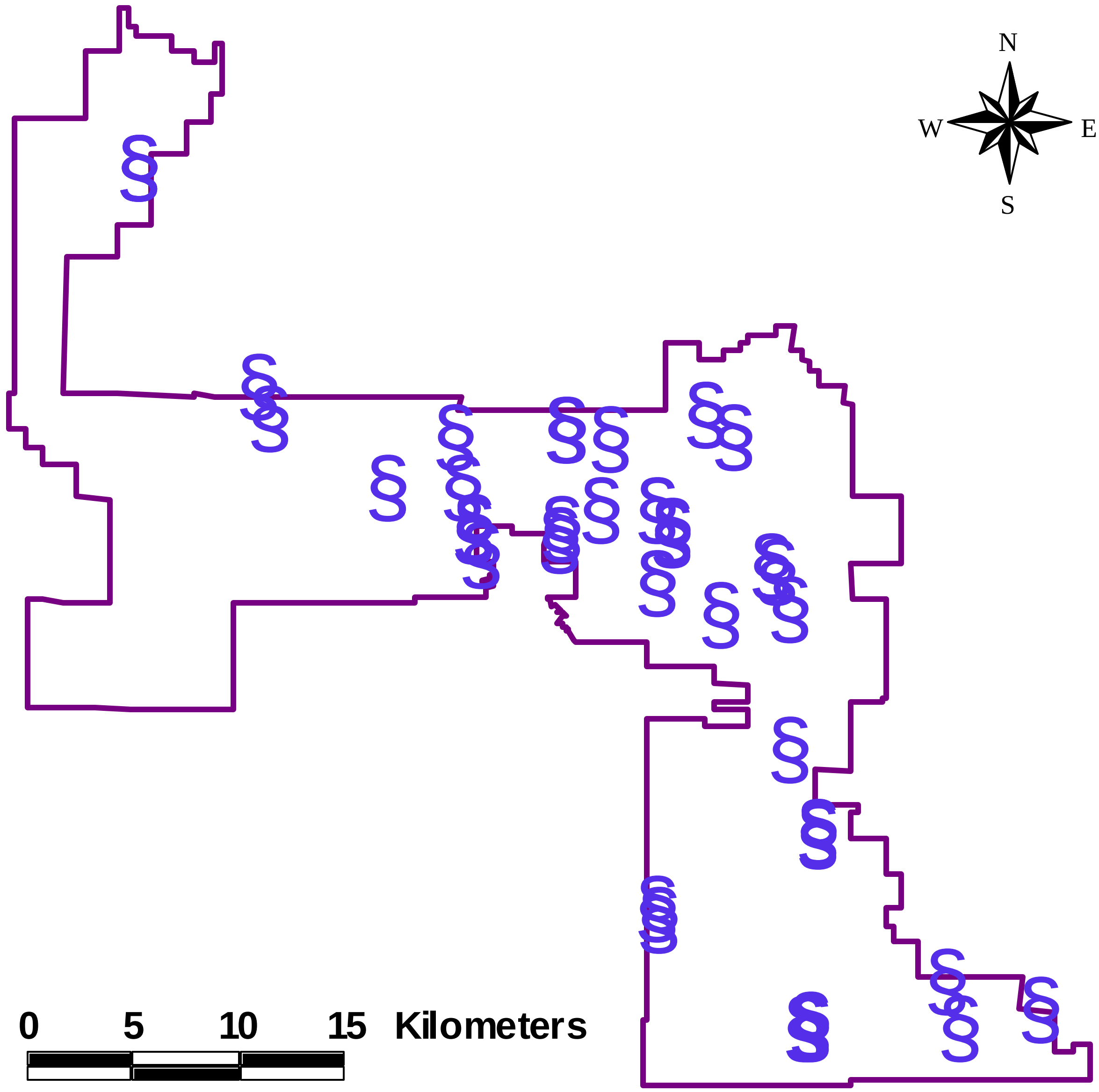

Figure 9. Distribution of balloons found on Ironwood Forest National Monument, 2001.

The uniform/cosine model provided the best fit in the DISTANCE analysis of balloon density (AIC = 177.09). The half-normal key function (no series expansion) followed with an AIC = 177.34. The uniform/simple polynomial (AIC = 178.34) and hazard rate (without series expansion; AIC = 178.84) models came in last. The effective strip width was 10.1 m (CV = 11.8%, 95% CI = 8.0-12.9). The estimated encounter rate was 0.30 balloons/km (CV = 19.5%, CI = 0.20-0.43). DISTANCE computed an estimate of 0.15 balloons/ha (CV = 21.9%, CI = 0.08-0.20), with an absolute abundance of 11,207 balloons on the monument (CV = 21.9%, CI = 5865-15,531).

Undocumented immigrant sign was numerous in certain areas of the monument, especially in desert washes in the Silverbell and West Silverbell mountain ranges (Figure 10). There is a distinct corridor of activity running from the Tohono O'odham Nation south of the monument north along the western edge of the ASARCO Silverbell Mine between the West Silverbell and Silverbell mountains. We observed immigrant sign on only a few transects, but we also noted heavy use of north-south oriented roads near the Waterman and Roskruge mountains in the southern part of the monument.

DISCUSSION

Balloon density was high on IFNM. The effective strip width was greater and the density estimate was more precise for balloons than tortoises. Because balloons are brightly colored and contrast greatly with the surrounding desert, they are likely easier to detect than tortoises. The high density of balloons is not surprising considering the proximity of the monument to a major urban area. Researchers found 130 balloons on a square-mile study plot in the Lucerne Valley, California, in 1990, which is about 9 miles from the nearest town (FWS 1994). Balloons probably do not cause population-level impacts to desert tortoises or other animals, but individual animals could accidentally consume or become entangled in such trash (A. Averill-Murray, personal observation; FWS 1994).

Undocumented immigrants may have deleterious effects on the landscape by trampling vegetation along well-used paths and cutting wood for campfires. The specific impact of undocumented immigrants on tortoises is unknown, but a rancher who runs cattle on the monument reported that he has observed fewer tortoises with the increase in undocumented immigrant activity over the past few years (E. Kyle, personal communication 2001). Additionally, he has encountered immigrants carrying tortoises, presumably with the intent to consume.

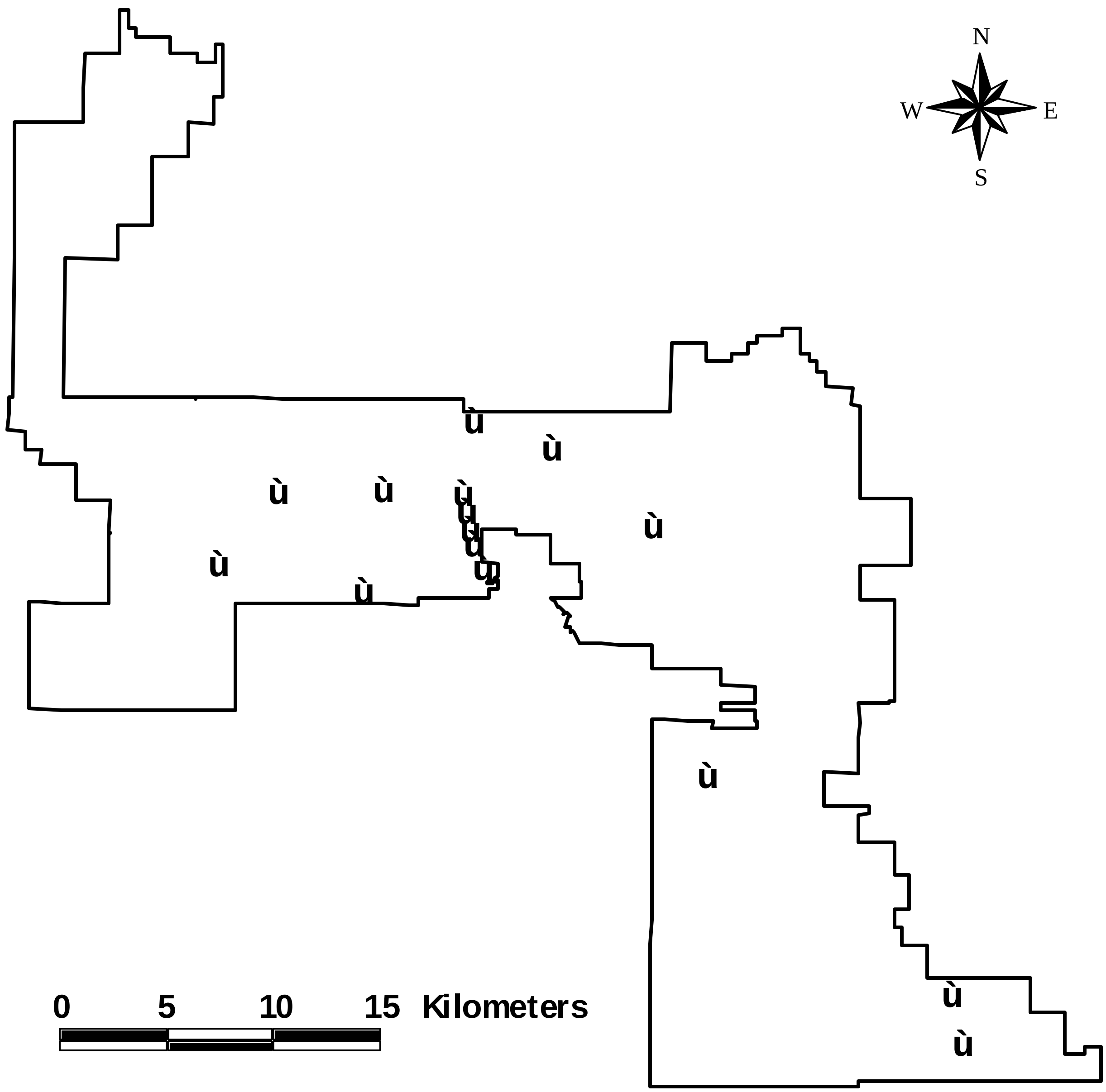

Figure 10. Distribution of undocumented immigrant sign observed on desert tortoise transects at Ironwood Forest National Monument, 2001.

CHAPTER 4: VERTEBRATE INVENTORY

Ironwood Forest National Monument is one of the most species-rich areas in the Sonoran Desert. Researchers have documented more than 670 species of plants and animals in the area that is now IFNM (Tersey and others 2001), including several federally listed Threatened or Endangered species (lesser long-nosed bat *Leptonycteris curasoae*, Nichol's Turk's head cactus *Echinocactus horizonthalonius*) and state listed Species of Special Concern (desert tortoise *Gopherus agassizii*; AGFD, in preparation). Extensive stands of saguaro *Carnegiea gigantea* and ironwood *Olneya tesota* create potential for Endangered cactus ferruginous pygmy owls *Glaucidium brasilianum cactorum*, a species known to nest in Sonoran desertscrub vegetation in Arizona and Sonora, Mexico (Cartron and others 2000). The historic range of the cactus ferruginous pygmy owl encompassed the area that is now IFNM (Phillips and others 1964); however, there are no known historical records (1880s-1990s) specific to this area (S Richardson, personal communication 2002). In 2000, Woodman and others (2000) documented at least one individual in the West Silverbell Mountains (Chapter 1, Figure 1). Lastly, the monument may contain the last viable population of desert bighorn sheep *Ovis canadensis* indigenous to the Tucson basin (Bristow and others 1996).

METHODS

We recorded all vertebrate species seen or heard while on or en-route to tortoise transects. Two of the 3 regular surveyors were skilled in identification of Sonoran Desert herpetofauna, and one was skilled in identification of Sonoran Desert birds. We calculated the number of transects on which we found each species, stratified according to general landscape features (see below). Species seen on IFNM but not on or near transects were recorded as incidental. For bird species, we also noted behaviors indicative of breeding. Scientific and common names follow Crother (2000) for amphibians and reptiles, American Ornithologists' Union (2000) for birds, and Hoffmeister (1986) for mammals.

At the end of the field season, we post-stratified the transects into 3 categories based on general landscape features in the monument: Category B, characterized by steep topography with boulders; Category W, characterized by incised washes and few to no boulders (with or without topographic relief); and Category X, characterized by the absence of incised washes and boulders. A transect was considered type B or W if any portion of the transect met the above criteria; therefore, these landscape features were not necessarily the primary component of a transect. These categories were chosen specifically to reflect features important to desert tortoises. However, they may also reflect habitat preferences of other vertebrate species because each category had an overall distinct vegetation composition and/or vegetation and landscape structure. Category B had vegetation typical of the Arizona Upland subdivision of the Sonoran Desert, including ironwood, foothill paloverde *Cercidium microphyllum*, white-thorn acacia

Acacia constricta, velvet mesquite *Prosopis velutina*, triangleleaf bursage *Ambrosia deltoidea*, and many cacti species, often with a chaparral component that was absent from the other habitat categories (for example, jojoba *Simmondsia chinensis*). Additionally, the boulders and rock piles provided microhabitats likely used by many reptile species. Category W often contained drainages with lush vegetation, including plant species found throughout the monument and some species restricted to areas within the monument with ephemeral water (for example, blue paloverde *Cercidium floridum*). Category X had the lowest structural diversity of all the habitat categories, consisting largely of creosotebush *Larrea tridentata*-dominated desert valleys with a sparse tree and shrub component, as well as smaller drainages with vegetation typical of the other habitat categories.

RESULTS AND DISCUSSION

We recorded 100 vertebrate species on the monument: 1 amphibian, 29 reptiles, 54 birds, and 16 mammals (Table 9). Potential tortoise predators observed on the monument included Gila monster *Heloderma suspectum*, 8 raptor species, greater roadrunner *Geococcyx californianus*, common raven *Corvus corax*, 3 canids, and a felid (bobcat *Felis rufus*). Habitat Category X had the highest species richness for all taxonomic groups, but this may be a function of the high number of transects surveyed in this category or increased visibility due to the absence of incised washes and boulders and lower vegetative cover.

REPTILES

The most frequently observed reptile species were western whiptail *Cnemidophorus tigris*, common side-blotched lizard *Uta stansburiana*, and zebra-tailed lizard *Callisaurus draconoides*. We observed several possible eastern fence lizards *Sceloporus undulatus* (subspecies *consobrinus*) on 3 transects in desert flats in the southern part of the monument (one east of the Roskruge Mountains, one north of Pan Quemado, and one in Avra Valley in the southeastern-most corner of the monument) and on one transect near the West Silverbell Mountains. The latter transect was primarily desert flats with one steep, bouldery area. This species occurs to the south and east of IFNM, including Saguaro National Park East and the Rincon Mountains (D. Swann, personal communication 2002; Stebbins 1985), but to our knowledge has not been documented in the area that is now IFNM. These observations, if valid, would constitute a slight range extension for *Sceloporus undulatus*. Unfortunately, we were unable to collect a specimen.

Table 9. Vertebrate species found on Ironwood Forest National Monument, 2001.

Common Name	Scientific Name	Stratum[1] B (26)	W (24)	X (59)	Total (109)
Reptiles					
Desert Tortoise[2]	*Gopherus agassizii*				
Transect		11	10	2	23
Incidental (near transect)					6
Sign Only		14	7	13	34
Zebra-tailed Lizard	*Callisaurus draconoides*	4	8	29	41
Sonoran Spotted Whiptail	*Cnemidophorus sonorae*			1	1
Western Whiptail	*Cnemidophorus tigris*	14	13	32	59
Eastern Collared Lizard	*Crotaphytus collaris*	3	1	1	5
Desert Iguana	*Dipsosaurus dorsalis*			5	5
Long-nosed Leopard Lizard	*Gambelia wislizenii*	1		5	6
Gila Monster	*Heloderma suspectum*	1	1	2	4
Regal Horned Lizard	*Phrynosoma solare*		2	11	13
Common Chuckwalla[3]	*Sauromalus ater*	1			1
Clark's Spiny Lizard	*Sceloporus clarkii*	3	3	2	8
Desert Spiny Lizard	*Sceloporus magister*	1	1	7	9
Eastern Fence Lizard	*Sceloporus undulatus*	1		3	4
Ornate Tree Lizard	*Urosaurus ornatus*	4	4	4	12
Common Side-blotched Lizard	*Uta stansburiana*	5	11	31	47
Glossy Snake	*Arizona elegans*	Incidental			
Western Diamond-backed Rattlesnake	*Crotalus atrox*	1	4	6	11
Sidewinder[3]	*Crotalus cerastes*	Incidental			
Black-tailed Rattlesnake	*Crotalus molossus*	6	1		7
Mojave Rattlesnake	*Crotalus scutulatus*			3	3
Tiger Rattlesnake	*Crotalus tigris*	5		1	6
Nightsnake	*Hypsiglena torquata*			1	1
Common Desert Kingsnake[4]	*Lampropeltis getula*	Incidental			
Sonoran Whipsnake	*Masticophis bilineatus*		2	1	3
Coachwhip	*Masticophis flagellum* (black phase/red phase[5])		1/0	8/1	9/1
Sonoran Coral Snake	*Micruroides euryxanthus*			1	1

Table 9. Continued.

Common Name	Scientific Name	B (26)	W (24)	X (59)	Total (109)
Gophersnake[4]	*Pituophis catenifer*	Incidental			
Western Patch-nosed Snake	*Salvadora hexalepis*	1	1		2
Western Lyresnake[4]	*Trimorphodon biscutatus*	Incidental			
Species Richness[6]		*16*	*15*	*21*	*29*
Amphibians					
Colorado River Toad	*Bufo alvarius*	Incidental			
Birds					
Turkey Vulture	*Cathartes aura*	6	5	10	21
Sharp-shinned Hawk	*Accipiter striatus*		1		1
Harris's Hawk	*Parabuteo unicinctus*			1	1
Red-tailed Hawk	*Buteo jamaicensis*	5	1	5	11
American Kestrel	*Falco sparverius*	1		4	5
Prairie Falcon	*Falco mexicanus*	Incidental			
Gambel's Quail	*Callipepla gambelii*	7	10	18	35
White-winged Dove	*Zenaida asiatica*	6	7	11	24
Mourning Dove	*Zenaida macroura*	9	8	24	41
Greater Roadrunner	*Geococcyx californianus*	1		4	5
Western Screech Owl	*Otus kennicottii*	1	1	1	3
Great Horned Owl	*Bubo virginianus*	2		2	4
Elf Owl	*Micrathene whitneyi*	3			3
Lesser Nighthawk	*Chordeiles acutipennis*	1	2	2	5
Common Poorwill	*Phalaenoptilus nuttallii*	3		4	7
White-throated Swift	*Aeronautes saxatalis*	Incidental			
Unidentified hummingbird				1	1
Gila Woodpecker	*Melanerpes uropygialis*	13	13	29	55
Ladder-backed Woodpecker	*Picoides scalaris*	6	4	8	18
Gilded Flicker	*Colaptes chrysoides*	11	12	34	57
Pacific-slope Flycatcher	*Empidonax difficilis*	Incidental			
Western Flycatcher	*Empidonax difficilis/occidentalis*		1		1
Say's Phoebe	*Sayornis saya*	Incidental			
Ash-throated Flycatcher	*Myiarchus cinerascens*	4	2	10	16

Table 9. Continued.

Common Name	Scientific Name	B (26)	W (24)	X (59)	Total (109)
Western Kingbird	*Tyrannus verticalis*			1	1
Loggerhead Shrike	*Lanius ludovicianus*	9	6	7	22
Bell's Vireo[3]	*Vireo bellii*		1		1
Common Raven	*Corvus corax*	3	2	5	10
Purple Martin	*Progne subis*			6	6
Cliff Swallow	*Hirundo pyrrhonota*	Incidental			
Verdin	*Auriparus flaviceps*	6	7	7	20
Cactus Wren	*Campylorhynchus brunneicapillus*	14	15	31	60
Rock Wren	*Salpinctes obsoletus*	8	8	6	22
Canyon Wren	*Catherpes mexicanus*	8	1	2	11
House Wren	*Troglodytes aedon*	Incidental			
Black-tailed Gnatcatcher	*Polioptila melanura*	13	12	26	51
Northern Mockingbird	*Mimus polyglottos*	5	2	7	14
Curve-billed Thrasher	*Toxostoma curvirostre*	12	14	28	54
Crissal Thrasher	*Toxostoma crissale*		1	2	3
Phainopepla	*Phainopepla nitens*	1	2	4	7
Orange-crowned Warbler	*Vermivora celata*			1	1
Nashville Warbler	*Vermivora ruficapilla*		1		1
Black-throated Gray Warbler	*Dendroica nigrescens*	Incidental			
Western Tanager	*Piranga ludoviciana*	Incidental			
Canyon Towhee	*Pipilo fuscus*	7	8	10	25
Rufous-winged Sparrow	*Aimophila carpalis*			2	2
Brewer's Sparrow	*Spizella breweri*	Incidental			
Black-throated Sparrow	*Amphispiza bilineata*	13	13	26	52
Lark Bunting	*Calamospiza melanocorys*			1	1
White-crowned Sparrow	*Zonotrichia leucophrys*	Incidental			
Pyrrhuloxia	*Cardinalis sinuatus*		5	2	7
Brown-headed Cowbird	*Molothrus ater*	5	1	3	9
Scott's Oriole	*Icterus parisorum*	5	1	6	12
House Finch	*Carpodacus mexicanus*	12	9	19	40
Lesser Goldfinch	*Carduelis psaltria*	Incidental			

Table 9. Continued.

Common Name	Scientific Name	B (26)	W (24)	X (59)	Total (109)
House Sparrow	*Passer domesticus*	Incidental			
Species Richness[6]		*31*	*32*	*38*	*54*
Mammals					
Big Brown Bat	*Eptesicus fuscus*	Incidental			
Desert Cottontail	*Sylvilagus audubonii*			4	4
Black-tailed Jack Rabbit	*Lepus californicus*		1	1	2
Rock Squirrel	*Spermophilus variegates*	Incidental			
Harris' Antelope Squirrel	*Ammospermophilus harrisii*	1		1	2
Kangaroo rat species	*Dipodomys sp.*	Incidental			
White-throated Wood Rat	*Neotoma albigula*	1			1
Coyote[3]	*Canis latrans*		1	1	2
Kit Fox	*Vulpes macrotis*	Incidental			
Gray Fox	*Urocyon cinereoargenteus*	2		1	3
Badger[3]	*Taxidea taxus*		1	1	2
Bobcat	*Felis rufus*	1			1
Collared Peccary	*Tayassu tajacu*	1	1	2	4
Mule Deer	*Odocoileus hemionus*		1	1	2
Bighorn Sheep	*Ovis Canadensis*	Incidental			
Domestic Cow	*Bos tarus*			2	2
Species Richness[6]		*5*	*5*	*9*	*16*

[1]Stratum B, steep topography with boulders; Stratum W, incised washes, few to no boulders (with or without topographic relief); Stratum X, absence of incised washes and boulders. The data indicate the number of transects on which the species or its sign was found, including species or sign found near a transect and in the same stratum. Species found on the Monument but not on or near a transect are listed as incidentals.

[2]Tortoise data are divided into 3 categories: transects with live tortoises; incidental, or transects without tortoises but with tortoises found nearby; sign only, or transects with tortoise scat, carcasses, tracks, or obvious (half-moon) tortoise burrows but without tortoises. Note that only incidental tortoises found near a transect are included in this table; other tortoises were found incidentally on the monument, but not near a surveyed transect.

[3]Sign only found (scat, skeleton, nest, or tracks).

[4]Found dead on road.

[5]An additional red phase was found on the monument.

[6] Number of species found in each stratum and overall. Incidentals are not included in stratum totals, but are included in overall totals (except the unidentified hummingbird and western flycatcher).

BIRDS

The most frequently observed bird species were cactus wren *Campylorhynchus brunneicapillus*, gilded flicker *Colaptes chrysoides*, Gila woodpecker *Melanerpes uropygialis*, curve-billed thrasher *Toxostoma curvirostre*, and black-throated sparrow *Amphispiza bilineata*. We observed breeding behavior or found evidence of breeding for 16 bird species (Table 10), including 2 species identified as priority species for Pima County's Sonoran Desert Conservation Plan: rufous-winged sparrow *Aimophila carpalis* and Bell's vireo *Vireo bellii* (Pima County 2001).

Table 10. Breeding confirmation for birds on Ironwood Forest National Monument, 2001.

Common Name	Breeding Behavior	Location[3]
Red-tailed Hawk[1]	Immature birds	RT; transect #62 (AV)
Prairie Falcon	Irritated pair, probable eyrie located	RT
Mourning Dove	Nest with eggs, eggshells on ground	RT; Transect #7 (WSB), 97 (AV), 103 (RH)
Lesser Nighthawk	Nest with young	RT
Ash-throated Flycatcher	Adult carrying food	RT
Purple Martin	Nest with young	Transect #26 (RM)
Cactus Wren	Adult carrying food, Nest with young	RT
Black-tailed Gnatcatcher	Adult feeding fledgling Brown-headed Cowbird	RT
Loggerhead Shrike	Fledglings	Transect #119 (North of RT)
Curve-billed Thrasher[2]	Nest with eggs	Transect #119 (North of RT)
Bell's Vireo	Used nest	Transect #53 (SBM)
Black-throated Sparrow	Fledglings	RT and throughout monument
Rufous-winged Sparrow	Nest with young	Transect #72 (AV)
Brown-headed Cowbird	Fledgling	RT
Scott's Oriole	Used nest	RT
House Finch	Fledglings	RT

[1]An immature Red-tailed Hawk was found freshly dead at Ragged Top on 01 July 2001.
[2]Eggs were cold- likely an abandoned nest
[3]AV = Avra Valley; WSB = West Silverbell Mountains; RT = Ragged Top; RH = Red Hill; RM = Roskruge Mountains; SBM = Silverbell Mountains.

We observed rufous-winged sparrows incidentally and on 2 transects; all but one of our observations were south of Avra Valley Road in flat areas with relatively dense grass cover and along washes thick with grass and shrubby vegetation. We found one rufous-winged sparrow nest with 2 nestlings on 3 September 2001, in a blue paloverde. The rufous-winged sparrow is a fairly common but local resident breeder in south-central Arizona. This species was at one point rare in the Tucson basin and may have been extirpated from the area for over 50 years during the late 1800s and early 1900s (Phillips and others 1964). Rufous-winged sparrows occur in semi-desert grassland, Sonoran desertscrub, and desert washes, especially in flat areas and in association with grassy cover. These landscape and vegetation associations make rufous-winged sparrows especially vulnerable to overgrazing of livestock (Latta and others 1999; Phillips and others 1964).

Bell's vireos are a migratory bird and summer resident in southern Arizona (Phillips and others 1964). This species is often associated with mesquite bosques and riparian areas and has experienced population declines locally within Arizona due to habitat destruction (Rosenberg and others 1991). Although we never observed a Bell's vireo on IFNM, we found a 1-2 year old nest in a mesquite and acacia-dominated arroyo in the Silverbell Mountains. This was an interesting find; Bell's vireos are typically found near water in the arid southwest (Brown 1993), and this nest was far from any known water source. Bell's vireos may breed sporadically on the monument during wet years when water is flowing in some of the desert washes.

MAMMALS

We infrequently observed mammals, whether in conjunction or incidental to tortoise surveys. We observed bighorn sheep on 6 occasions on the highest ridges of Ragged Top in the Silverbell Mountains (Table 11). Ragged Top is an important lambing area for the Silverbell Mountain bighorn population (Bristow and others 1996), and BLM has taken protective measures (for example, gating roads) to secure this rugged area. We observed domestic cows on only 2 transects, but this species was observed almost daily throughout the desert valleys of the monument and occasionally at Ragged Top.

Table 11. Bighorn sheep observations on Ragged Top in the Silverbell Mountains, Ironwood Forest National Monument, 16 July – 11 October 2001.

Date	Observation
July 30	1 male, 3 females
August 21	1 large male
August 28	2 large males, several juveniles
August 29	2 sheep, sex not indicated
September 11	2 males
September 24	≥ 5 sheep, sex not indicated

CHAPTER 5: RECOMMENDATIONS

Surveys to determine tortoise density in specific mountain ranges may be useful for particular management decisions. Obtaining these estimates will require intensive surveys, with about 80-130 km of transects per range (concentrated in boulder habitat) needed on average for CVs of 20-25% (Table 8). The total line length should be somewhat lower in the West Silverbell, Silverbell, and possibly Sawtooth mountains, where overall encounter rates across all habitats (Table 5) approached those for boulder-specific habitat (Table 3). Line lengths in the remaining ranges may need to be higher. Effort concentrated within individual mountain ranges would be more efficient than the current study, as a result of reduced travel across the entire monument. In addition, telemetry may not be needed to estimate g_0 based on results from this and other studies, greatly reducing the cost and effort required. Surveys at the Rocking K Ranch and Saguaro National Park in 2000 and 2001 produced g_0 estimates of 0.79 ($\pm$0.122 SE) and 0.81 ($\pm$0.125), respectively (unpublished data). Within environmental conditions and tortoise activity similar to those of 2000 and 2001, using the overall average of 0.84 ($\pm$0.105) may be adequate. Additional study quantifying g_0 and correlating it with geography and environmental conditions would be beneficial to future distance sampling of tortoises in the Sonoran Desert. For example, we found tortoises observability to be higher and less variable during evening surveys (mean = 0.92 $\pm$ 0.068) than in the morning (mean = 0.78 $\pm$ 0.152).

Even though we did not observe any tortoises symptomatic of URTD during our survey, the discovery that a small sample produced 2 positive *Mycoplasma* antibody tests indicates that more health sampling should be conducted at Ragged Top to determine the potential prevalence of URTD in this population. We also recommend additional focal study (with radio telemetry) of positive individuals to determine whether these tortoises actually become symptomatic for URTD or show any effects relative to negative tortoises. Managers need studies of both positive and negative individuals to determine whether Sonoran Desert tortoises are resistant to the disease. We also recommend blood sampling in other ranges on IFNM to determine the extent of URTD across the monument. We recommend improved education and outreach efforts to increase public awareness of the risks to wild populations of releasing pet tortoises. Greater enforcement visibility would also help this effort.

Some areas on the monument appear to support very low density populations of tortoises (for example, pockets in the Waterman and Roskruge mountains, in addition to those in the valley floors). Study of areas such as these is important to better understand population dynamics and demographics relative to more dense populations. Research on home range and habitat use in isolated, low density areas would provide informative comparative data to those from prior studies in areas of higher tortoise density. These studies, especially if combined with genetic data, would contribute to our understanding of potential metapopulation dynamics between local populations and effects of habitat fragmentation.

BLM has few options to reduce or eliminate balloons or undocumented Mexican immigrant traffic on the monument. Other than maintaining an enforcement presence to discourage immigrants, which may or may not be effective, the scope of this problem exceeds that of this project. Balloons are probably a greater eyesore than an actual threat to desert tortoises or other wildlife, at least on a large scale. However, we recommend that local governments discourage the release of balloons during public and private events. Other governments have gone so far as to expressly prohibit balloon releases. For example, the state of Florida considers it unlawful to intentionally release 10 or more balloons within a 24-hour period, with some exceptions, subject to a $250 fine (Florida Statutes Chapter 372.995).

Finally, we recommend that other potential human impacts be monitored, especially as nearby urban areas continue to grow. Ragged Top is a popular recreation area, and education and law enforcement will be important not only in preventing releases of captive tortoises as mentioned above, but also in preventing take and harassment of individual animals. Of perhaps distant concern at IFNM are potential effects of roads on tortoises through direct mortality and habitat fragmentation. Currently, the major roads on or adjacent to the monument do not pass directly through high-quality tortoise habitat, but as traffic increases (especially on Avra Valley Road, which is already paved) so does the possibility of road kills and prevention of tortoise movement between mountain ranges.

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APPENDIX 1. SUMMARY OF TRANSECT INFORMATION SORTED BY BLM TORTOISE HABITAT CATEGORY, IRONWOOD FOREST NATIONAL MONUMENT, 2001.

Line ID	UTMs[1] NE-East	NE-North	Line Length[2]	BLM Category[3]	Natural Category[4]	Live tortoise	Dead tortoise	Tortoise Sign[5]	Balloon	Alien[6]
6	436941	3593502	1	1	B			X		
7	447249	3590202	1	1	W					
8	446288	3589188	1	1	W			X		
11	451173	3590453	1	1	W	X		X		
17	440745	3591000	1	1	B	X		X		
19	442771	3592246	1	1	W					X
21	441391	3592467	1	1	W	X		X		
27	446453	3592120	1	1	X			X		X
30	442652	3588062	1	1	X					
31	436971	3596575	1	1	B		X	X	X	
33	454659	3590319	1	1	B	X	X	X		
35	444286	3592491	1	1	W	X		X		
39	443378	3589561	1	1	W	X		X		
40	452957	3590712	1	1	B	X	X	X	X	
43	436602	3594725	1	1	B	X		X		
44	439107	3592947	1	1	B	X	X	X	X	
46	443412	3592574	1	1	X					
47	446823	3590296	1	1	X					X
49	440430	3590334	1	1	W					
50	439856	3591153	1	1	W	X		X		
51	446595	3591240	1	1	X					X
53	450921	3589705	1	1	W				X	
59	446389	3591699	1	1	X				X	
63	437389	3594928	1	1	B	X		X		
80	446994	3589674	1	1	X					X
87	443030	3591593	1	1	W				X	
4	429186	3608697	1	2	W	X		X		
5	455777	3576674	1	2	B			X		
9	465668	3565007	1	2	X					
12	455121	3588849	1	2	X					
13	456623	3577421	1	2	X					
14	457604	3577586	1	2	X					
15	429704	3604793	1	2	B			X		
16	457397	3571587	1	2	W					
18	457876	3578791	1	2	W			X		X
20	455710	3575627	1	2	X					
22	460678	3578218	1	2	X			X		
23	455826	3577902	1	2	B			X		
24	457341	3581120	1	2	X				X	
25	431013	3606802	1	2	B			X	X	
26	455764	3571568	1	2	X			X	X	
28	459662	3576207	1	2	X					

Appendix 1. Continued.

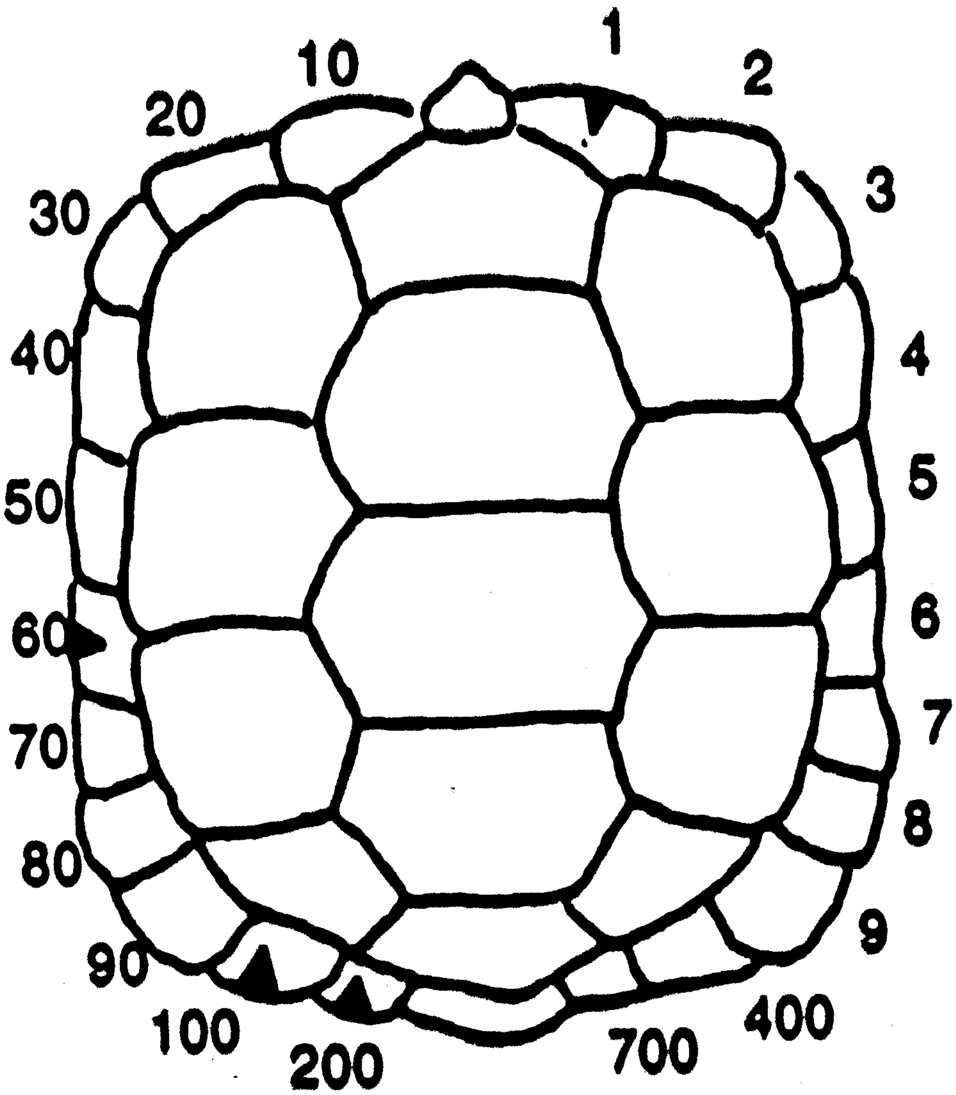
Line ID	UTMs[1] NE-East	NE-North	Line Length[2]	BLM Category[3]	Natural Category[4]	Live tortoise	Dead tortoise	Tortoise Sign[5]	Balloon	Alien[6]
29	452893	3587239	**0**	2						
32	451542	3587039	**0**	2						
34	455660	3571910	1	2	X				X	
36	456153	3586941	1	2	X			X		
37	461413	3565853	1	2	B				X	
38	457403	3578296	1	2	B					
41	456624	3572889	1	2	X				X	
42	454274	3588931	1	2	W					
45	429982	3608575	1	2	X			X		
48	451015	3589114	1	2	B	X		X		
52	458252	3580110	1	2	X			X		
54	459073	3572339	1	2	X					
56	448381	3590812	1	2	X	X		X		
57	458949	3572895	1	2	X					
58	463030	3577039	1	2	B	X	X	X		
60	456256	3569492	1	2	W			X		
65	458178	3569686	1	2	W			X		
68	431812	3607943	1	2	B	X	X	X		
70	455982	3576431	1	2	W	X		X		
71	427924	3607586	**0**	2						
73	457896	3575309	1	2	W	X		X		
77	455973	3578339	1	2	B	X	X	X		
81	460056	3576559	1	2	X					
86	460791	3576767	1	2	B			X		
91	455589	3587266	1	2	B			X	X	
96	455346	3590555	1	2	X					X
112	456357	3589418	1	2	W			X	X	
1	463389	3574892	**0**	3						
2	458429	3585659	1	3	X				X	
3	463545	3586774	**0**	3						
10	463070	3575446	1	3	X			X	X	
55	440729	3587930	1	3	B			X		
61	456332	3590085	1	3	B	X		X		
64	463884	3574477	**0**	3						
67	459196	3593893	1	3	B			X	X	
74	461778	3585887	0.75	3	X				X	
76	441752	3587466	1	3	W	X		X		X
78	459673	3590525	1	3	X			X		
79	457988	3595241	1	3	X					
82	439604	3590589	1	3	W			X		
84	463119	3566955	1	3	X			X		
89	468251	3565243	1	3	X			X		
90	458426	3591307	1	3	X					
92	460861	3573804	1	3	X					

Appendix 1. Continued.

Line ID	UTMs[1] NE-East	NE-North	Line length[2]	BLM category[3]	Natural category[4]	Live tortoise	Dead tortoise	Tortoise Sign[5]	Balloon	Alien[6]
98	457885	3594913	1	3	X				X	
100	461900	3579284	1	3	X				X	
101	460592	3579906	1	3	X					
102	463178	3570234	1	3	X					
103	461085	3587823	1	3	X			X	X	
104	459065	3598071	1	3	X					
105	457955	3591843	1	3	X					
106	437855	3592148	1	3	X			X		X
107	446077	3593961	1	3	X					
108	463753	3575819	1	3	B			X		
109	461141	3596574	1	3	X					
110	464566	3576999	1	3	B			X		
111	456861	3596033	1	3	W	X		X		
113	459420	3584793	1	3	W			X	X	
114	447311	3588557	1	3	X					X
115	451389	3594476	1	3	X				X	
116	462270	3579917	1	3	X					
117	450550	3594174	1	3	X					X
118	446974	3595480	1	3	X					X
119	453380	3593759	1	3	B		X	X	X	
120	462621	3566360	1	3	X			X	X	
62	473473	3567264	1	0	X					
66	435320	3584721	**0**	0						
69	433081	3612118	**0**	0						
72	469717	3566332	1	0	X				X	X
75	460817	3599248	1	0	X	X		X		
83	435578	3582665	**0**	0						
85	461607	3591285	1	0	X					
88	462874	3573132	1	0	X					
93	435147	3588812	0.5	0	X					X
94	443138	3587243	1	0	X					
95	470878	3565839	**0**	0						
97	469204	3568560	1	0	X				X	X
99	465023	3569335	**0**	0						
Total			108.25			23	8	55	27	15

[1]UTM coordinates in NAD27 for the northeast corner of each transect.
[2] Kilometers surveyed (1 = entire transect, **0** = transect not surveyed).
[3] [1]Pre-stratified categories are defined by BLM (1988), with BLM 0 as uncategorized
[4] Category B - steep topography with boulders; Category W - incised washes, few to no boulders (with or without topographic relief); Category X - absence of incised washes and boulders. Left blank if transect not surveyed.
[5]Tortoise sign includes carcasses (partial or whole), scat, tracks, or obvious (half-moon) burrows, as well as live tortoises.
[6] Signs of Undocumented Immigrant activity, including bedrolls, backpacks, clothing, food and water jugs.

APPENDIX 2. MARKING SYSTEM



Tortoise # = 361

APPENDIX 3. DESERT TORTOISES OBSERVED ON IRONWOOD FOREST NATIONAL MONUMENT, 2000-2001.

ID	Date	Sex[1]	MCL[2]	Transect[3]	Locality[4]	Notes
	07/16/01	J			RT	Could not extract from burrow
	07/25/01	UA		68	Central SM	Could not extract from burrow
	07/31/01	J	115	73	S of WM	
	08/28/01	U			RT	Could not extract from burrow
	08/29/01	U			RT	Prob. same as 08/28
	09/04/01	UA			In drainage N of E end WSB	Could not extract from caliche cave
	09/04/01	M		111	SH	Could not extract from burrow
	09/25/01	UA			SH	Probably same tortoise found on 09/04/01; could not extract from burrow
	09/04/01	UA		35	Small hill N of WSB	Could not extract from burrow
	09/11/01	U			RT	
75	08/07/01	F	230	63	N end WSB	Flaky shell and couple of cracks on shell; 4 toes on both back legs; previously marked on WSB plot
102	08/06/01	J	117	63	N end WSB	Previously marked on WSB plot
114	08/07/01	F	235	63	N end WSB	Previously marked on WSB plot
144	07/22/00	J	106		RT	Marked by T. Edwards, UA
145	07/22/00	F	218		RT	Marked by T. Edwards, UA; underweight and lethargic; not notched – epoxy number only
145	03/02/02	F	218		RT	
146a	07/22/00	J	104		RT	Marked by T. Edwards, UA
146a	06/30/01	J	121		RT	
146b	08/07/01	F	238	63	N end WSB	Missing 1 vertebral scute; egg shell fragments in burrow; previously marked on WSB plot
147	07/22/00	M	251		RT	Marked by T. Edwards, UA
147	07/23/01	M			RT	
147	08/22/01	M	251		RT	
147	08/28/01	M			RT	
147	08/29/01	M	251		RT	
148	07/22/00	F	231		RT	Marked by T. Edwards, UA
148	**06/30/01**	**F**	**231**		**RT**	**Telemetered tortoise**
149	07/22/00	F	204		RT	Marked by T. Edwards, UA
150	07/22/00	J	161		RT	Marked by T. Edwards, UA; blood-engorged gnats around eyes
161	08/06/01	M	230	63	N end WSB	Evidence of shell disease on plastron; previously marked on WSB plot
180	08/07/01	M	261	43	N end WSB	New tortoise W of WSB plot
181	08/07/01	F	252	43	N end WSB	Chip on L costal scute, showing bone; new tortoise W of WSB plot

Appendix 3. Continued.

ID	Date	Sex[1]	MCL[2]	Transect[3]	Locality[4]	Notes
400	10/11/00	M	213		RT	
400	09/12/01	M			RT	
400	03/02/02	M	219		RT	
401	10/11/00	F	216		RT	
402	**06/30/01**	**F**	**230**		**RT**	**Telemetered tortoise**
403	**06/30/01**	**M**	**180**		**RT**	**Telemetered tortoise; 10 L marginals**
407	08/08/01	J	115		RT	
408	**06/30/01**	**F**	**224**		**RT**	**Telemetered tortoise**
409	**07/01/01**	**F**	**215**		**RT**	**Telemetered tortoise**
410	07/17/01	J			RT	
410	08/20/01	J	180		RT	
411	07/01/01	J	142		RT	
411	08/01/01	J	141		RT	
412	07/01/01	J	149		RT	
413	**07/04/01**	**M**	**200**		**RT**	**Telemetered tortoise**
417	**07/04/01**	**M**	**256**		**RT**	**Telemetered tortoise**
418	08/08/01	J	163		RT	Divided supracaudal; deformity on plastron
419	08/13/01	J	136	33	RT	
420	**07/11/01**	**M**	**185**		**RT**	**Telemetered tortoise**
421	**08/13//01**	**M**	**234**	**33**	**RT**	**Telemetered tortoise**
422	08/13/01	J	172		RT	Notched on first L marginal and 3rd, 9th, and 10th R marginal to get #422
422	09/12/01	J			RT	
423	**08/13/01**	**F**	**203**	**33**	**RT**	**Telemetered tortoise**
427	08/13/01	F	208	33	RT	
428	08/13/01	F	226	33	RT	
429	08/13/01	J	95		RT	10 L marginal scutes; 11th marginal on R side is unusually small
430	08/20/01	J	178		RT	
430	09/24/01	J			RT	
431	08/20/01	F	226		RT	
432	08/20/01	M	200		RT	
433	08/14/01	F	252	75	N of SH	12 marginals- nuchal scute divided into thirds
437	08/15/01	J	153	11	SBM	Sunken crease lengthwise across top of carapace
438	07/17/01	J	166		RT	
439	07/17/01	F	243	50	Central WSB	10 L marginals
470	07/17/01	M	220		In flats S of central WSB	Sitting on cow bone, calcium from bone on beak; ~15 growth rings
471	07/18/01	J	161	77	S end WM	
472	07/18/01	M	242	77	S end WM	
473	07/25/01	M	266		SM	Worn shell, flaking on plastron

Appendix 3. Continued.

ID	Date	Sex[1]	MCL[2]	Transect[3]	Locality[4]	Notes
477	07/26/01	M	241	4	W of SM	
478	07/26/01	F	238	4	W of SM	
479	07/30/01	M	263	56	Flats between WSB and SBM	Shell very worn on top
480	08/01/01	M	255	39	In drainage near S end WSB	Very flaky shell, both top and bottom; big crack up 9th R marginal scute and on top of shell.
481	08/01/01	F	230		On road near drainage close to S end WSB	
482	08/08/01	M	265	21	E of central WSB	Scar on R front leg, flaky plastron
483	08/09/01	M	195	76	S end WSB, just N of Tohono O'odham Nation	
487	08/21/01	F	196		RT	Broken piece on plastron
488	08/20/01	J	123		RT	
489	08/21/01	M	205		RT	
490	08/21/01	M	200		RT	
491	08/22/01	M	210		RT	Pot mark on scute above R 3rd marginal
492	08/23/01	M	244		RT	
492	09/24/01	M			RT	
493	08/29/01	J	120		RT	Small deformity/scar on top of shell
497	09/03/01	F	210		RT	
497	09/24/01	F			RT	
498	09/03/01	J	146		RT	
499	09/12/01	M	224		RT	
500	08/22/01	M	284		On pipeline road SE of hill E of WP	
501	08/22/01	M	241		Next to pipeline road about 5.5 miles E of Cocio Wash near Silverbell Mine	
502a	08/28/01	M	238		About 15 m off pipeline road, at end of hills E of WP	
502a	09/12/01	M	238		On pipeline road, at end of hills E of WP	
502b	08/28/01	J	115		RT	R front foot missing
503	08/28/01	J	139		RM	
507	08/29/01	J	-----		Near N end WSB	
508	08/28/01	M	235		RT	Small, abnormal growth on snout
508	08/29/01	M			RT	
509	08/30/01	M	189	17	WSB	Nuchal scute missing or malformed; 10 marginals on both sides
510	08/27/01	F	213		In flats near RM	N of Tohono O'odham Nation

Appendix 3. Continued.

ID	Date	Sex[1]	MCL[2]	Transect[3]	Locality[4]	Notes
511	08/27/01	M	207	61	Hill E of WP	
512	09/17/01	M	245	58	PQ	9th and 10th R marginals broken; shell worn and sunken in spots
513	09/19/01	M	226		RT	Inch-long crack that has healed on top of carapace
517	09/19/01	M	267		RT	
520	10/09/01	M	250	44	Central WSB	Missing part of 8th scute on R side
521	09/24/01	M	262		RT	Nuchal and 1st and 2nd R marginals deformed; only 3 claws on R forelimb
521	10/03/01	M			RT	
522	09/24/01	F	235		RT	
523	10/09/01	M	250		In flats near Central WSB	Small growth on rear of carapace, indentations on 1st and 2nd R marginals
527	10/09/01	M	258	44	Central WSB	
528	10/09/01	M	219	44	Central WSB	Bad L eye
530	09/04/01	F	228	111	SH	No nuchal scute; 12 L marginals
531	09/04/01	F	182	111	SH	
532	09/04/01	F	240	35	Small hill N of WSB	Knobby shell; deformity between 6th and 7th L marginals
532	09/10/01	F	240	35	Small hill N of WSB	
533	09/05/01	M	249		S end PQ	
537	09/05/01	M	253		S end PQ	
538	09/05/01	J	143	40	W side RT	
539	09/06/01	F	211	70	S of WM	No nuchal scute
540	09/06/01	M	261	70	S of WM	
570	09/10/01	M	246	35	Small hill N of WSB	
571	09/12/01	M	240		On pipeline road, near SBM, E of WP	
572	09/12/01	M	248		On pipeline road, near SBM, E of Silverbell Peak	Flared scutes over rear legs
573	09/22/01	M	237		Flats/drainage near E end WSB	12 marginals each side
577	09/24/01	M	247	48	SBM	
578	09/24/01	F	244	48	SBM	
579	10/10/01	M	231		S of RH, E of SBM	

[1]F = Female, M = Male, UA = Unknown Adult, U = Unknown, J = Juvenile.
[2]Midline carapace length (mm).
[3]Transect on which tortoise was found (blank if tortoise was not found on a transect = “incidental”).
[4]General location of tortoise: PQ = Pan Quemado, RH = Red Hill, RT = Ragged Top, SH = Samaniego Hills, SM = Sawtooth Mountains, SBM = Silverbell Mountains, WM = Waterman Mountains, WP = Wolcott Peak, WSB = West Silverbell Mountains.

APPENDIX 4. DESERT TORTOISE CARCASSES FOUND ON IRONWOOD FOREST NATIONAL MONUMENT, 2001.

Carcass Condition	Locality
No info recorded	Transect #31, West Silverbell Mountains
Disarticulated shell fragments with some scutes	Transect #33, east side of Ragged Top
Shell pieces	Transect #33, east side of Ragged Top
Broken-up pile of bones	Transect #33, east side of Ragged Top
Single costal scute	Transect #40, west side of Ragged Top
Half-dozen broken pieces, including few marginals & gular	Transect #44, West Silverbell Mountains
Pieces of plastron in caliche cave/packrat nest	Transect #44, West Silverbell Mountains
Broken-up plastron, several scutes	Transect #44, West Silverbell Mountains
Piece of plastron	Transect #58, Pan Quemado
Intact shell with pelvic bone inside; male	Transect # 68, Sawtooth Mountains
Intact empty shell with scutes falling off; male	Transect #77, Waterman Mountains
Piece of plastron	Transect #119, hill north of Ragged Top
Complete shell with 2 legs; female	West Silverbell Mountains
Old, broken shell	North of Roskruge Mountains
Single scute	South of Sawtooth Mountains
Plastron fragment	East of Waterman Mountains
Plastron and several scutes	Northeast of Silverbell Mountains
3 bone fragments	Samaniego Hills
Broken pieces and scutes	Ragged Top
Piece of carapace & vertebrae in packrat den	Ragged Top
Full shell in burrow under rock, old	Ragged Top
Full shell with most scutes, broken in 1/2; pelvic bone	Ragged Top
Full shell with desiccated legs and head intact, half of scutes missing	Ragged Top
Many plastron pieces and scutes	Ragged Top
Part of L and R side of shell, top and posterior gone; scutes fallen off	Ragged Top
Disarticulated shell- loose bone, scute fragments	Ragged Top
Mostly complete shell- missing L rear costals and vertebrals, scutes peeling off carapace, plastron intact	Ragged Top
Scattered bone fragments	Ragged Top
Disarticulated bones and scutes	Ragged Top
Mostly intact shell, most scutes peeled off, adult male	Ragged Top
Juvenile shell- missing posterior R plastron, most vertebrals, and anterior L and posterior R costals; scutes peeling off	Ragged Top
Fragments of plastron	Ragged Top
Broken shell; old	Ragged Top
Plastron fragments and a few scutes	Ragged Top