DESERT TORTOISE HABITAT USE AND HOME RANGE SIZE ON THE FLORENCE MILITARY RESERVATION: 2002 PROGRESS REPORT

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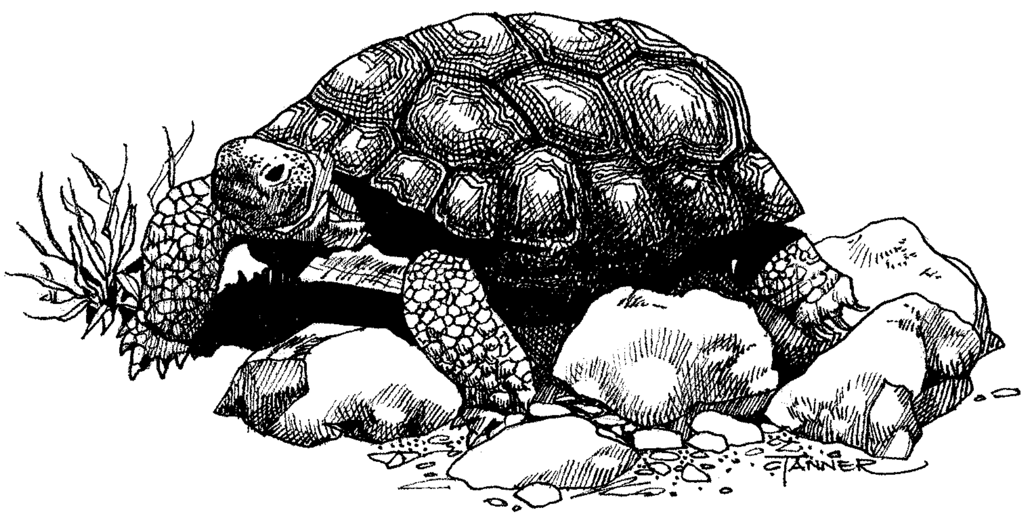

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INTRODUCTION

The desert tortoise *Gopherus agassizii* has the broadest range of latitude and habitats of the 4 species of North American tortoises (Germano and others 1994). Throughout the Mojave Desert, tortoises occur on sandy loam to rocky soils on valley bottoms and bajadas and occasionally on rocky hillsides (Germano and others 1994). In both the Lower Colorado River Valley and Arizona Upland subdivisions of the Sonoran Desert, tortoises typically occur on rocky hillside slopes and bajadas and are absent from intermountain valley floors (Germano and others 1994). Tortoises in the Sonoran Desert may also be found in soil burrows and caliche caves of incised washes extending from the bajadas (Woodman and others 1996). Tortoises at the southern end of their distribution in Sinaloan thornscrub and Sinaloan deciduous forest have only been found on hillsides (Fritts and Jennings 1994; Germano and others 1994).

Tortoises use burrows extensively throughout their range (Germano and others 1994). Burrow depths reach 10 m in the northeastern Mojave Desert, which is subject to cold winter temperatures (Woodbury and Hardy 1948). Burrow depths at lower (warmer) elevations in the Mojave Desert usually range from 1-3 m (Luckenbach 1982). Burrow depths in the tortoise's Sonoran and Sinaloan distribution are also usually relatively shallow, except in washes, probably as a result of rocky substrates and mild winters (Germano and others 1994). Rocky substrates also limit the number of available burrow sites in the Sonoran Desert (Averill-Murray and others 2002a).

Tortoises use multiple burrows, often exceeding 20 in a year, within their home ranges (Averill-Murray and others 2002b). Annual home range areas are highly variable, with averages ranging from 9.2-25.8 ha for males and 2.6-23.3 ha for females in the Sonoran Desert (Averill-Murray and others 2002b). Environmental conditions play a role in this variability. In the Mojave Desert, tortoise home ranges were smaller in a drought year than in a wet year (Duda and others 1999).

A unique Sonoran Desert tortoise population occurs in the San Pedro Valley, Arizona. Tortoises occur mainly on steep canyon slopes at this site, but it differs from other Sonoran Desert populations in that it lacks large boulders (Woodman and others 1996). Most tortoise burrows at the San Pedro site occur in terrace gravel caves or diatomaceous earth, rather than below rocks or boulders as in other populations (Woodman and others 1996). Two-year home range sizes were relatively small for tortoises in this population (mean = 11.0 and 2.6 ha for males and females, respectively), possibly due to the well-developed soils and dense vegetation at the site (Bailey 1992).

Based on preliminary data (Averill-Murray and Klug 2000; Riedle and others 2002), tortoises at Florence Military Reservation also occur in atypical desert tortoise habitat. In the absence of boulder-strewn hillsides, tortoises use deeply incised washes and associated caliche caves.

FLORENCE MILITARY RESERVATION

The Florence Military Reservation (FMR) is a 10,421-ha site in Pinal County, Arizona, approximately 80 km southeast of metropolitan Phoenix (Department of Emergency and Military Affairs [DEMA] 1997). FMR contains gently sloping to nearly flat alluvial fan slopes in the north and steep, rugged hills in most of the south; elevations range from about 450 to 610 m (DEMA 1997). Erosion of the mountains to the east has filled the alluvial valley with unconsolidated to weakly consolidated silts, sands, clays, and gravels; the hills consist of prominent volcanic outcrops (DEMA 1997). Vegetation at FMR contains components of the Lower Colorado River Valley and Arizona Upland subdivisions of the Sonoran Desert, with microphyll woodlands along many washes (Snetsinger and Spicer 2001; Figure. 1).

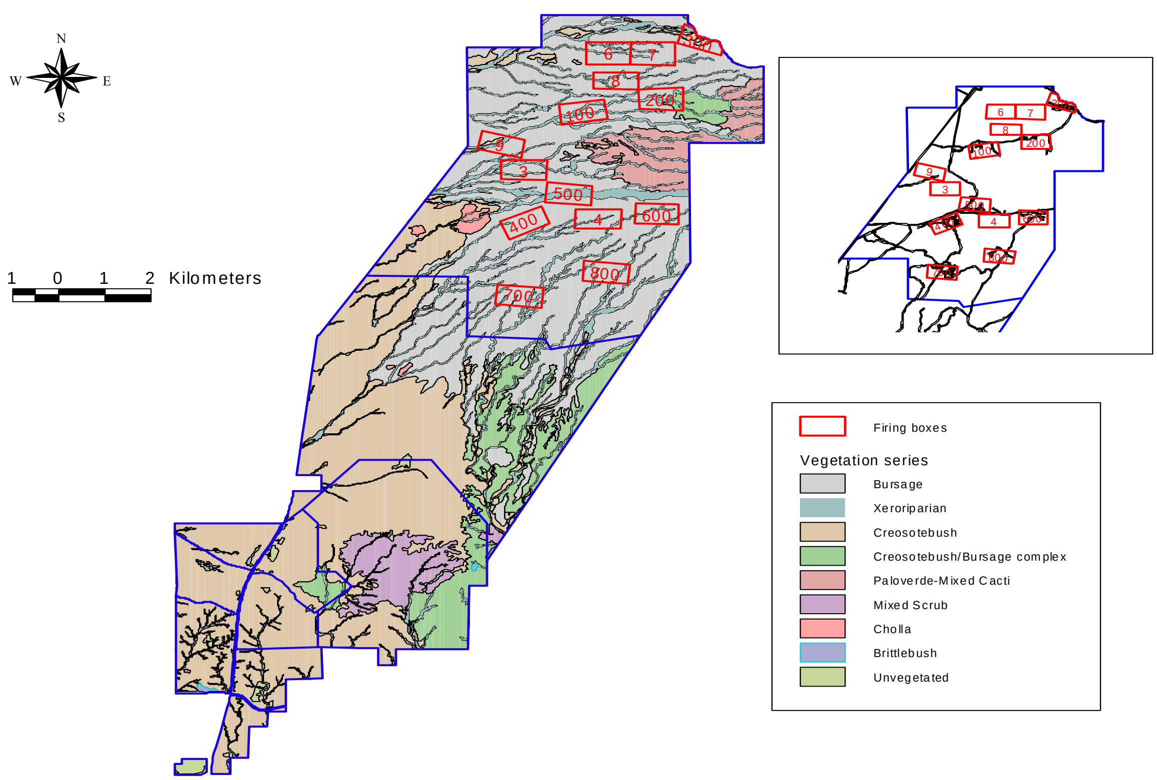

Figure 1. Map of Florence Military Reservation with vegetation series, firing boxes, and roads. Inset highlights Training Area B.

In August 1997, Arizona Army National Guard personnel conducted a desert tortoise survey at FMR. Thirty-four tortoises were located during the 1997 surveys, supplementing several previous records from 1993. All tortoises were located in or near washes (C. Pedersen, personal communication 1997).

This report presents the results of the first 3 years of an ongoing study of desert tortoise habitat use relative to lands used for military training activities at FMR, particularly in Training Area B. Training Area B is located in the northern, mostly alluvial, portion of FMR and is used for training and artillery firing (DEMA 1997). This area contains 14 designated ground support training areas (firing boxes), each measuring about 500 x 1000 m; 6 of these firing boxes have been newly established but not yet opened (Fig. 1). Artillery units are authorized to maneuver their howitzers, vehicles, and troops off-road within these designated areas (DEMA 1997). The objective of this study was to determine the spatial and temporal use of habitat at FMR relative to these firing boxes and roads.

METHODS

We searched all areas in which tortoises had previously been found in Training Area B (Figure 1), and we spent additional time searching for incised washes containing caliche caves or other sites suitable for burrow excavation. We recorded midline carapace length (MCL) to the nearest mm with pottery calipers and a metal rule. Each tortoise was assigned a number, and marginal scutes were permanently notched with triangular files (Berry, 1984; Appendix). Bridge marginals were not notched on tortoises <120 mm MCL. We also wrote the identification number on a dot of correction fluid painted on the right fourth costal scute and covered it with clear epoxy. We determined gender for tortoises ≥180 mm MCL; we considered those with concave plastrons to be males. We took close-up photographs of the full carapace, full plastron, and left fourth costal of each tortoise.

We attached radio transmitters (ATS, AVM Instrument Company or Wildlife Materials) to the anterior carapace of a subset of adult tortoises using 5-minute gel epoxy (Devcon) and monitored telemetered tortoises each week. During the winter months (November through February) when tortoises were inactive, they were located once a week, but not inspected. During the activity season (March through October) we located tortoises 2-3 times a week. We visually inspected each tortoise for injuries, morphological anomalies, and symptoms of cutaneous dyskeratosis and upper respiratory tract disease (URTD). We handled all tortoises with disposable latex gloves to minimize the potential spread of pathogens between individual tortoises. Any instruments coming into contact with a tortoise during handling were disinfected prior to use on another tortoise (Averill-Murray 2000). We recorded tortoise positions with Garmin GPS III Plus (Garmin Corporation) receivers and mapped the locations with ArcView GIS 3.2 (Environmental Systems Research Institute, Inc.).

We use the term 'burrow' to specifically refer to a subsurface cavity formed by erosion and/or excavated by a tortoise or another animal (Burge 1978), including cavities eroded or excavated into hard calcium carbonate (caliche) soils along incised arroyo (dry stream) banks. We marked burrows with individually numbered aluminum tags which we affixed with epoxy to rock faces above the burrow, wired to overhanging vegetation, or wired to a nail driven into caliche above the burrow entrance. We only marked relatively permanent burrows, defined as modified shelters ≥1/2 the tortoise's shell length. We did not include pallets (shallow, scraped out areas <1/2 tortoise length) or other temporary shelters unmodified by the tortoise (for example, under trees, shrubs, or rocks).

During the winter of 2001, we began mapping all caliche caves within Training Area B. Data collected at each cave included latitude and longitude, depth, aspect, orientation of cave opening, depth, height of cave opening at the tallest point, and width of cave opening at widest point. Data collection is still ongoing and no analysis on the current data set has been completed.

Nest site selection was determined by use of X-radiography. In May 2002 females were located and brought to a central point to be X-rayed. Females were radiographed using a HF-80 (MinXray) portable X-ray machine powered by a gasoline generator. Eggs could be felt by palpitation, but radiographs were used to confirm presence of shelled eggs and to determine clutch size. After confirmation of shelled eggs, tortoises were palpitated on a weekly basis until eggs were no longer detected. Nest sites were located by observing female movement patterns. Female desert tortoises typically lay eggs in the loose soil of a burrow. They may remain in the burrow prior to and after oviposition. Field workers also looked for nests in the burrow entrance using hand trowels.

We estimated minimum convex polygon (MCP) home ranges for telemetered tortoises with the Animal Movement extension to ArcView (Hooge and Eichenlaub 1997). We overlaid tortoise locations and home range polygons on a draft vegetation map in ArcView (resolution to the series level of Brown and others 1979) prepared for FMR (Snetsinger and Spicer 2001).

We used compositional analysis (Aebischer and others 1993) to determine habitat use based on home range of tortoises. Compositional analysis takes into account that each individual's movements determine a trajectory through space and time, and habitat use is the proportion of that trajectory contained within each habitat type. If there is no selection for any habitat type, one assumes that the individual is using each habitat in direct relation to its availability. For the radio telemetry data collected at FMR, we computed the proportion of each vegetation association within each home range polygon and computed the proportion of each tortoise's observed locations in each association. Log-ratio transformations were performed on the given proportions. The log-ratio differences between habitat types were used to determine habitat selection by desert tortoises. We analyzed these data using Resource Selection Analysis Software (Leban 1999) to determine habitat use and selection by tortoises at FMR.

RESULTS

Project personnel completed a total of 58 person field days in 2000, 86 person field days in 2001, and 162 person field days in 2002. Volunteers contributed an additional 35 days for a total of 341 person-field days searching for and monitoring tortoises. Through March 2002, we have marked 29 tortoises: 10 males, 12 females, and 7 juveniles (Table 1), 4 of which were added in 2002. We mapped 2118 tortoise locations. In 2001 we followed the movements of 17 adult tortoises: 7 males, 7 females and 3 juveniles. Differences in numbers of tortoises followed between years are due to mortality of the tortoise, or early transmitter failure.

We found 2 carcasses in 2000, 3 in 2001, and 1 in 2002 (Figure 2). The 2002 carcass was a hatchling found inside an old nest. Only one carcass, female 409, has shown signs of vehicular damage. The damage occurred prior to her initial capture in September 2000, and fragments of her shell were found in November 2001.

HOME RANGE

The 17 tortoises tracked through 2002 were divided into 2 telemetry groups. The northern group contained up to 9 tortoises and was located near firing box 200 (Fig. 3-5). The southern group was situated around firing box 700 and contained 9 tortoises (Fig. 6-7). We estimated tortoise home range sizes up to 53.7 ha (Table 2). Mean home range for males (20.9 ha $\pm$ 19.56 SD) was twice the size as the mean home range for females (10.1 ha $\pm$ 8.69 SD). Four tortoises in the northern group used firing box 200, although only 2 tortoises occupied a large area within the firing box. Firing box 700 was used by 5 of the tortoises, although most of their movements were confined to a major wash running through the southeastern corner of the firing box.

BURROWS

We marked 71 permanent burrows at FMR. Tortoises used up to 12 different burrows during the study. Tortoises used 4 basic types of shelter at FMR: caliche caves, soil burrows, pallets, and woodrat middens. Caliche caves are associated with deeply incised washes, while soil burrows were generally found along stretches of a wash with more gently sloping sides. On one occasion male 413 used a soil burrow constructed on a flat bench between 2 washes. Pallets and unmodified resting sites were generally found under shrub clumps, primarily triangle leaf bursage (*Ambrosia deltoidea*). Tortoises also used pallets under dead and fallen woody debris. Several tortoises occupied wood rat (*Neotoma albigula*) middens. A typical midden is constructed of woody debris and pieces of cacti, primarily cholla, providing shelter and protection for the tortoise.

Table 1. Desert tortoises marked on Florence Military Reservation. Tortoise numbers with asterisks represent individuals currently being monitored by radio telemetry. Tortoise numbers skip sequence to avoid marking bridge scutes. Tortoise 1000 was marked out of sequence due to a marking error.

Tortoise #	Sex	MCL	Date Marked
400*	M	216	23 March 00
401	U	63	04 Apr 00
402	M	242	18 Apr 00
403*	M	277	25 Apr 00
404*	F	265	25 Apr 00
405*	F	234	24 May 00
406*	M	248	25 Jul 00
407	M	267	29 Aug 00
408	F	231	05 Sep 00
409	F	238	26 Sep 00
410*	F	250	03 Oct 00
411*	M	240	03 Oct 00
412*	F	246	22 Feb 01
413*	M	243	17 May 01
414*	M	246	17 May 01
417	U	131	08 Aug 01
418	U	162	05 Sep 01
419*	M	229	05 Sep 01
420*	F	245	05 Sep 01
421	F	232	12 Sep 01
422	F	236	20 Sep 01
423	U	157	20 Sep 01
424	M	265	31 Oct 01
430*	U	185	16 Jul 02
500	F	240	06 Jun 02
501*	U	198	28 Aug 02
502*	F	222	08 Aug 01
503*	U	206	16 Jul 02
1000	F	247	21 June 01

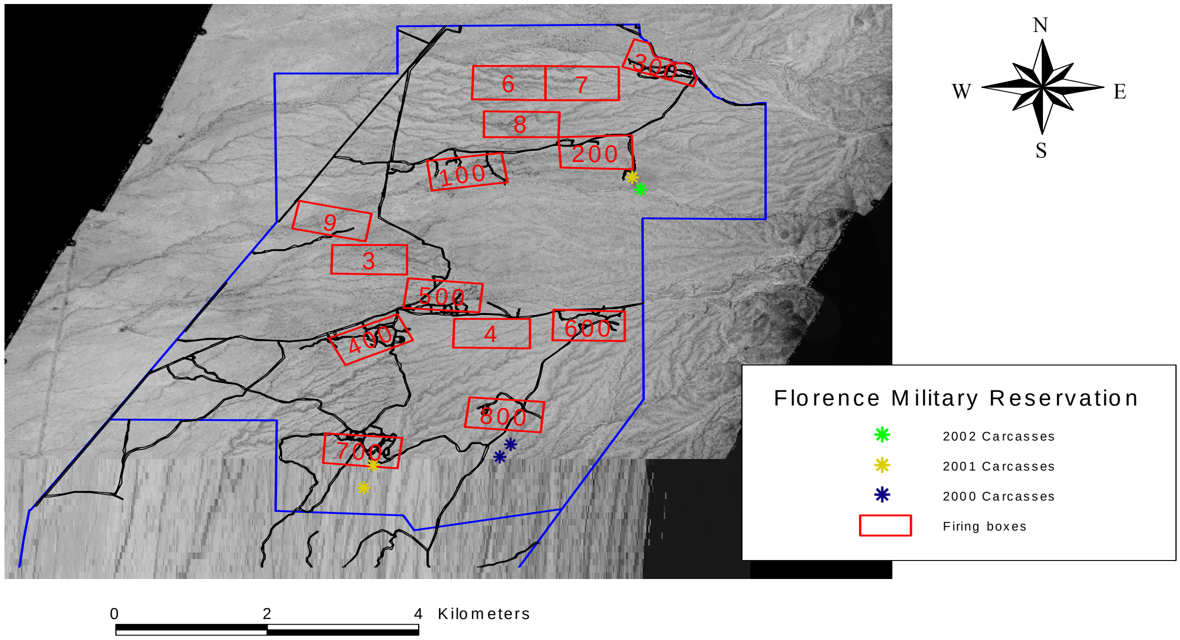

Figure 2. Distribution of tortoise carcasses found at Florence Military Reservation in the years 2000, 2001 and 2002.

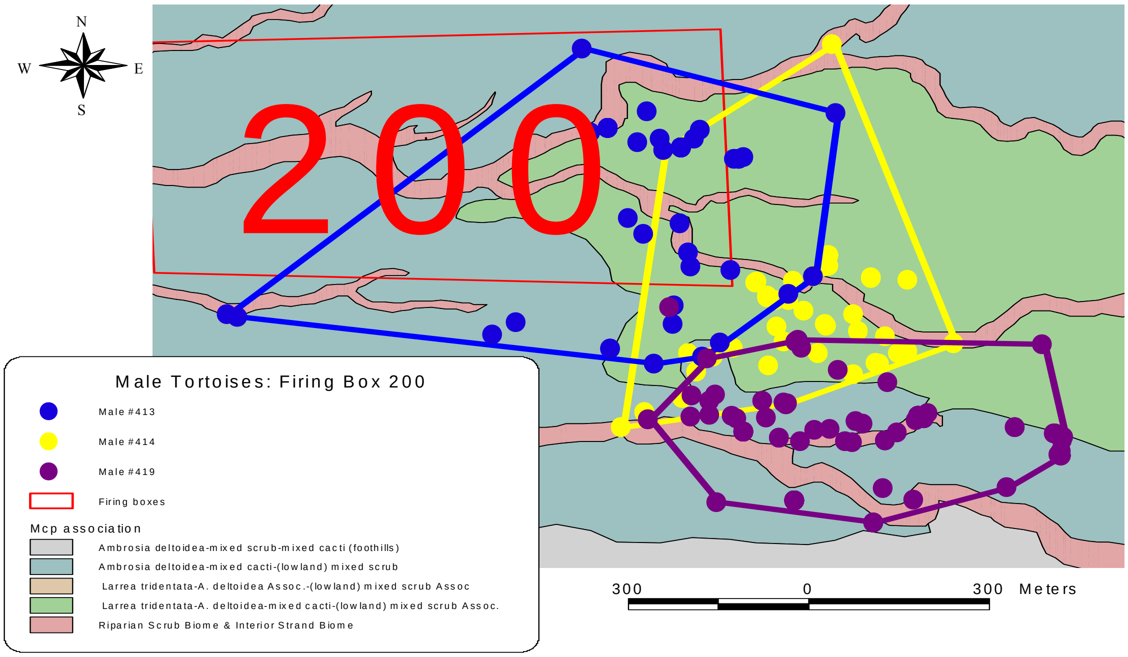

Figure 3. Locations and MCP home range polygons for male desert tortoises in the northern telemetry group on the Florence Military Reservation. Inset shows Training Area B.

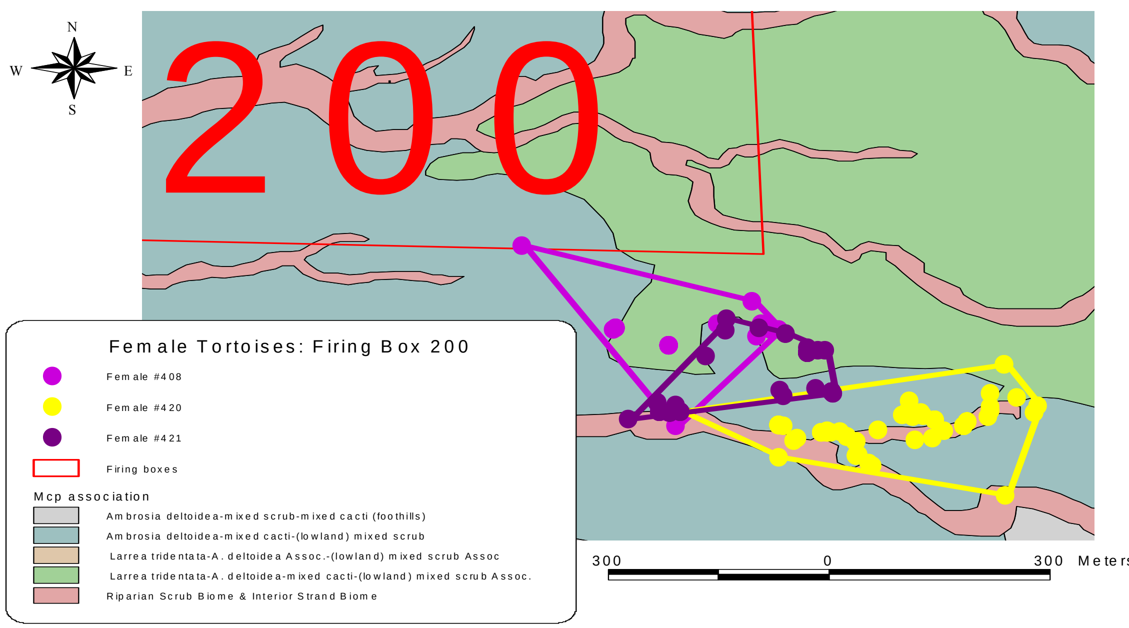

Figure 4. Locations and MCP home range polygons for female desert tortoises in the northern telemetry group on the Florence Military Reservation. Inset shows Training Area B.

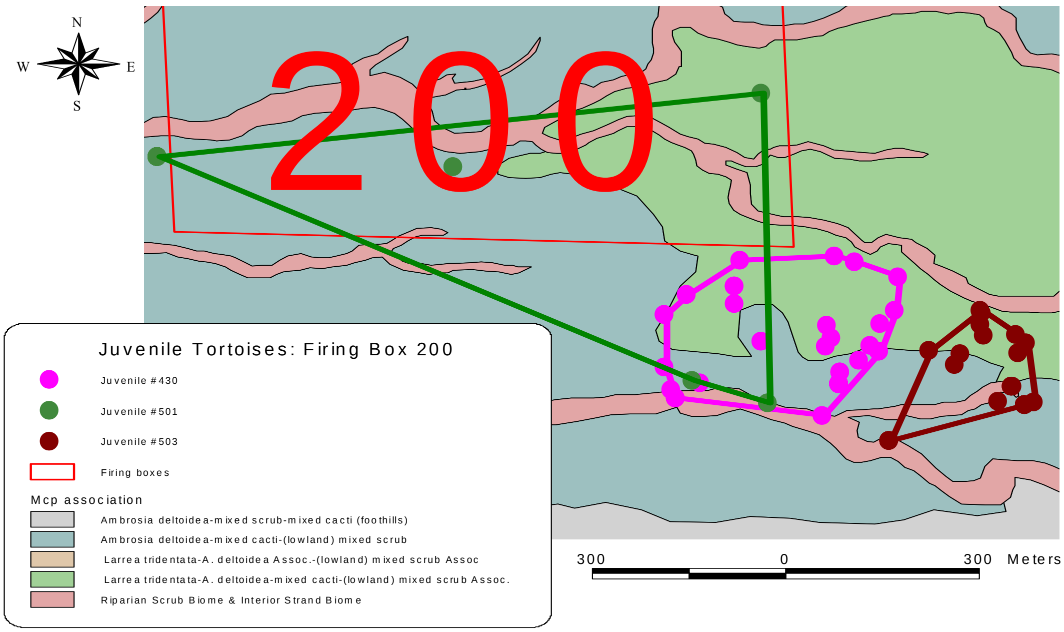

Figure 5. Locations and MCP home range polygons for juvenile desert tortoises in the northern telemetry group on the Florence Military Reservation. Inset shows Training Area B.

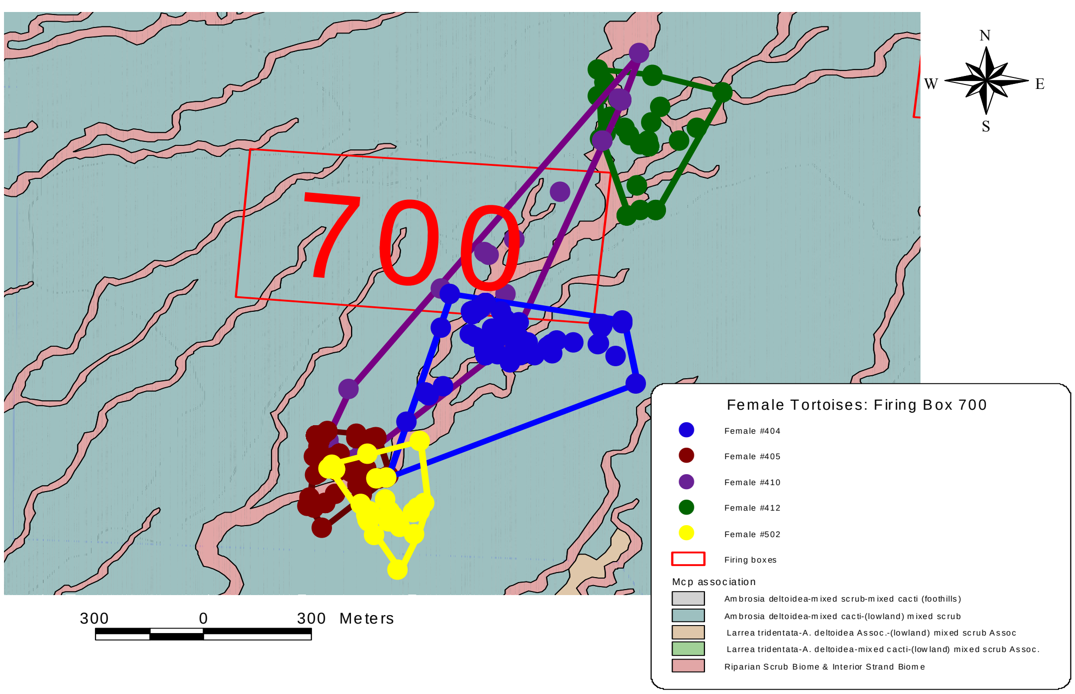

Figure 6. Locations and MCP home range polygons of female desert tortoises in the southern telemetry group on the Florence Military Reservation. Inset shows Training Area B.

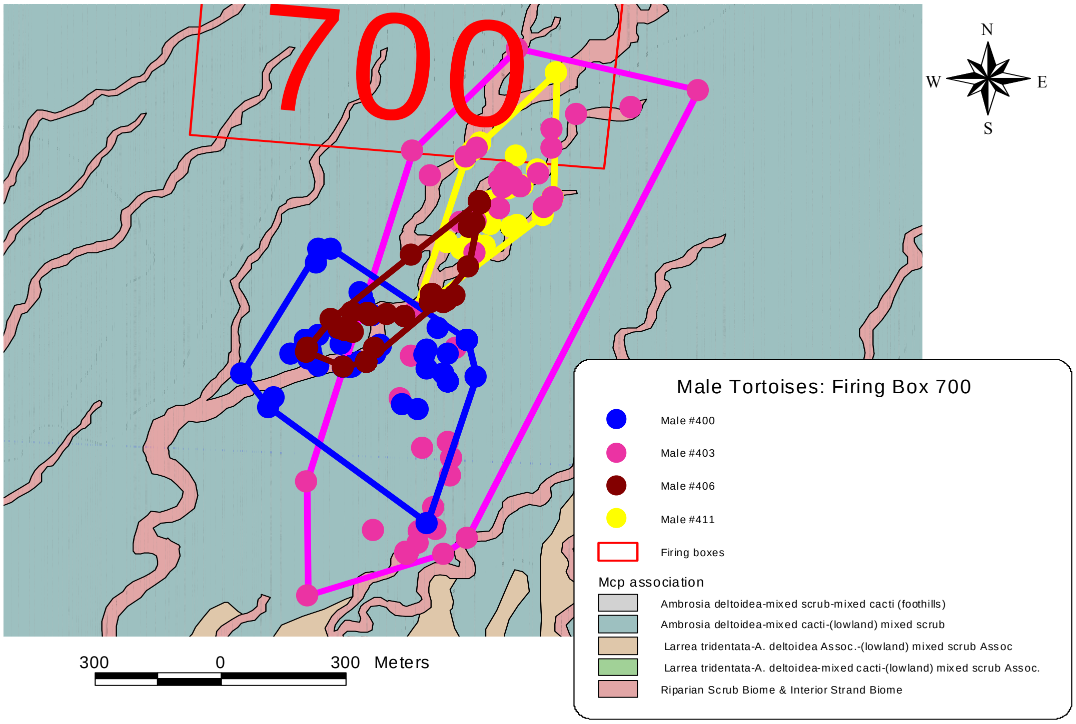

Figure 7. Locations and MCP home range polygons of male desert tortoises in the southern telemetry group on the Florence Military Reservation. Inset shows Training Area B.

Table 2. Number of radio telemetry locations, minimum convex polygon (MCP) home range areas, and shelter use by type at Florence Military Reservation. Proportions may not sum to 100% due to rounding. Numbers of tortoise locations taken at shelters are not equal to numbers of tortoise locations used to determine MCP; not all tortoise locations were taken at a shelter.

Tort		MCP		Caliche Caves		Soil Burrow		Pallet		Woodrat Midden	
#	Sex	ha	n	n	%	n	%	n	%	n	%
400	M	23.04	171	116	81	10	7	12	8	6	4
403	M	69.16	148	63	53	45	38	11	9	0	0
404	F	23.59	166	111	83	0	0	22	17	0	0
405	F	4.85	162	53	42	3	2	7	6	62	50
406	M	6.32	148	133	99	0	0	1	1	0	0
408	F	5.03	30	9	47	8	42	2	11	0	0
410	F	25.83	133	101	86	5	4	11	9	0	0
411	M	6.79	141	124	96	1	1	3	2	1	1
412	F	10.69	137	78	67	27	23	12	10	0	0
413	M	43.08	128	36	33	4	4	5	4	65	59
414	M	29.10	131	36	36	5	5	6	6	53	53
419	M	21.82	109	39	55	22	31	3	4	7	10
420	F	6.86	121	2	2	42	42	11	11	40	40
421	F	2.88	51	15	58	10	38	1	4	0	0
430	U	9.30	36	2	11	8	42	9	47	0	0
501	U	30.84	20	0	0	0	0	0	0	13	100
502	F	6.55	136	26	27	54	56	9	9	8	8
503	U	3.32	35	1	5	14	67	6	28	0	0

HABITAT USE

Compositional analysis looks at the differences in log-ratios between the proportion of the availability of each habitat type (Table 3) and the proportion at which an individual uses each habitat type (Table 4). Desert tortoises at FMR used 3 different vegetation associations, labeled A, B, and C. Association descriptions are based on those in Snetsinger and Spicer (2001). Vegetation association A (triangle leaf bursage-mixed cacti-(lowland) mixed scrub) is characterized by no overstory and a midstory dominated by triangle leaf bursage. Interspersed throughout the association is a mix of various cacti including chainfruit cholla (*Opuntia fulgida*), buckhorn cholla (*Opuntia acanthocarpa*), brownspine prickly pear (*Opuntia phaecantha*), Engelmann prickly pear (*Opuntia engelmanii*), and creosote bush (*Larrea tridentate*). Vegetation association B is a complex of creosote bush–triangle leaf bursage–mixed cacti-(lowland mixed scrub) association and triangle leaf bursage–mixed cacti-(lowland) mixed scrub association. This association is generally found along hillsides and ridge tops. Triangle leaf bursage dominates along the side slopes and creosote bush is found along the ridge tops. Vegetation association C (complex of riparian scrub biome and interior strand biome) is characterized as xeroriparian habitat, which is an area periodically submerged and is dominated by an overstory of palavered (*Parkinsonia microphylla*), desert ironwood (*Olneya tesota*), and velvet mesquite (*Prosopis velutina*).

The matrix of mean log-ratio differences of habitat use by desert tortoises at FMR (Table 5), displays negative values denoting selection against a certain habitat and positive values representing selection for a certain habitat. Habitat can then be ranked by adding the number of positive values associated with a different habitat type, with the type having the highest value being the one selected for by the study animal. The ranking for habitat use by desert tortoises at FMR in Table 5 shows that vegetation association C was selected over the other 2 habitat types used. When available (n = 9), vegetation association B was chosen over vegetation association A.

Table 3. Proportional habitat available in each desert tortoise MCP at Florence Military Reservation. Vegetation associations are defined as: A = triangle leaf bursage–mixed cacti; B = complex of creosote bush-triangle leaf bursage-mixed cacti; and C = complex of riparian scrub biome.

	Vegetation Association		
Tortoise #	A	B	C
400	0.92	0	0.09
403	0.88	0	0.12
404	0.79	0	0.21
405	0.81	0	0.19
406	0.59	0	0.41
408	0.53	0.46	0.01
410	0.79	0	0.21
411	0.69	0	0.31
412	0.69	0	0.31
413	0.41	0.45	0.14
414	0.09	0.82	0.09
419	0.57	0.29	0.14
420	0.74	0.04	0.21
421	0.69	0.27	0.03
430	0.37	0.58	0.04
501	0.61	0.31	0.10
502	0.86	0	0.15
503	0.52	0.33	0.15

Table 4. Proportional use of habitat by desert tortoises at Florence Military Reservation. Vegetation associations are defined as: A = triangle leaf bursage–mixed cacti; B = complex of creosote bush-triangle leaf bursage-mixed cacti; and C = complex of riparian scrub biome.

Tortoise #	Vegetation Association		
	A	B	C
400	0.34	0.00	0.66
403	0.40	0.00	0.60
404	0.24	0.00	0.76
405	0.88	0.00	0.12
406	0.26	0.00	0.74
408	0.23	0.57	0.20
410	0.23	0.00	0.77
411	0.08	0.00	0.91
412	0.43	0.00	0.57
413	0.04	0.65	0.31
414	0.06	0.66	0.28
419	0.75	0.06	0.20
420	0.41	0.03	0.57
421	0.40	0.29	0.31
430	0.39	0.45	0.15
501	0.84	0.10	0.10
502	0.94	0.00	0.06
503	0.32	0.41	0.25

Table 5. Matrix of mean log-ratio differences of habitat use by desert tortoises at Florence Military Reservation. Ranking is assigned by counting the number of positive values in each row. Vegetation associations are defined as: A = triangle leaf bursage–mixed cacti; B = complex of creosote bush-triangle leaf bursage-mixed cacti; and C = complex of riparian scrub biome.

Vegetation Association	A	B	C	Ranking
A		-0.5219	-1.6516	0
B	0.5219		-1.1297	1
C	1.6516	1.1297		2

Vegetation association B was only available to tortoises in the northern telemetry group so the same process was used to determine if those tortoises were choosing the rocky hillside over the incised washes and caliche caves. Only tortoises shown to use vegetation association B in Table 4 were selected for this analysis. The final rankings are shown in Table 6. The results are similar to those when all tortoises are pooled. Vegetation association C is selected over A and B, and vegetation association B is selected over A.

Table 6. Matrix of mean log-ratio differences of habitat use by desert tortoises in the northern telemetry group at Florence Military Reservation Ranking is assigned by counting the number of positive values in each row. Vegetation associations are defined as: A = triangle leaf bursage–mixed cacti; B = complex of creosote bush-triangle leaf bursage-mixed cacti; and C = complex of riparian scrub biome.

Vegetation Association	A	B	C	Ranking
A		-0.2123	-1.6710	0
B	0.2123		-1.4588	1
C	1.6710		1.4588	2

Nest Site Selection

Four of the 7 monitored females produced eggs and mean clutch size was 5.0. Three of the 4 tortoises are suspected to have nested in caliche caves. Although no nests were found in the shelter entrance by observers, females stayed at the shelter sites several weeks pre-and post-oviposition. The nest site for the fourth female is uncertain, as she was very mobile, moving from shelter site to shelter site during the time of oviposition.

Discussion

Home Range

Observed home ranges in this study generally fell within ranges observed at other populations in the Sonoran (Averill-Murray and Klug 2000; Bailey 1992; Barrett 1990; Martin 1995; Murray and others 1995; Trachy and Dickinson 1993) and Mojave deserts (Burge 1977; Duda and others 1999; O'Connor and others 1994). One recognized problem with the MCP method is the inclusion of area not actually used by the individual animal (White and Garrot 1990). For example, it is not evident whether male #403 used much, if any, of the eastern portion of his home range polygon (Figure 5). Rautenstrauch and Holt (1995) did find that the MCP method performed well with $\geq$60 locations per individual.

Desert tortoise movement patterns at other sites consist of a period of time spent around a burrow or group of burrows before moving to another area, thus resulting in multiple, sometimes distant, centers of activity (O'Connor and others 1994; Rautenstrauch and Holt 1995). In 2000, tortoises were not observed long enough to establish centers of activity. With the additional locations recorded in 2001 and 2002, we have begun to establish primary activity areas for most of the tortoises at FMR. A combination of home range estimators, such as MCP's and Kernels that display overall movements in relation to activity centers may better describe home range use and seasonal movement patterns.

Tortoises may alternate between several different burrows, occupying each burrow for a day or up to several weeks. In areas where several tortoise MCPs overlap, one burrow may be used by multiple tortoises. For instance, burrow #36 is a >1-m caliche cave that is used by 4 different radio-marked tortoises. On October 24, 2001, 3 of the 4 tortoises occupied burrow #36 at the same time.

HABITAT USE

Training Area B, the focal area of interest on FMR for this study, is characterized by gently sloping to flat alluvial slopes. This area is dominated by bursage, creosote bush, and paloverde/mixed cacti, bisected by xeroriparian scrub (Figure 1). Most of our initial captures occurred within xeroriparian areas (vegetation association C) as a result of our focus on searching caliche caves. Most of the tortoises we tracked spent a substantial amount of time in washes. We initially expected to find tortoises using relatively linear home ranges along the washes as they moved between caliche caves. Somewhat surprisingly, due to the fact that Sonoran desert tortoises do not typically inhabit valley floors outside of washes (Germano and others 1994), we also found telemetered tortoises (primarily in the northern telemetry group) spending substantial time within bursage-dominated habitat (vegetation association A) (Table 4). Most of the locations taken within the bursage-dominated habitat were of actively moving tortoises, resting tortoises, or hibernating tortoises. During periods of moderate temperatures, resting tortoises were primarily found under a bursage clump in an unmodified shelter or a shallow scraped-out pallet. Several tortoises spent long periods of inactivity (hibernation and hot dry periods) in woodrat middens.

The results from compositional analysis (Table 6) show that tortoises selected for washes (vegetation association C). Although they did use vegetation association A, tortoise home ranges seem to be centered around the washes and their associated caliche caves. In the northern telemetry group though, many tortoises used all 3 vegetation associations equally. On the northern end of the reservation the composition of vegetation association A is different on the south end. Prickly-pear cactus occurs in much higher density, and is a major tortoise food source for short periods of time every year. In addition, wood rats build their houses within large prickly-pear clumps. Several tortoises used these woodrat middens fairly extensively, especially during hibernation. Vegetation association B is a rocky hillside that is more typical Sonoran desert tortoise habitat (Germano and others 1994). The northern portion of training area B may provide a wider variety of shelter-types than the southern portion, allowing tortoises to use other vegetation associations more frequently. The results of the compositional analysis reflect the low proportion of vegetation association C available to tortoises in relation to the other two vegetation associations. Caliche caves are still important shelter sites to both the northern and southern groups based on the compositional analysis and preliminary nest site selection results.

Tortoises monitored in the vicinity of firing box 200 used a considerable portion of the firing box (Figures 3-5). A major wash runs down the middle of firing box 200, which has been used by telemetered tortoises. Also, several tortoises have hibernated within woodrat middens within firing box 200. Tortoise use of firing box 700 was constrained to a major wash running through the southeastern corner (Figures 6 and 7).

CONCLUSIONS

The presence of tortoises and their observed use of primarily xeroriparian (vegetation association C) and bursage (vegetation association A) dominated habitats is important relative to National Guard training activities because of the preponderance of both habitat types within all firing boxes (Figure 1). Preliminary data suggests that tortoise use of xeroriparian areas is tied to the presence of caliche caves. It is unknown whether tortoise distribution across FMR is clustered around particular habitat features such as caliche caves or if tortoises are more or less uniformly distributed at low density in areas with adequate shelter sites. The high proportion of burrow/pallet use in non-xeroriparian habitats also suggests that tortoises in those burrows may be at increased risk of injury from training activities or other off-road vehicle recreation (Berry and others 2000).

Continual study of radio-marked tortoises would allow more precise measurements of proportional habitat use. Continued monitoring would increase the reliability of habitat use within a tortoise's home-range, while more searches for tortoises within other habitat types would provide information concerning tortoise distribution throughout Training Area B. Continued mapping of caliche caves within Training Area B would help determine if tortoise density is clustered around caves, which in turn could provide pertinent information concerning the placement and use of firing boxes. Finally, other potential sources of variation in tortoise habitat use should not be overlooked. For example, do females select different habitats relative to reproductive cycle (for example, Berry and others 2000)? Do juvenile tortoises select different habitat than adults (for example, Duda and others 1999)?

Much progress has been made in understanding desert tortoise habitat use at FMR, but there is still much to be learned. Additional research will provide valuable information concerning management recommendations regarding National Guard training activities, especially relative to firing boxes, and recreational off-road uses in the area.

RECOMMENDATIONS

- Conduct additional surveys for tortoises throughout Training Area B for a minimum of 1 additional year. Continue mapping all tortoise locations and all caliche caves.

- Continue monitoring telemetered tortoises for a minimum of 1 additional year, maintaining an equal sex ratio of 14 adult tortoises, and up to 5 juvenile desert tortoises, as available.

- Monitor telemetered tortoises approximately 2-3 times per week during the active season (March-October) and 1 day per week during the inactive season (November through February).

- Radiograph females for 1 additional reproductive season to determine nesting locations.

- Evaluate the utility of home range estimators that allow multiple activity centers, including cluster methods and kernel analyses (Hooge and Eichenlaub 1997; Kenward and Hodder 1996), relative to the minimum convex polygon method.

- Relate cave abundance, habitat use, nest site selection and home range analysis to firing box placement and use.

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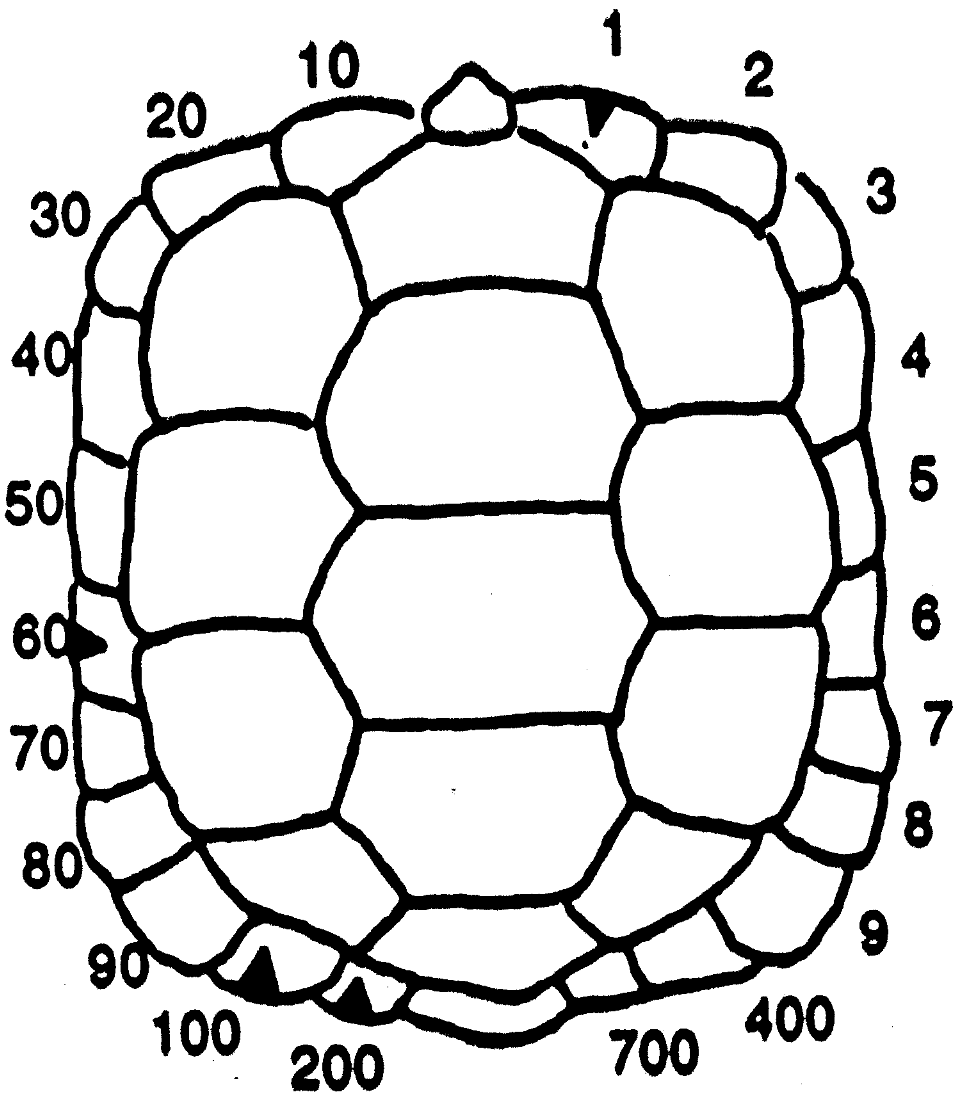
APPENDIX: TORTOISE MARKING SYSTEM



Tortoise number = 361