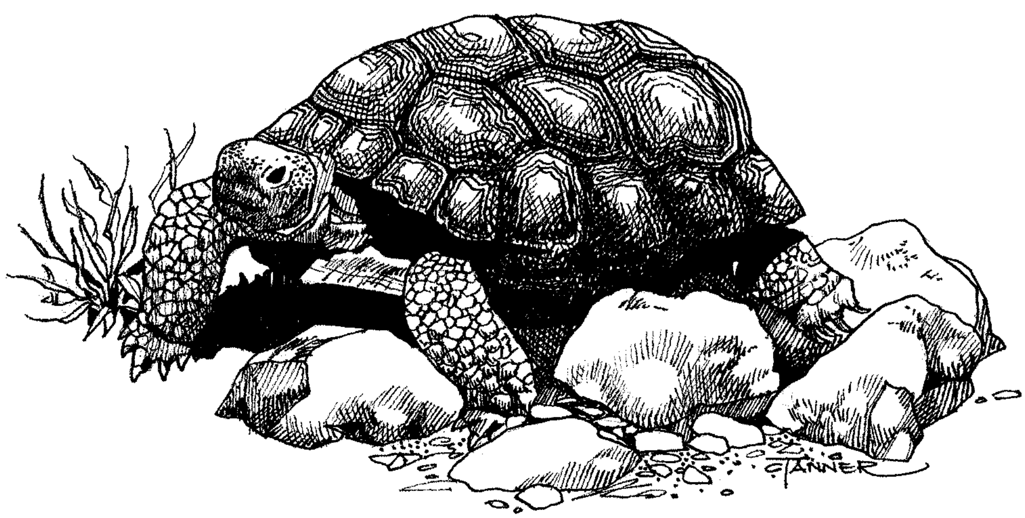
DESERT TORTOISE HABITAT USE AND HOME RANGE SIZE ON THE FLORENCE MILITARY RESERVATION: FINAL REPORT

Clayton L. Lutz, Nongame Wildlife Specialist
J. Daren Riedle, Desert Tortoise Coordinator
Roy C. Averill-Murray, Amphibians and Reptiles Program Manager

Nongame Branch, Wildlife Management Division
Arizona Game and Fish Department



Technical Report 242
Nongame and Endangered Wildlife Program
Program Chief: Eric Gardner
Arizona Game and Fish Department
2221 West Greenway Road
Phoenix, Arizona 85023-4399

March, 2005
AZ National Guard project number AZ#08098002

Civil Rights and Diversity Compliance

The Arizona Game and Fish Commission receives federal financial assistance in Sport Fish and Wildlife Restoration. Under Title VI of the 1964 Civil Rights Act, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, Title IX of the Education Amendments of 1972, the U.S. Department of the Interior prohibits discrimination on the basis of race, color, religion, national origin, age, sex, or disability. If you believe you have been discriminated against in any program, activity, or facility as described above, or if you desire further information please write to:

Arizona Game and Fish Department
Office of the Deputy Director, DOHQ
2221 West Greenway Road
Phoenix, Arizona 85023-4399

and

The Office for Diversity and Civil Rights
U.S. Fish and Wildlife Service
4040 North Fairfax Drive, Room 300
Arlington, Virginia 22203

Americans with Disabilities Act Compliance

The Arizona Game and Fish Department complies with all provisions of the Americans with Disabilities Act. This document is available in alternative format by contacting the Arizona Game and Fish Department, Office of the Deputy Director at the address listed above or by calling (602) 789-3290 or TTY 1-800-367-8939.

RECOMMENDED CITATION

Lutz, C.L., Riedle, J.D., and R.C. Averill-Murray. 2005. Desert tortoise habitat use and home range size on the Florence Military Reservation: Final Report. Nongame and Endangered Wildlife Program Technical Report 242. Arizona Game and Fish Department, Phoenix, Arizona.

ACKNOWLEDGMENTS

We thank Dan Adikes, Shea Armstrong, Andrew Cordery, Melinda Frankus, Josh Fuller, Aaron Goodwin, Rusty Grimpe, Joe Hackler, Richard Kazmaeir, Coral Kiep, Chris Klug, Brandi Kuhlman, Day Ligon, Ed Moll, Tina Poole, Shondra Seils, Jim Shurtliff, Shell Stachowicz and Tom Taylor for their valuable volunteer assistance in the field. Susan Snetsinger and Jim Hatten provided GIS logistical support for base maps. Catherine Ripley provided logistical support from the Arizona Army National Guard. Cover image by Cindy Tanner.

PROJECT FUNDING

Funding for this project was provided by the Arizona Game and Fish Department's Heritage Fund and Nongame Checkoff, the U.S. Fish and Wildlife Service's Partnerships for Wildlife program administered by the National Fish and Wildlife Foundation, and the Arizona Army National Guard (DEMA No. M0-0041).

Table Of Contents

List of Figures

List of Tables

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

Clayton L. Lutz, J. Daren Riedle, and Roy C. Averill-Murray

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 and habitat 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).

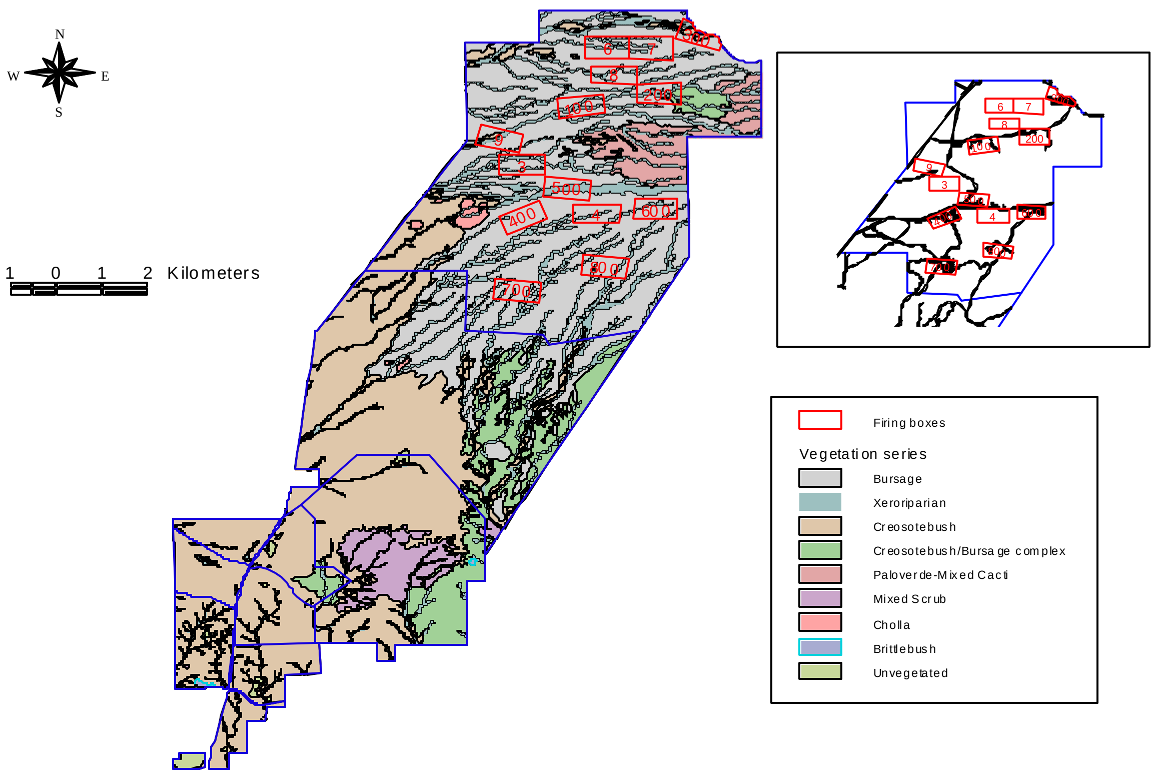


Figure 1. Map of Florence Military Reservation with vegetation series, firing boxes, and roads. Inset highlights Training Area B.

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 a 5 year study on 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 is 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 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 1). 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, Telonics, 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, predominantly during morning and late afternoon to coincide with peak activity periods. 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).

We mapped caliche caves by searching all washes within Training Area B. Data collected at each cave included UTM location, depth, aspect, orientation of cave opening, height of cave opening at the tallest point, and width of cave opening at widest point.

Nest site selection was determined by use of X-radiography. In May 2002 and May 2004 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 palpation, but radiographs were used to confirm presence of shelled eggs and to determine clutch size. After confirmation of shelled eggs, tortoises were palpated 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 (Murray and others 1996). Field workers also looked for nests in the burrow entrance using hand trowels.

We calculated minimum convex polygon (MCP) home ranges and used the kernel method to estimate probability densities for telemetered tortoises with the Animal Movement extension to ArcView (Hooge and Eichenlaub 1997). MCP home ranges are constructed by linearly connecting the outer most location of each animal and the home range size can be determined by calculating the area of the resulting polygon (Mohr 1947). Kernel home ranges are established by estimating the probability that the animal will be located within an area at any given time (Worton 1989). Probability contours of 0.95, 0.80, 0.65, 0.50, 0.35, 0.20, and 0.05 were used and the smoothing parameter was determined using least-squares cross-validation (Worton 1989). Kernel probability contours were used to identify centers of activity. We overlaid tortoise locations and home range polygons as well as probability densities 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 MCP home range. 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. We performed compositional analysis based on two types of habitat classification. One classification uses vegetation association defined by Snetsinger and Spicer (2001). The other classification is based on geomorphology and includes habitats designated as incised washes, gently sloping to flat alluvial slopes, and volcanic hills. Incised washes were considered to be the same areas that Snetsinger and Spicer (2001) designated as riparian scrub as this vegetation association is found only within incised washes at FMR. Only one volcanic hill is located in Training Area B and this habitat was delineated with the use of aerial photography. All other areas located in Training area B were considered to be gently sloping to flat alluvial slopes. We computed the proportion of each habitat type within each home range polygon and computed the proportion of each tortoise's observed locations in each habitat. 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, 162 person field days in 2002, 80 person field days in 2003, and 51 person field days in 2004. Volunteers contributed an additional 40 days for a total of 465 person field days searching for and monitoring tortoises. The locations of 597 caliche caves were mapped (Figure 2). We marked 37 tortoises: 10 males, 18 females, and 9 juveniles (Table 1). We recorded 3132 tortoise locations. We followed the movements of 18 tortoises: 7 males, 9 females and 2 juveniles of unknown sex. One individual was originally designated as a juvenile but was later determined to be a female. 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, 1 in 2002, 2 in 2003 and none in 2004 (Figure 3). The 2002 carcass was a hatchling found inside an old nest. Only one carcass, female 409, showed signs of vehicular damage but it is unclear as to whether this damage was the cause of death. The damage occurred prior to her initial capture on 26 September 2000, and she was last captured alive on 17 October 2000. Her carcass was found in fragments in November 2001.

HOME RANGE

The 18 tortoises tracked with radio telemetry equipment were divided into 2 groups. The northern group contained nine tortoises and was located near firing box 200 (Fig. 4-6). The southern group also contained 9 tortoises and was situated near firing box 700 (Fig. 7-8). We estimated tortoise MCP home range sizes up to 93.5 ha (Table 2). Mean home range for males (33.4 ha ± 29.0 SD) was twice the size as the mean home range for females (14.85 ha ± 14.1 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 telemetered tortoises, with most locations near a major wash running through the eastern half of the firing box.

The kernel method was used to estimate probability densities and to identify centers of activity for 6 tortoises in the southern group and 8 tortoises in the northern group (Figure 9 and Appendix 2). The remaining telemetered tortoises did not have enough location points to create comparable kernels. All 6 tortoises in the southern group had a circular or slightly linear kernel home range that surrounds one center of activity. The northern group had 3 tortoises that follow this pattern and 5 tortoises that had 2 or more centers of activity.

BURROWS

We marked 125 permanent burrows at FMR. Tortoises used up to 16 different burrows during the study. Tortoises used 5 basic types of shelter at FMR: caliche caves, soil burrows, burrows under boulders, pallets, and woodrat (*Neotoma albigula*) middens (Table2). 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. Burrows under boulders were only found on the hill in the northern telemetry area. 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. A typical woodrat 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 that were 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	218	23 March 00
401	U	63	04 Apr 00
402	M	242	18 Apr 00
403*	M	277	25 Apr 00
404*	F	267	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	244	17 May 01
414*	M	246	17 May 01
417	U	131	08 Aug 01
418	U	162	05 Sep 01
419*	M	232	05 Sep 01
420*	F	245	05 Sep 01
421*	F	232	12 Sep 01
422	F	236	20 Sep 01
423	U	158	20 Sep 01
424	M	268	31 Oct 01
430*	U	189	16 Jul 02
431	U	189	15 Jul 03
432	F	233	27 Aug 03
433	F	246	23 Sep 03
434	F	231	23 Sep 03
500	F	240	06 Jun 02
501*	U	202	28 Aug 02
502*	F	222	08 Aug 01
503*	U	210	16 Jul 02
509	F	241	26 May 04
510	F	235	29 Jun 04
511	U	115	14 Jul 04
512	U	55	14 Jul 04
1000	F	247	21 Jun 01

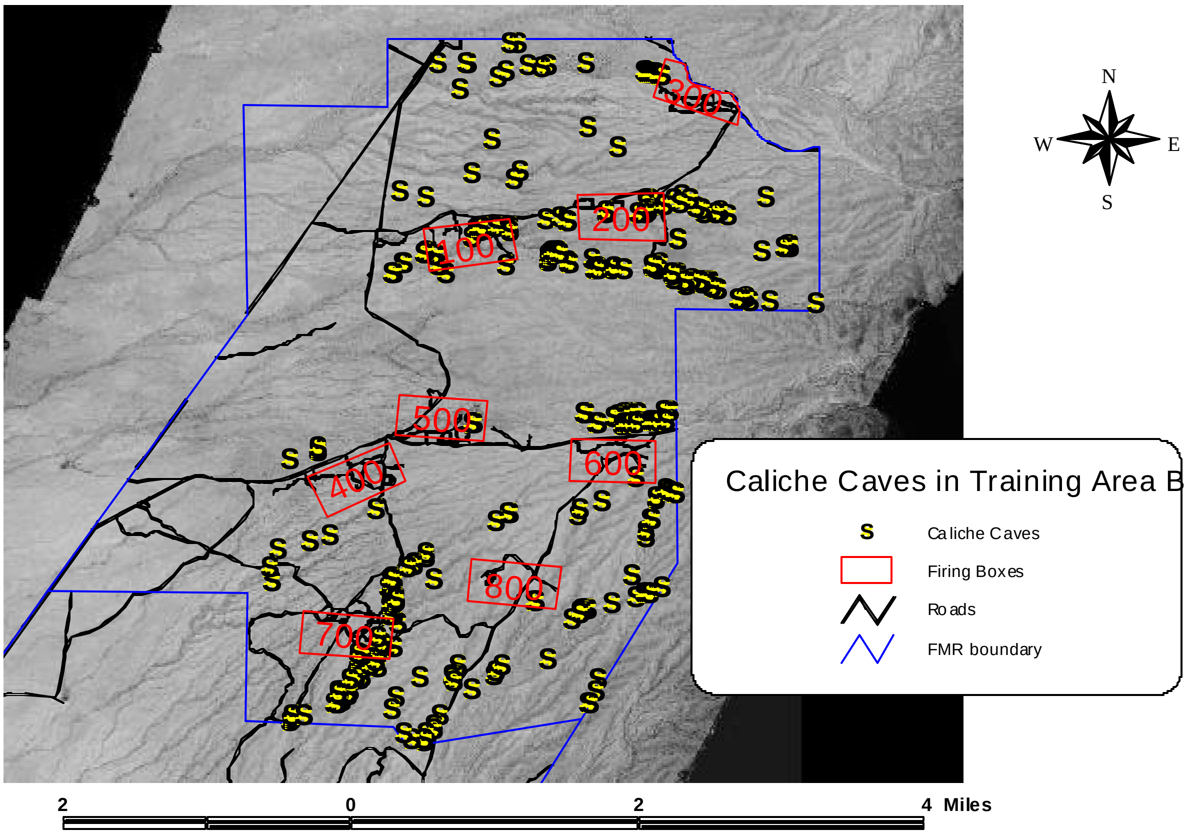


Figure 2. Distribution of caliche caves within Training Area B on the Florence Military Reservation

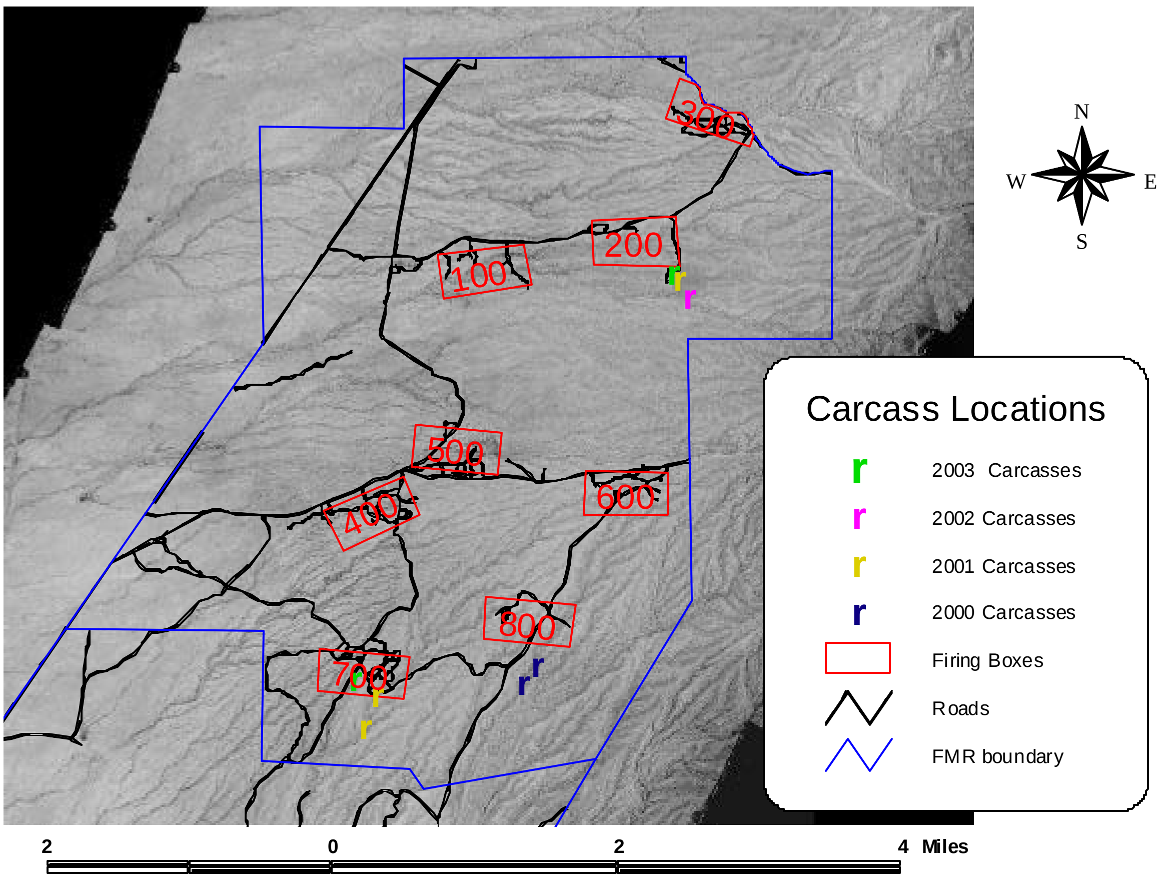


Figure 3. Distribution of tortoise carcasses found at Florence Military Reservation.

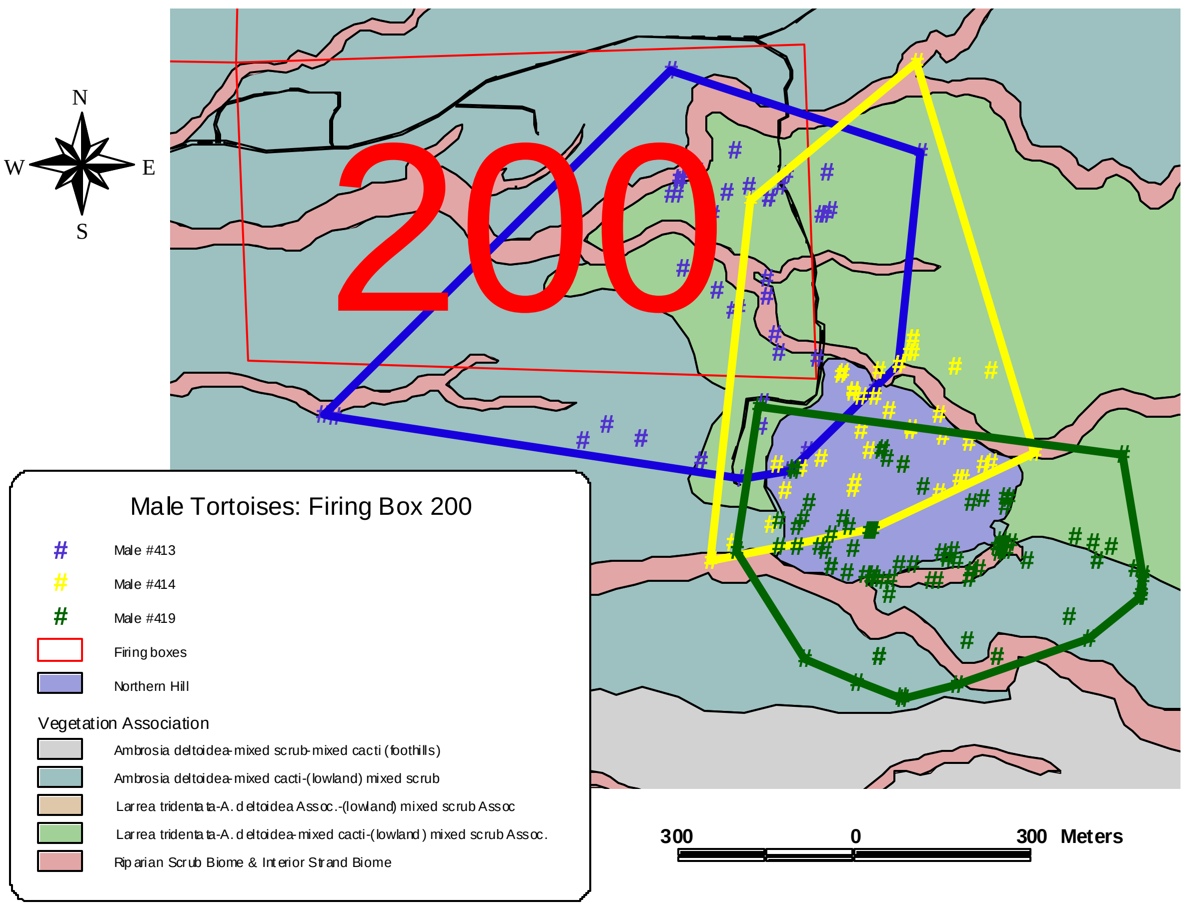


Figure 4. Locations and MCP home range polygons for male desert tortoises in the northern telemetry group on the Florence Military Reservation.

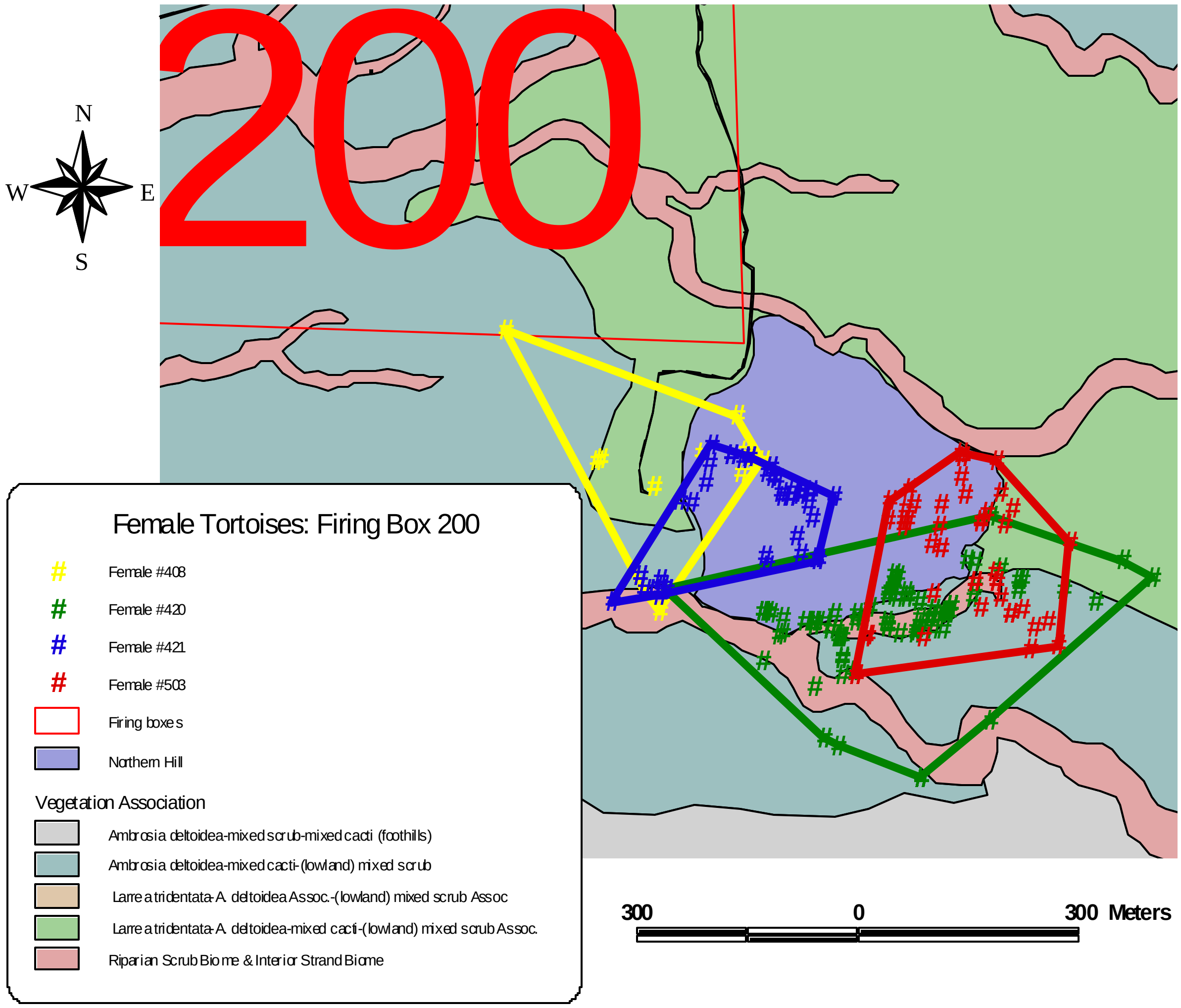


Figure 5. Locations and MCP home range polygons for female desert tortoises in the northern telemetry group on the Florence Military Reservation.

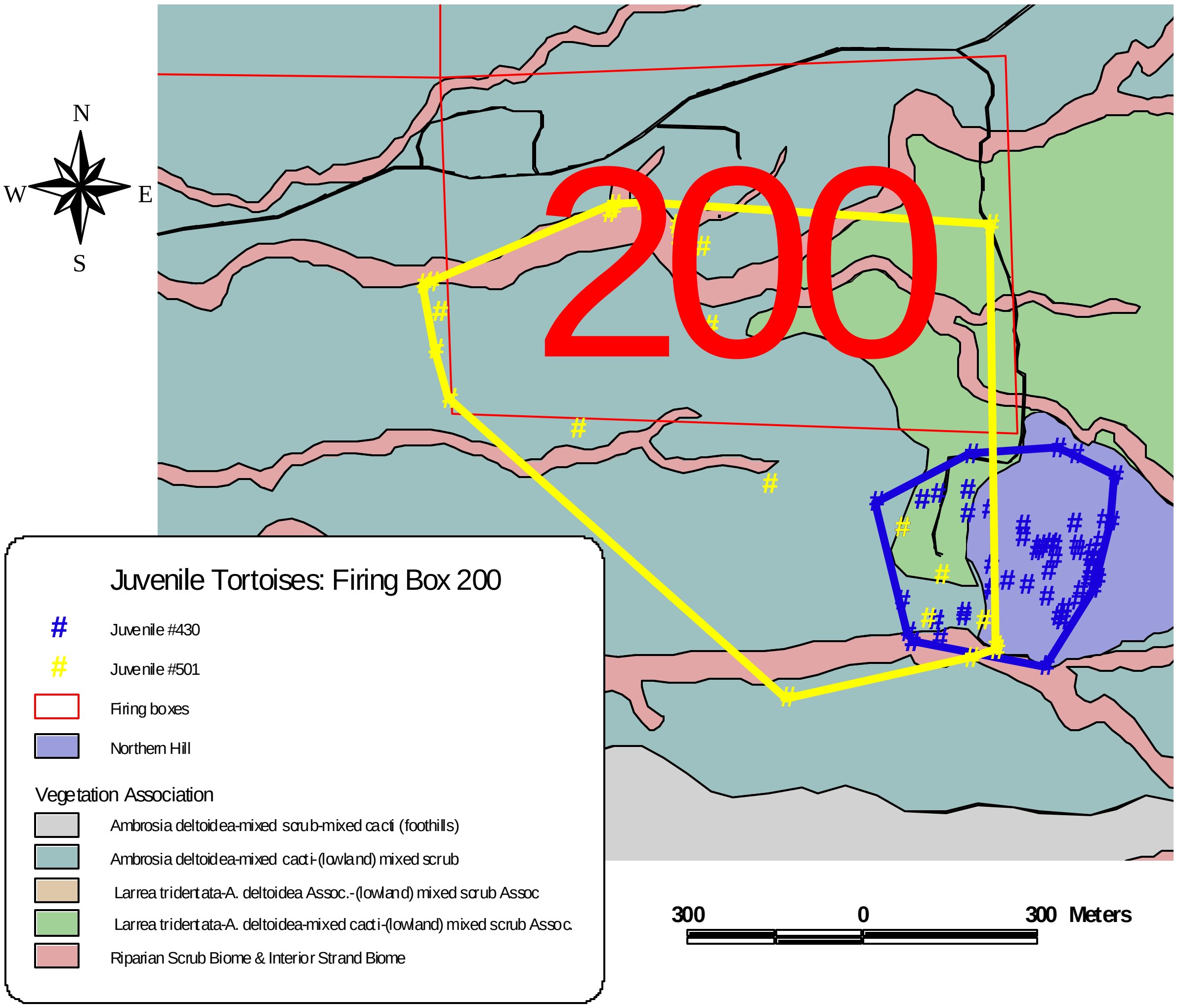


Figure 6. Locations and MCP home range polygons for juvenile desert tortoises in the northern telemetry group on the Florence Military Reservation.

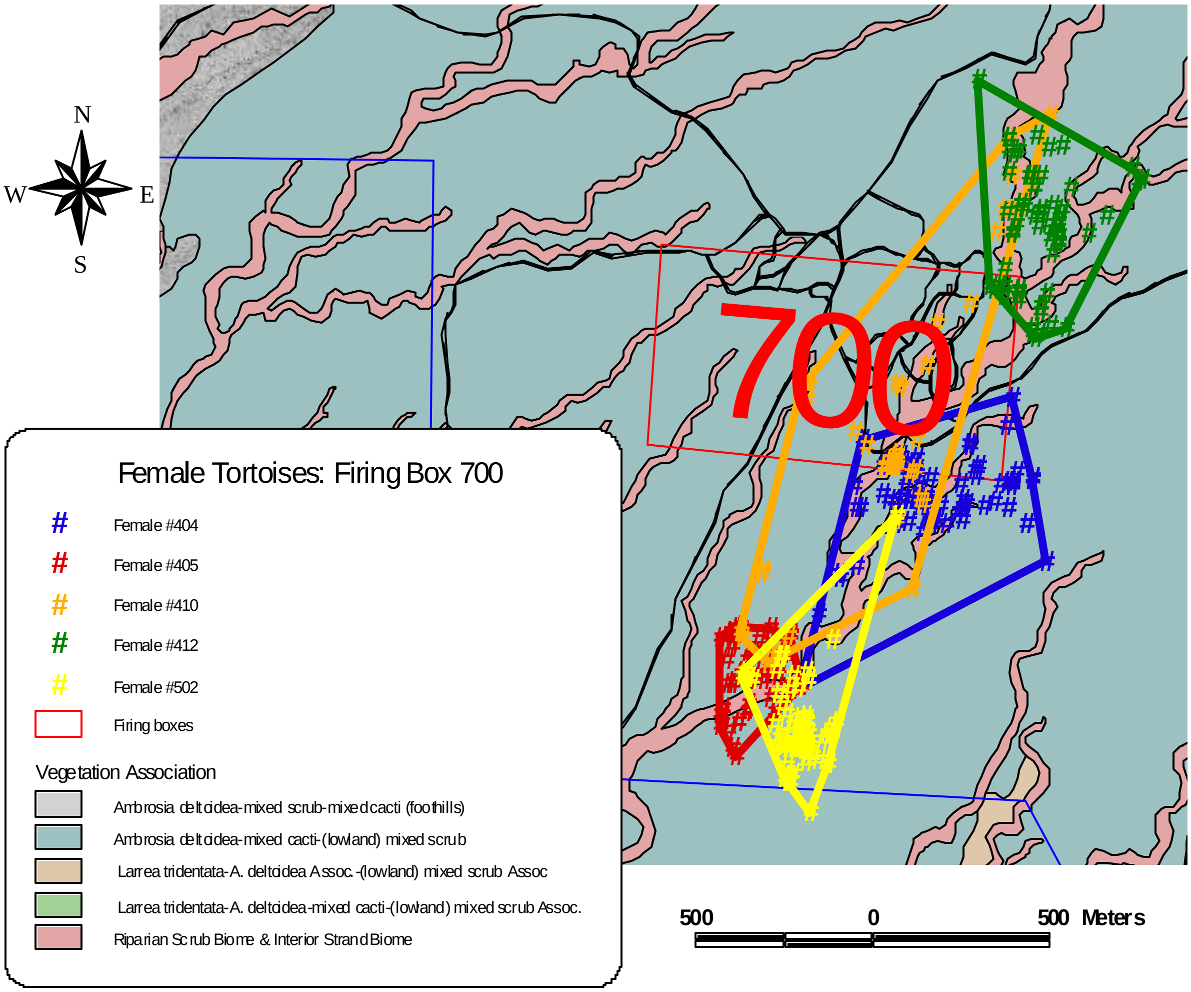


Figure 7. Locations and MCP home range polygons for female desert tortoises in the southern telemetry group on the Florence Military Reservation.

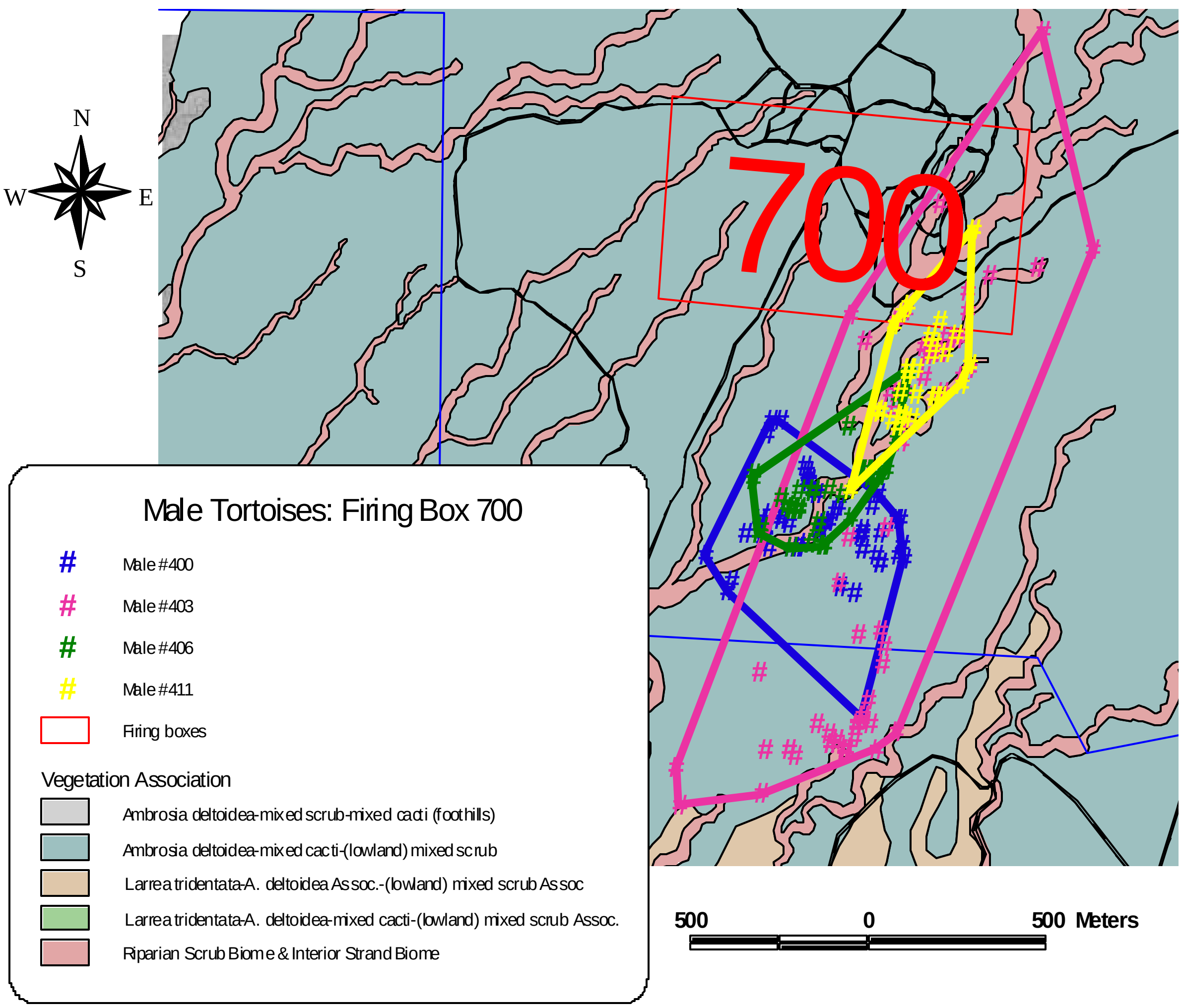


Figure 8. Locations and MCP home range polygons for male desert tortoises in the southern telemetry group on the Florence Military Reservation.

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		Boulder Burrow	
#	Sex	ha	n	n	%	n	%	n	%	n	%	n	%
400	M	23.54	215	144	80	6	3	16	9	14	8	0	0
403	M	93.45	210	86	50	55	32	12	7	19	11	0	0
404	F	28.07	232	150	82	0	0	32	17	1	1	0	0
405	F	5.14	229	80	45	4	2	10	6	84	47	0	0
406	M	9.72	221	197	97	0	0	7	3	0	0	0	0
408	F	5.03	30	9	50	8	44	0	0	0	0	1	6
410	F	46.17	177	123	83	4	3	18	12	4	3	0	0
411	M	9.01	156	138	97	1	1	3	2	1	1	0	0
412	F	17.45	222	120	65	41	22	21	11	2	1	0	0
413	M	43.08	188	70	43	8	5	7	4	79	48	0	0
414	M	29.1	142	36	32	0	0	6	5	63	56	7	6
419	M	25.67	191	50	36	26	19	10	7	14	10	40	29
420	F	11.19	216	21	12	29	16	23	13	73	41	33	18
421	F	3.14	139	36	31	0	0	4	3	0	0	77	66
430	U	9.98	124	35	37	6	6	15	16	0	0	39	41
501	U	52.85	58	3	3	22	23	7	7	63	66	1	1
502	F	11.99	223	51	32	71	45	14	9	22	14	0	0
503	F	5.5	110	5	6	52	64	10	12	0	0	14	17

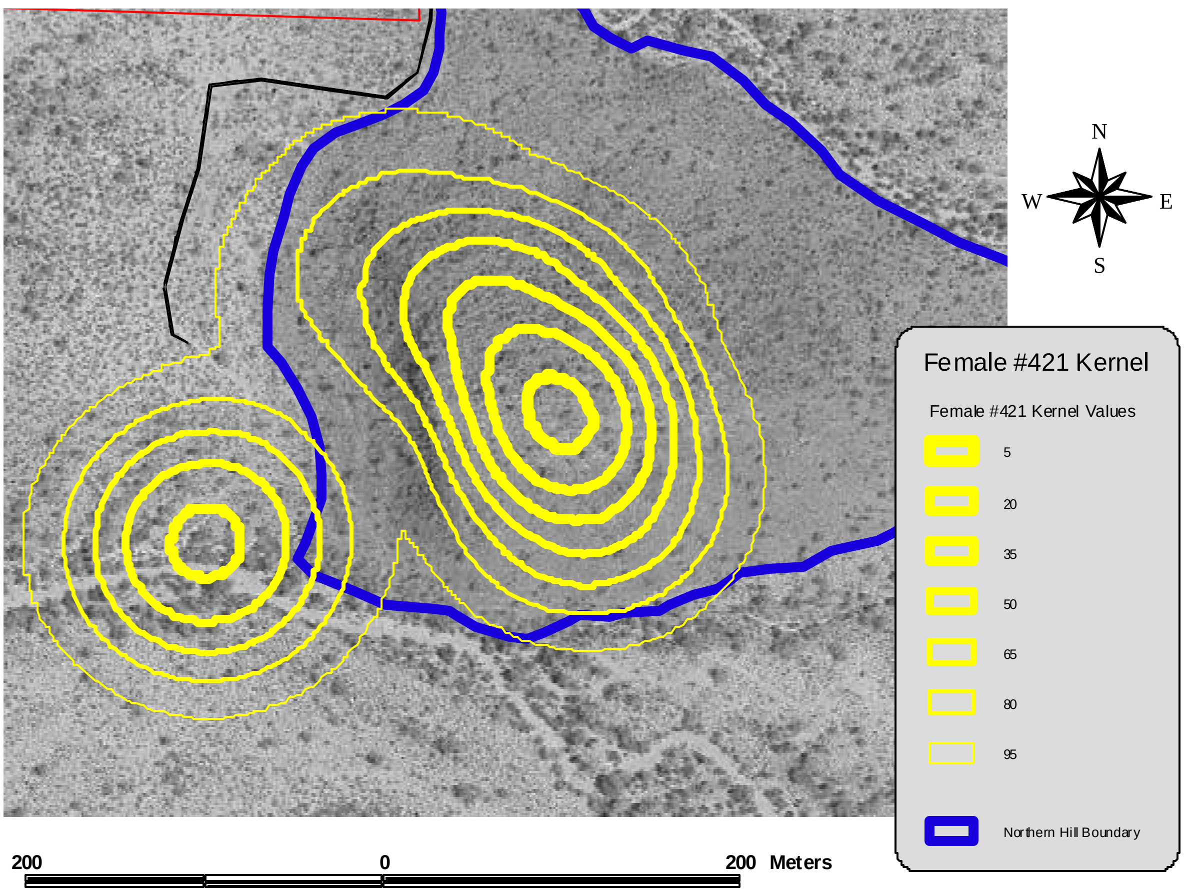


Figure 9. An example of kernel probability density contours for female tortoise #421 in the northern telemetry group on the Florence Military Reservation. All kernel maps can be located in Appendix 2.

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). 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. We performed compositional analysis on the FMR habitat based on vegetation associations and geomorphology.

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 aconthocarpa*), 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 paloverde (*Parkinsonia microphylla*), desert ironwood (*Olneya tesota*), and velvet mesquite (*Prosopis velutina*).

The ranking for vegetation 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 FMR. 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	0.91	0	0.09
403	0.87	0	0.13
404	0.80	0	0.20
405	0.82	0	0.18
406	0.70	0	0.30
408	0.53	0.46	0.01
410	0.83	0	0.17
411	0.69	0	0.31
412	0.69	0	0.31
413	0.41	0.46	0.14
414	0.09	0.82	0.09
419	0.52	0.35	0.13
420	0.68	0.11	0.21
421	0.67	0.29	0.03
430	0.39	0.57	0.04
501	0.66	0.19	0.15
502	0.77	0	0.23
503	0.55	0.36	0.09

Table 4. Proportional use of habitat by desert tortoises at FMR. 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	0.33	0.00	0.67
403	0.81	0.00	0.39
404	0.28	0.00	0.72
405	0.82	0.00	0.18
406	0.26	0.00	0.74
408	0.27	0.53	0.20
410	0.36	0.00	0.64
411	0.10	0.00	0.90
412	0.28	0.00	0.72
413	0.04	0.59	0.38
414	0.06	0.69	0.25
419	0.68	0.08	0.24
420	0.54	0.02	0.44
421	0.40	0.34	0.26
430	0.48	0.35	0.18
501	0.64	0.05	0.31
502	0.82	0.00	0.18
503	0.46	0.26	0.27

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		-0.3148	-1.6621	0
B	0.3148		-1.3473	1
C	1.6621	1.3473		2

Tortoises were located in 3 different geomorphic habitats, labeled as A, B, and C. Habitat A consists of gently sloping to flat alluvial slopes. Habitat B is characterized by having volcanic boulders and outcrops, and is only located on the northern hill. Habitat C consists of incised washes that often contain caliche soils and their associated caves. The ranking for habitat use by desert tortoises in Table 8 shows that vegetation association C was selected over the other 2 habitat types used. When available, vegetation association B was chosen over vegetation association A.

Table 6. Proportional habitat available in each desert tortoise MCP at Florence Military Reservation. Geomorphic habitats are defined as: A = gently sloping or flat alluvial slopes; B = volcanic hills; and C = incised washes.

Tortoise #	Geomorphic Habitat		
	A	B	C
400	0.91	0	0.09
403	0.87	0	0.13
404	0.80	0	0.20
405	0.82	0	0.18
406	0.70	0	0.30
408	0.76	0.22	0.02
410	0.83	0	0.17
411	0.69	0	0.31
412	0.69	0	0.31
413	0.83	0.03	0.14
414	0.65	0.26	0.09
419	0.50	0.37	0.13
420	0.55	0.23	0.21
421	0.24	0.73	0.03
430	0.37	0.59	0.04
501	0.83	0.01	0.15
502	0.77	0	0.23
503	0.54	0.36	0.09

Table 7. Proportional use of geomorphic habitat by desert tortoises at Florence Military Reservation. Geomorphic habitats are defined as: A = gently sloping or flat alluvial slopes; B = volcanic hills; and C = incised washes.

Tortoise #	Geomorphic Habitat		
	A	B	C
400	0.33	0.00	0.67
403	0.81	0.00	0.39
404	0.28	0.00	0.72
405	0.82	0.00	0.18
406	0.26	0.00	0.74
408	0.53	0.27	0.20
410	0.36	0.00	0.64
411	0.10	0.00	0.90
412	0.28	0.00	0.72
413	0.61	0.02	0.38
414	0.54	0.21	0.25
419	0.44	0.32	0.24
420	0.31	0.25	0.44
421	0.04	0.70	0.26
430	0.27	0.56	0.18
501	0.66	0.03	0.31
502	0.82	0.00	0.18
503	0.46	0.26	0.27

Table 8. Matrix of mean log-ratio differences of geomorphic habitat use by desert tortoises at Florence Military Reservation. Ranking is assigned by counting the number of positive values in each row. Geomorphic habitats are defined as: A = gently sloping or flat alluvial slopes; B = volcanic hills; and C = incised washes.

Vegetation Association	A	B	C	Ranking
A		-0.6104	-1.6393	0
B	0.6104		-1.0289	1
C	1.6393	1.0289		2

NEST SITE SELECTION

In 2002, 4 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.
In 2004, 2 tortoises were known to have produced eggs and mean clutch size was 3.5. One female is thought to have nested in a soil burrow as she was located in 1 of 3 different soil burrows during the time of oviposition. The other female is suspected of nesting in a woodrat midden since eggshell fragments were found near the female when she was located on 23 June 2004.

DISCUSSION

HOME RANGE

Observed MCP 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). However, Rautenstrauch and Holt (1995) did find that the MCP method performed well with $\geq$60 locations per individual.

Desert tortoise movement patterns at other locations often 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). At FMR, home ranges constructed using the kernel method illustrate these centers of activity. Some tortoises had only one apparent center of activity and this resulted in circular or slightly linear home ranges. Others had 2 or more apparent centers of activity. For example, female 421 had two distinct centers of activity within her home range. The western side of her home range lies in an area of dense caliche caves that she utilized for estivation during the hot, dry foresummer. During other times of the year, she was located on the hill utilizing relatively shallow shelters provided by boulders. Juvenile 430 showed a very similar pattern of using caliche caves only during times of estivation.

Tortoises alternate between several different burrows, occupying each burrow for a hours 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 was 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, mostly consists of 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 spending substantial time within bursage-dominated habitat in the gently sloping to flat alluvial slopes. 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 incised washes over the volcanic hill, which was selected over gently sloping to flat alluvial slopes. However, tortoises utilized all habitat types and all habitats provided shelter sites. Tortoise home ranges appear to be centered around washes and their associated caliche caves or around the northern hill and its associated boulders. Woodrat middens appeared to be an important shelter substrate when tortoises utilized the gently sloping to flat alluvial slopes. Brown (1968) found that woodrat middens offer considerable protection from the extremes of daily ambient temperatures and provide higher relative humidity.

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 was used by telemetered tortoises. Also, several tortoises had hibernated within woodrat middens within firing box 200. Tortoise use of firing box 700 was extensive but mostly constrained to a major wash running through the southeastern corner (Figures 6 and 7).

CONCLUSIONS

The presence of tortoises in and their observed use of all habitat types found throughout Training Area B is important relative to National Guard training activities. Our data suggest that tortoise density is positively correlated with shelter sites, in particular caliche caves and boulders. Tortoise distribution across FMR appears to be clustered around washes containing many caliche caves and the northern hill and its associated boulders. However, it is possible that tortoises could be distributed at very low densities throughout the area. To minimize impacts of training activities, firing boxes should be located away from clusters of caliche caves and away from the northern hill. 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).

LITERATURE CITED

Aebischer, N.J., P.A. Robertson, and R.E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313-1325.

Averill-Murray, R.C. 2000. Survey protocol for Sonoran desert tortoise monitoring plots: reviewed and revised. Arizona Interagency Desert Tortoise Team.

Averill-Murray, R.C., and C.M. Klug. 2000. Monitoring and ecology of Sonoran Desert tortoises in Arizona. Nongame and Endangered Wildlife Program Technical Report 161. Arizona Game and Fish Department, Phoenix, Arizona.

Averill-Murray, R.C., A.P. Woodman, and J.M. Howland. 2002a. Population ecology of the desert tortoise in Arizona. Pp. 109-134 *In* T.R. Van Devender (ed.), The Sonoran Desert Tortoise: Natural History, Biology, and Conservation. Tucson: University of Arizona Press.

Averill-Murray, R.C., B.E. Martin, S.J. Bailey, and E.B. Wirt. 2002b. Activity and behavior of the Sonoran desert tortoise in Arizona. Pp. 135-158 *In* T.R. Van Devender (ed.), The Sonoran Desert Tortoise: Natural History, Biology, and Conservation Tucson: University of Arizona Press.

Bailey, S.J. 1992. Hibernacula use and home range of the desert tortoise (*Gopherus agassizii*) in the San Pedro Valley, Arizona. M.S. Thesis, University of Arizona, Tucson.

Barrett, S.L. 1990. Home range and habitat of the desert tortoise (*Xerobates agassizii*) in the Picacho Mountains of Arizona. Herpetologica 46:202-206.

Berry, K.H. 1984. A description and comparison of field methods used in studying and censusing desert tortoises. Appendix 2 *in* K. H. Berry (ed.), The status of the desert tortoise (*Gopherus agassizii*) in the United States. Report to U.S. Fish and Wildlife Service on Order 11310-0083-81.

Berry, K.H., G. Goodlett, and T. Goodlett. 2000. Effects of geology and cover site choice on desert tortoise populations at the Tiefort Mountains, California. Paper presented at the 25th Annual Meeting and Symposium of the Desert Tortoise Council, April 20-23, 2000.

Brown, D.E., C.H. Lowe, and C.P. Pase. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. Journal of the Arizona-Nevada Academy of Science 14 (Supplement 1):1-16.

Brown, J.H. 1968. Adaptation to environmental temperature in two species of woodrats, *Neotoma cinerea* and *N. albigula*. Miscellaneous Publication no. 135, University of Michigan, Ann Harbor.

Burge, B.L. 1977. Daily and seasonal behavior, and areas utilized by the desert tortoise *Gopherus agassizii* in southern Nevada. Proceedings of the Desert Tortoise Council Symposium 1977:59-94.

Burge, B.L. 1978. Physical characteristics and patterns of utilization of cover sites used by *Gopherus agassizii* in southern Nevada. Proceedings of the Desert Tortoise Council Symposium 1978:80-111.

[DEMA] Department of Emergency and Military Affairs. 1997. Environmental assessment of changes to training facilities and operations at the Florence Military Reservation. Arizona Army National Guard, Phoenix.

Duda, J.J., A.J. Krzysik, and J.E. Freilich. 1999. Effects of drought on desert tortoise movement and activity. Journal of Wildlife Management 63:1181-1192.

Fritts, T.H., and R.D. Jennings. 1994. Distribution, habitat use, and status of the desert tortoise in Mexico. Pp. 49-56 *in* Bury, R.B., and D.J. Germano (eds.). Biology of North American Tortoises. Washington, D.C.: National Biological Survey, Fish and Wildlife Research 13.

Germano, D.J., R.B. Bury, T.C. Esque, T.H. Fritts, and P.A. Medica. 1994. Range and habitats of the desert tortoise. Pp. 73-84 *in* Bury, R.B., and D.J. Germano (eds.). Biology of North American Tortoises. Washington, D.C.: National Biological Survey, Fish and Wildlife Research 13.

Hooge, P.N., and B. Eichenlaub. 1997. Animal movement extension to ArcView. Version 1.1. Anchorage: U.S. Geological Survey, Alaska Biological Science Center.

Jennrich, R.J., and F.B. Turner. 1969. Measurement of non-circular home range. Journal of Theoretical Biology 22:227-237.

Kenward, R.E., and K.H. Hodder. 1996. Ranges V: an analysis system for biological location data. Wareham, Dorset, United Kingdom: Institute of Terrestrial Ecology.

Leban, F. 1999. Resource Selection For Windows. University of Idaho, Moscow.

Luckenbach, R.A. 1982. Ecology and management of the desert tortoise (*Gopherus agassizii*) in California. Pp. 1-37 *in* R.B. Bury (ed.), North American Tortoise Conservation and Ecology. Washington, D.C.: U.S. Fish and Wildlife Service, Wildlife Research Report 12.

Martin, B.E. 1995. Ecology of the desert tortoise (*Gopherus agassizii*) in a desert-grassland community in southern Arizona. M.S. Thesis, University of Arizona, Tucson.

Mohr, C.O. 1947. Table of equivalent populations of North American mammals. American Midland Naturalist 37:223-249.

Murray, R.C., C.R. Schwalbe, S.J. Bailey, S.P. Cuneo, and S.D. Hart. 1995. Desert tortoise (*Gopherus agassizii*) reproduction in the Mazatzal Mountains, Maricopa County, Arizona. Report to Arizona Game and Fish Department and Tonto National Forest, Phoenix.

Murray, R.C., C.R. Schwalbe, S.J. Bailey, S.P. Cuneo, and S.D. Hart. 1996. Reproduction in a population of the desert tortoise, *Gopherus agassizzi*, in the Sonoran Desert. Herpetological Natural History 4:83-88.

O'Connor, M.P., L.C. Zimmerman, D.E. Ruby, S.J. Bulova, and J.R. Spotila. 1994. Home range size and movements by desert tortoises, *Gopherus agassizii*, in the eastern Mojave Desert. Herpetological Monographs 8:60-71.

Rautenstrauch, K.R., and E.A. Holt. 1995. Selecting an appropriate method for calculating desert tortoise home range size and location (abstract). Proceedings of the Desert Tortoise Council Symposium 1994:172-173.

Riedle, J. D., R. C. Averill-Murray, and D. K. Bolen. 2002. Desert tortoise habitat use and home range size on the Florence Military Reservation: 2001 progress report. Nongame and Endangered Wildlife Program Technical Report 194. Arizona Game and Fish Department, Phoenix, Arizona.

Snetsinger, S.D., and R.B. Spicer. 2001. Vegetation classification and mapping of the Florence Military Reservation, Pinal County, Arizona. Nongame and Endangered Wildlife Program Technical Report 176. Arizona Game and Fish Department, Phoenix, Arizona.

Trachy, S., and V.M. Dickinson. 1993. Use areas and sheltersite characteristics of Sonoran desert tortoises. Report to Arizona Game and Fish Department, Phoenix.

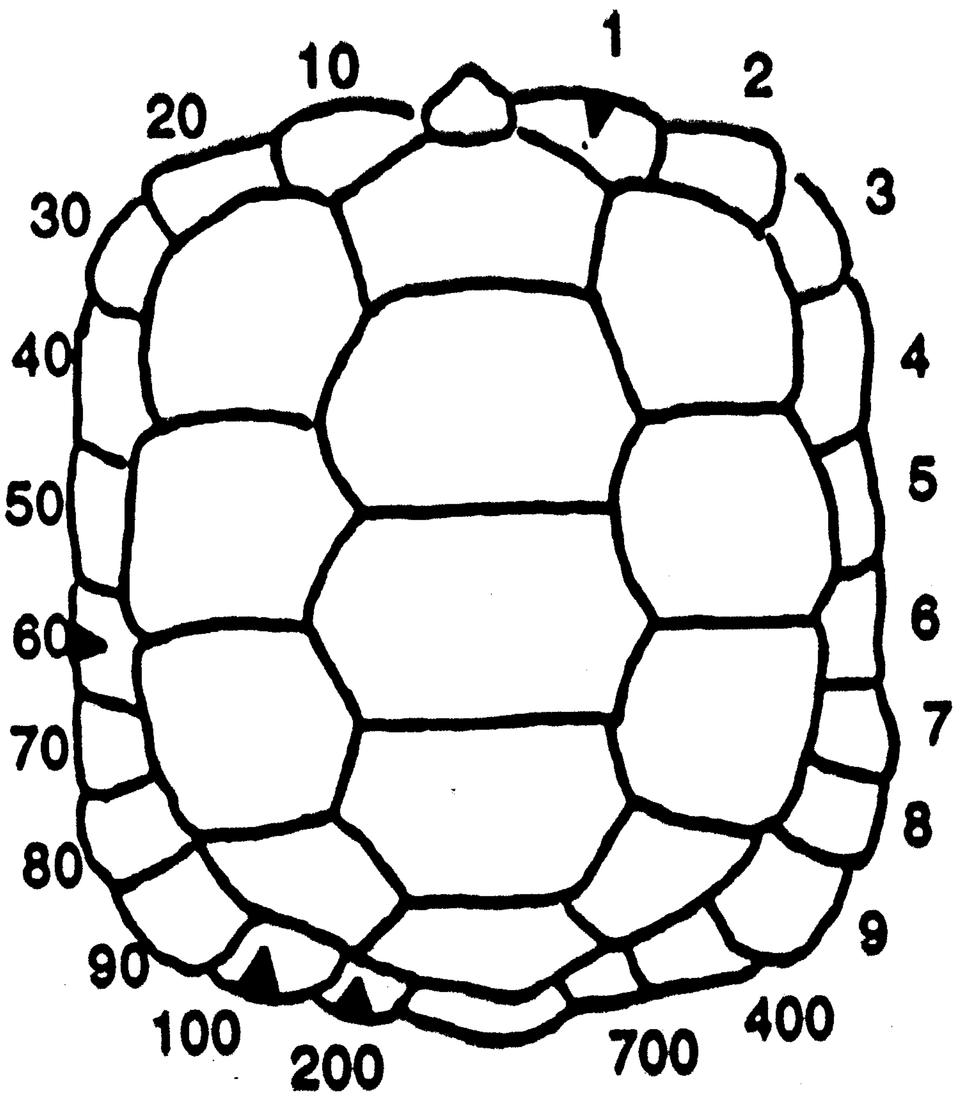
White, G.C., and R.A. Garrott. 1990. Analysis of Wildlife Radio-Tracking Data. San Diego: Academic Press.

Woodbury, A.M., and R. Hardy. 1948. Studies of the desert tortoise, *Gopherus agassizii*. Ecological Monographs 18:145-200.

Woodman, P., S. Hart, S. Bailey, and P. Frank. 1996. Desert tortoise population surveys at two sites in the Sonoran Desert of Arizona, 1995. Report to Arizona Game and Fish Department, Phoenix.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.

APPENDIX 1: TORTOISE MARKING SYSTEM



Tortoise number = 361

APPENDIX 2: KERNEL HOME RANGE MAPS

NORTHERN TELEMETRY GROUP

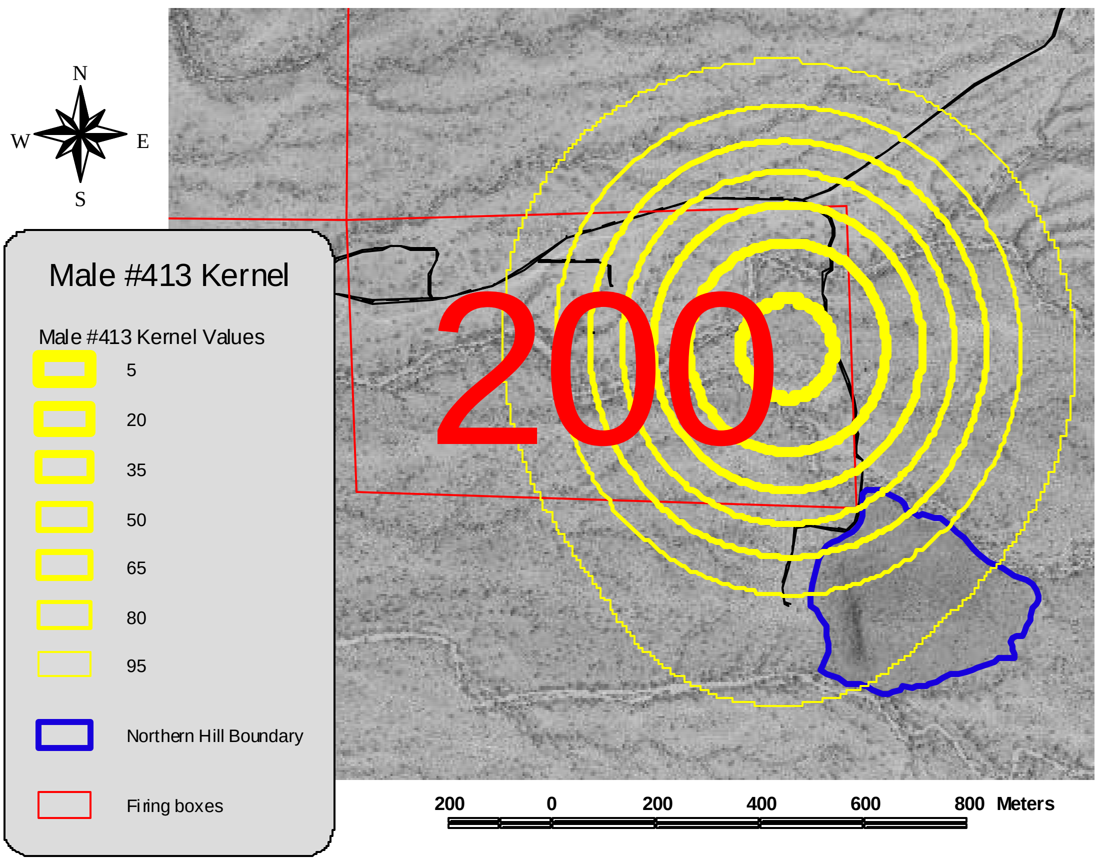


Figure 1. Kernel home range map of male #413 on Florence Military Reservation.

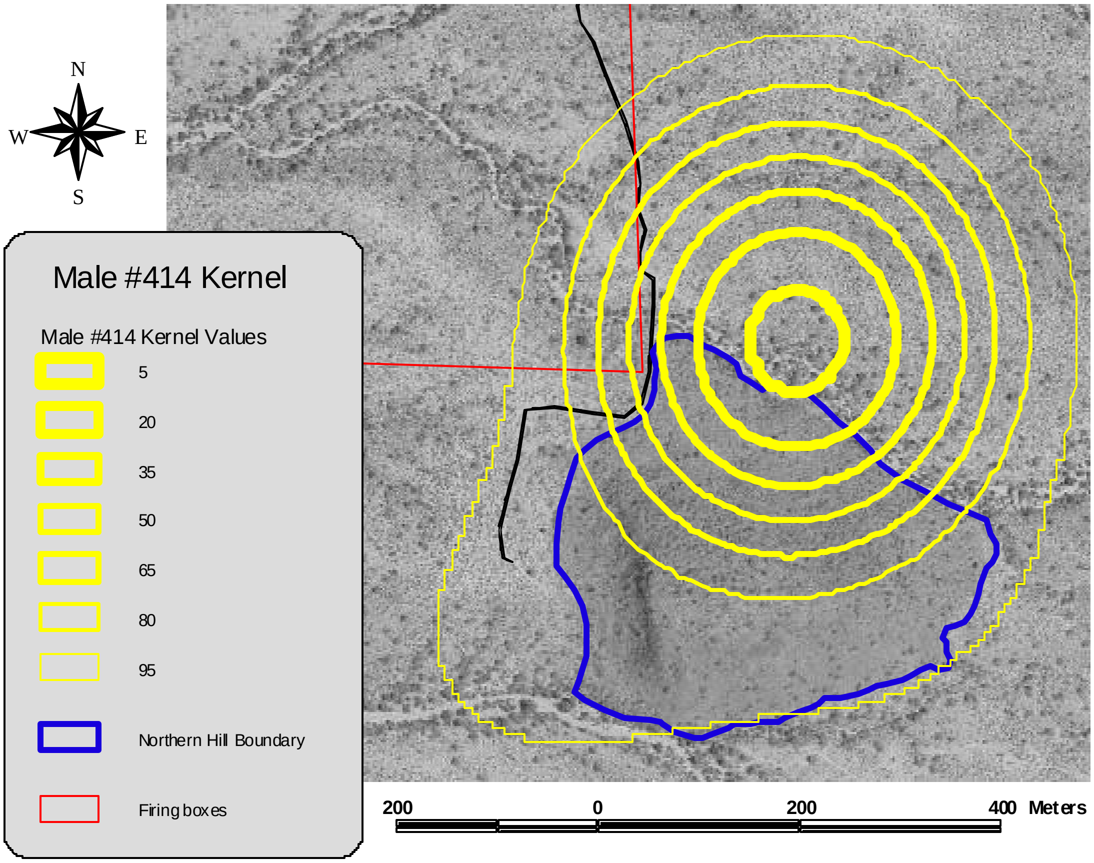


Figure 2. Kernel home range map of male #414 on Florence Military Reservation.

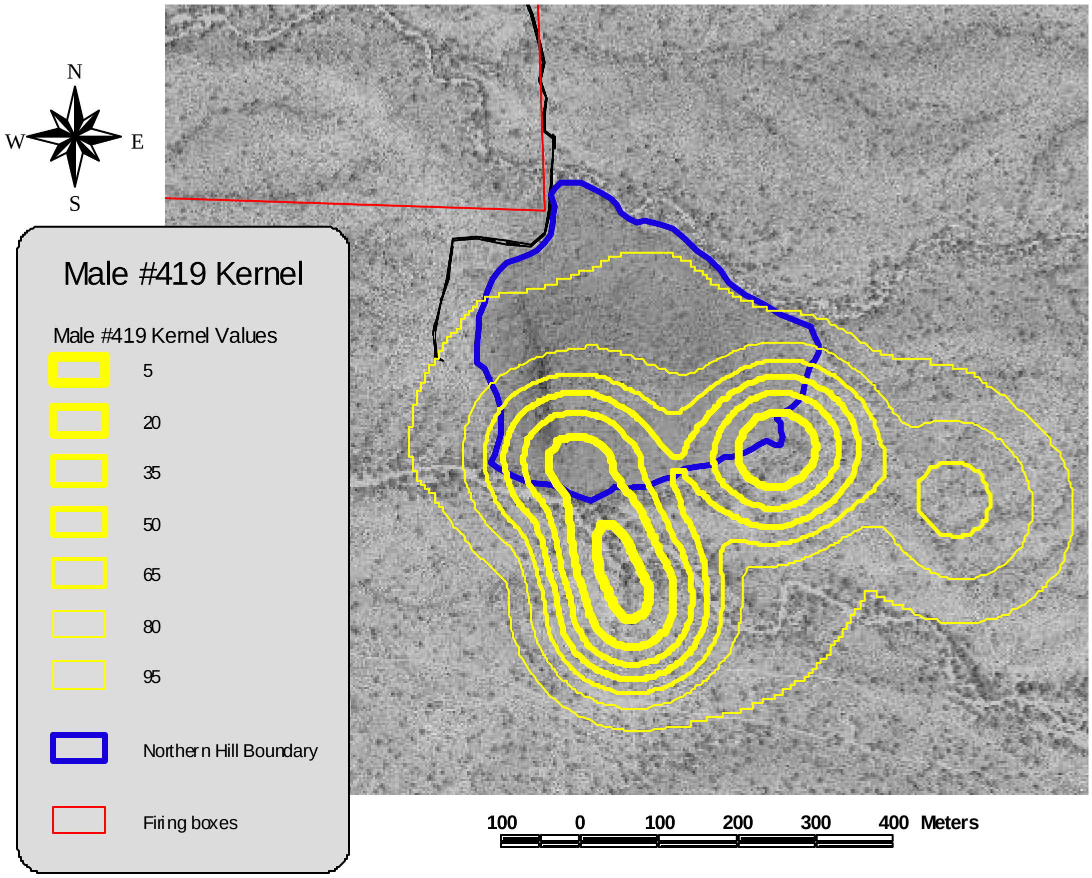


Figure 3. Kernel home range map of male #419 on Florence Military Reservation.

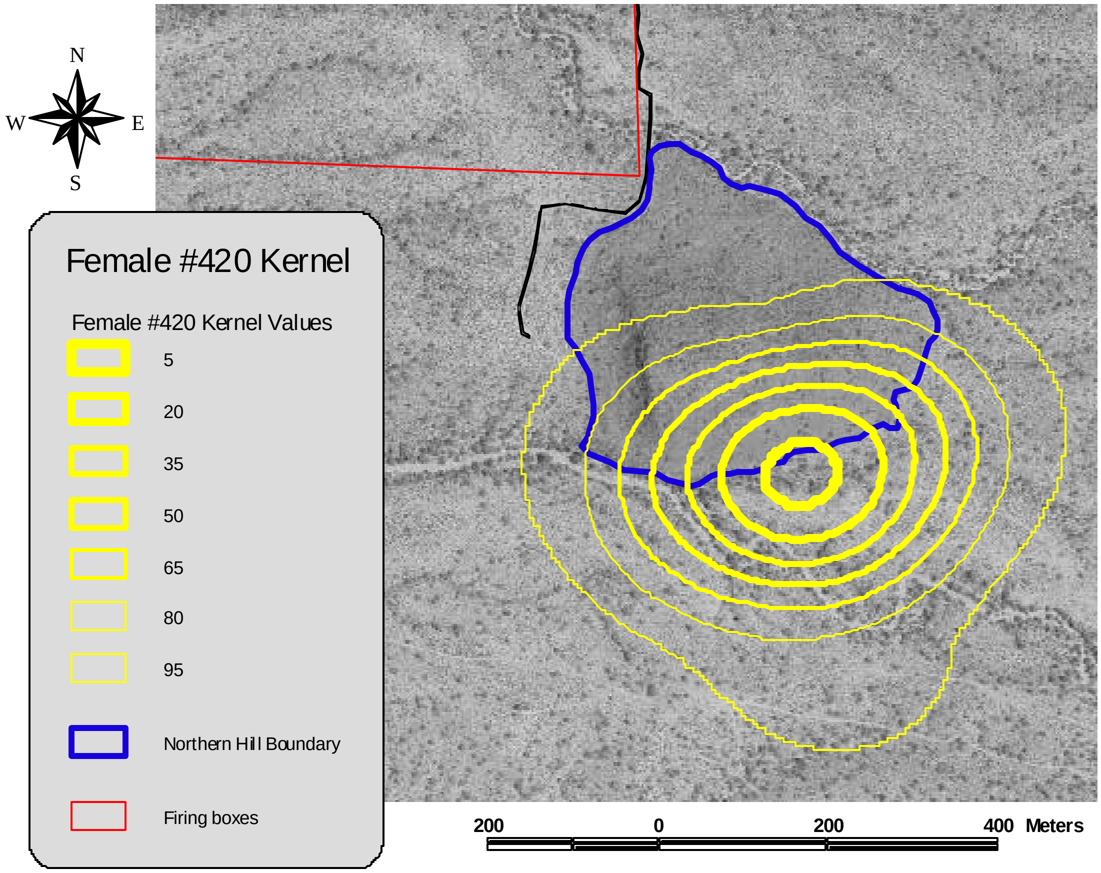


Figure 4. Kernel home range map of female #420 on Florence Military Reservation.

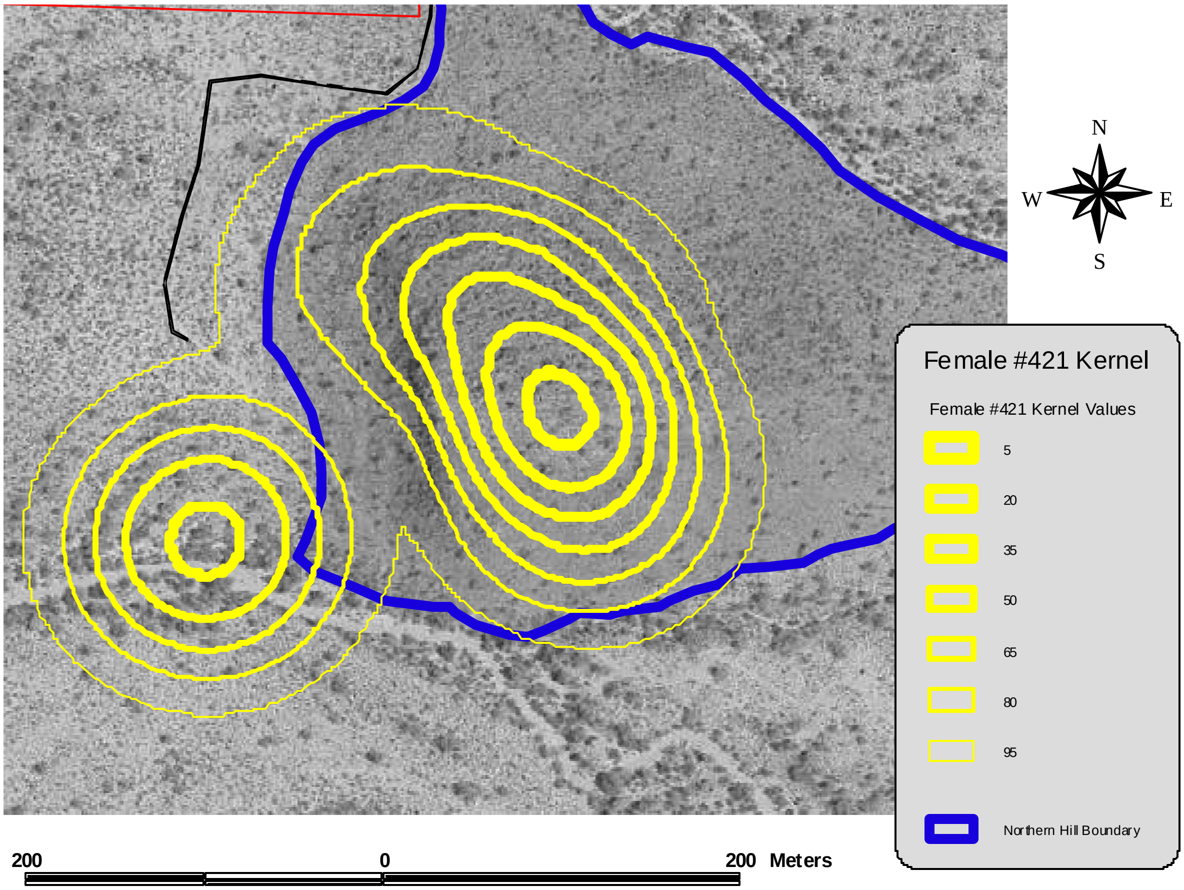


Figure 5. Kernel home range map of female #421 on Florence Military Reservation.

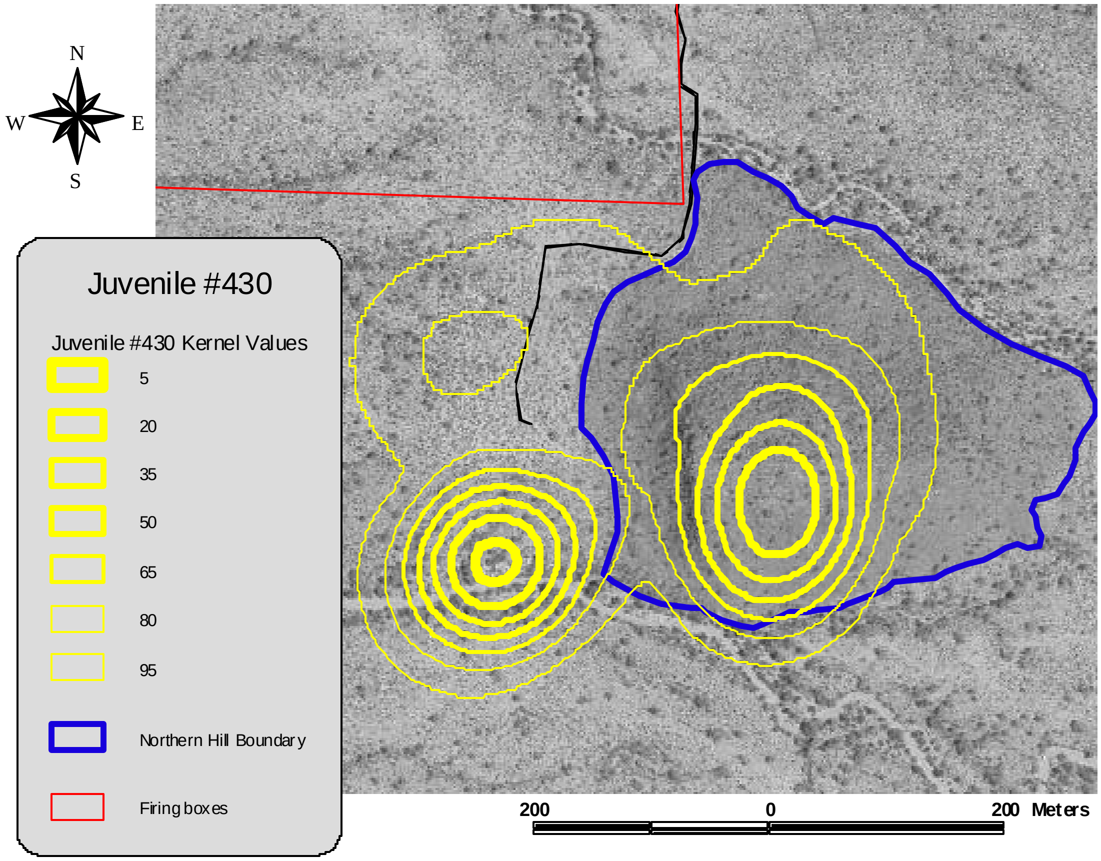


Figure 6. Kernel home range map of juvenile #430 on Florence Military Reservation.

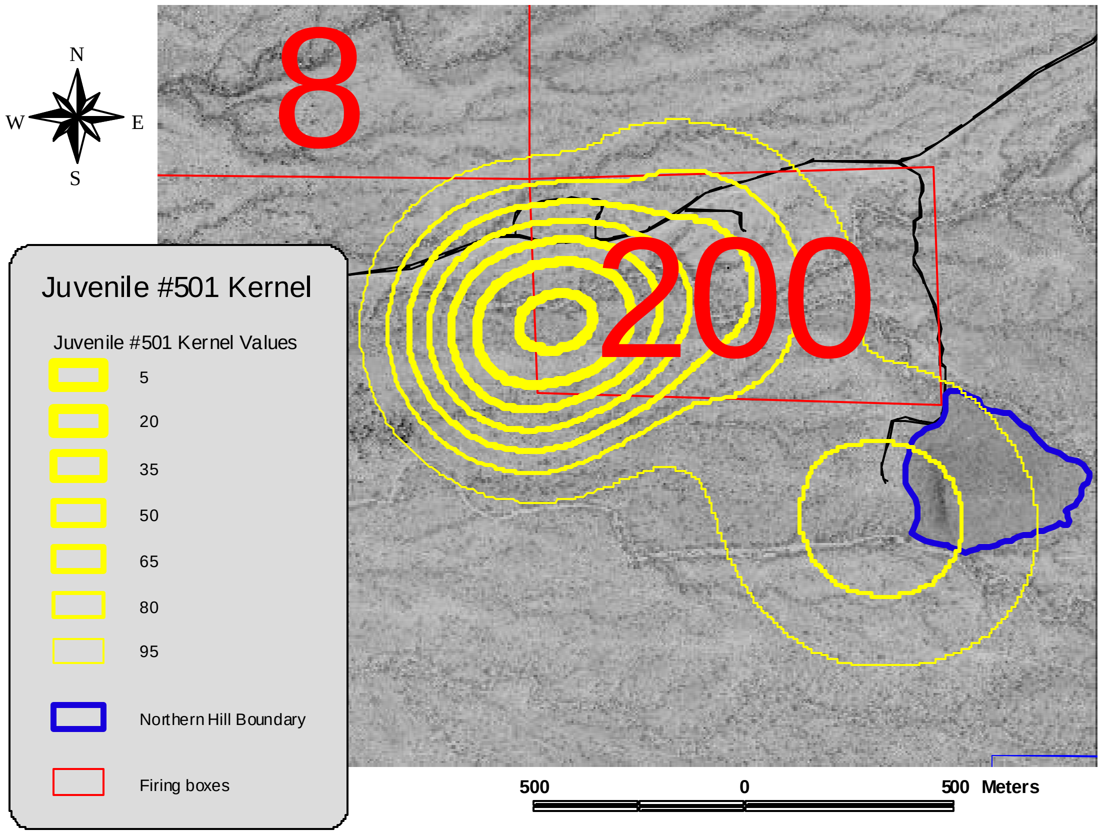


Figure 7. Kernel home range map of juvenile #501 on Florence Military Reservation.

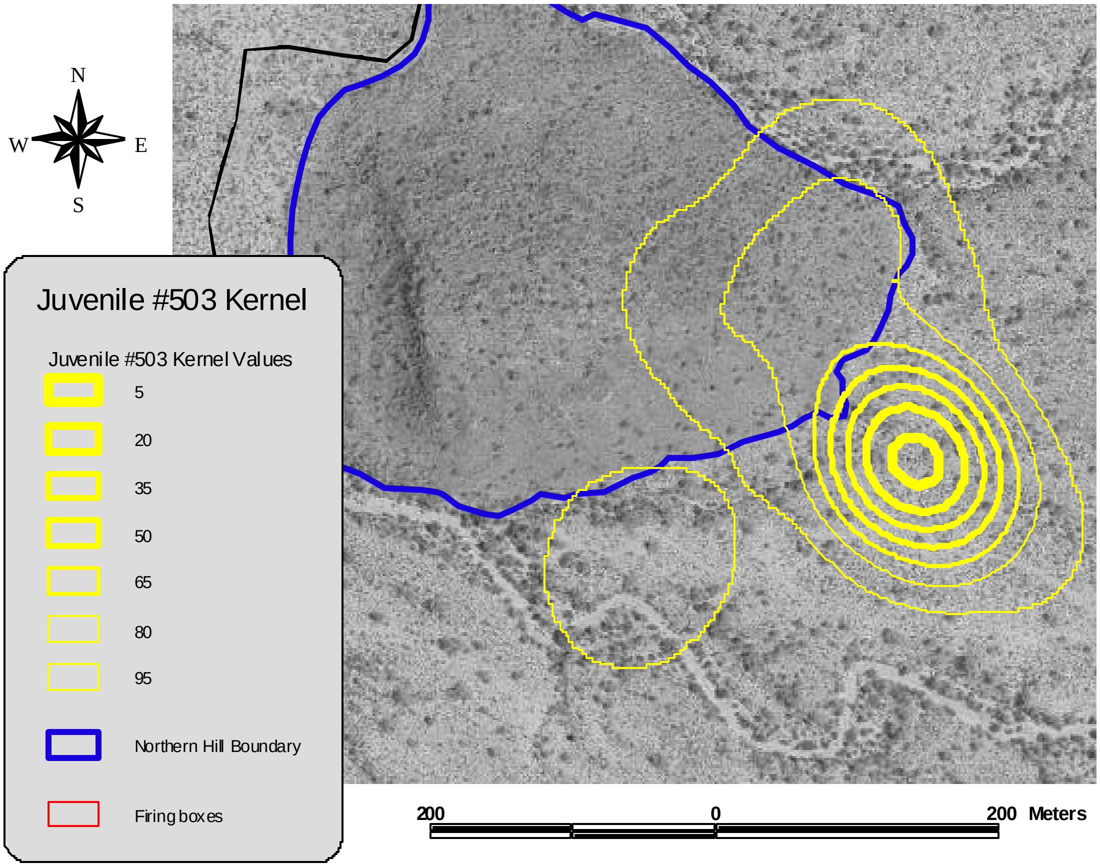


Figure 8. Kernel home range map of juvenile #503 on Florence Military Reservation.

SOUTHERN TELEMETRY GROUP

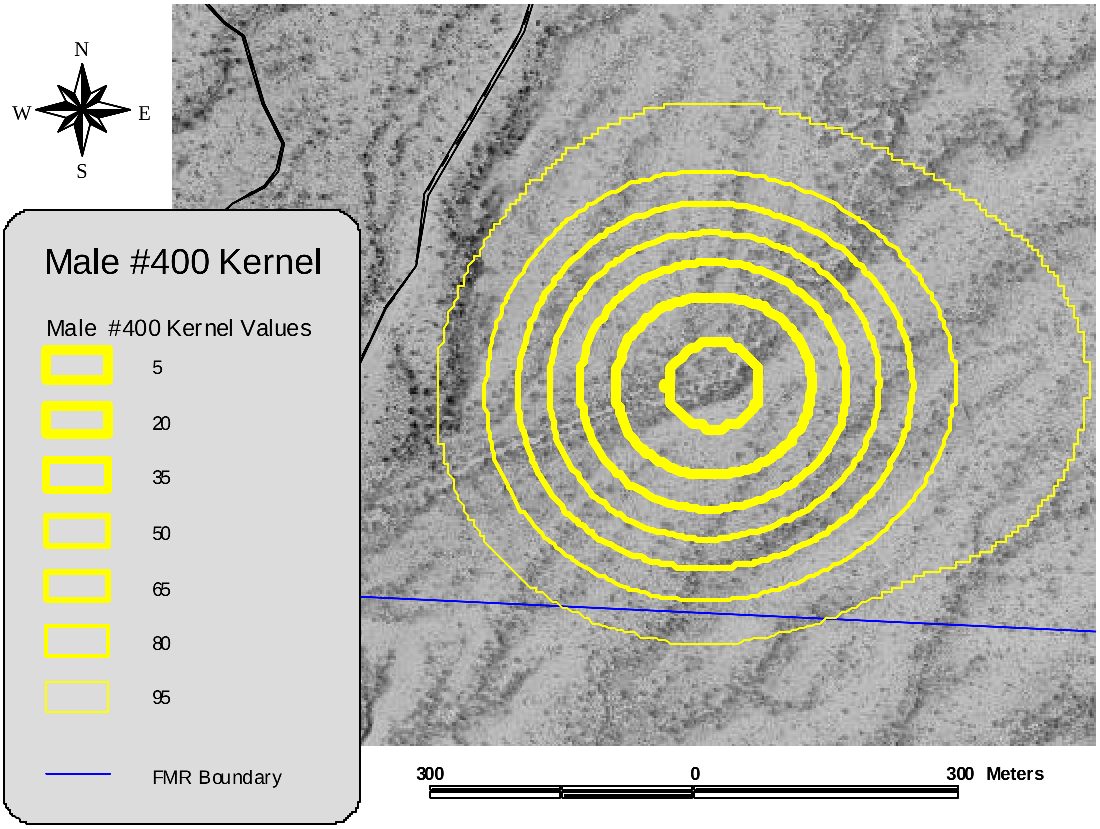


Figure 9. Kernel home range map of male #400 on Florence Military Reservation.

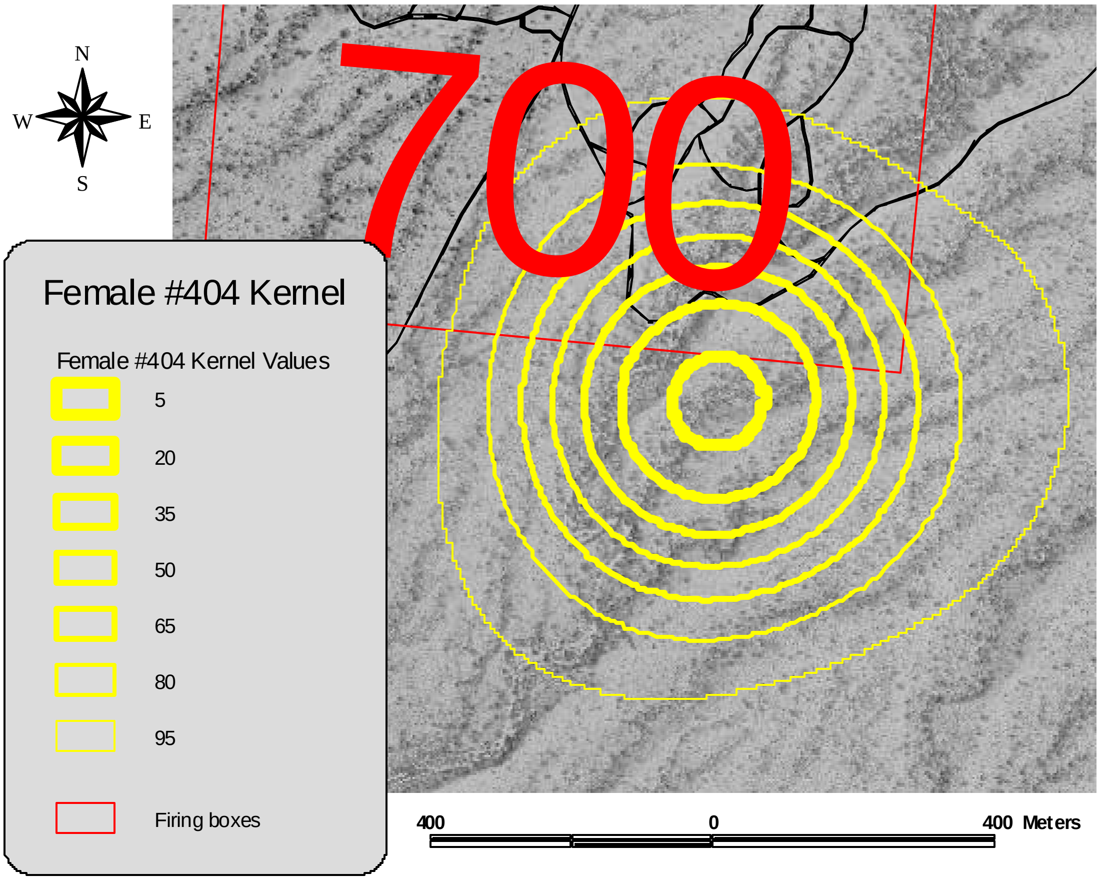


Figure 10. Kernel home range map of female #404 on Florence Military Reservation.

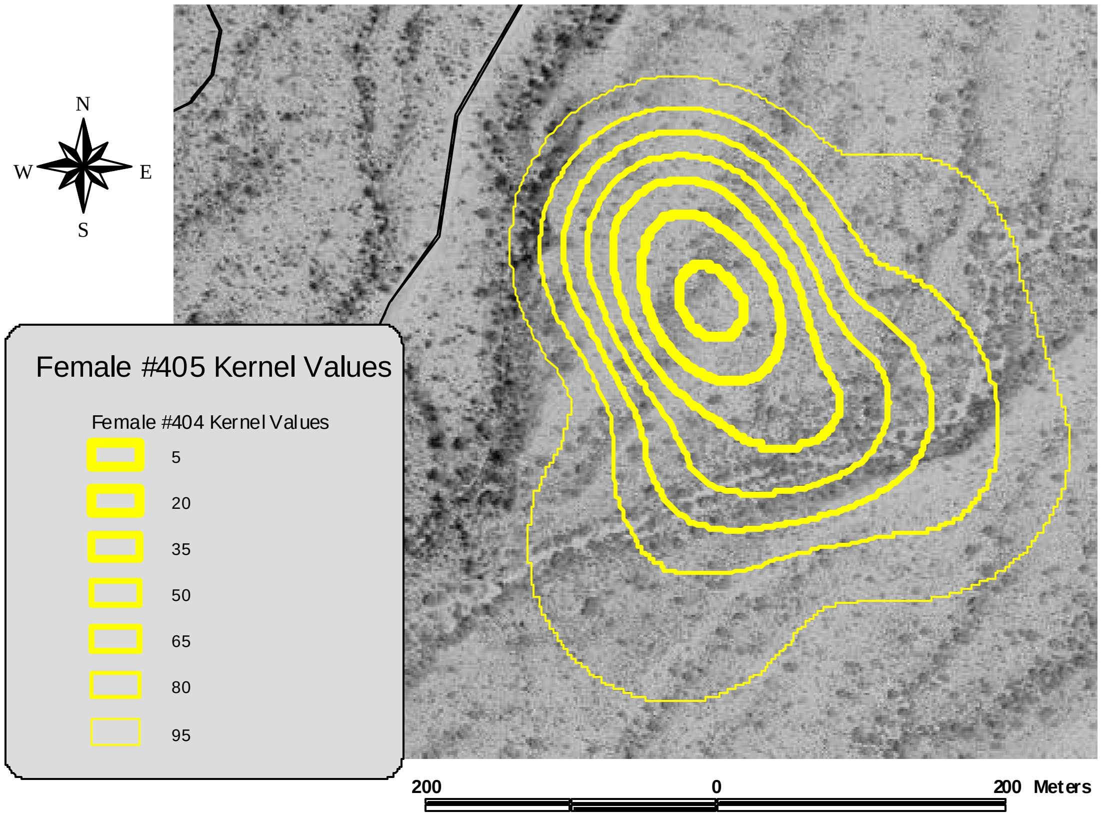


Figure 11. Kernel home range map of female #405 on Florence Military Reservation.

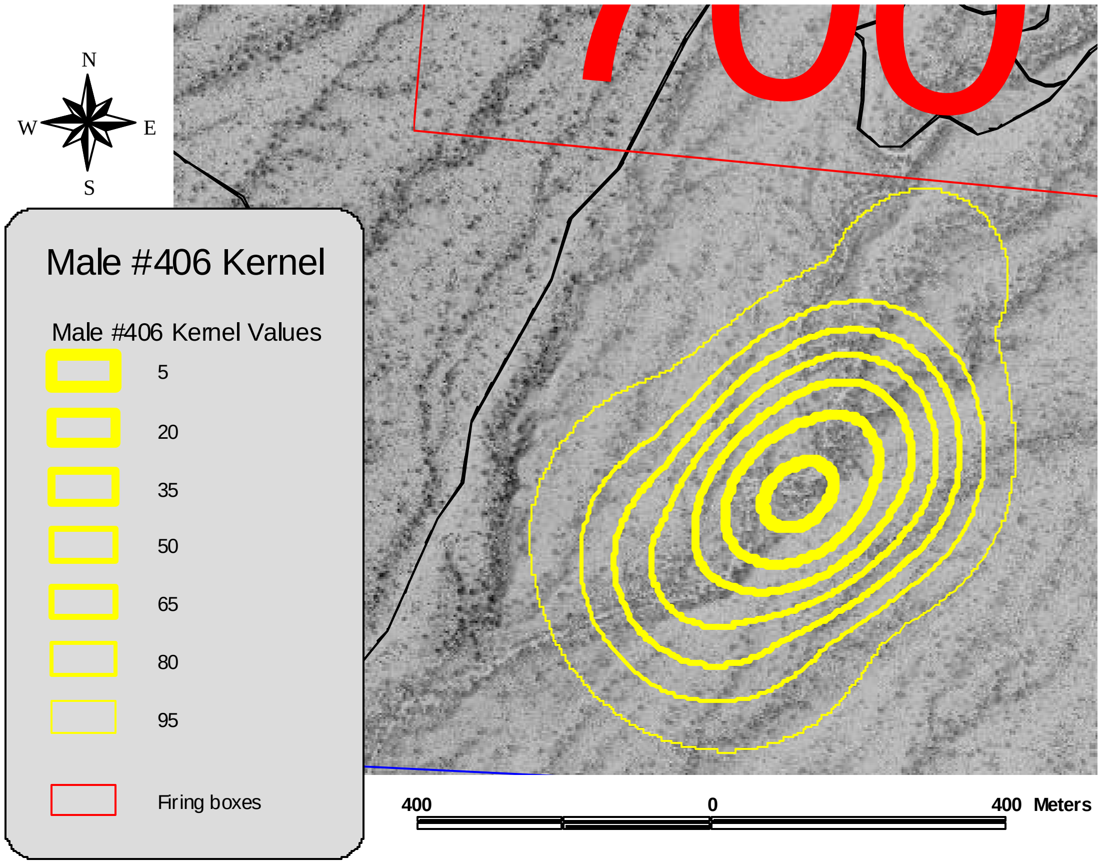


Figure 12. Kernel home range map of male #406 on Florence Military Reservation.

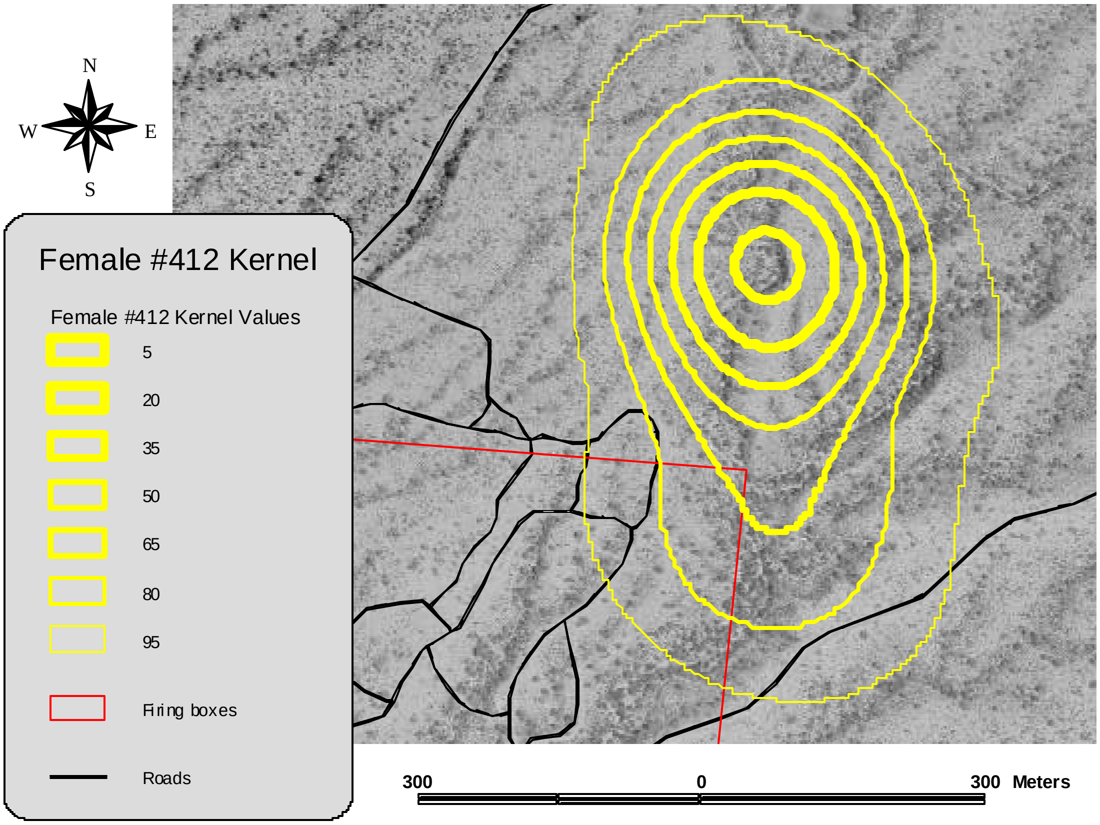


Figure 13. Kernel home range map of female #412 on Florence Military Reservation.

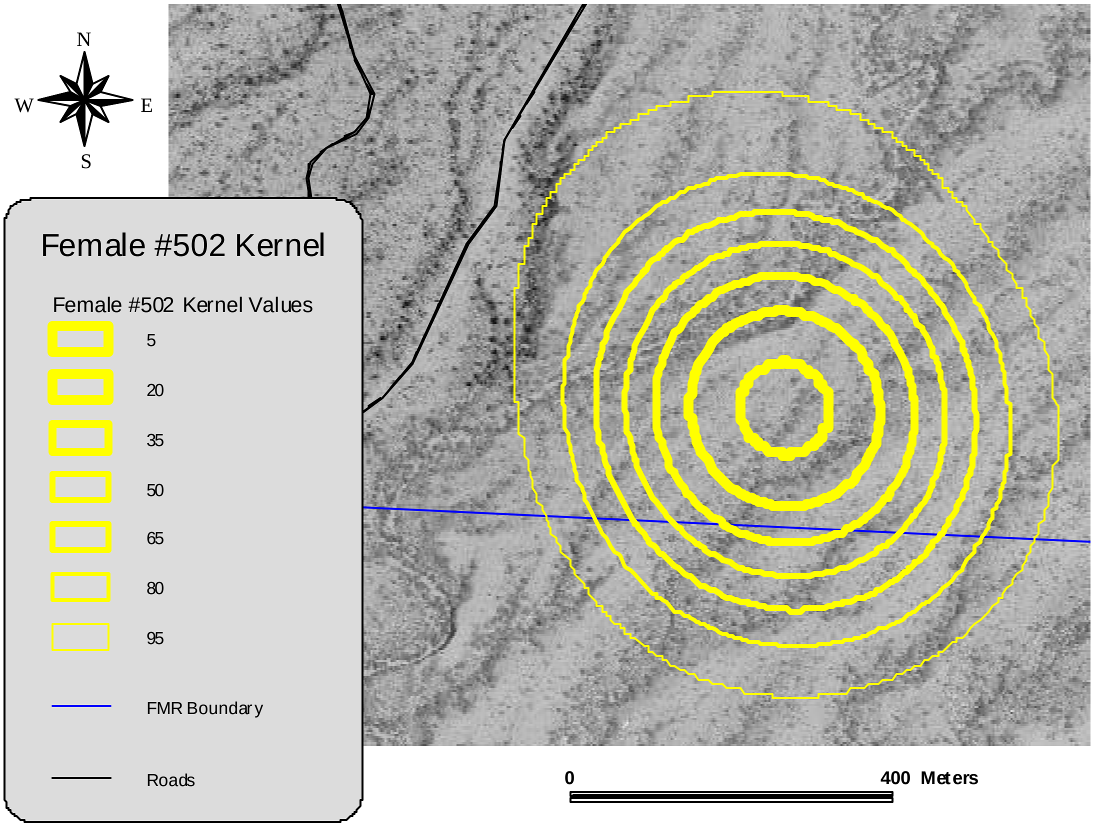


Figure 14. Kernel home range map of female #502 on Florence Military Reservation.