Final Report:

The Occupation of Steep Slopes by Desert Tortoises (*Gopherus agassizii*) in the Western Mojave Desert: A Description of Occupied Habitats, Habitat Use, and Desert Tortoise Density

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Natural and Cultural Resources,

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A Description of Occupied Habitats, Habitat Use, and Desert Tortoise Density

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ABSTRACT

Desert tortoises (*Gopherus agassizii*) were located on steep slopes at three sites in the western Mojave Desert. These sites were located at: 1) The rifle range of the Marine Corps Logistics Base, Barstow, 2) The Southern Boundary of the Fort Irwin National Training Center, immediately West of Manix Tank Trail, and 3) The Lava Range of the Marine Corps Air Ground Combat Center, Twentynine Palms. Additionally, a valley site was selected in the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, for comparison. Desert tortoises were found on slopes up to 36 degrees at MCLB, up to 25 degrees at FINTC, and up to 33 degrees at Lava. Substrate particle sizes were variable at MCLB and FINTC, but were uniformly coarse at Lava. Tortoises at Sand Hill were found on slopes as steep as 3 degrees and occupied a habitat with a uniformly fine, sandy substrate. Sites with steep slopes offered more cover-site options (Burrows, Pallets, Caliche caves, Rocks, Rodent Middens) than did Sand Hill (Burrows, Pallets).

Desert tortoises were present on hillside sites at different densities: 1) MCLB = 27.1 tortoises/km^2, 2) FINTC = 8.1 tortoises/km^2, 3) Lava = 6.1 tortoises/km^2. These densities range from low to moderate relative to other populations in the western Mojave Desert. Evidence of reproduction was observed at MCLB and FINTC, including: 1) Copulations at both sites, 2) Juvenile tortoises 97mm to 164mm maximum carapace length at MCLB, and 3) Egg shell fragments at MCLB. We found that desert tortoises occupy steep slopes as resident populations, and that some of these areas support moderately sized populations. A remodeling of habitat that may potentially be occupied by the desert tortoise, such as that recently undertaken for the Western Mojave Recovery Unit, and increased surveys in areas with a high degree of topographic complexity may be in order for the entire Mojave Desert. It is likely that such surveys would increase not only the amount of known occupied habitat, but would also increase population size estimates across the Mojave Desert.

ACKNOWLEDGEMENTS

This research was funded by the U.S. Marine Corps Logistics Base, Barstow, California, and administered by the Southwest Division Naval Facilities Engineering Command, Natural and Cultural Resources Branch. Additional funding was provided by the Fort Irwin National Training Center, California. Assistance was provided by the Marine Corps Air Ground Combat Center, Twentynine Palms, California.

This research would not have been possible without the assistance of numerous persons including: Stephanie Gardner, Jesse Meik, Art Gleason, Mickey Quillman, Rhys Evans, and William Fisher. Additionally we would like to thank Patricia Cutler as well as those listed above for providing comments on the draft report.

INTRODUCTION

Project Overview

The desert tortoise (Gopherus agassizii) is widely distributed, with a range extending from southeastern California, southern Nevada, and extreme southwestern Utah, through western Arizona and Sonora (including Isla Tiburon), into the most northwestern portion of Sinaloa (Fig. 1). The desert tortoise is adapted to life in desert regions in its behavior (e.g., Woodbury and Hardy, 1948), physiology (e.g., Nagy and Medica, 1986), and morphology (e.g., Bailey, 1928). Desert tortoises are often locally abundant, but occur at a wide range of densities across their range (Bury et al., 1994). The United States Fish and Wildlife Service listed the Mojave population of the desert tortoise as Threatened on April 2, 1990.

Figure 1. —Range of the desert tortoise adapted from Stebbins (1985).

The biology of desert tortoises has been well studied. Numerous studies investigated abundance (e.g., Berry, 1986; Karl, 1983; Luckenbach, 1982). Relationships among desert tortoise populations were studied using both genetic (e.g., Lamb et al., 1989; Rainboth et al., 1989) and morphological (Weinstein and Berry, 1987) data. Additionally, the relationship between the desert tortoise and the other North American tortoise species was investigated (Crumly, 1994; Lamb et al., 1989; Bramble, 1982; Auffenburg, 1976). Crumly (1994) found that the use of the genus *Xerobates* (to identify the desert tortoise and Bolson tortoises) rendered the genus *Gopherus* paraphyletic, and suggested that all North American tortoises be included in the monophyletic genus *Gopherus*. Fecundity was studied in a number of populations (e.g., Henen, 1997; Turner et al., 1986). Diseases such as upper respiratory tract disease (Jacobson et al., 1991) and cutaneous dyskeratosis (Jacobson et al., 1994) recently received attention. Diet (Jennings, 1993) and digestion (Barboza, 1995) were studied, as was the nutritional quality of introduced plant species (Nagy et al., 1998). Researchers also investigated homeostasis (Henen, 1997; Peterson, 1996), mortality (e.g., Peterson, 1994; Turner et al., 1984), home range (e.g., Duda and Krzysik, 1998; O'Connor et al. 1994; Barrett, 1990), and habitat use (e.g., Bailey et al., 1995; Bulova, 1994, 1992; Barrett, 1990). The majority of these studies were, however, performed on flat areas and bajadas in the Mojave Desert. Studies that have been performed on hillsides and areas of complex topography have primarily been restricted to the Sonoran Desert.

Although it has been recognized that desert tortoise habitat varies in topography across its range (Germano et al. 1994), the degree of slopes occupied by desert tortoises was quantified only in a few studies restricted to the Sonoran Desert. Desert tortoises were found to occupy (Barrett, 1990) and to select hibernacula on (Bailey et al., 1995) slopes up to 65 percent (33.0 degrees). No studies quantitatively described the substrates occupied by desert tortoises.

It is possible that, at least in some portions of its range, the desert tortoise occurs on slopes only during part of the year. Such a shift between slopes and surrounding areas could occur to take advantage of seasonal changes in ambient temperature and exposure to solar radiation, or to utilize a locally abundant resource. Barrett (1990) documented movements to steeper slopes for winter, possibly to avoid thermal sinks, in a Sonoran Desert population. Such behavior is supported by the hibernacula preferences reported by Bailey et al. (1995), also in a Sonoran Desert population. No elevational migrations have been reported within the western Mojave Desert. However, Woodbury and Hardy (1948) reported a seasonal migration from deep winter dens to shallow summer burrows in Utah, though this may more accurately be considered a seasonal shift in cover-site use.

Cover-site use by the desert tortoise, like slope occupation, varies with latitude (Germano et al., 1994). Although desert tortoises occupy burrows throughout their range, they shift from the use of rocky caves and overhangs in the southern portion of their range to a reliance on burrows in the northern, or Mojave Desert, portion of their range (Germano et al., 1994). Germano et al. (1994) suggested that such a pattern of cover-site use might reflect the availability of rocky caves and overhangs on the slopes occupied at southern latitudes. However, such differences may also reflect the need for greater wintertime thermal protection in the northern portion of the tortoises range, as indicated by the increased depth of winter dens in the northeastern Mojave Desert relative to the warmer western Mojave Desert (Bury et al., 1994).

The aspect of a slope determines its exposure to the sun, thereby regulating air and substrate temperatures; therefore, differences in exposure to the sun may result in animals occupying slopes with a particular range of aspects, or burrows that open in a particular range of directions. Desert tortoises occupy hibernacula on south facing slopes in the Sonoran Desert (Bailey et al., 1995). Berry and Turner (1986) observed that juvenile tortoise burrows open in a westerly to southeasterly arc. However, studies of adults in the Mojave Desert differed, indicating that: 1) captive tortoises selected burrows opening to the North, Northeast, and South (Bulova, 1992); and 2) wild tortoises occupied more north facing burrows (315 to 45 degrees, Bulova, 1994). Unfortunately, Bailey et al. (1995) did not discuss the direction in which the burrow openings faced, and neither Bulova (1994; 1992) nor Berry and Turner (1986) discussed the degree or aspect of the slope on which the burrows were located. We propose that, on slopes, it should be expected that the aspect of the slope would determine the direction in which the cover site opens.

Despite numerous investigations of desert tortoise biology, some details of desert tortoise ecology are still incompletely understood. In particular, Germano et al. (1994) provided a range-wide review of the distribution and habitat of desert tortoises that did not resolve questions regarding the types of habitats occupied in the western Mojave Desert. Desert tortoises occupy hills and mountain slopes in Sinaloa and the Sonoran Desert (Bailey et al., 1995; Germano et al., 1994; Barrett, 1990; Lowe, 1964), and occupy rocky substrates and hillsides in some portions of the Mojave Desert (Rautenstrauch and O'Farrell, 1998; Bury et al., 1994; Luckenbach, 1982; Jaeger, 1981). However, desert tortoises have been thought to occur mainly on bajadas and in valleys in the western Mojave Desert, and to occur at low densities on only the lower portions of mountains (Germano et al., 1994; Berry, 1986). Resource managers (Tom Egan and William Fisher personal communication) have however, observed desert tortoises on hillsides at locations near Barstow, California. The full range of occupied habitat is currently unknown.

If desert tortoises do occupy hillsides in the western Mojave Desert, current estimates of potential habitat, and therefore estimates of desert tortoise population sizes, may be too low (Bury et al., 1994). Additionally, slopes differ from flat areas in vegetation, soils, and microclimate (Bury et al., 1994). Tortoises occupying hillsides may therefore be exposed to a different variety of forage and cover types as well as a different topographic and geological habitat. Additionally, tortoises occupying hillsides may be less exposed to various mortality factors such as off-road vehicles and some types of predators.

To ensure the proper management of habitat we must gain a more complete understanding of the types of habitats occupied by the desert tortoise so that Critical Habitat, as discussed in the recovery plan, may be recognized and correctly assigned in all portions of its range. A more complete understanding of habitat use should include: 1) the quantification of topography (slope) and surface materials (substrate particle size), 2) information on how tortoises occupy these habitats (cover-site use), 3) how they move and partition their space (home range), and 4) at what densities tortoises occur in various habitat types. A detailed study that investigates those aspects of habitat is particularly warranted to investigate the occupation of hillsides in the western Mojave Desert. This study addresses all of the ecological details discussed above, and compares three hillside sites and one valley site over a period of two years.

Study Objectives

Our objectives were to confirm reports of desert tortoises occupying hillside habitats within the western Mojave Desert, and to investigate the habitat use and movement patterns of tortoises occupying these hillside areas. Additionally, we sought to estimate tortoise densities in these habitats. The specific questions that follow were formulated to compare and contrast details of the habitat in such areas, and habitat use by tortoises occupying such areas with traditionally studied tortoise habitats, and habitat use by tortoises occupying those areas. Additionally, we explain how we approached these questions.

At what densities do desert tortoises occur on hillside sites?

We sought to provide a conservative estimate of tortoise density on three hillside sites. Our estimates only concern adult animals, as juveniles are known to be difficult to sample accurately. We used an abbreviated technique to estimate tortoise density. Our density estimates can be considered lower than, or at most equal to, the actual densities at those sites.

On what degree of slopes are tortoises and their cover-sites found?
Of what particle size classes are the substrates in tortoise habitat composed?

We sought to provide a quantitative measure of both slope and substrate particle size that could be used to compare not only the sites in this study, but also other sites within the Mojave Desert and other portions of the range of the desert tortoise. Additionally, we set out to determine the variation in slope and substrate within a site, between hillside sites, and in particular between hillside sites and a site representative of those traditionally studied in the western Mojave Desert.

What types of cover-sites do desert tortoises occupy in hillside habitats?

Does cover-site use differ between hillside and valley sites?

Do desert tortoises select a range of aspects on which cover-sites are placed?

Do desert tortoises select a range of directions in which cover-sites open?

We sought to determine if tortoises in the western Mojave Desert do in fact rely on burrows for cover-sites, or if they occupy a wide variety of available cover-sites as they do in other portions of their range. By recording cover-site occupancy at four sites over two years, we hoped to determine if cover-site choice differed between hillside sites, between hillside and traditional sites, and between years within a site. Additionally, we sought to determine if desert tortoises occupy cover-sites on a particular range of aspects, if they occupy cover-sites that open in a particular range of directions, and if such use is consistent among sites. We also investigated the hypothesis that the slope a cover-site is located on determines the direction in which it opens.

Do desert tortoises make seasonal movements up or down slopes in the western Mojave Desert?

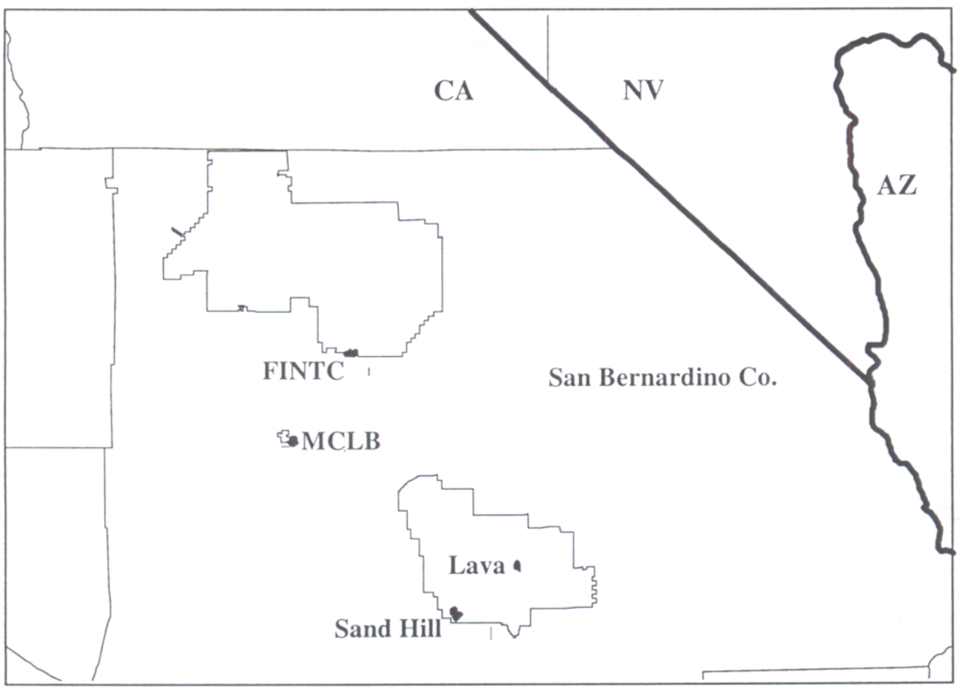
What sizes of home range do tortoises occupying hillsides occupy?

The primary goal of studying desert tortoise movements was to determine if tortoises were making seasonal movements between slopes and adjacent bajadas or flats, or if they existed on hillsides as resident populations. A secondary goal was to determine the home ranges of tortoises occupying hillsides, and to determine if patterns in home range size were similar to other studies of the desert tortoise. We sought to determine if home range varied between the sexes and between years. The sampling schedule, dictated by site availability, precluded any statistical comparison of home range size among the sites included in this study, and between our sites and those of other studies.

Study Area

Three hillside sites (the Marine Corps Logistics Base, Barstow [MCLB]; the southern boundary of the Fort Irwin National Training Center [FINTC]; and the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms) and one valley site, (the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms), all within San Bernardino County, CA, were selected for this project (Fig. 2). These sites were chosen to represent a range of locations across the Western Mojave Recovery Unit where tortoises were known (MCLB and Sand Hill) or suspected (FINTC and Lava) to occur. These sites differed in elevation, latitude, and topography. Site-specific elevations were as follows: MCLB (640–800 m), FINTC (700–830 m), Lava (640–800 m), and Sand Hill (760–820 m). Site-specific latitudes, from North to South, were: FINTC (35 degrees 8 minutes), MCLB (34 degrees 51 minutes), Lava (34 degrees 26 minutes), and Sand Hill (34 degrees 17 minutes). Topography, and the degree of topographic variation, differed among sites as did plant community.

Figure 2. —Locations of study sites within San Bernardino Co., CA.



The MCLB site (Fig. 3) included an East to West running ridgeline, divided by washes, from which finger-like extensions of hillside protruded. Between these extensions ran washes that began steep on the ridge, but which gradually became broad fans of 3 to 5 degrees as they ran north to Highway 40. Creosote (*Larrea tridentata*) and white bursage (*Ambrosia dumosa*) were the dominant members of the shrub community at the MCLB site. Other abundant shrubs were *Ephedra californica*, *Krameria erecta*, *Lycium andersonii*, and *Yucca schidigera*. Several species of cacti were present on the site including *Opuntia basilaris*, *O. echinocarpa*, *O. ramosissima*, and *Echinocactus polycephalus*. *Atriplex hymenelytra* and *Encelia farinosa* were present on steep clay slopes and steep rocky slopes respectively. *Hymenoclea salsola* was abundant in areas of human disturbance. Additionally, *Acacia greggii* and *Atriplex polycarpa* were abundant in washes. Annual grasses were comprised almost exclusively of *Schismus* *barbatus* (particularly on flat areas) and *Bromus madritensis* (on rocky slopes and around shrubs); however, *Achnatherum hymenoides* was found in several areas on the site. Dominant forbs included *Eriogonum* spp., *Amsinckia tessellata* (on rocky slopes), and *Erodium cicutarium*. Annual plant diversity and abundance appeared to be relatively low in 1997 with the exception of *Schismus barbatus*. The rains of 1998 produced an increased annual biomass, particularly in the legume family (*Astragalus* and *Lupinus*) and in *Camissonia brevipes*.

Figure 3. —Photograph of the study site at the Marine Corps Logistic Base, Barstow, CA (1998).

The site at FINTC (Fig. 4) consisted primarily of a continuous bajada with several hills and small mountains, offering both gradual slopes and steep slopes divided by deep washes. *Larrea tridentata* and *Ambrosia dumosa* dominated this site. Other abundant shrubs included *Ephedra californica*, *Hymenoclea salsola*, *Krameria erecta*, *Senna armata*, and *Xylorhiza tortifolia* (locally abundant). The parasitic dodder (*Cuscuta*) was present on many shrubs in both years. The dominant annual was *Schismus barbatus*. *Eriogonum* spp. and *Plantago insularis* were also present. Numerous annuals of the Legume (Fabacea) family were present in 1998 including the genera *Astragalus* and *Lupinus*.

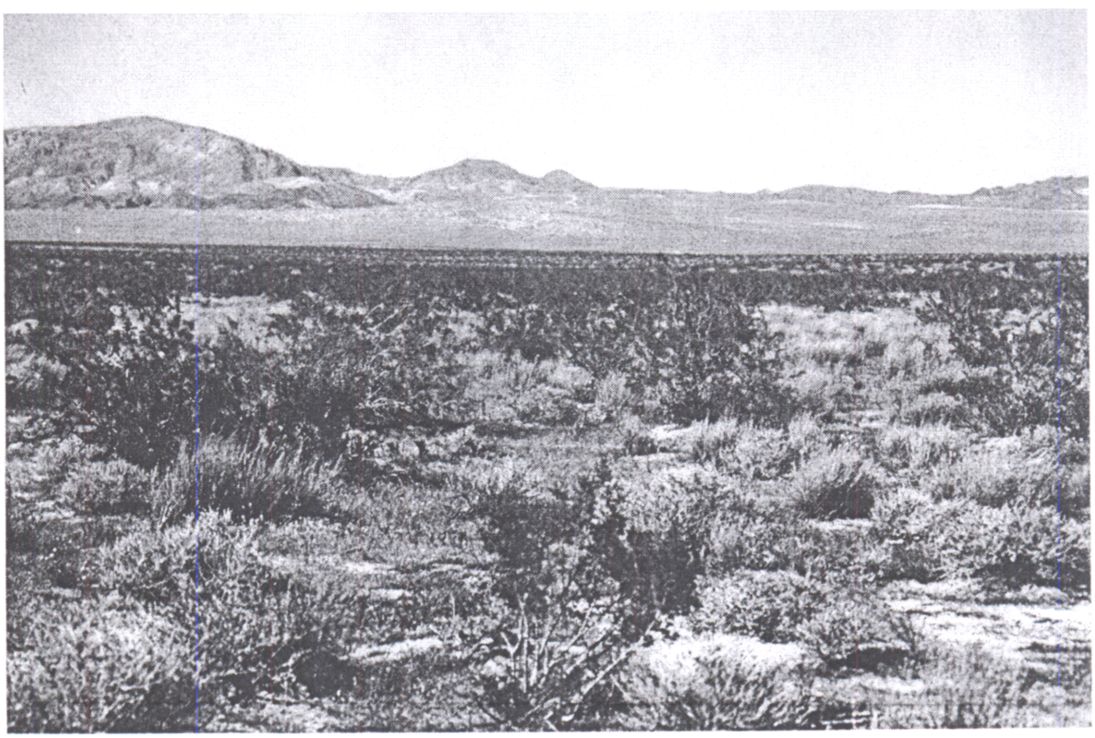
Figure 4. —Photograph of the study site at the southern boundary of the Fort Irwin National Training Center, CA (1997).

The Lava site (Fig. 5) presented the most extreme topography of the three hillside sites; steep mountains of approximately 100–150 meters surrounded rocky washes on all sides. It was evident that rainfall events had scoured all small substrate particles from the area. Lava was dominated by *Larrea tridentata*, with an alternating co-dominant of either *Ambrosia dumosa* (flats and near washes) or *Encelia farinosa* (slopes), although both co-dominants could be found throughout the site. Additional shrubs present on the site include *Acacia greggii*, *Hymenoclea salsola*, *Hyptis emoryi*, and *Opuntia ramosissima*. The dominant annual was *Plantago insularis*; however, *Bromus madritensis* and *Schismus barbatus* were both present. Other annuals, present in 1998, include *Amsinckia tessellata*, *Chorizanthe brevicornu*, and *Escholzia minutiflora*.

The site at Sand Hill (Fig. 6) exhibited the most homogeneous topography of all the sites: Small rolling hills of minimal slope and shallow washes were scattered on a nearly flat landscape. *Larrea tridentata* and *Ambrosia dumosa* were the dominant shrub species, however *Pleuraphis rigida* was the sole dominant, or was mixed with *Larrea tridentata*, in many areas. Other shrubs present included *Ephedra* spp., *Senna armata*, and *Yucca brevifolia*. *Schismus barbatus* was the dominant annual, however *Bromus madritensis* was present around shrubs in some areas.

Figure 5. —Photograph of the study site at the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997).

Figure 6. —Photograph of the study site at the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1998).



Additional annuals at Sand Hill included *Amsinckia tessellata*, *Chaenactis fremontii*, *Eriogonum* spp., *Erodium cicutarium*, and *Phacelia crenulata*. Almost no annuals were present in 1997 until late summer rains produced an abundance of *Pectis papposa* (chinch weed). A large male tortoise (M95-2) was observed consuming various annuals and fresh shoots of *Pleuraphis rigida*, but not chinch weed, after these summer rains although chinch weed was far more abundant than any other species.

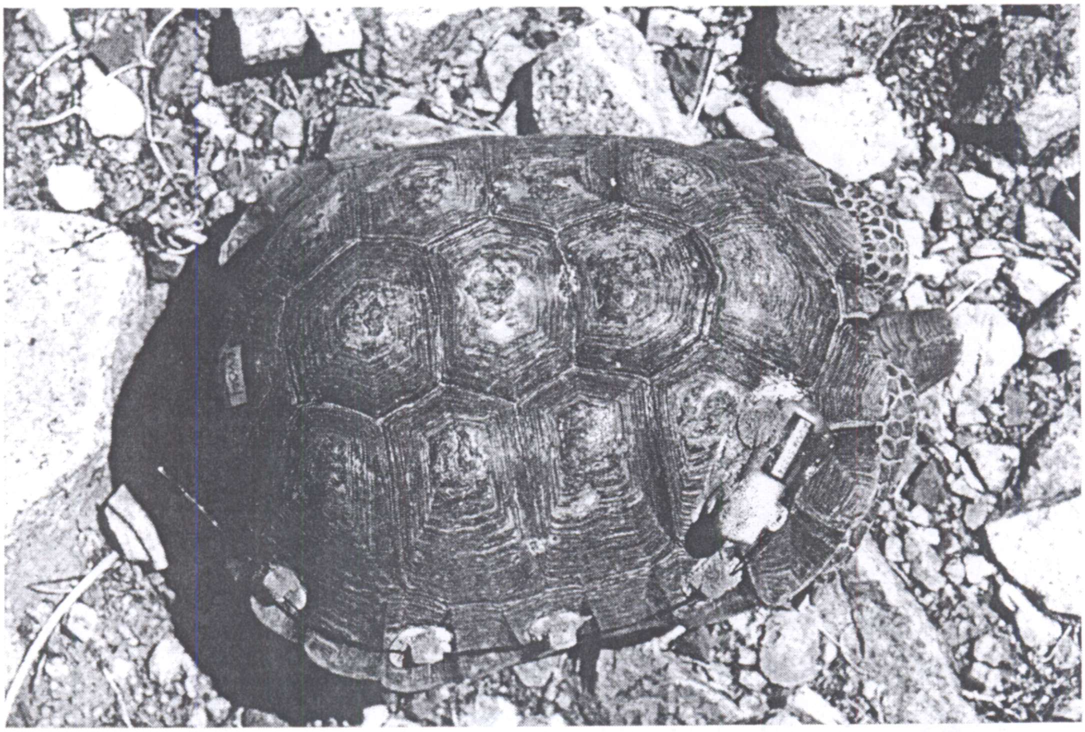
METHODS

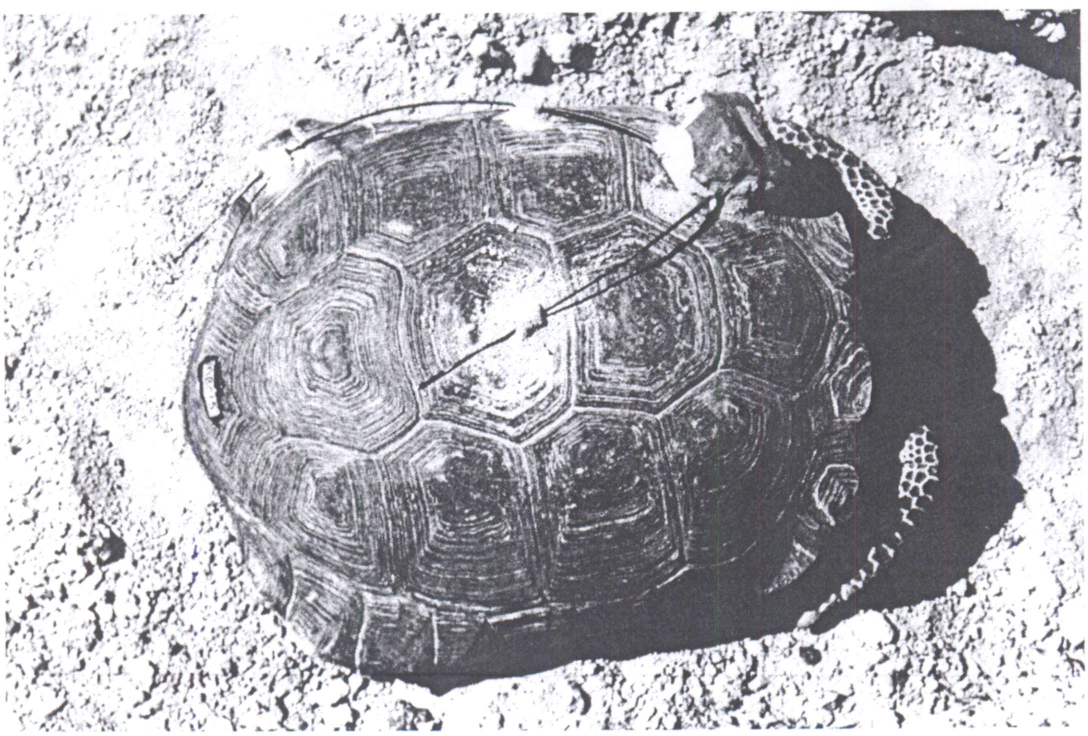
Tortoises were selected for this study by two methods. Tortoises used at Sand Hill were selected randomly from a pool of tortoises from a previous study (Duda and Krzysik, 1998) that were of adult size (MCL > 180 mm) and in the appropriate area of the range. Tortoises used at the three hillside sites were selected by searching the sites for tortoises of adult size. All tortoises of the appropriate size located on hillside sites in the spring of 1997 were used in the study.

Adult tortoises selected for this study were measured, weighed, and numbered with an epoxy-covered tag placed on the fifth vertebral scute (tags were replaced by paint marks in 1998 for increased durability and legibility). AVM model SB-2 transmitters, powered by a single AA (Lava and Sand Hill) or two K16-F (FINTC and MCLB) batteries, were attached to the first right (AA) or left (K16-F) costal scute (Fig. 7) with putty epoxy (Power Poxy Adhesives, Inc., Power Poxy ® #40001), following a protocol similar to Boarman et al. (1998). Modifications of this protocol include the placement of antenna guides along the marginal scutes rather than the vertebral scutes and the placement of antenna guides for a ground-plane antenna down the vertebral scutes (K-16F transmitters only). This method was altered for two reasons: 1) to allow for the attachment of the transmitters with ground-plane antennas, and 2) to ensure that antennas did not extended beyond the carapace, along the vertebral line, of female tortoises as this may interfere with copulation. After attachment the transmitters were tested, and working frequencies were recorded.

Tortoises were located on an approximately weekly (MCLB and FINTC) or semi-weekly (Lava and Sand Hill) basis, as dictated by military activities, from late March until late September in 1997 and 1998. Universal Transverse Mercanter (UTM) coordinates were taken with a Trimble Scoutmaster ® GPS unit, utilizing the Acu-loc ® point averaging feature with 300 points and a five second update rate, to achieve an accuracy radius of approximately 25 m. Individual tortoise locations are presented in maps 1–4 (Appendix 1). Slopes were measured to the nearest half-degree, over an approximately five-meter distance, with a Suunto clinometer. If a tortoise was found less than one meter up the side of a wash the slope of the wash, rather than the slope of the wash side, was recorded. Aspects were determined by sight, often assisted by evidence of water flow, and measured with a Suunto Leader compass to the nearest degree. Surface substrate particle size distributions within a 10 m ring around each tortoise were estimated into five particle size classes: grain (< 2 mm), granule (2–4 mm), pebble (4–64 mm), cobble (64–256 mm), and boulder (> 256 mm) (Bates and Jackson 1984).

Fig. 7—Photographs illustrating radio transmitter attachment. A transmitter with a AA battery, used at Lava and Sand Hill, is shown on LV04 (top). A transmitter with a K16-F battery, used at Barstow and Irwin, is shown on MB15 (bottom).





If the tortoise was located at a cover-site location the cover-site was given a unique number that incorporated the identification number of the tortoise and the date (e.g., MB01-3JUN97), and was marked with an aluminum tag. Additionally, a series of cover-site specific data were obtained. Cover-site type (burrow, caliche cave, rock—pallet under a boulder, pallet—under a shrub, rodent midden) or a combination of types was recorded. The direction in which a cover-site opening faced (DCSO) was measured perpendicular to the plane of the opening with a Suunto Leader compass. The aspect of the slope the cover-site was on (ACS) was also recorded. Location, slope, and substrate were measured as at other locations.

To obtain an estimate of minimum tortoise density on the three hillside sites we marked (with an epoxy covered paint mark and permanent ink number) and measured all tortoises encountered during the field season of 1998 (Appendix 2). We added the number of adult tortoises (MCL > 180mm) encountered in 1998 to the number of adult tortoises that had received transmitters in 1997, then divided the total number of adult tortoises by an estimated area searched in 1998. All locations for both 1997 and 1998 were used for FINTC and Lava, as all animals located in 1997 were given transmitters. The estimated area searched was calculated from all tortoise locations (radiotelemetry and marked animals) using Ranges V (Kenward and Hodder, 1996). Three home range models were used to calculate the area searched: 1) Minimum convex polygon, 2) Minimum concave polygon, and 3) Kernel (Harmonic Mean). We compared ranges produced by these methods to the actual routes traveled during sampling to determine which model's estimate most closely matched the actual area searched at each site.

Statistical Analyses

All statistical analyses, with the exception of analyses of circular variables, were performed with SAS 7.0 (SAS Institute, 1998). All necessary data transformations, to achieve normality and when possible homogeneous variances, were accomplished with the guided data analysis function of SAS 7.0 (SAS Institute, 1998). All circular analyses were performed with Oriana 1.0 (Kovach, 1994).

The issue of independence of data points was addressed separately for each comparison. Multiple locations of an individual tortoise are judged to be independent if they were not the same geographic location. Thus, all locations away from a cover-site were considered independent. This assumption may have been violated in cases where the tortoise was near a known cover-site (locations within 2 meters were considered to be at that cover-site unless the physical characteristics of the locations differed), near a previously sampled location on a homogeneous slope, or if the tortoise had a preference for a particular microhabitat type. Inter-site comparisons of two-year cover-site variables (slope at cover-sites, substrate at cover-sites, ACS, DCSO) were performed on a data set in which each cover-site was included only once, regardless of the number of tortoises that occupied the cover-site or the number of years in which the cover-site was occupied. Inter-year comparisons of cover-site variables were performed on a data set in which each cover-site was included only once per year, regardless of the number of tortoises occupying it in that year, but in which the same cover-site could be included in both years if used by at least one tortoise in each year.

Slope data were analyzed to determine if sites differed in the distribution of slopes occupied, and if sites differed in the mean slope occupied. Slope data at all cover-sites, for the combined years of 1997 and 1998, were transformed by adding one and raising them to the power of -0.2. Slope data at all non-cover-site locations, for the combined years of 1997 and 1998, were transformed by adding one and raising them to the power of -0.3. To determine if sites differed in the variance of slopes occupied (at all cover-sites and at all non-cover-site locations) data were analyzed with a Bartlett's Test for homogeneity of variances (Zar, 1996). To determine if sites differed in mean slope occupied (at all cover-sites and at all non-cover-site locations) data were analyzed with a Welch's ANOVA for heterogeneous variances (Zar, 1996). Pair-wise comparisons were performed at an alpha of 0.05 with Tukey's Studentized Range Test.

A substrate particle size score, designed to indicate the overall coarseness of the substrate, was calculated from particle size estimates for each location as follows: grain + 2(granule) + 3(pebble) + 4(cobble) + 5(boulder). Substrate particle size scores (all cover-sites and all non-cover-site locations) were square root transformed. The distributions of substrate particle size scores were then compared with a Welch's ANOVA for heterogeneous variances (Zar, 1996). Pair-wise comparisons were performed at an alpha of 0.05 with Tukey's Studentized Range Test.

Cover-site type was analyzed to determine if cover-site choice differed between sites. Analysis was performed separately on two data sets. The first data set (cover-sites occupied) included all cover-sites used in a year, each included once for each individual tortoise using it, regardless of the number of times an individual was located at it. The second data set (cover-site occupation frequency) represents a usage frequency; therefore each use of the cover-site by each individual tortoise is included. Each data set was analyzed in two ways by a two-tailed Fisher's Exact Test: 1) a contingency table of cover-site type by site was analyzed for each year separately to determine if cover-site use differed between sites, and 2) a contingency table of cover-site type by year was analyzed separately for each site to determine if cover-site use differed between years within each site. Expected values were calculated from row and column totals, and indicate the number of observations of that type expected if no difference exists between the compared groups.

Circular variables were analyzed to determine if sites and years differed in aspect at all locations, aspect at all non-cover-site locations, ACS, and DCSO. A mean vector, standard deviation, and 95% confidence interval were calculated for each data set. A Rayleigh's Test was performed to determine if the sample differed from a uniform distribution. A Watson's F-Test was used for comparisons of interest (inter-site comparisons of ACS and DCSO, intra-site comparisons of both ACS and DCSO between years, and intra-site comparisons of ACS and DCSO) for all samples that differed from a uniform distribution and had a sufficiently large concentration. Circular histograms were created for measures of interest with a bar width of 15 degrees.

Home ranges were calculated as 100 percent minimum convex polygons with Ranges V (Kenward and Hodder, 1996). Home ranges for each tortoise were calculated for both years and for a combined (2-year) range. To ensure that the number of locations did not affect home range comparisons, a correction method (Barrett, 1990) was used to calculate corrected home ranges. Separate analyses were performed for raw and corrected home ranges. Analyses were performed on a data set restricted to tortoises located in both years. However, tables also include home ranges for tortoises located in only one year. Inter-sex and inter-year comparisons of home ranges, transformed by square root (raw and corrected MCPs at MCLB) or logarithm (raw and corrected MCPs at Sand Hill), were performed by ANOVA for the MCLB and Sand Hill sites. Inter-sex comparisons of two-year ranges, logarithm transformed (raw and corrected MCPs at MCLB), were performed with a two-sample T-test for both MCLB and Sand Hill. Two-year ranges at Sand Hill did not require a transformation to meet the test assumptions. A between site comparison of home range sizes was not performed because of differences in sampling frequency between MCLB and Sand Hill. Statistical analyses were not performed on home ranges from FINTC and Lava because too few tortoises were located in both years.

RESULTS

Desert tortoises occupied steep slopes and coarse substrate at all three hillside sites. Steep slopes and coarse substrates were not present at the valley site (Sand Hill). Individual data points discussed list either a cover-site number or the date of the location if away from a cover-site. Tortoises with transmitters were located on a maximum slope of 33 degrees at both MCLB and Lava (MCLB: MB06, male, MB06-10AUG97; Lava: LV04, male, LV04-7JUN97). Additionally, one tortoise (B12, male, 04/22/98) was located on a slope of 36 degrees at MCLB. Tortoises were found on substrates comprised of up to 70 percent boulders (Lava: LV03, female; LV06, male; and LV08, male; LV03-25MAY97 and LV03-7JUN97).

Desert tortoises occurred at low to moderate densities on our three hillside sites. The area searched at each site (km^2), listed in the form (Minimum convex polygon, minimum concave polygon, kernel) with the most reasonable estimate in bold were: MCLB (**2.10**, 1.96, 2.47); FINTC (1.61, **1.48**, 3.49); Lava (1.65, 1.43, **1.32**). Estimates of tortoise density (tortoises/km^2), listed in the same series, were: MCLB (**27.1**, 29.1, 23.1); FINTC (7.5, **8.1**, 3.4); Lava (4.8, 5.6, **6.1**). Re-sightings of marked tortoises without transmitters were rare at MCLB, and did not occur at FINTC or Lava.

Tortoises included in the telemetry study, while all adults, varied widely in MCL and weight (Tables 1a–d). Sizes (MCL) ranged from 205 mm (Sand Hill, M95-26, female) to 331 mm (Sand Hill, M95-2, male). Males were significantly larger (MCL) than females ($p < 0.0001$, 95%CI = 229–249 [Females] and 267–290 [Males]), and MCL differed between sites ($p = 0.0463$). Additionally, a sex—site interaction was observed ($p = 0.0649$) where the difference between male and female mean MCLs ranged from 21.6 (MCLB) to 60.5 (Sand Hill). No differences in MCL were recorded between years that were in excess of the estimated error of this measurement (± 2mm). Weights ranged from 1.27 kg (MCLB, 1997, MB06, male) to 6.46 kg (Sand Hill, 1998, M95-2, male). Males weighed significantly more ($p < 0.0001$) than females, and tortoises were significantly heavier in 1998 than in 1997 ($p = 0.0387$); however, it was unclear if weights differed between sites ($p = 0.0924$). Additionally, a significant interaction was found between site and sex ($p = 0.0126$); however, the sex-year ($p = 0.6458$) and site-year ($p = 0.7126$) interactions were not significant. The significant interaction of site and sex is most likely a result of the similarity of male and female weights, as observed in MCL, at MCLB compared to the other sites.

Table 1a. —Measurements of study tortoises at the Marine Corps Logistics Base, Barstow, CA (1997 – 1998). Unless noted, measurements were taken in March or April. Linear measurements are in millimeters, weights in grams.

		1997				1998				
Tortoise	Sex	MCL	Width	Weight	PLN	MCL	Width	Weight	Girth	
MB02	F	231.0	177.0	2420	203.0	232.0	177.0	2540	472.0	
MB08	F	235.0	177.5	2240	217.0	235.5	177.0	2140	455.0	
MB09	F	267.5	211.0	3320	252.0	270.0	210.0	3690	540.0	
MB10	F	246.0	188.0	2740	216.0	245.5	187.0	2610	492.0	
MB11	F	247.5	188.0	2860	227.0	246.5	187.5	2990	487.0	
MB16	F	219.5	165.0	1830	201.0	219.0	165.0	1830	431.0	
MB18	F	221.0	162.0	1780	205.4	222.0	162.0	1780	429.0	
MB19	F	239.0	182.3	2510	218.0	242.0	184.0	2510	488.0	
MB21	F	254.0	188.5	2720	240.0	255.0	189.5	3010	498.0	a
MB22	F					213.0	160.5	1880	428.0	
MB01	M	212.5	158.0	1650	195.0					
MB03	M	276.0	215.5	3700	220.0	275.0	217.0	4210	574.0	
MB04	M	253.5	181.0	2830	227.0	254.0	181.0	2940	493.0	
MB05	M	287.5	213.0	4100	259.0	283.0	212.0	4040	561.0	
MB06	M	216.0	152.5	1270	190.0	214.0	153.0	1810	417.0	
MB07	M	236.5	174.0	2300	216.0	235.0	174.0	2460	471.0	
MB12	M	290.0	231.8	4690	277.0	293.0	232.0	4940	609.0	
MB13	M	225.0	173.5	2090	200.0	223.0	173.0	2090	460.0	
MB14	M	308.0	222.7	4250	270.0	304.0	223.0	4590	589.0	
MB15	M	276.8	220.5	4140	266.0					
MB17	M	255.0	187.0	3060	239.0	253.0	187.0	3080	508.0	
MB20	M	269.4	198.2	3580	253.5	269.0	198.0	3720	537.0	

a. Measurements for 1997 taken when tortoise was added to the study on June 6.

Table 1b. —Measurements of study tortoises at the southern boundary of Fort Irwin, CA (1997 - 1998). Unless noted, measurements were taken in April (1997) or May (1998). Linear measurements are in millimeters, weights in grams.

		1997				1998				
Tortoise	Sex	MCL	Width	Weight	PLN	MCL	Width	Weight	Girth	
TC01	F	234.0	174.8	2260	218.0	234.5	174.0	2210	463.0	a
TC02	F	259.0	194.0	2750	239.0	261.0	193.0	3160	506.0	
TC04	F	218.0	173.3	2150	210.0					
TC05	F	224.0	172.5	2200	191.0	226.0	174.0	2340	454.0	
TC06	F	243.0	189.2	2580	220.0					
TC03	M	281.0	218.0	4250	265.0	283.0	218.0	4600	579.0	
TC08	M	276.0	210.5	3330	253.5	278.0	211.0	4430	566.0	b
TC09	M			3440		286.0	212.0	4550	567.0	b

a. Measurements for 1998 taken when the tortoise was located on August 18. No other locations for that year.
b. Measurements for 1997 taken when tortoises were first located: September 9 (TC08) and September 14 (TC09)

Table 1c. —Measurements of study tortoises at the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 – 1998). Unless noted, measurements were taken in March or April. Linear measurements are in millimeters, weights in grams.

		1997				1998				
Tortoise	Sex	MCL	Width	Weight	PLN	MCL	Width	Weight	Girth	
LV02	F	236.0	185.5	2130	210.0	238.0	184.0	2790	499.0	
LV03	F	242.5	183.0	2370	218.0	246.0	183.0	2760	482.0	
LV05	F	248.0	191.0	1760	210.0					
LV07	F					254.0	185.0	3240	490.0	a
LV01	M	275.0	198.0	3560	260.0	276.0	198.0	3560	528.0	
LV04	M	259.7	191.0	3340	256.0	265.0	192.0	3710	516.0	
LV06	M	300.0	221.2	4800	277.0	299.5	221.0	5960	586.0	
LV08	M					263.0	191.0	3250	512.0	b

a. Measurements for 1997 taken when tortoise was first located on September 15.
b. Measurements for 1998 taken when tortoise was first located on May 10.

Table 1d. — Measurements of study tortoises at the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 – 1998). Unless noted, measurements were taken in March or April. Linear measurements are in millimeters, weights in grams.

		1997				1998				
Tortoise	Sex	MCL	Width	Weight	PLN	MCL	Width	Weight	Girth	
M95-01	F	262.5	201.0	3160	226.0	267.0	201.0	3410	51.8	
M95-08	F	249.0	184.5	1800	225.0					
M95-13	F	247.0	190.0	2200	221.0	248.0	189.0	2900		
M95-14	F	246.0	183.6	2480	226.0					
M95-22	F	233.7	170.5	2220	170.5	235.0	176.0	2350	458.0	
M95-26	F	205.0	161.0	1420	183.0	212.0	165.0	1910	453.0	
M95-31	F	223.5	168.0	1580	207.0	226.0	167.0	2160	452.0	
M95-32	F	245.0	188.0	2250	220.0	241.0	187.0	2730	486.0	
M95-02	M	331.0	264.5	5750	300.0	333.0	265.0	6460	675.0	
M95-15	M	301.0	225.0	4180	263.0	300.0	224.0	4960	597.0	a
M95-18	M	282.0	219.0	3070	253.0	284.0	220.0	4030	573.0	
M95-21	M	311.6	246.4	4300	244.0					
M95-33	M	286.0	232.0	4280	262.0	292.0	232.0	5060		
M96-36	M	285.0	222.0	3530	255.0	288.0	222.0	4450	589.0	

a. Measurements for 1997 taken when tortoise was first removed from a burrow to change its transmitter on May 28.

Physical Habitat

The mean slope occupied by desert tortoises differed between sites both at cover-site and non-cover-site locations (both cases: $p < 0.0001$). Variances for both data sets were found to be heterogeneous (cover-site: $p < 0.0001$, non-cover-site: $p = 0.0011$). All pair-wise comparisons of mean slope at cover-sites were significant except for MCLB vs. Lava and MCLB vs. FINTC (Table 2a). All pair-wise comparisons of mean slope at all non-cover-site locations were significant except MCLB vs. Lava (Table 2b). Additionally, slopes occupied varied widely between locations for an individual and among individuals within a site (Fig. 8a–d).

Mean substrate particle size scores of locations occupied by desert tortoises were found to differ between sites at both cover-sites and at non-cover-site locations (both cases: $p < 0.0001$). Variances for both data sets were heterogeneous (both cases: $p < 0.0001$). All pair-wise comparisons of mean substrate particle size scores at cover-sites indicated significant differences (Table 3a), as did all pair-wise comparisons of mean substrate particle size scores at non-cover-sites (Table 3b). Additionally, substrate particle size scores varied between locations for an individual and among individuals within a site (Figs. 9a–d).

Table 2a. —Between-site comparisons of slopes at desert tortoise cover-sites occupied during 1997 and 1998. The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges at the Marine Corps Air Ground Combat Center, Twentynine Palms.

Comparison (Site 1 - Site 2)	Site1 mean (95% CI)	Site 2 mean (95% CI)	Significant[a]
MCLB - FINTC	12.93 (11.64-14.22)	7.61 (6.04-9.19)	yes
MCLB - Lava	12.93 (11.64-14.22)	14.74 (11.91-17.58)	yes
MCLB - Sand Hill	12.93 (11.64-14.22)	1.06 (0.92-1.19)	yes
FINTC - Lava	7.61 (6.04-9.19)	14.74 (11.91-17.58)	yes
FINTC - Sand Hill	7.61 (6.04-9.19)	1.06 (0.92-1.19)	yes
Lava - Sand Hill	14.74 (11.91-17.58)	1.06 (0.92-1.19)	yes

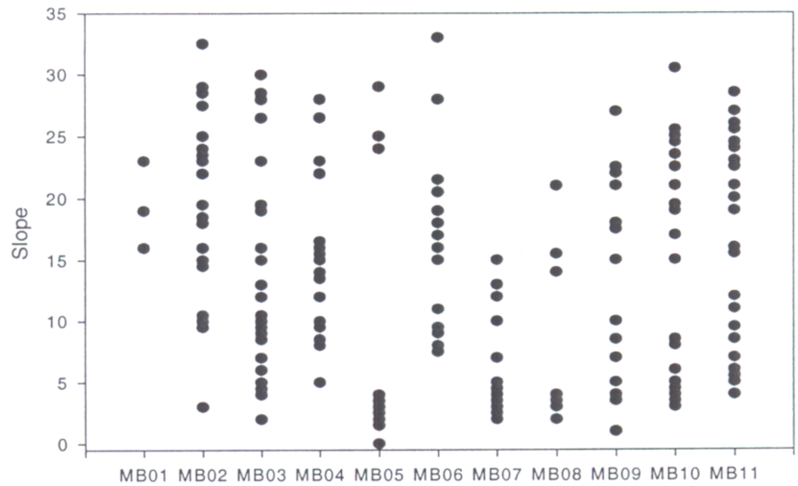
a. Significance was tested with transformed variables

Table 2b. —Between-site comparisons of slope at non-cover-site locations of desert tortoises during 1997 and 1998. The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges at the Marine Corps Air Ground Combat Center, Twentynine Palms.

Comparison (Site 1 - Site 2)	Site1 mean (95% CI)	Site 2 mean (95% CI)	Significant[a]
MCLB - FINTC	10.63 (9.69-11.57)	6.11 (4.87-7.34)	yes
MCLB - Lava	10.63 (9.69-11.57)	12.09 (9.48-14.69)	yes
MCLB - Sand Hill	10.63 (9.69-11.57)	1.07 (0.91-1.22)	yes
FINTC - Lava	6.11 (4.87-7.34)	12.09 (9.48-14.69)	yes
FINTC - Sand Hill	6.11 (4.87-7.34)	1.07 (0.91-1.22)	yes
Lava - Sand Hill	12.09 (9.48-14.69)	1.07 (0.91-1.22)	yes

a. Significance was tested with transformed variables

Figure 8a. — Distributions of slope occupied by individual tortoises at the Marine Corps Logistics Base, Barstow, CA (1997 and 1998). Each dot represents an independent location for that tortoise.



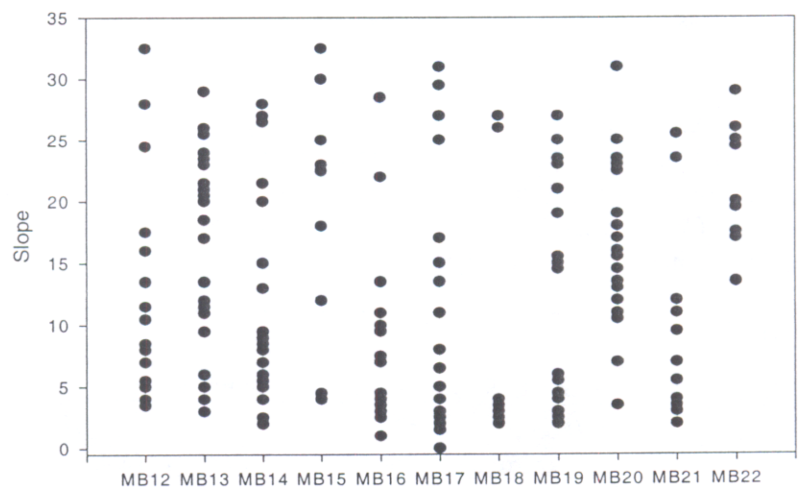


Figure 8b. —Distributions of slope occupied by individual tortoises at the southern boundary of the Fort Irwin National Training Center, CA (1997 and1998). Each dot represents an independent location for that tortoise.

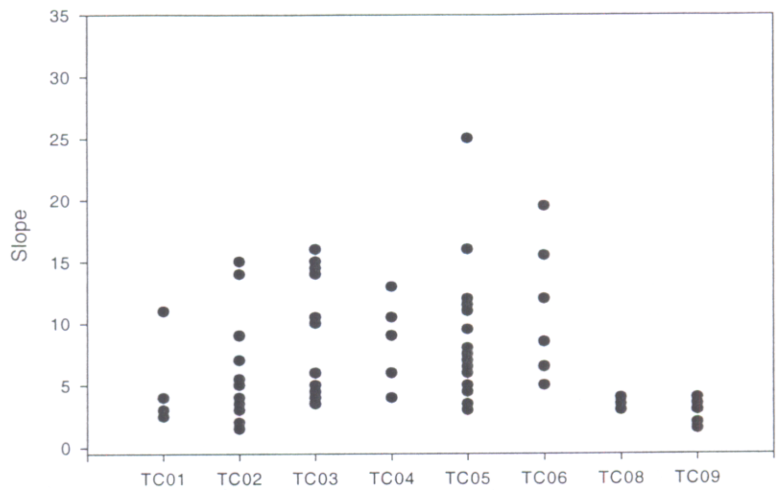


Figure 8c. —Distributions of slope occupied by individual tortoises at the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 and 1998). Each dot represents an independent location for that tortoise.

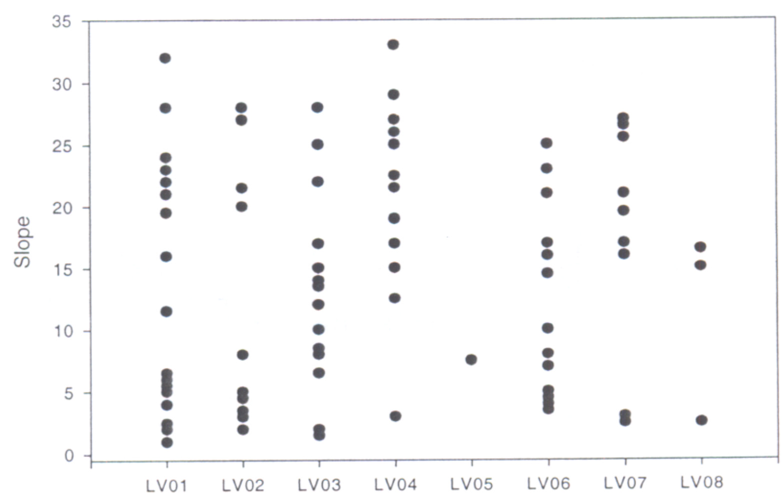
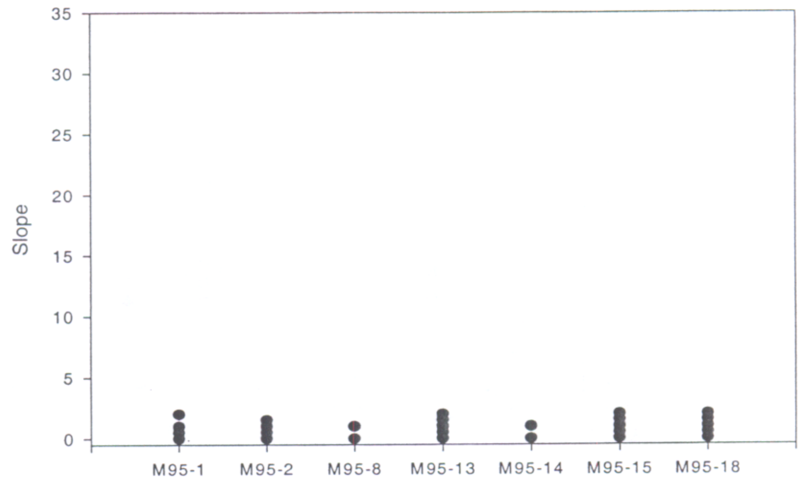


Figure 8d. — Distributions of slope occupied by individual tortoises at the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 and 1998). Each dot represents an independent location for that tortoise.



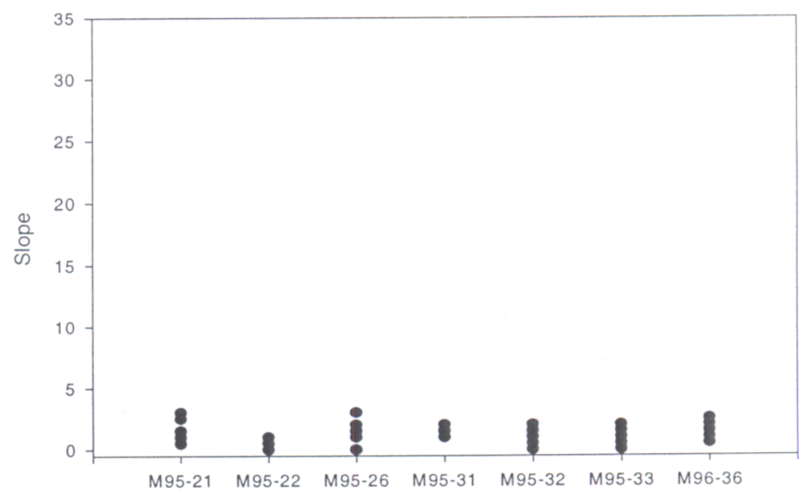


Table 3a. —Between-site comparisons of substrate score at cover-sites occupied by desert tortoises during 1997 and 1998. Substrate score is an indicator of the overall coarseness of the surface substrate calculated as (% grains) + 2(% granules) + 3(% pebbles) + 4(% cobbles) + 5(% boulders). The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges at the Marine Corps Air Ground Combat Center, Twentynine Palms.

Comparison (Site 1 - Site 2)	Site1 mean (95% CI)	Site 2 mean (95% CI)	Significant[a]
MLCB - FINTC	278.6 (274.3-282.9)	239.4 (225.3-253.4)	yes
MCLB - Lava	278.6 (274.3-282.9)	358.1 (347.5-368.7)	yes
MCLB - Sand Hill	278.6 (274.3-282.9)	167.2 (163.7-170.7)	yes
FINTC - Lava	239.4 (225.3-253.4)	358.1 (347.5-368.7)	yes
FINTC - Sand Hill	239.4 (225.3-253.4)	167.2 (163.7-170.7)	yes
Lava - Sand Hill	358.1 (347.5-368.7)	167.2 (163.7-170.7)	yes

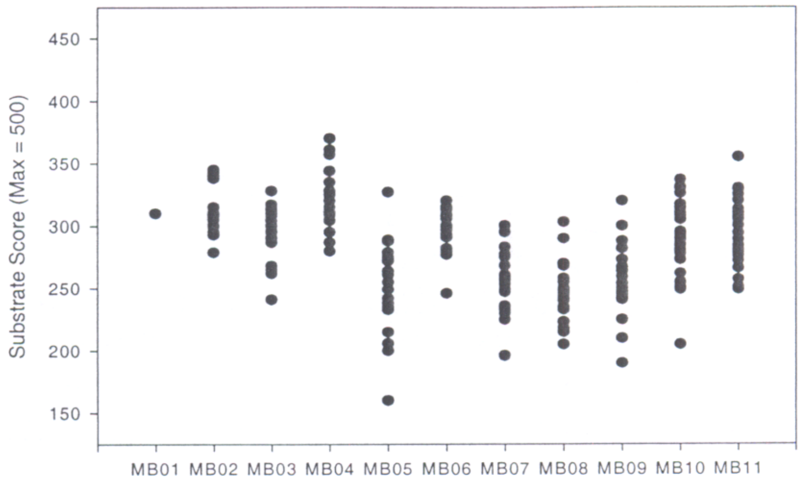
a. Significance was tested with transformed variables

Table 3b. —Between-site comparisons of substrate score at non-cover-site locations of desert tortoises during 1997 and 1998. Substrate score is an indicator of the overall coarseness of the surface substrate calculated as (% grains) + 2(% granules) + 3(% pebbles) + 4(% cobbles) + 5(% boulders). The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges at the Marine Corps Air Ground Combat Center, Twentynine Palms.

Comparison (Site 1 - Site 2)	Site1 mean (95% CI)	Site 2 mean (95% CI)	Significant[a]
MCLB - FINTC	292.5 (288.7-296.4)	234.8 (222.5-247.0)	yes
MCLB - Lava	292.5 (288.7-296.4)	353.2 (342.2-364.2)	yes
MCLB - Sand Hill	292.5 (288.7-296.4)	170.4 (166.4-174.5)	yes
FINTC - Lava	234.8 (222.5-247.0)	353.2 (342.2-364.2)	yes
FINTC - Sand Hill	234.8 (222.5-247.0)	170.4 (166.4-174.5)	yes
Lava - Sand Hill	353.2 (342.2-364.2)	170.4 (166.4-174.5)	yes

a. Significance was tested with transformed variables

Figure 9a. —Distributions of substrate scores at locations occupied by individual tortoises at Barstow for the combined years 1997 and 1998. Each dot represents an independent location for that tortoise.



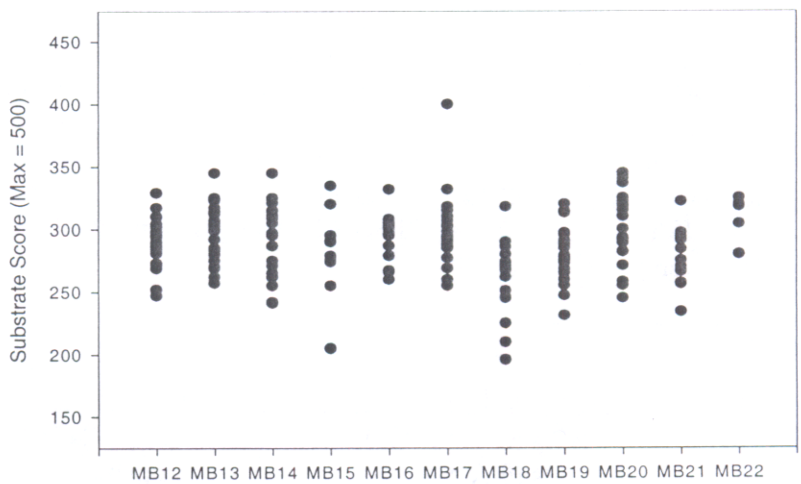


Figure 9b. —Distributions of substrate scores at locations occupied by individual tortoises the Fort Irwin National Training Center, CA (1997 and 1998). Each dot represents an independent location for that tortoise.

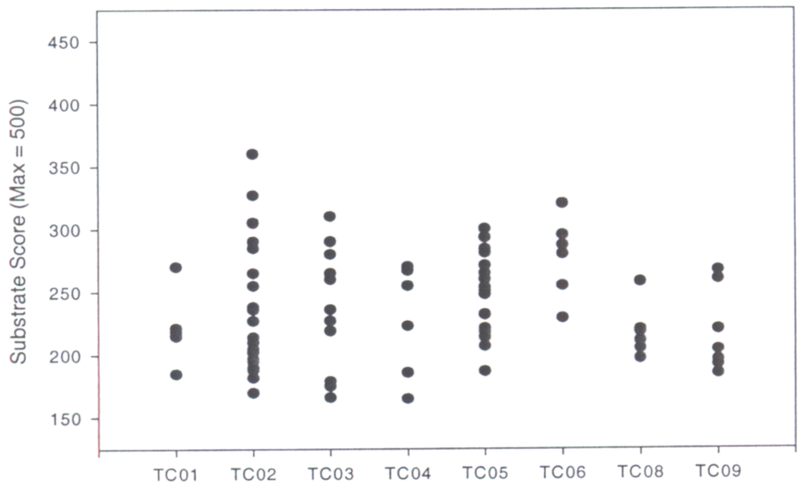


Figure 9c. —Distributions of substrate scores at locations occupied by individual tortoises the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 and 1998). Each dot represents an independent location for that tortoise.

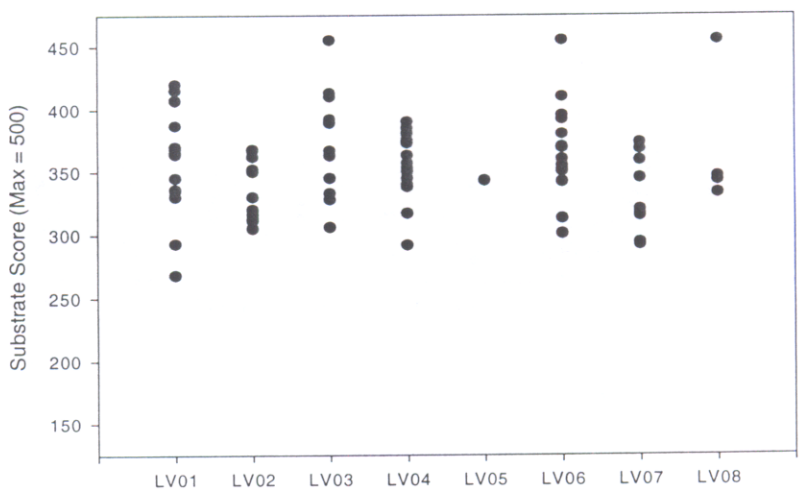
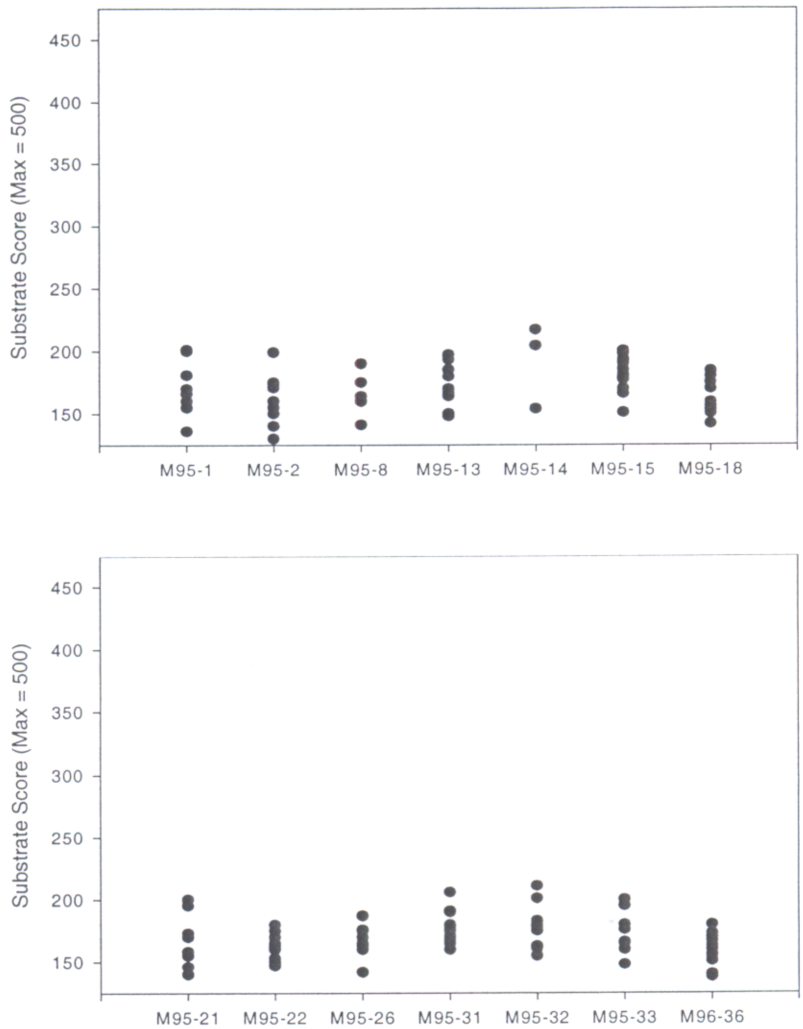


Figure 9d. —Distributions of substrate scores at locations occupied by individual tortoises at the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 and 1998). Each dot represents an independent location for that tortoise.



Cover-site Use

Inter-site differences in cover-sites occupied were found in both years (both $p < 0.0001$). Table 4 presents cover-site type by site contingency tables for both 1997 and 1998. Two cover-sites from MCLB defied classification and were not included in these analyses: 1) MB08-11JUN97, a wood rat (*Neotoma lepida*) midden (composed of rocks, sticks, and pencil cholla [*Opuntia ramosissima*] spines under an *Ephedra californica*) without any apparent opening; and

2) MB17-17JUL98, a cave above the soil surface in the hollowed out base of a Mojave Yucca (*Yucca schidigera*). Two burrows in wood rat middens and two burrows that began under small rocks, all at MCLB, were simply referred to as burrows.

Table 4. —Contingency tables and p-values for Fisher's exact tests of cover-site type occupation by site for both 1997 and 1998. Two cover sites, both from Barstow, were excluded from this analysis: 1) A wood rat (*Neotoma lepida*) midden without any apparent opening, and 2) A cave in the base of a Mojave Yucca (*Yucca schidigera*). Cover-site type occupation differed significantly between sites in both years. The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges at the Marine Corps Air Ground Combat Center, Twentynine Palms.

			Cover Type				
				Caliche			Fisher's
Year	Site		Burrow	Cave	Pallet	Rock	Exact
1997	MCLB	Observed	83	10	4	1	$p < 0.0001$
		Expected	75.1	12.9	2.5	7.5	
	FINTC	Observed	18	0	0	5	
		Expected	17.6	3.0	0.6	1.8	
	Lava	Observed	3	16	0	9	
		Expected	21.5	3.7	0.7	2.1	
	Sandhill	Observed	47	0	1	0	
		Expected	36.8	6.3	1.2	3.7	
1998	MCLB	Observed	98	18	26	5	$p < 0.0001$
		Expected	101.0	19.6	16.8	9.5	
	FINTC	Observed	17	0	0	2	
		Expected	13.1	2.5	2.2	1.2	
	Lava	Observed	4	17	3	10	
		Expected	23.4	4.5	3.9	2.2	
	Sandhill	Observed	61	0	1	0	
		Expected	42.6	8.3	7.1	4.0	

Although tortoises at Sand Hill were found to occupy only burrows and pallets (one pallet in each year) in both years, tortoises at the hillside sites occupied caliche caves, rocks, and rodent middens in addition to burrows and pallets (Figure 10a–e). Tortoises at MCLB occupied all four cover-site types in both years, however burrows were by far the most common cover type. Tortoises at FINTC primarily occupied burrows, and were not observed occupying caliche caves or pallets in either year. Tortoises at Lava were not observed occupying a pallet in 1997, but did occupy all four cover-site types in 1998. Caliche caves were the most commonly occupied cover-site type at lava, although rocks were occupied more than twice as much as burrows or pallets in both years. Tortoises at Sand Hill were not observed occupying a caliche cave or rock in either year, nor were any of these cover types observed at this study site.

Figure 10a. —Photograph of burrow from the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997).

Figure 10b. —Photograph of a caliche cave from the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1998).

Figure 10c. —Photograph of a rock lean-to from the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1998).

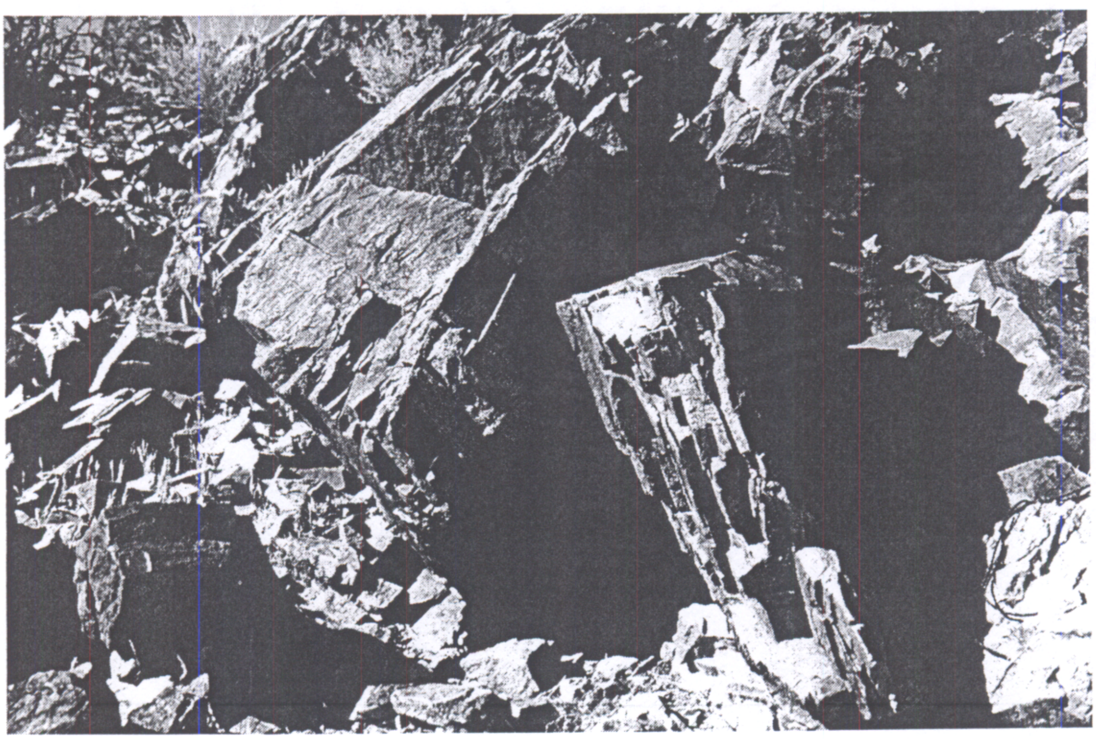


Figure 10d. —Photograph of a rock cave from the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997).

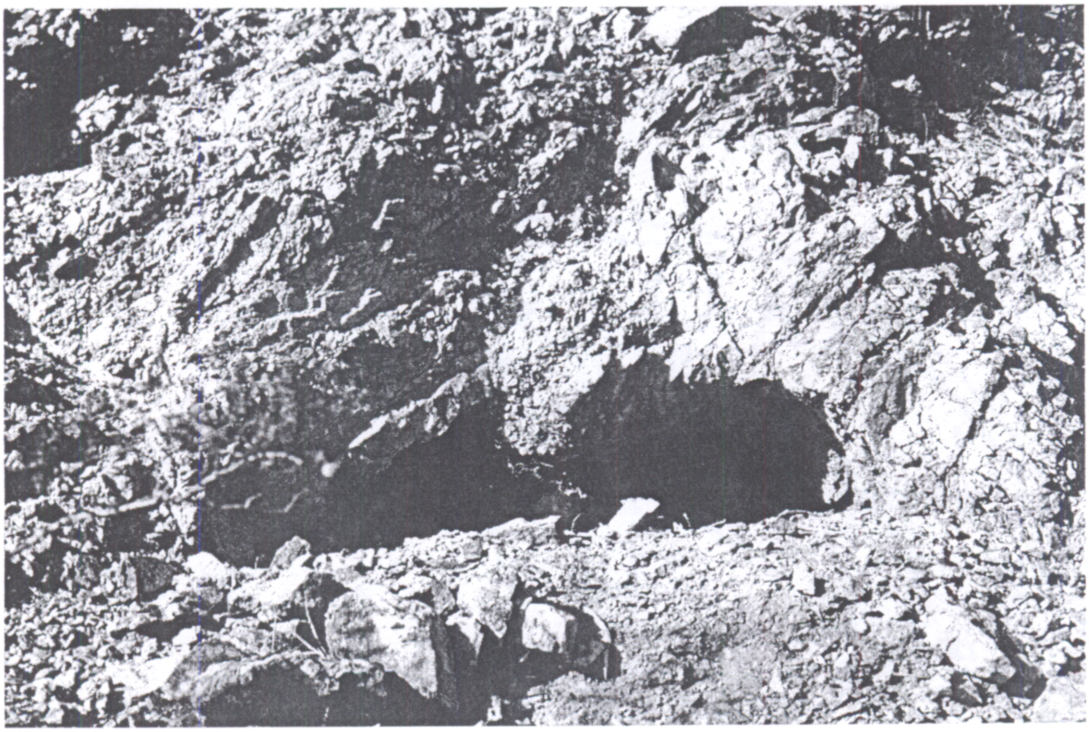


Figure 10e. —Photograph of a wood rat (*Neotoma lepida*) midden in an *Ephedra californica* from the Marine Corps Logistics Base, Barstow, CA (1997).

Cover-sites occupied differed between 1997 and 1998 only at MCLB (p = 0.0025; Table 5). Tortoises at MCLB occupied more pallets in 1998 (17.7% of all cover-sites) than in 1997 (4.1% of all cover-sites).

Table 5. —Contingency tables and p-values for Fisher's exact tests of cover-sites occupied by year for all sites. Two cover-sites, both from Barstow, were excluded from this analysis: 1) A wood rat (*Neotoma lepida*) midden without any apparent opening, and 2) A cave in the base of a Mojave Yucca (*Yucca schidigera*). Cover type occupation differs significantly between years only at Barstow. This difference is likely because of the increased use of pallets in the El Niño year of 1998. The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges at the Marine Corps Air Ground Combat Center, Twentynine Palms.

			Cover Type				
Site	Year		Burrow	Caliche Cave	Pallet	Rock	Fisher's Exact
MCLB	1997	Observed	83	10	4	1	p = 0.0025
		Expected	72.4	11.2	12	2.4	
	1998	Observed	98	18	26	5	
		Expected	108.6	16.8	18	3.6	
FINTC	1997	Observed	18	0	0	5	p = 0.4275
		Expected	19.2			3.8	
	1998	Observed	17	0	0	2	
		Expected	15.8			3.2	
Lava	1997	Observed	3	16	0	9	p = 0.5599
		Expected	3.2	14.9	1.4	8.6	
	1998	Observed	4	17	3	10	
		Expected	3.8	18.1	1.6	10.4	
Sand Hill	1997	Observed	47	0	1	0	p = 1.0000
		Expected	47.1		0.9		
	1998	Observed	61	0	1	0	
		Expected	60.9		1.1		

Frequency of occupation of cover-site types differed between sites in both 1997 and 1998 (both cases: p =< 0.0001, Table 6). There was an increased representation of burrows and caliche caves used repeatedly by the same tortoise, either in sequence or revisited in that year, and an increased representation of those burrows and caliche caves occupied by more than one tortoise in a single year. While it was most common for a burrow or caliche cave to be occupied repeatedly, some rocks and pallets were also used on repeated occasions. Tortoises at MCLB occupied burrows most frequently in both years, as did tortoises at FINTC and Sand Hill. Tortoises at Lava occupied caliche caves most frequently in both years.

Table 6. —Contingency tables and p-values for Fisher's exact tests of cover-site type frequency of occupation by site for both 1997 and 1998. Two cover-sites, both from Barstow, were excluded from this analysis: 1) A wood rat (*Neotoma lepida*) midden without any apparent opening; and 2) A cave in the base of a Mojave Yucca (*Yucca schidigera*). Cover type occupation frequency differs significantly between sites in both years. The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges at the Marine Corps Air Ground Combat Center, Twentynine Palms.

			Cover Type				
Year	Site		Burrow	Caliche Cave	Pallet	Rock	Fisher's Exact
1997	MCLB	Observed	235	31	4	1	$p < 0.0001$
		Expected	227.3	31.6	2.5	9.5	
	FINTC	Observed	88	0	0	5	
		Expected	78.0	10.9	0.9	3.3	
	Lava	Observed	4	32	0	13	
		Expected	41.1	5.7	0.5	1.7	
	Sand Hill	Observed	126	0	1	0	
		Expected	106.5	14.8	1.2	4.5	
1998	MCLB	Observed	199	38	27	8	$p = < 0.0001$
		Expected	193.9	45.6	17.7	14.8	
	FINTC	Observed	31	0	0	3	
		Expected	24.2	5.7	2.2	1.9	
	Lava	Observed	5	42	3	15	
		Expected	46.3	10.9	4.2	3.5	
	Sand Hill	Observed	105	0	1	0	
		Expected	75.6	17.8	6.9	5.8	

Frequency of occupation of cover-site types differed between 1997 and 1998 only at MCLB ($p < 0.0001$; Table 7). Tortoises at MCLB occupied pallets and rocks more frequently in

1998 (pallets = 9.9%, rocks = 2.9% of all occupations) than in 1997 (pallets = 1.5%, rocks = 0.4% of all occupations).

Table 7. —Contingency tables and p-values for Fisher's exact tests of cover-site type frequency of occupation by year for all sites. Two cover-sites, both from Barstow, were excluded from this analysis: 1) A wood rat (*Neotoma lepida*) midden without any apparent opening; and 2) A cave in the base of a Mojave Yucca (*Yucca schidigera*). Cover type occupation frequency differs significantly between years only at Barstow. This difference is likely because of the increased use of pallets, rocks, and caliche caves in the El Niño year of 1998. The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges at the Marine Corps Air Ground Combat Center, Twentynine Palms.

			Cover Type				
Site	Year		Burrow	Caliche Cave	Pallet	Rock	Fisher's Exact
MCLB	1997	Observed	235	31	4	1	$p < 0.0001$
		Expected	216.6	34.4	15.5	4.5	
	1998	Observed	199	38	27	8	
		Expected	217.4	34.6	15.5	4.5	
FINTC	1997	Observed	88	0	0	5	$p = 0.4406$
		Expected	87.1			5.9	
	1998	Observed	31	0	0	3	
		Expected	31.9			2.1	
Lava	1997	Observed	4	32	0	13	$p = 0.5781$
		Expected	3.9	31.8	1.3	12	
	1998	Observed	5	42	3	15	
		Expected	5.1	42.2	1.7	16	
Sand Hill	1997	Observed	126	0	1	0	$p = 1.0000$
		Expected	125.9		1.1		
	1998	Observed	105	0	1	0	
		Expected	105.1		0.9		

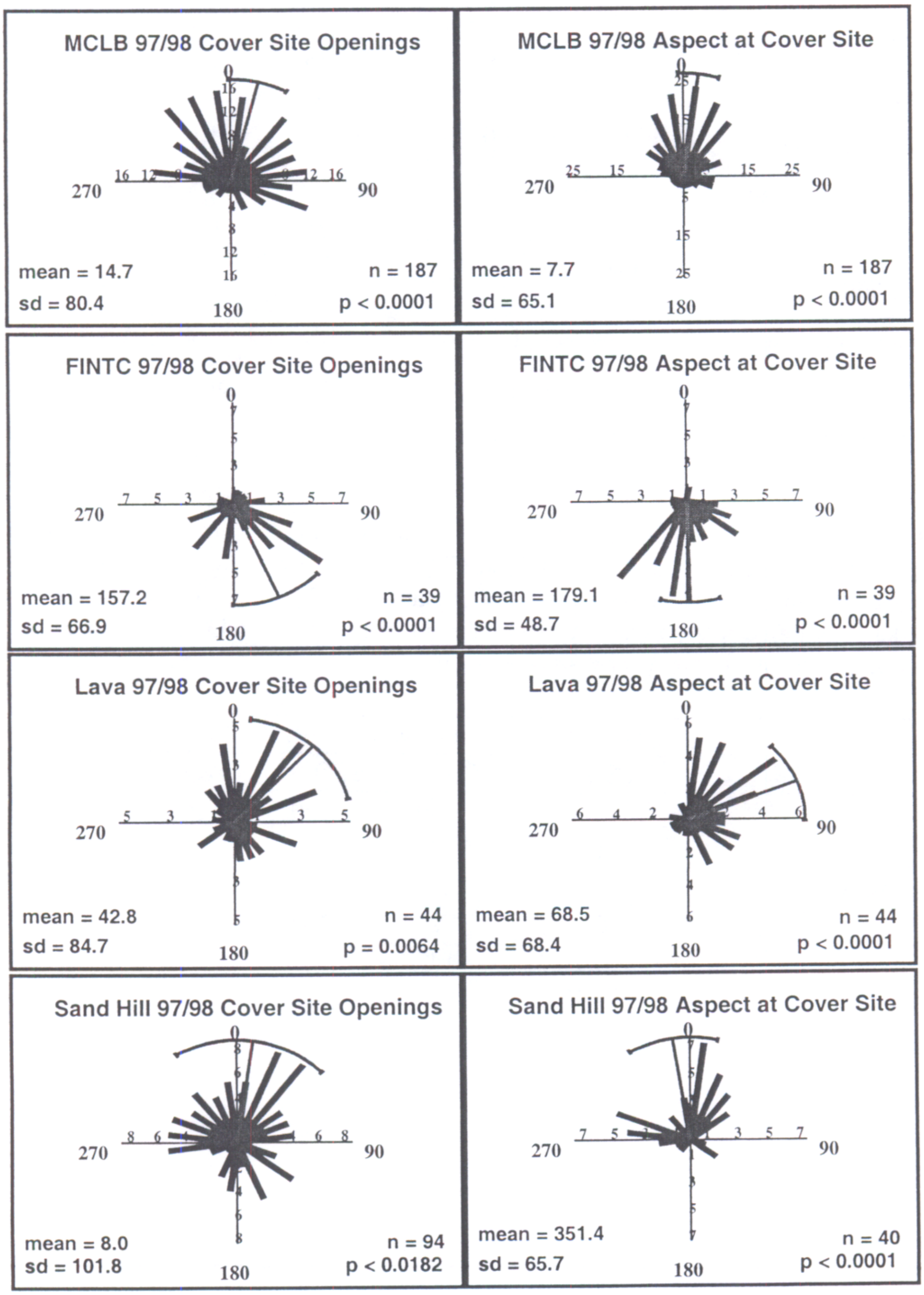
The distributions of ACS and DCSO for the combined years 1997 and 1998 differed from a uniform distribution at all sites (Table 8; Fig. 11), although the distribution of DCSO at Sand Hill had a low concentration (c = 0.422). One cover-site from MCLB and one cover-site from FINTC were removed from this analysis because data for one of the two measures were missing. The data from Sand Hill used in this analysis included all data, although a majority of cover-sites had no aspect data due to insufficient slope. There was no within-site difference between the distributions of ACS and DCSO (Table 9). Low concentrations for distributions from Lava and Sand Hill may make those results unreliable due to the potential violation of a test assumption (non-uniform distribution).

Table 8. —Descriptive statistics of aspect at cover-site (ACS) and direction of cover-site opening (DCSO), for the combined years of 1997 and 1998, for all sites. All measures are in degrees. The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges at the Marine Corps Air Ground Combat Center, Twentynine Palms.

	MCLB		FINTC	
	ACS	DCSO	ACS	DCSO
Observations	187	187	39	39
Mean vector (μ)	7.70	14.72	179.12	157.18
Length of mean vector (r)	0.52	0.37	0.70	0.51
Concentration	1.23	0.81	1.98	1.17
Circular variance	0.48	0.63	0.30	0.49
Circular standard deviation	65.10	80.36	48.74	66.88
Standard error of mean	5.23	7.63	7.80	11.93
95% confidence interval (-/+) for μ	357.45	359.77	163.82	133.79
	17.94	29.68	194.42	180.56
Rayleigh test of uniformity (p)	< 0.0001	< 0.0001	< 0.0001	< 0.0001

	Lava		Sand Hill	
	ACS	DCSO	ACS	DCSO
Observations	44	44	40	94
Mean vector (μ)	68.48	42.80	351.37	8.02
Length of mean vector (r)	0.49	0.34	0.52	0.21
Concentration	1.12	0.71	1.21	0.42
Circular variance	0.51	0.66	0.48	0.79
Circular standard deviation	68.40	84.66	65.67	101.78
Standard error of mean	11.64	17.66	11.45	20.02
95% confidence interval (-/+) for μ	45.65	8.18	328.93	328.77
	91.30	77.42	13.81	47.28
Rayleigh test of uniformity (p)	< 0.0001	0.0064	< 0.0001	0.0182

Figure 11. —Distributions of aspect at cover-site and direction of cover-site opening (bar width= 15 degrees) for all cover-sites occupied in 1997 or 1998. Mean angle, standard deviation, and sample size are given. P-values are for a Rayleigh's test of uniformity. Mean angle and 95% confidence interval are shown on graph. The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges of the Marine Corps Air Ground Combat Center, Twentynine Palms.



Directions of cover-site openings for cover-sites at Sand Hill on slopes of one or less ($n = 60$), and those that had a corresponding aspect ($n = 40$) were subject to analysis separately (Table 10). The distribution of DCSO for Sand Hill cover-sites with a slope of one or less did not differ from a uniform distribution ($p = 0.1145$). The distribution of ACS for cover-sites at Sand Hill for which both measures were available differed from a uniform distribution ($p < 0.0001$); however, the distribution of DCSO at these sites did not ($p = 0.3296$). Therefore, a Watson's F-Test was not performed. A restriction of the data to slopes of two or greater failed to produce a non-uniform distribution.

Table 9. —F-test values for within-site comparisons of aspect at cover-site and direction of cover-site opening, for 1997 and 1998. The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges at the Marine Corps Air Ground Combat Center, Twentynine Palms.

	MCLB	FINTC	Lava	Sand Hill
F-Value	0.7587	2.5257	2.0562	0.8685
df	372	76	86	132
p-value	0.3843	0.1162	0.1552[a]	0.3531[a]

a. The low concentration of one or both measures may have influenced the test results.

Table 10. —Descriptive statistics for three special case distributions of the direction of cover-site opening (DCSO) and aspect at cover-site (ACS) at Sand Hill for 1997 and 1998 combined. The special cases are, 1) cover-sites with a slope less than or equal to one, 2) cover-sites for which both an aspect and an opening direction were measurable, and 3) cover-sites which, both meet the previous criteria, and had a slope greater than or equal to two.

	Slope <= 1	Both Measures		Slope >= 2	
	DCSO	ACS	DCSO	ACS	DCSO
Observations	60	40	40	14	14
Mean vector (μ)	21.76	351.37	314.23	302.03	263.08
Length of mean vector (r)	0.19	0.52	0.17	0.62	0.22
Concentration	0.39	1.21	0.34	1.52	0.14
Circular variance	0.81	0.48	0.83	0.38	0.78
Circular standard deviation	104.41	65.67	108.39	55.62	99.61
Standard error of mean	27.27[a]	11.45	38.08[a]	15.70	88.17[a]
95% confidence interval (-/+) for μ	328.30[a]	328.93	239.58[a]	271.24	90.23[a]
	75.21[a]	13.81	28.88[a]	332.81	75.94[a]
Rayleigh test of uniformity (p)	0.1145	< 0.0001	0.3296	0.0028	0.5142

a. These values may be unreliable because of a low concentration

Analysis of individual years (Tables 11a-d) produced similar results, although distributions of DCSO and ACS at Sand Hill for the year 1997 did not differ from a uniform distribution ($p = 0.1445$ and $p = 0.0612$) and were not contrasted. In no case was a significant difference found between distributions of ACS and DCSO (Table 12a). Additionally, no significant differences were found between years in distributions of ACS or DCSO at any site (Table 12b). Low concentrations for distributions of DCSO at MCLB in both years and distributions of DCSO at Lava in 1998 may have influenced comparisons involving these measures.

Table 11a. —Descriptive statistics for yearly distributions of aspect at cover-site (ACS) and direction of cover-site opening (DCSO), for the Marine Corps Logistic Base, Barstow, CA (1997 and 1998).

	1997		1998	
	ACS	DCSO	ACS	DCSO
Observations	94	94	120	120
Mean vector (μ)	359.38	3.01	11.30	20.73
Length of mean vector (r)	0.50	0.36	0.51	0.36
Concentration	1.15	0.77	1.18	0.78
Circular variance	0.50	0.64	0.49	0.64
Circular standard deviation	67.62	82.03	66.43	81.47
Standard error of mean	7.82	11.25	6.73	9.81
95% confidence interval (-/+) for μ	344.05	340.96	358.11	1.50
	14.71	25.07	24.49	39.96
Rayleigh test of uniformity (p)	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Table 11b. —Descriptive statistics for yearly distributions of aspect at cover-site (ACS) and direction of cover-site opening (DCSO), for the southern boundary of the Fort Irwin National Training Center, CA (1997 and 1998).

	1997		1998	
	ACS	DCSO	ACS	DCSO
Observations	23	23	18	18
Mean vector (μ)	173.19	153.90	180.01	148.60
Length of mean vector (r)	0.65	0.55	0.77	0.43
Concentration	1.72	1.32	2.53	0.96
Circular variance	0.35	0.45	0.23	0.57
Circular standard deviation	53.43	62.60	41.55	74.08
Standard error of mean	11.32	14.00	9.69	20.92[a]
95% confidence interval (-/+) for μ	150.99	126.45	161.02	107.58[a]
	195.39	181.36	199.00	189.62[a]
Rayleigh test of uniformity (p)	< 0.0001	0.0006	< 0.0001	0.0316

a. These values may be unreliable because of a low concentration.

Table 11c. —Descriptive statistics for yearly distributions of aspect at cover-site (ACS) and direction of cover-site opening (DCSO), for the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 and 1998).

	1997		1998	
	ACS	DCSO	ACS	DCSO
Observations	28	28	31	31
Mean vector (μ)	58.14	31.06	69.42	37.39
Length of mean vector (r)	0.54	0.35	0.45	0.35
Concentration	1.28	0.75	1.02	0.75
Circular variance	0.46	0.65	0.55	0.65
Circular standard deviation	63.65	82.81	72.07	82.77
Standard error of mean	13.01	21.05	15.16	19.98
95% confidence interval (-/+) for μ	32.64	349.78	39.69	358.21
	83.65	72.33	99.15	76.56
Rayleigh test of uniformity (p)	0.0002	0.0298	0.0013	0.0201

Table 11d. —Descriptive statistics for yearly distributions of aspect at cover-site (ACS) and direction of cover-site opening (DCSO), for the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 and 1998).

	1997		1998	
	ACS	DCSO	ACS	DCSO
Observations	13	47	32	61
Mean vector (μ)	9.94	17.09	357.23	8.32
Length of mean vector (r)	0.46	0.20	0.49	0.25
Concentration	0.89	0.41	1.13	0.52
Circular variance	0.54	0.80	0.51	0.75
Circular standard deviation	71.41	102.33	68.09	95.26
Standard error of mean	24.90[a]	28.82	13.55	20.33
95% confidence interval (-/+) for μ	321.12[a]	320.60	330.66	328.47
	58.76[a]	73.58	23.80	48.18
Rayleigh test of uniformity (p)	0.0612	0.1445	0.0003	0.0214

a. These values may be unreliable because of a low concentration.

Table 12a. —F-test values for intra-year comparisons of aspect at cover-site and direction of cover-site opening within each site. The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava and Sand Hill ranges at the Marine Corps Air Ground Combat Center, Twentynine Palms. Only 1998 data are included for Sand Hill because the distributions of aspect at cover-site and direction of cover-site opening did not differ from uniform distributions in 1997.

	MCLB		FINTC		Lava		Sandhill
	1997	1998	1997	1998	1997	1998	1998
F-Value	0.0950	0.8391	1.1504	2.1403	1.5781	2.2015	0.3113
df	186	238	44	34	54	60	91
p-value	0.7582	0.3606	0.2893	0.1527	0.2144	0.1431	0.5783
	a	a				a	a

a. The low concentration of one or both measures may have influenced the test results.

Table 12b. —F-test values for inter-year comparisons of both aspect at cover-site (ACS) and direction of cover-site opening (DCSO) within each site. The sites, all within San Bernardino Co., CA, are the rifle range at the Marine Corps Logistics Base, Barstow (MCLB); the southern boundary of the Fort Irwin National Training Center (FINTC); and the Lava range at the Marine Corps Air Ground Combat Center, Twentynine Palms. The Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms is not represented because distributions of ACS and DCSO did not differ from uniform distributions in 1997.

	MCLB		FINTC		Lava	
	ACS	DCSO	ACS	DCSO	ACS	DCSO
F-Value	1.5205	2.0920	0.1613	0.0522	0.3570	0.0706
df	212	212	39	39	57	57
p-value	0.2189	0.1497	0.6902	0.8205	0.5525	0.7914
		a				a

a. The low concentration of one or both measures may have influenced the test results.

Movement Patterns and Home Range

No seasonal migratory pattern was apparent in the movements of desert tortoises at any sites. Additionally, no resource (i.e. forage, mates) was observed to occur in a pattern that would drive such a seasonal migration up or down slope. Tortoise home ranges (Maps 5–12, Appendix 1) were generally non-linear. Those tortoise ranges that were largely linear ran up slope in the summer, down slope in the summer, and parallel to the ridgeline. Additionally, tortoises were found to move up and down slope on an alternating basis throughout the active times of the year. An inter-year fidelity to a particular range shape was observed in most individuals.

Raw home range size (Tables 13a-d) varied between individuals and years, but not between sexes. Analysis of variance of raw home range data indicated that home ranges were significantly larger in 1998 than in 1997 at both MCLB ($p = 0.0004$) and Sand Hill ($p = 0.0002$). No significant difference was found between males and females at either site (MCLB $p = 0.5297$; Sand Hill $p = 0.1312$). Additionally, there was no interaction between sex and year (MCLB $p = 0.5456$; Sand Hill $p = 0.6128$). Means for each sex and year are presented in Tables 14a-b. Two-year ranges also varied between individuals; however, there was no significant difference between sexes at either site (MCLB $p = 0.3023$; Sand Hill $p = 0.2277$).

Table 13a. —Raw minimum convex polygon (MCP) home range sizes (ha) for tortoises at the Marine Corps Logistics Base, Barstow, CA (1997 and 1998). Combined year ranges include all locations from 1997 and 1998. Tortoises without combined year data were excluded from all home range comparisons.

		1997		1998		Combined	
Tortoise	Sex	n	MCP	n	MCP	n	MCP
MB02	F	23	1.27	26	2.87	49	2.97
MB08	F	20	4.06	25	2.69	46	5.00
MB09	F	21	9.01	25	6.60	47	10.93
MB10	F	21	9.05	26	17.59	47	17.68
MB11	F	20	2.19	26	9.04	46	9.04
MB16	F	17	1.58	26	5.99	43	6.12
MB18	F	18	1.63	18	8.31	36	8.64
MB19	F	18	1.78	19	6.13	37	6.23
MB21	F	14	1.31	26	7.00	40	7.48
MB22	F			17	0.58		
MB01	M	4	1.08				
MB03	M	22	2.27	26	16.99	48	16.99
MB04	M	22	3.10	25	6.55	47	9.34
MB05	M	21	3.83	26	3.75	47	5.03
MB06	M	21	0.07	26	5.75	47	5.88
MB07	M	21	3.87	26	20.57	47	21.98
MB12	M	11	3.98	26	5.72	37	6.94
MB13	M	19	3.44	26	8.71	45	11.70
MB14	M	19	0.49	26	5.00	45	5.32
MB15	M	18	1.42				
MB17	M	17	11.83	25	15.38	42	17.26
MB20	M	18	4.01	26	6.03	44	7.74

Table 13b. —Raw minimum convex polygon (MCP) home range sizes (ha) for tortoises at the southern boundary of the Fort Irwin National Training Center, CA (1997 and 1998). Combined year ranges include all locations from 1997 and 1998.

		1997		1998		Combined	
Tortoise	Sex	n	MCP	n	MCP	n	MCP
TC01	F	21	1.74				
TC02	F	21	0.57	19	23.32	40	24.21
TC04	F	19	1.00				
TC05	F	18	4.32	18	2.31	36	5.99
TC06	F	17	8.50				
TC03	M	20	5.65	13	4.53	33	18.11
TC08	M	2		7	1.10	9	1.97
TC09	M	1		6	6.90	7	7.86

Table 13c. —Raw minimum convex polygon (MCP) home range sizes (ha) for tortoises at the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 and 1998). Combined year ranges include all locations from 1997 and 1998. Inadequate sample size prevents comparisons.

		1997		1998		Combined	
Tortoise	Sex	n	MCP	n	MCP	n	MCP
LV02	F	14	1.36	14	4.23	28	4.89
LV03	F	13	4.02	14	5.26	27	5.46
LV05	F	6	0.00				
LV07	F	1		14	3.67	15	3.67
LV01	M	14	27.85	13	86.39	27	86.99
LV04	M	13	4.47	14	4.96	27	6.63
LV06	M	12	4.26	14	7.09	26	9.53
LV08	M			11	0.88		

Table 13d. —Raw minimum convex polygon (MCP) home range sizes (ha) for tortoises at the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 and 1998). Combined year ranges include all locations from 1997 and 1998. Tortoises without combined year data were excluded from all home range comparisons.

		1997		1998		Combined	
Tortoise	Sex	n	MCP	n	MCP	n	MCP
M95-1	F	11	2.58	7	10.81	18	10.81
M95-8	F	10	1.65				
M95-13	F	13	2.34	14	2.00	27	2.99
M95-14	F	12	0.09				
M95-22	F	8	1.20	14	2.27	22	2.39
M95-26	F	13	0.41	14	5.37	27	7.04
M95-31	F	12	0.84	11	4.78	23	5.30
M95-32	F	11	2.35	14	4.99	25	11.00
M95-2	M	11	6.27	13	8.19	24	11.54
M95-15	M	12	1.43	14	9.55	26	11.21
M95-18	M	11	0.76	14	6.29	25	6.97
M95-21	M	12	3.94	4	1.70	16	8.97
M95-33	M	12	1.47	14	4.26	26	4.26
M96-36	M	12	1.95	14	13.28	26	13.82

Table 14a. —Descriptive statistics for raw minimum convex polygon home range sizes (ha) for male and female tortoises at the Marine Corps Logistics Base, Barstow, CA (1997 - 1998). Two-year ranges include all locations for 1997 and 1998.

	Female			Male		
	1997	1998	2 Year	1997	1998	2 Year
Observations	9	9	9	10	10	10
Mean	3.54	7.35	8.23	3.69	9.45	10.81
Variance	10.39	19.31	18.07	10.25	35.14	35.53
Standard deviation	3.22	4.39	4.25	3.20	5.93	5.96
Standard error	1.07	1.46	1.42	1.01	1.87	1.88
Minimum	1.27	2.69	2.97	0.07	3.75	5.03
Maximum	9.05	17.59	17.68	11.83	20.57	21.98

Table 14b. —Descriptive statistics for raw minimum convex polygon home range sizes (ha) for male and female tortoises at the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 – 1998). Two-year ranges include all locations for 1997 and 1998.

	Female			Male		
	1997	1998	2 Year	1997	1998	2 Year
Observations	6	6	6	5	5	5
Mean	1.62	5.04	6.59	2.38	8.31	9.56
Variance	0.84	10.08	13.94	4.92	11.68	14.90
Standard deviation	0.92	3.17	3.73	2.22	3.42	3.86
Standard error	0.38	1.30	1.52	0.99	1.53	1.73
Minimum	0.41	2.00	2.39	0.76	4.26	4.26
Maximum	2.58	10.81	11.00	6.27	13.28	13.82

The correction of home range sizes for number of locations dramatically increased the size estimates of the ranges (Table 15a-d), but did not change the results of any comparisons. Analysis of variance for corrected ranges indicated that 1998 home ranges were significantly larger than those of 1997 at both MCLB ($p = 0.0027$) and Sand Hill ($p = 0.0011$), but there was not a significant difference between sexes or an interaction between sex and year at either site (MCLB: Sex $p = 0.5640$, Interaction $p = 0.6891$; Sand Hill: Sex $p = 0.2681$, Interaction $p = 0.7569$). Furthermore, no difference between sexes was suggested by the analysis of two-year home ranges at either MCLB ($p = 0.3297$) or Sand Hill ($p = 0.3266$).

Table 15a. —Correction factors [a] and corrected minimum convex polygon (MCP) home range sizes (ha) for tortoises at the Marine Corps Logistics Base, Barstow, CA (1997 – 1998). Combined year ranges include all locations from 1997 and 1998. Tortoises without combined year data were excluded from all home range comparisons.

		1997			1998			Combined		
Tortoise	Sex	n	C.F.	MCP	n	C.F.	MCP	n	C.F.	MCP
MB02	F	23	0.496	2.56	26	0.527	5.44	49	0.690	4.30
MB08	F	20	0.460	8.83	25	0.517	5.20	46	0.674	7.42
MB09	F	21	0.472	19.07	25	0.517	12.76	47	0.679	16.09
MB10	F	21	0.472	19.16	26	0.527	33.36	47	0.679	26.02
MB11	F	20	0.460	4.76	26	0.527	17.14	46	0.674	13.41
MB16	F	17	0.418	3.78	26	0.527	11.36	43	0.657	9.32
MB18	F	18	0.433	3.77	18	0.433	19.20	36	0.611	14.14
MB19	F	18	0.433	4.11	19	0.447	13.72	37	0.618	10.08
MB21	F	14	0.368	3.56	26	0.527	13.27	40	0.638	11.72
MB22	F				17	0.418	1.39			
MB01	M	4	0.046	23.34						
MB03	M	22	0.484	4.69	26	0.527	32.22	48	0.68	24.81
MB04	M	22	0.484	6.40	25	0.517	12.66	47	0.68	13.75
MB05	M	21	0.472	8.11	26	0.527	7.11	47	0.68	7.40
MB06	M	21	0.472	0.15	26	0.527	10.90	47	0.68	8.65
MB07	M	21	0.472	8.19	26	0.527	39.01	47	0.68	32.35
MB12	M	11	0.306	13.00	26	0.527	10.85	37	0.62	11.23
MB13	M	19	0.447	7.70	26	0.527	16.52	45	0.67	17.51
MB14	M	19	0.447	1.10	26	0.527	9.48	45	0.67	7.96
MB15	M	18	0.433	3.28						
MB17	M	17	0.418	28.29	25	0.517	29.73	42	0.65	26.53
MB20	M	18	0.433	9.26	26	0.527	11.43	44	0.66	11.68

a. Barrett (1990)

Table 15b. —Correction factors[a] and corrected minimum convex polygon (MCP) home range sizes (ha) for tortoises at the southern boundary of the Fort Irwin National Training Center, CA (1997 – 1998). Combined year ranges include all locations from 1997 and 1998. Inadequate sample size prevents comparisons.

		1997			1998			Combined		
Tortoise	Sex	n	C.F.	MCP	n	C.F.	MCP	n	C.F.	MCP
TC01	F	21	0.472	3.68						
TC02	F	21	0.472	1.21	19	0.447	52.20	40	0.638	37.94
TC04	F	19	0.447	2.24						
TC05	F	18	0.433	9.98	18	0.433	5.34	36	0.611	9.80
TC06	F	17	0.418	20.33						
TC03	M	20	0.460	12.29	13	0.349	12.97	33	0.589	30.77
TC08	M				7	0.190	5.79			
TC09	M				6	0.150	45.85			

a. Barrett (1990)

Table 15c. —Correction factors[a] and corrected minimum convex polygon (MCP) home range sizes (ha) for tortoises at the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 – 1998). Combined year ranges include all locations from 1997 and 1998. Inadequate sample size prevents comparisons.

		1997			1998			Combined		
Tortoise	Sex	n	C.F.	MCP	n	C.F.	MCP	n	C.F.	MCP
LV02	F	14	0.368	3.69	14	0.368	11.49	28	0.546	8.95
LV03	F	13	0.349	11.51	14	0.368	14.28	27	0.537	10.17
LV05	F	6	0.150	0.00						
LV07	F				14	0.368	9.97			
LV01	M	14	0.368	75.63	13	0.349	247.40	27	0.537	161.98
LV04	M	13	0.349	12.80	14	0.368	13.47	27	0.537	12.35
LV06	M	12	0.329	12.96	14	0.368	19.25	26	0.527	18.07
LV08	M				11	0.306	2.87			

a. Barrett (1990)

Table 15d. —Correction factors[a] and corrected minimum convex polygon (MCP) home range sizes (ha) for tortoises at the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 – 1998). Combined year ranges include all locations from 1997 and 1998. Tortoises without combined year data were excluded from all home range comparisons.

		1997			1998			Combined		
Tortoise	Sex	n	C.F.	MCP	n	C.F.	MCP	n	C.F.	MCP
M95-1	F	11	0.306	8.42	7	0.190	56.87	18	0.433	24.98
M95-8	F	10	0.282	7.35						
M95-13	F	13	0.349	6.70	14	0.368	5.43	27	0.537	5.57
M95-14	F	12	0.329	0.27						
M95-22	F	8	0.224	5.35	14	0.368	6.16	22	0.484	4.93
M95-26	F	13	0.349	1.17	14	0.368	14.58	27	0.537	13.11
M95-31	F	12	0.329	2.56	11	0.306	15.61	23	0.496	10.69
M95-32	F	11	0.306	7.67	14	0.368	13.55	25	0.517	21.27
M95-2	M	11	0.306	20.47	13	0.349	23.45	24	0.507	22.77
M95-15	M	13	0.349	4.35	14	0.368	25.93	26	0.527	21.26
M95-18	M	11	0.306	2.48	14	0.368	17.08	25	0.517	13.48
M95-21	M	12	0.329	11.99	4	0.046	36.73	16	0.403	22.28
M95-33	M	12	0.329	4.47	14	0.368	11.57	26	0.527	8.08
M96-36	M	12	0.329	5.93	14	0.368	36.06	26	0.527	26.21

a. Barrett (1990)

Natural History Observations

Desert tortoises were found to forage, copulate, nest, and shelter on slopes. Tortoises were commonly seen foraging on both steep slopes and bajadas/flats, and were often observed consuming leguminous forbs, particularly Arizona lupine (*Lupinus arizonicus*).

We observed copulations on two occasions at MCLB (03/22/97, male = unknown, female = unknown, slope = 12.0 degrees; 04/17/97, male = MB12, female = MB11, slope = 5.5 degrees) and once at FINTC (04/19/97, male = TC03, female = TC02, slope = 4.0 degrees). We also observed courtship rings and/or moisture and abrasion on the fifth vertebral scute (suggestive of ejaculate), as well as mountings on numerous occasions at MCLB and Sand Hill. Additionally, we found males, far from their normal area of movements, in association with females at the Lava study site, and observed possible courtship behaviors.

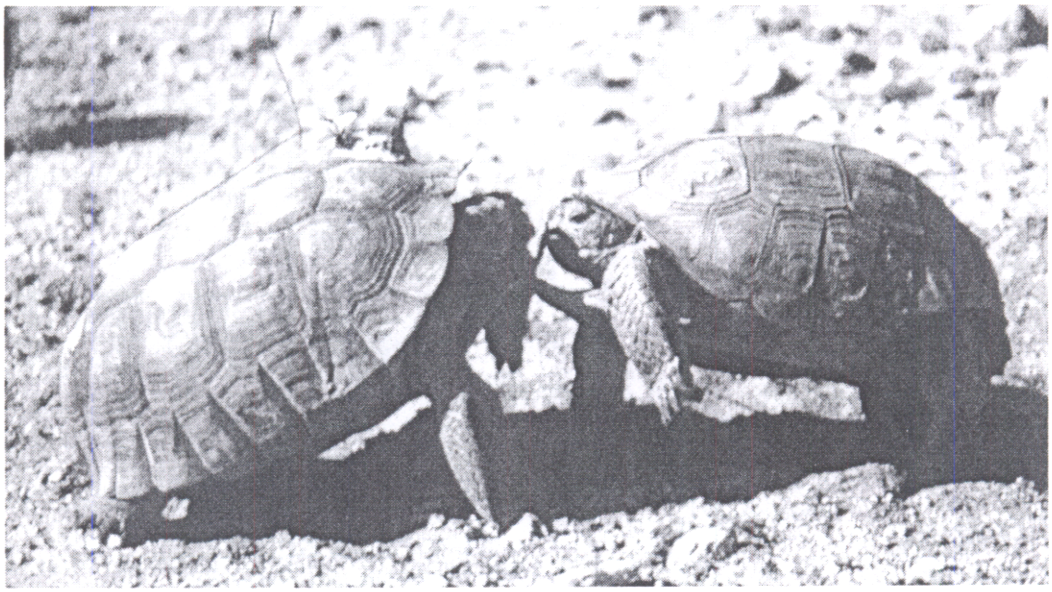
In addition to courtship and copulations, we observed juvenile tortoises (<180 mm) and eggshell fragments at MCLB. We marked eleven tortoises of less than 180 mm MCL at MCLB in 1998 (Table 16). We also observed carcasses of first or second year young at MCLB and FINTC. We observed eggshell fragments at a minimum of 5 locations at MCLB, including one area on a steep slope (~5 eggs, slope = 28 degrees, 08/09/98, ~0.6m from entrance to MB04-4AUG98).

Table 16. —Measurements (mm) and weights (g) of juvenile and sub-adult tortoises marked at the Marine Corps Logistics Base, Barstow, CA in 1998.

Tortoise	Date	MCL	Width	Girth	Weight	Easting	Northing
A	4/18/98					near A: 6/10/98	
A	6/10/98	103.5	80.5	214.5	245	508066	3855838
B	4/18/98					near A: 6/10/98	
C	4/22/98	159.0	119.0	32.5	860	507996	3856410
D	5/12/98	153.0	113.0	307.0	770	507946	3857081
E	5/22/98	162.0	131.0	350.0	970	507187	3856856
F	6/11/98	143.0	106.0	284.0	605	508075	3857159
G	7/1/98	147.0	112.5	305.0	723	507663	3856997
H	7/2/98	164.0	128.0	338.0	860	507272	3856337
I	8/9/98	159.0	118.0	321.0	836	507892	3857071
J	9/25/98	97.2	78.2	208.0	206	507908	3856816
L	9/10/98	124.0	101.0	262.0	440	507384	3856032

We observed male combat behaviors on one occasion at MCLB and one occasion at FINTC. We observed two males (B4, MCL = 252 mm, weight = 3120 g; B5, MCL = 272 mm, weight = 3740 g) in combat on 4/16/98 at 14:30 hrs on a 17-degree slope. Male B5 repeatedly hit male B4, pushing him down slope, until male B4 left the area at high speed. Male B4 ran approximately 15 m, over a small hill, before stopping to rest. We marked and measured both individuals after this interaction was observed. We observed two males (TC08, MCL = 278 mm, weight = 4430 g; TC09, MCL = 286 mm, weight = 4550 g) in combat on 08/24/98 at 09:20 hrs on a 3-degree slope (Fig. 12). Male TC09 retreated after approximately 15 minutes of combat. Air temperature was high (35.0 degrees), and may have affected the combat as both tortoises immediately sought shade.

Figure 12. —Two males (TC08, MCL = 278 mm, weight = 4430 g; TC09, MCL = 286 mm, weight = 4550 g) in combat (08/24/98, 09:20 hrs, slope = 3 degrees) at the southern boundary of the Fort Irwin National Training Center, CA.



DISCUSSION

Density

We found tortoises on hillsides at low to moderate densities (6.1–27.1 tortoises/km^2). These estimates are based on the total numbers of tortoises encountered in 1998, and we believe them to be conservative because of the low rate of re-sightings. Berry (1984) considered population densities below 19 tortoises/km^2 non-viable. However, Bury and Corn (1995) argued that this position was without evidence. While populations at both FINTC (8.1 tortoises/km^2) and Lava (6.1 tortoises/km^2) occurred at densities below this threshold, populations at MCLB (27.1 tortoises/km^2) occurred at densities well above it. Furthermore, while the density estimate for MCLB is conservative, it is similar to, or higher than, two of three estimates (48.3, 31.7, and 6.9 tortoises/ km^2) from the adjacent Ord-Rodman Desert Wildlife Management Area (U.S. Fish and Wildlife Service, 1994). Densities for the majority of the Ord-Rodman Desert Wildlife Management Area are thought to be much lower (U.S. Fish and Wildlife Service, 1994).

Physical Habitat

Desert tortoises occupied hillside habitats at three study sites within the Western Mojave Recovery Unit (MCLB, FINTC, and Lava). Desert tortoises were also observed, but not studied, on hillsides at Iron Mountain, approximately 25 miles northwest of Barstow. Slopes occupied by tortoises at all hillside sites were significantly steeper than those for a representative valley site (Sand Hill). The slopes occupied at the hillside sites were similar in maximum slope to those occupied by desert tortoises at two Sonoran Desert sites (Bailey et al., 1995; Barrett, 1990). Elevations of our study sites (640–800m) were lower than those of Bailey et al. (1995; 800–950m), but overlapped those of Barrett (1990; 538–719m). The similarity of slopes occupied by tortoises at our study sites and those occupied by tortoises at the study sites of Bailey et al. (1995) and Barrett (1990) suggests that the degree of slopes occupied by tortoises does not differ between the Mojave and Sonoran Deserts. However, differences could occur between such sites in factors such as tortoise density, the range elevations occupied, the seasonal timing of slope occupation, and the selection.

Hillside habitats occupied by desert tortoises were comprised of coarse substrates (up to 70 percent boulders). Distributions of substrate particle sizes differed between sites, and were variable among locations for an individual and among individuals within a site at all hillside sites. Substrates occupied by tortoises at all hillside sites differed significantly from those occupied at a representative valley site (Sand Hill). This difference, an overall decrease in substrate size and complexity between the hillside sites and Sand Hill, is an expected product of erosion. Because of a lack of studies quantifying substrate particle sizes, the values found in this study cannot be compared to sites in the Sonoran Desert or to other sites in the Mojave Desert. Qualitative statements do, however, suggest that the sites studied here are similar to rocky areas described from the Sonoran (Bailey et al., 1995; Germano et al, 1994; Osorio and Bury, 1994; Barrett, 1990) Desert. It is possible that substrate particle size influences such details of desert tortoise ecology as cover-site choice and nest construction.

Cover-site Use

Cover-site use differed among sites. Tortoises used burrows almost exclusively at Sand Hill. This is likely a result of the homogeneous topography and substrate of that site which, due to the absence of boulders and deep washes with vertical sides, limits tortoises to burrows and pallets. Tortoises at hillside sites were shown to use caliche caves and/or rocks (pallets under boulders), at different frequencies, in addition to burrows and pallets. These results are expected because of the availability of such cover-sites in areas with complex topographies. Additionally, tortoises at MCLB and Lava were found in association with woodrats (*Neotoma lepida*) both in caliche caves and in middens at the base of shrubs or trees (*Ephedra californica* and *Acacia greggii*). Pallets were occupied frequently only at MCLB, and only in 1998. This was most likely in response to cool temperatures and abundant shrub leaf cover associated with the wet spring. It is possible that a lack of leaves on most perennial shrubs (i.e. *Ambrosia dumosa*, *Krameria erecta*, *Lycium andersonii*) other than creosote (*Larrea tridentata*) made the occupation of pallets at poor choice in 1997. The frequent use of rocks and caliche caves as cover-sites at Lava was likely influenced by the high proportion of large particle sizes on the ground surface and the abundance of deeply cut washes with vertical sides. The occupation of burrows, caliche caves, pallets, and rocks at MCLB is indicative of the variation in substrate and topography, as well as the quality of the shrub cover, at that site. It is apparent that both large scale, between site (hillside vs. valley), and small scale, within site (slope vs. wash vs. bajada), differences in topography, substrate particle size, and vegetation influence cover-site availability, and therefore cover-site use.

Study sites differed in both DCSO and ACS. However, DCSO did not differ from ACS at any site. Mean DCSO for the sites were North to Northeast and South. Our results are consistent with those of Bulova (1992; 1994), but not Berry and Turner (1986). However, the latter study was investigating juvenile, not adult, burrows. This study of four sites indicates that the direction in which a cover-site opens is more variable than shown by these previous single site studies. Furthermore, because none of the distributions of DCSO differed from the corresponding distribution of ACS, our expectation that the aspect of the slope a cover-site is on influences the direction in which that cover-site opens is supported. The fact that the distribution of DCSO for Sand Hill sites with a slope of one or less did not differ from a uniform distribution may indicate that in the absence of an influential aspect, cover-site orientation is random. The degree of thermal protection provided by a cover-site at such flat locations may be determined more by burrow depth than by burrow orientation.

Movement Patterns and Home Range

Desert tortoises appear to occupy hillsides as resident, rather than migratory populations. Movements occurred both up and down slope throughout the active season. Tortoises at Lava appeared to use broad washes as movement corridors while occupying cover-sites mostly in smaller washes and on hillsides. The home ranges of desert tortoises on hillsides were of a variety of shapes, and appeared to be conserved between years, though the area of home range changed. Resources were not distributed in such a manner as to necessitate a seasonal migration, however this does not imply that resources occur in a homogeneous fashion across a site. Movement patterns may be driven by selection of sites based on food resources, social interactions, or thermal properties. The importance of any individual factor can change throughout the year.

Home range size differed among individuals and between years, but did not differ significantly between sexes. Home ranges for a single year ranged from 0.07 ha (MCLB, MB06, male, 1997) to 86.39 ha (Lava, LV01, male, 1998). A similarly broad range of values has been found in other studies (Duda and Krzysik, 1998; O'Connor et al., 1994; Barrett, 1990; Berry, 1986). In this study females appeared to have smaller ranges than males, as was found in other studies, however the differences between sexes were not significant at the two sites (MCLB and Sand Hill) with sufficient sample sizes for comparison.

The smallest home range values are similar to those found by Duda and Krzysik (1998) in a drought year, and were observed in 1997, also a drought year. Home range sizes at both MCLB and Sand Hill were significantly smaller in 1997 than in the El Niño year of 1998. Many tortoises that moved very little in 1997 greatly increased their ranges in 1998, while many of those that had large ranges in 1997 maintained home range size and shape in 1998. It is likely that the increased ranges of 1998 can be attributed in part to the improved physical condition of tortoises in 1998, as indicated by increased weights. Increased forage and cool temperatures, resulting in increased activity in the spring of 1998, may have also contributed to this increase in home range size.

The minimum convex polygon home range estimates discussed above should be treated as a movement boundary, rather than as an area of resource use (O'Connor et al., 1994). Such home ranges do not reflect the area requirements of an individual, both because the home range includes a large area never visited by the tortoise (O'Connor et al., 1994) and because desert tortoise home ranges overlap. A correction for the number of locations collected for an individual (Barrett, 1990) was used to confirm the results of raw home range comparisons between years and sexes at the two sites (MCLB and Sand Hill) with sufficient sample sizes of tortoises. While this correction factor approximately doubled the MCP size estimates for all tortoises, likely increasing the included area never visited, the correction did not change the results of any comparisons.

The data from this study, in conjunction with that of Barrett (1990), Bury et al. (1994), Germano et al. (1994), and Rautenstrauch and O'Farrell (1998), indicate that desert tortoises occupy steep slopes and course substrates across their entire range. Specifically, this study supports the assertion by Germano et al. (1994) that the lack of observations of desert tortoises on hillsides in the Mojave Desert may be a result of insufficient surveying of such habitats. Additionally, our data suggests that this lack of surveys has resulted in a biased view of the distribution and habitat use of desert tortoises as suggested by Germano and Bury (1994). A remodeling of potentially occupied habitat of the desert tortoise such as the emphasis zone concept recently applied for purposes of route designation in the Ord Mountain Critical Habitat Unit of the West Mojave Desert (BLM 1997), as well as increased surveys in areas with a high degree of topographic complexity, may be in order for the entire Mojave Desert. It is likely that such surveys would increase not only the amount of known occupied habitat, but also increase population size estimates across the Mojave Desert.

This study also shows that habitat composition and complexity, as well as habitat use, varies within the western Mojave Desert. Study sites differed in tortoise density, slope, aspect, elevation, latitude, substrate particle size, and cover-site options. Additionally, differences were observed in cover-site use and home range between the dry year of 1997 and the wet year of 1998. Because of these differences it is important that studies of desert tortoise ecology be undertaken at a number of different localities, and that they span multiple years. Additionally, quantitative data such as those recorded in this study should be taken in order to catalog the variations in habitat and habitat use that occur across the range of the desert tortoise, allowing comparisons across the range to be made in a less arbitrary manner.

CONCLUSIONS

Listed below is a summary of specific questions addressed in this project and the answers found in our research

At what densities do desert tortoises occur on hillside sites?

Desert tortoises were found at densities of 27.1tortoises/km^2 (MCLB), 8.1 tortoises/km^2 (FINTC), and 6.1 tortoise/km^2 (Lava). Density estimates are conservative, and only concern adult tortoises, as juveniles are known to be difficult to sample accurately. These densities are similar to some other areas in the Western Mojave Recovery Unit, and can be considered low to moderate.

On what degree of slopes are tortoises and their cover-sites found?

Desert tortoises were found on slopes of up to 36 degrees (MCLB). Tortoises included in our telemetry study were found on slopes up to 33 degrees (MCLB and Lava), 25 degrees (FINTC), and 3 degrees (Sand Hill). Cover-sites were located on these maximum slopes at MCLB, Lava, and Sand Hill. The maximum slope a cover-site was found on at FINTC was 19.5 degrees.

Of what particle size classes are the substrates in tortoise habitat composed?

Desert tortoises occupied habitats with sandy to coarse surface substrates. The percent composition of boulders was up to 70% (Lava). Desert tortoises were found to occupy sites with substrates ranging from grains and granules (Sand Hill) to mostly cobbles and boulders (Lava). Intermediate substrate types were observed at MCLB (variable grains, granules, pebbles, cobbles, and boulders) and FINTC (mostly grains and granules with scattered boulders).

What types of cover-sites do desert tortoises occupy in hillside habitats?

Desert tortoises were found to occupy burrows, pallets, caliche caves, rocks, rodent middens, and in a single occurrence, a cave in the base of a Mojave Yucca. Variation in cover-site use at a site was associated with variation in topography and substrate.

Does cover-site use differ between hillside and valley sites?

Cover-site use differed between the three hillside sites and the representative valley site. This difference in cover-site use was likely due to the relative availability of different cover-site types. Tortoises at the valley site occupied burrows almost exclusively (one pallet was occupied in each year). Tortoises at MCLB primarily occupied burrows, but occupied caliche caves, rocks, pallets, a rodent midden (not associated with another cover-site type), and a cave in the base of a Mojave Yucca. Tortoises at FINTC also primarily occupied burrows, but occupied a number of rocks in both years. Tortoises at Lava most commonly occupied caliche caves and rocks, but also occupied burrows and pallets. Tortoises at MCLB were shown to occupy pallets more often in the cool, wet year of 1998 than in the hot, dry year of 1997.

Do desert tortoises select a range of aspects on which cover-sites are placed?

Desert tortoises did not appear to select a range of aspects on which cover-sites were placed. The three hillside sites differed in mean angle of the aspect on which cover-sites were located. Additionally, there was a great deal of variability in the aspect on which cover-sites were placed within each site.

Do desert tortoises select a range of directions in which cover-sites open?

Desert tortoises did not appear to select a range of directions in which cover-sites open. The distribution of directions in which cover-sites opened did not differ from the distributions of aspects on which cover-sites were located at any site. Additionally, the distribution of directions in which cover-sites opened did not differ from a uniform distribution at locations in the Sand Hill range with a negligible slope.

Do desert tortoises make seasonal movements up or down slopes in the western Mojave Desert?

A seasonal migration up or down slope was not observed in tortoises at any hillside site. Desert tortoises were found to exhibit a range of movements, including: moving up slope in summer, moving down slope in summer, moving up and down slope throughout the year, and occupying either a slope or adjacent bajada throughout the year. Furthermore, no habitat components were observed to vary across the landscape in a pattern that would suggest that such a seasonal migration would improve an animal's fitness. No seasonal variation in habitat use was observed except for decreased movements during the hot period from July to August.

What sizes of home range do tortoises occupying hillsides occupy?

Home ranges for a single year ranged from 0.07 ha to 86.39 ha. A similarly broad range of values has been found in other studies. However, the largest home range observed in this study (86.39ha, LV01, Male, 1998) was heavily influenced by a few widespread locations. Home range size differed among individuals and between years, but did not differ significantly between sexes. Females did however appear to have smaller ranges than males. The smallest home range values were observed in 1997, a drought year. Home range sizes at both MCLB and Sand Hill were significantly smaller in 1997 than in the El Niño year of 1998. In particular, many tortoises that moved very little in 1997 greatly increased their ranges in 1998. Increased ranges of 1998 may be attributable in part to improved physical condition (hydration), cooler spring temperatures and increased cloud cover, and increased spring forage quality and quantity. The sampling schedule, dictated by site availability, precluded any statistical comparison of home range size among the sites included in this study, and between those sites and those of other studies.

Management Recommendations

MCLB

The rifle range at the Marine Corps Logistics Base at Barstow, CA supports a moderate-high density population of desert tortoises. There is sufficient evidence to suggest that this population is reproducing. Signs of upper respiratory tract disease and cutaneous dyskeratosis were observed in some animals on this site; however there are no indications these diseases are impacting the population in a negative manner. The monitoring of tortoises health, at an interval of every three to five years, is advisable at this location. Additionally, two animals were observed with tar encrusted on their plastrons. It is recommended that range staff clean up areas with tar and other waste, as tar may inhibit growth and reproduction.

The staff of the rifle range has been well instructed in methods to limit their impact on the desert tortoises, and is conscientious in their regularly scheduled uses of the range. The continued use of this range should not negatively impact the desert tortoises present on this site. Irregularly scheduled activities (drills with troops and/or vehicles on the lands adjacent to the arms ranges proper) however, are likely to have a negative impact on the desert tortoises in those areas. Densities are too high to avoid accidental mortality in such drills. It is recommended that such activities be limited or discontinued so that such mortalities may be avoided. Additionally, we do not oppose the fencing of the Marine Corps property in this area (provided fencing is 12" above the ground surface to allow for movements of tortoises and other wildlife). However, such fencing may provide perching locations for ravens, which are known to prey on juvenile tortoises. Any fence plan should seek to limit perching opportunities for ravens and other large birds.

FINTC

Our tortoise density estimate for the area near the southern boundary of FINTC (near Mannix trail) is considered low by USFWS standards. A previous study (Chambers Group, 1994) provided a density estimate for this site and the surrounding area of between 21 and 250 tortoises/mi^2 (8.1 to 96.5 tortoises/km^2). Our estimate of 8.1 tortoises/km^2 falls at the lower boundary of this range. Furthermore, as the area is full of burrows that appeared inactive, but which remained structurally sound throughout our research, it is possible that the Chambers Group estimates are high for some locations along the southern boundary. Additionally, carcasses were nearly as abundant as live tortoises. While we make no specific recommendations for management of this area, we suggest that it be considered as a possible area for expansion if, 1) expansion is imminent, and 2) other potential areas are found to support higher densities of desert tortoises. Furthermore, this area appears to have been subjected to repeated drought. Areas that are known to have a more regular and abundant crop of winter annuals may be more deserving of protection. We do not; however have enough information to determine a cause of these low densities or to suggest that they are permanent.

Lava

Our study site at Lava was found to support a low density of desert tortoises (6.1 tortoises/km^2). This density is similar to that found for the surrounding non-mountainous areas (Jones & Stokes Associates, Inc., 1998). This population is in a difficult to access area of the base, and is located on rugged terrain where off-road vehicle use is limited. Additionally, this population is near the boundary of two ranges, and should therefore see limited firing. We make no special recommendations regarding this location and population.

Sand Hill

We did not estimate the density of tortoises in this range. A large portion of this area is already under protection from off-road vehicle use. We recommend the continued protection of this area. The southern portion of our research area is however, still susceptible to vehicular mortalities. Additionally, canines (presumably feral dogs) have been known to harass tortoises in this area (see Appendix 3). Further information on the impacts of vehicles and canines in this area would be required to make any recommendations regarding a change in management of this area.

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APPENDIX 1: HOME RANGE MAPS

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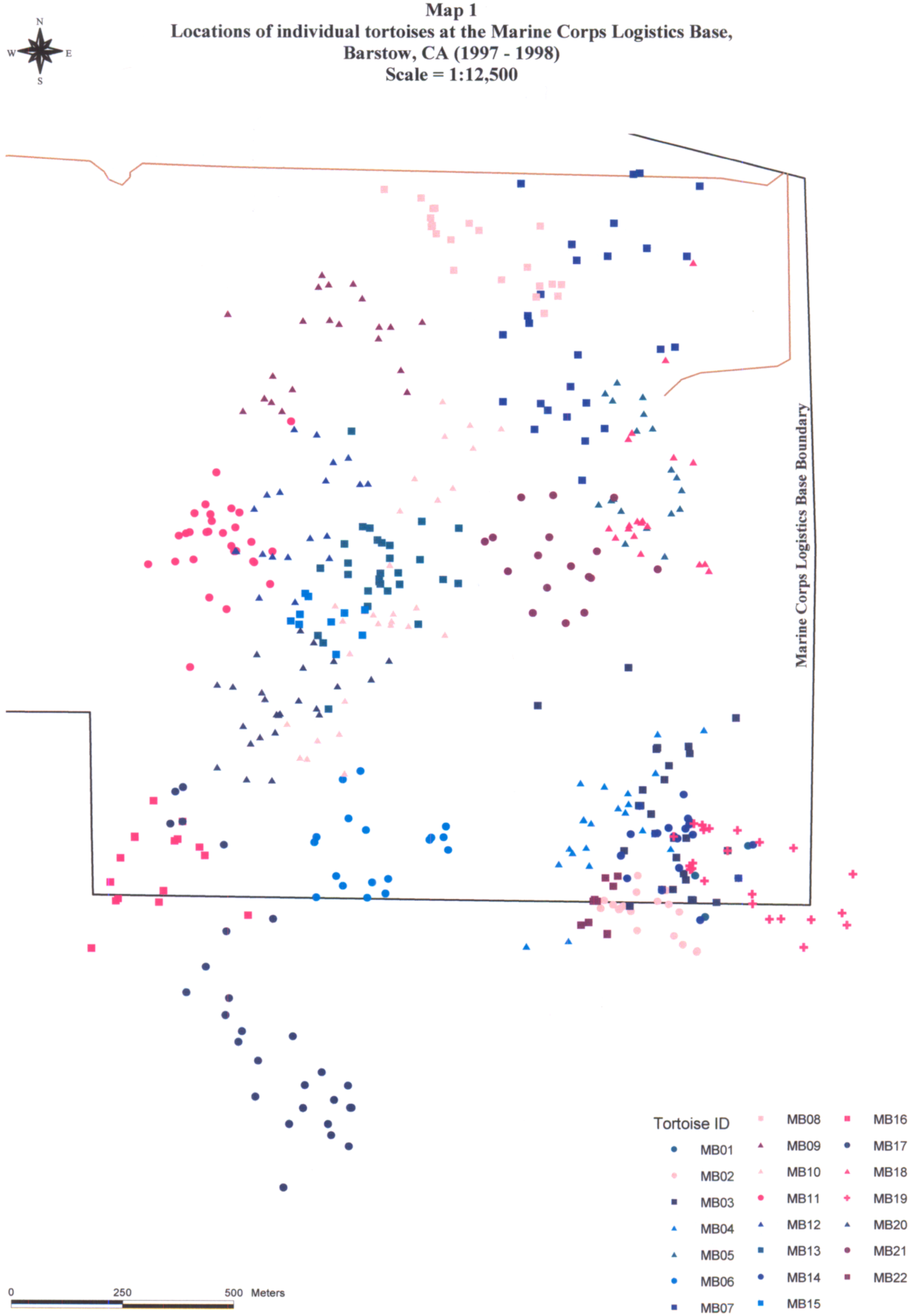
Map 1

Locations of individual tortoises at the Marine Corps Logistics Base, Barstow, CA (1997 - 1998)

Scale = 1:12,500

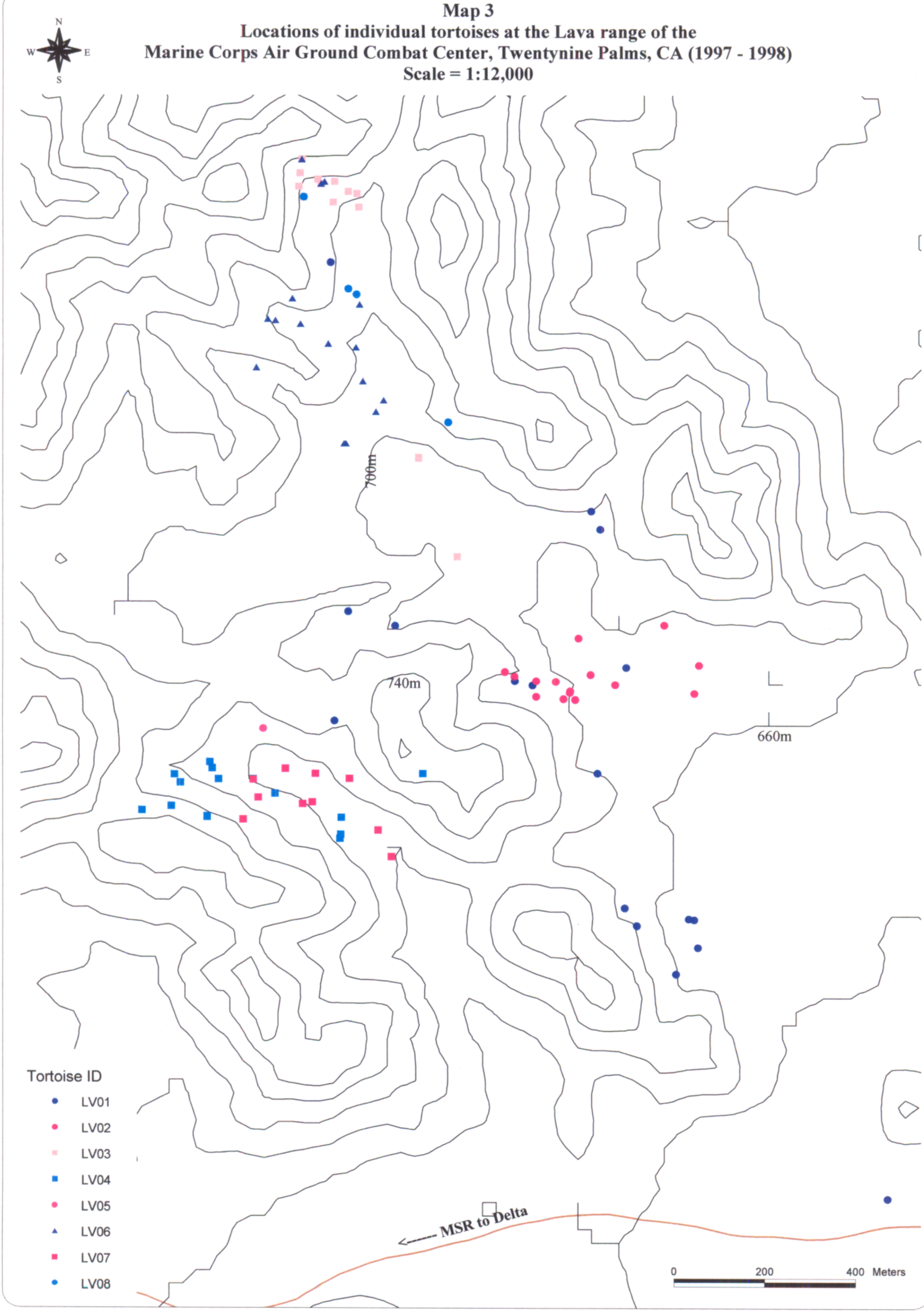


Map 2

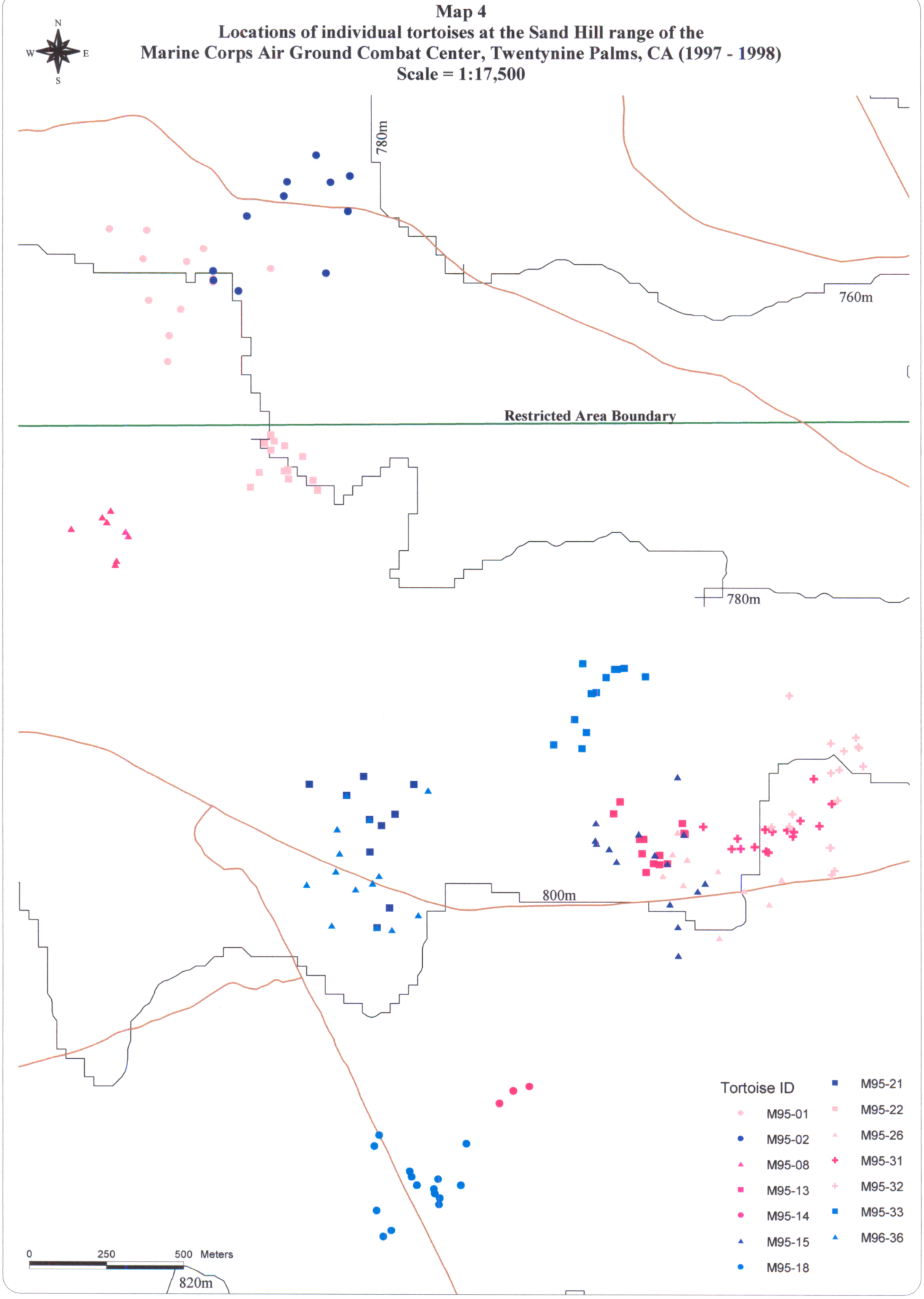
Location of individual tortoises at the southern boundary of the Fort Irwin National Training Center, CA (1997 - 1998)

Scale = 1:15,000

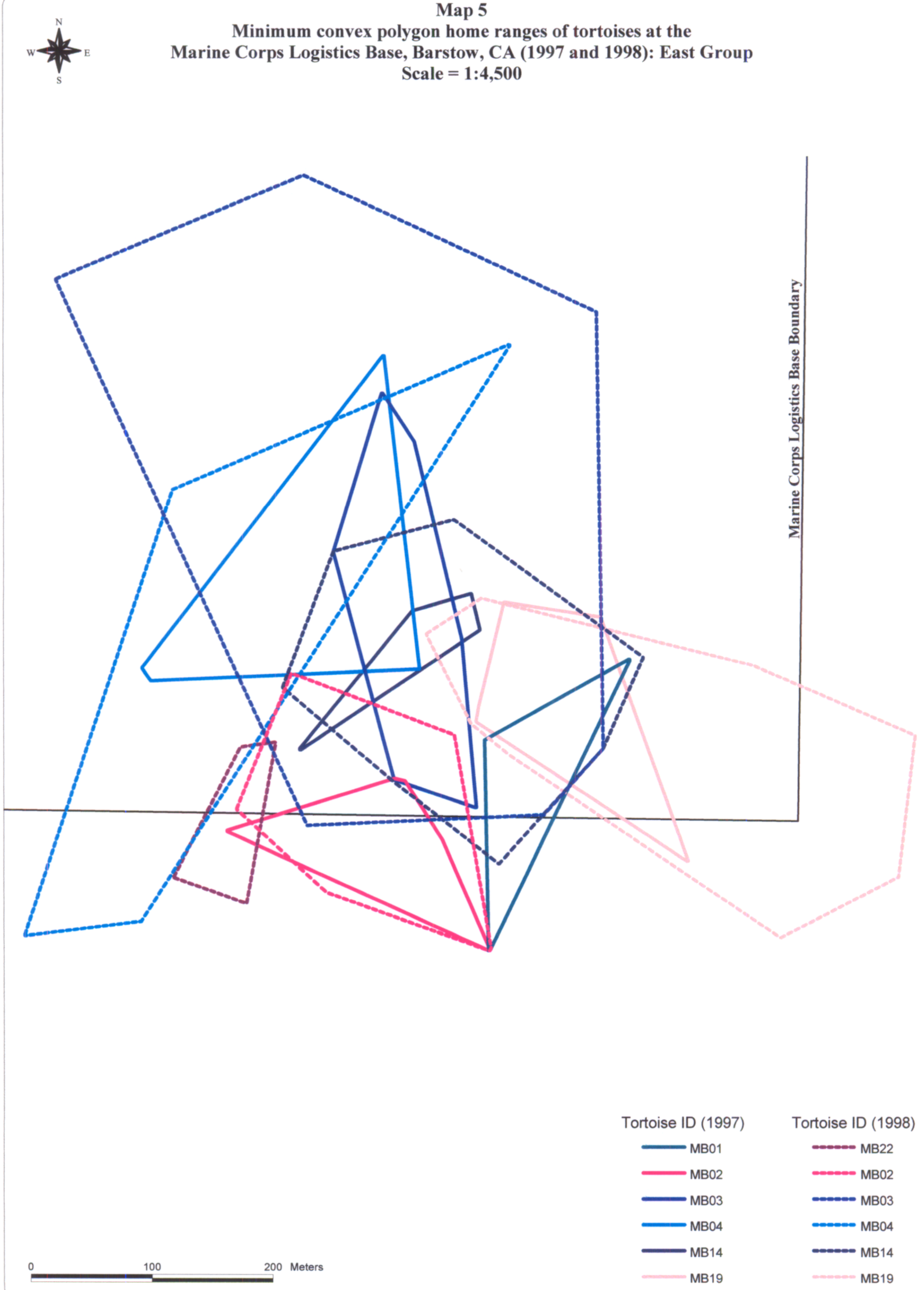
Map 3
Locations of individual tortoises at the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 - 1998)
Scale = 1:12,000



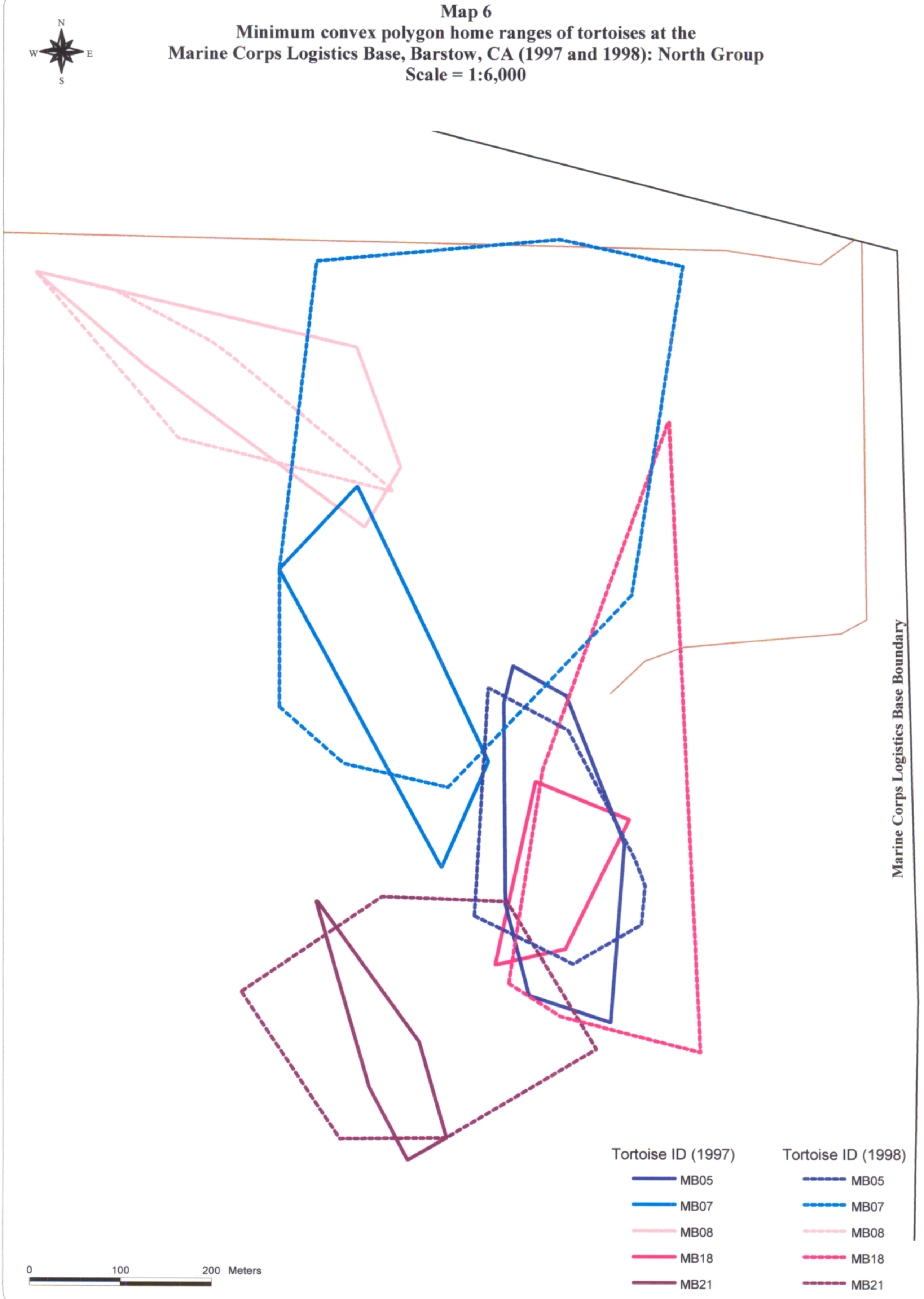
Map 4
Locations of individual tortoises at the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 - 1998)
Scale = 1:17,500



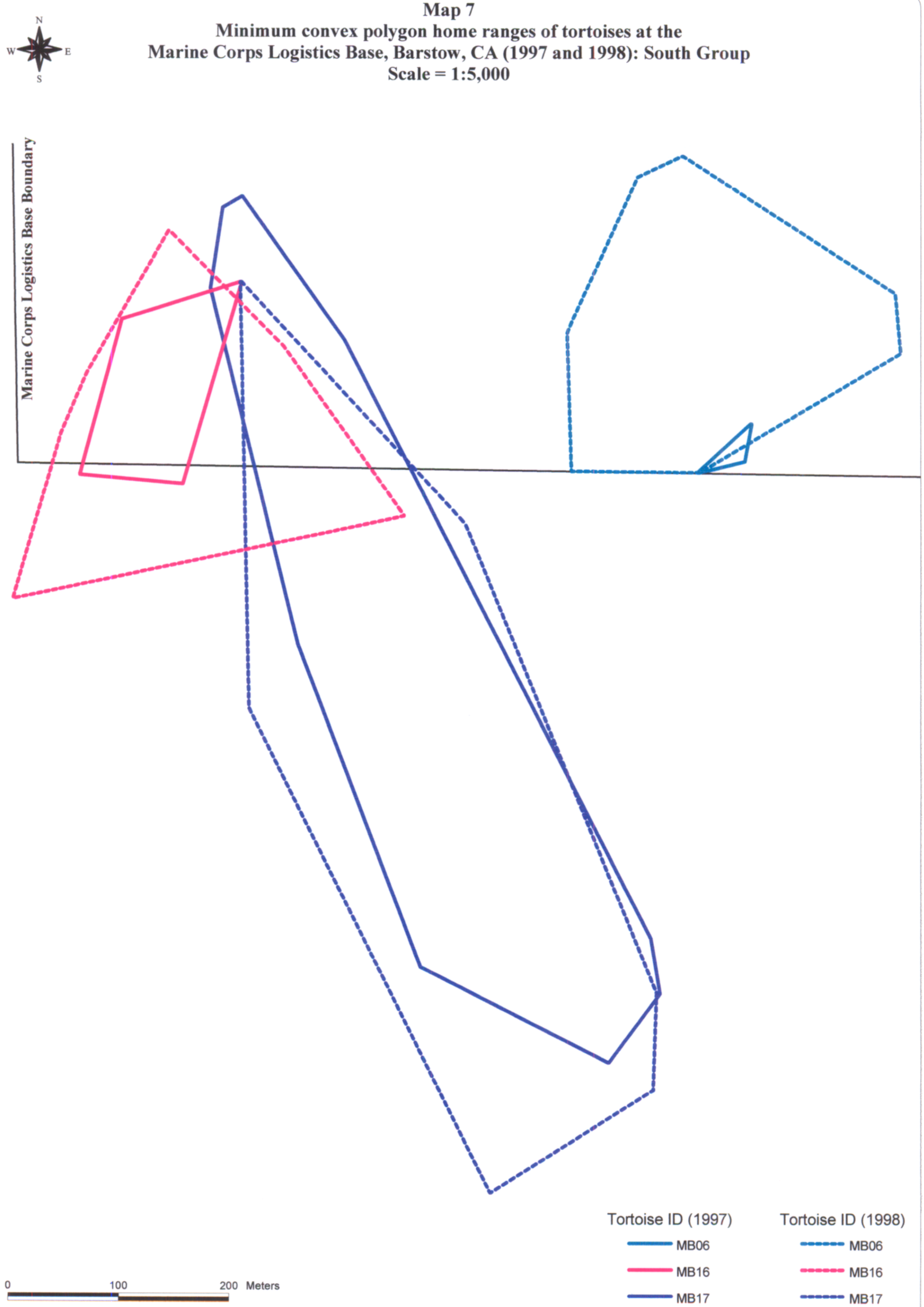
Map 5
Minimum convex polygon home ranges of tortoises at the Marine Corps Logistics Base, Barstow, CA (1997 and 1998): East Group
Scale = 1:4,500



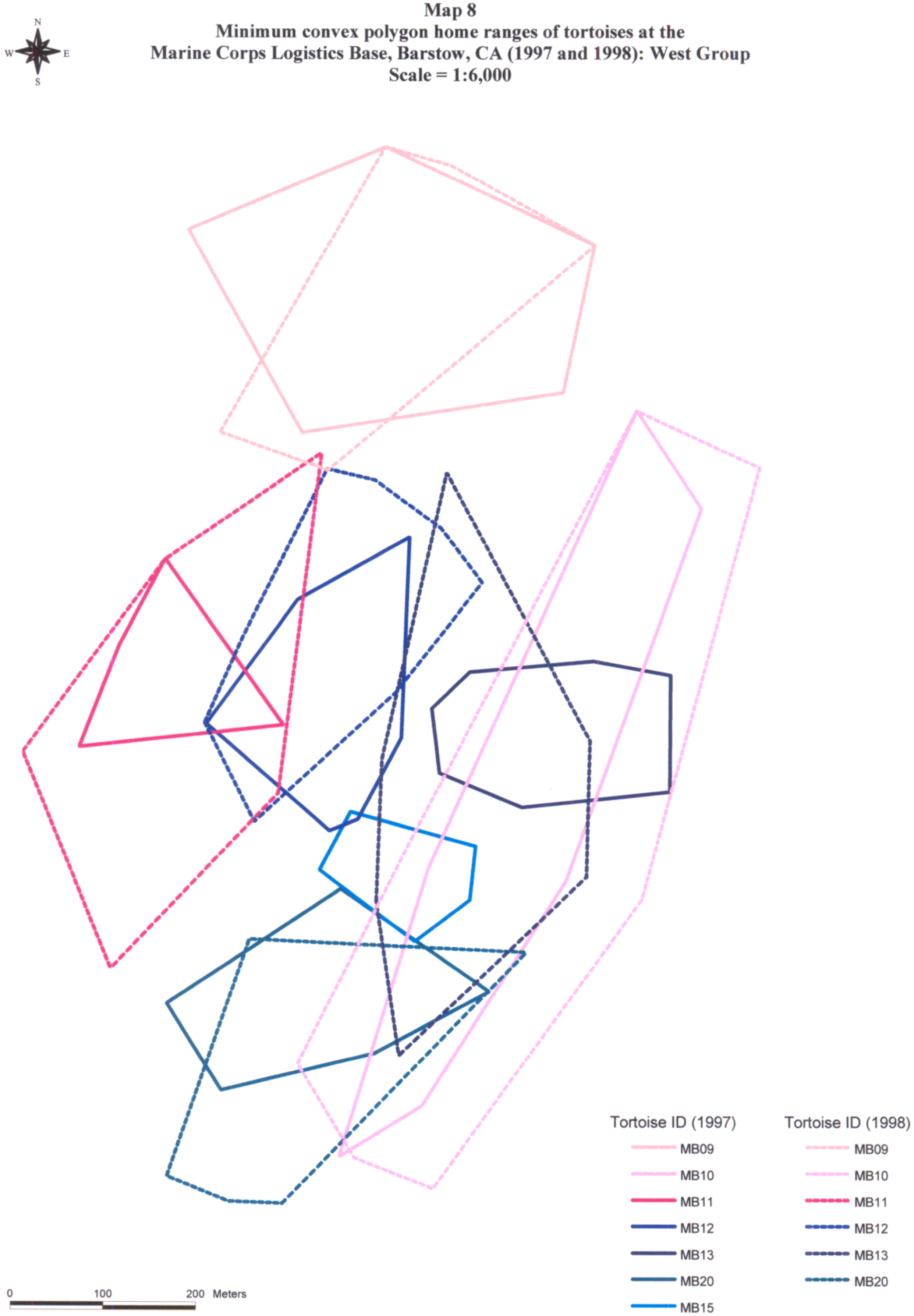
Map 6
Minimum convex polygon home ranges of tortoises at the Marine Corps Logistics Base, Barstow, CA (1997 and 1998): North Group
Scale = 1:6,000



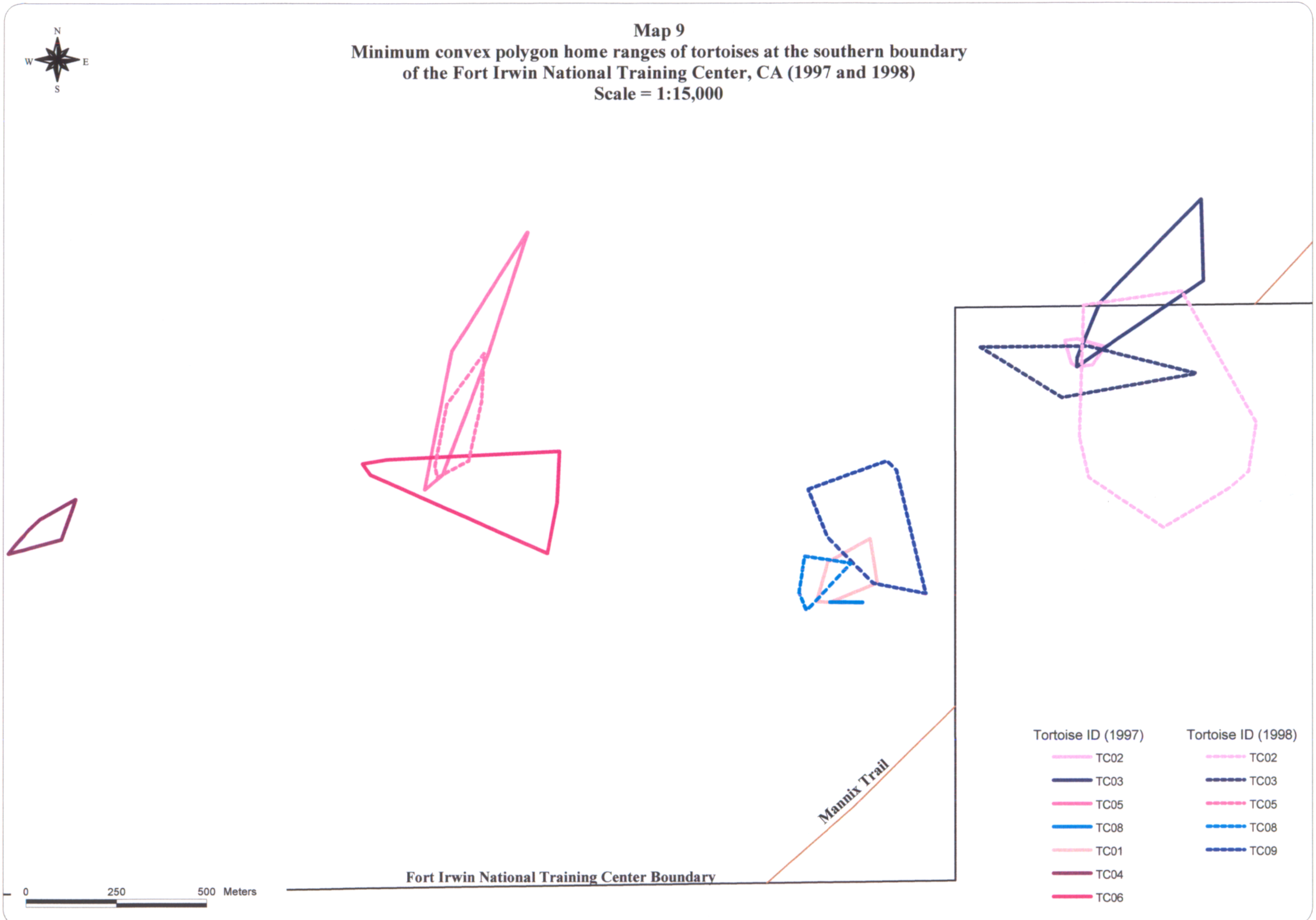
Map 7
Minimum convex polygon home ranges of tortoises at the Marine Corps Logistics Base, Barstow, CA (1997 and 1998): South Group
Scale = 1:5,000



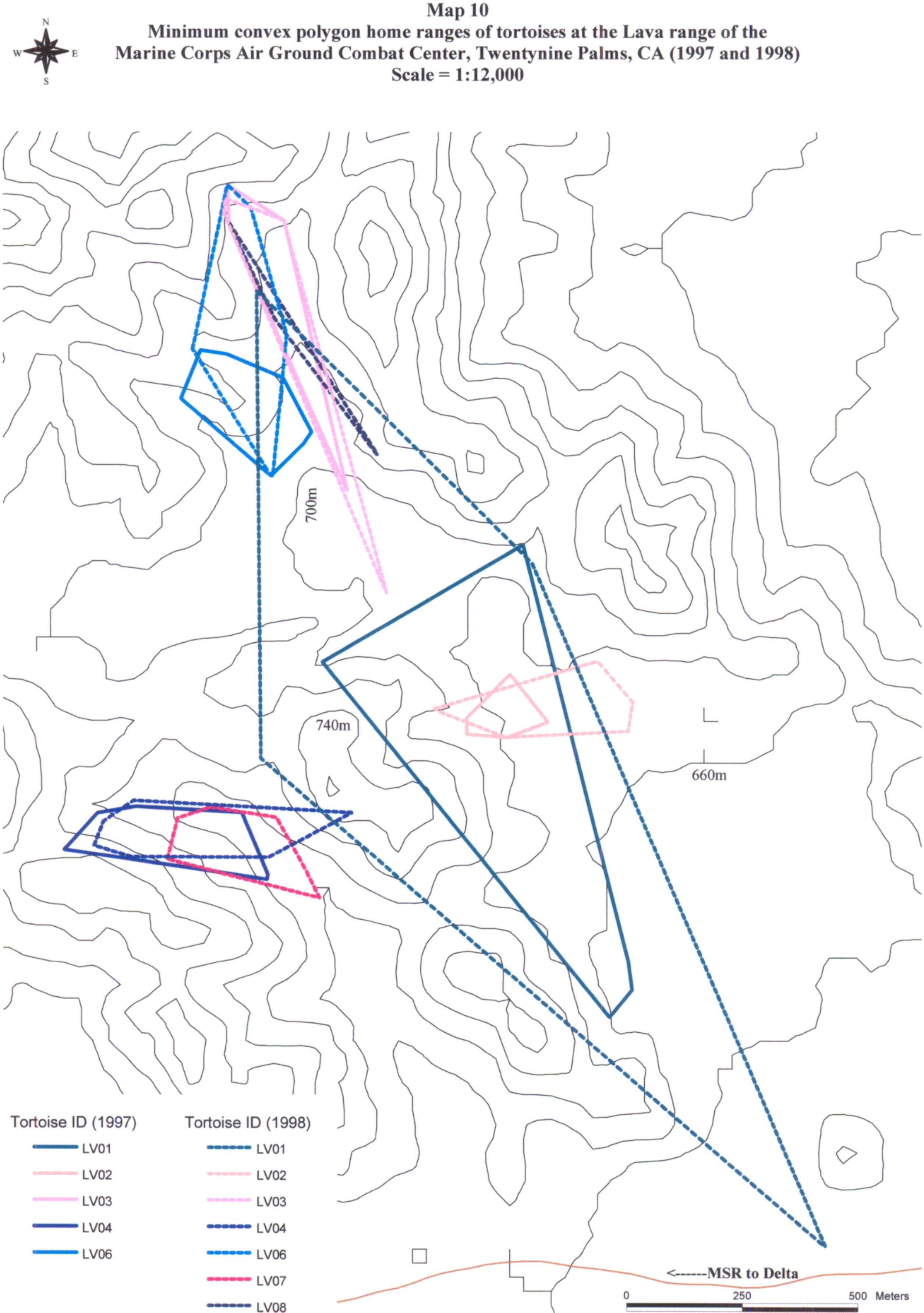
Map 8
Minimum convex polygon home ranges of tortoises at the Marine Corps Logistics Base, Barstow, CA (1997 and 1998): West Group
Scale = 1:6,000



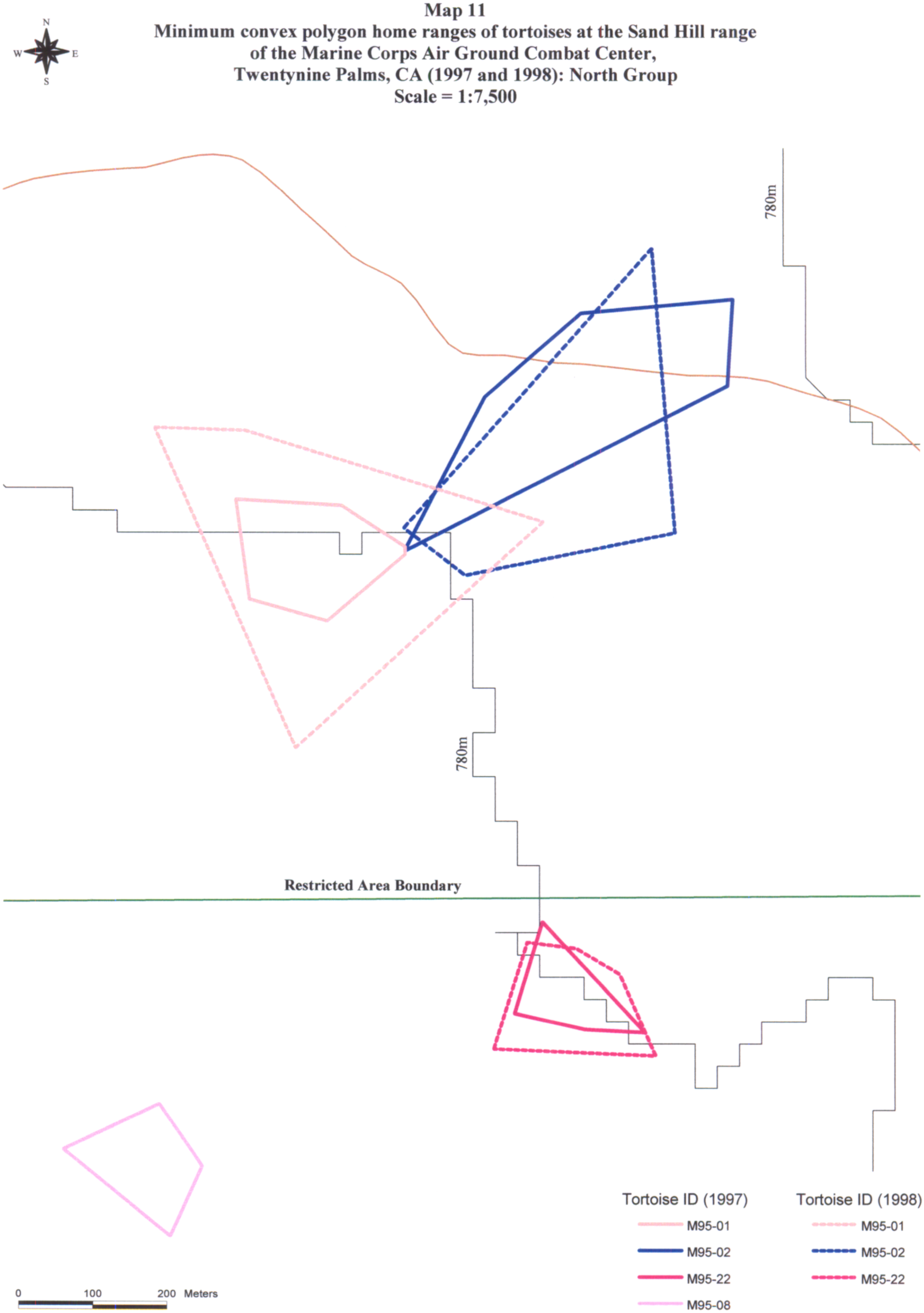
Map 9
Minimum convex polygon home ranges of tortoises at the southern boundary of the Fort Irwin National Training Center, CA (1997 and 1998)
Scale = 1:15,000



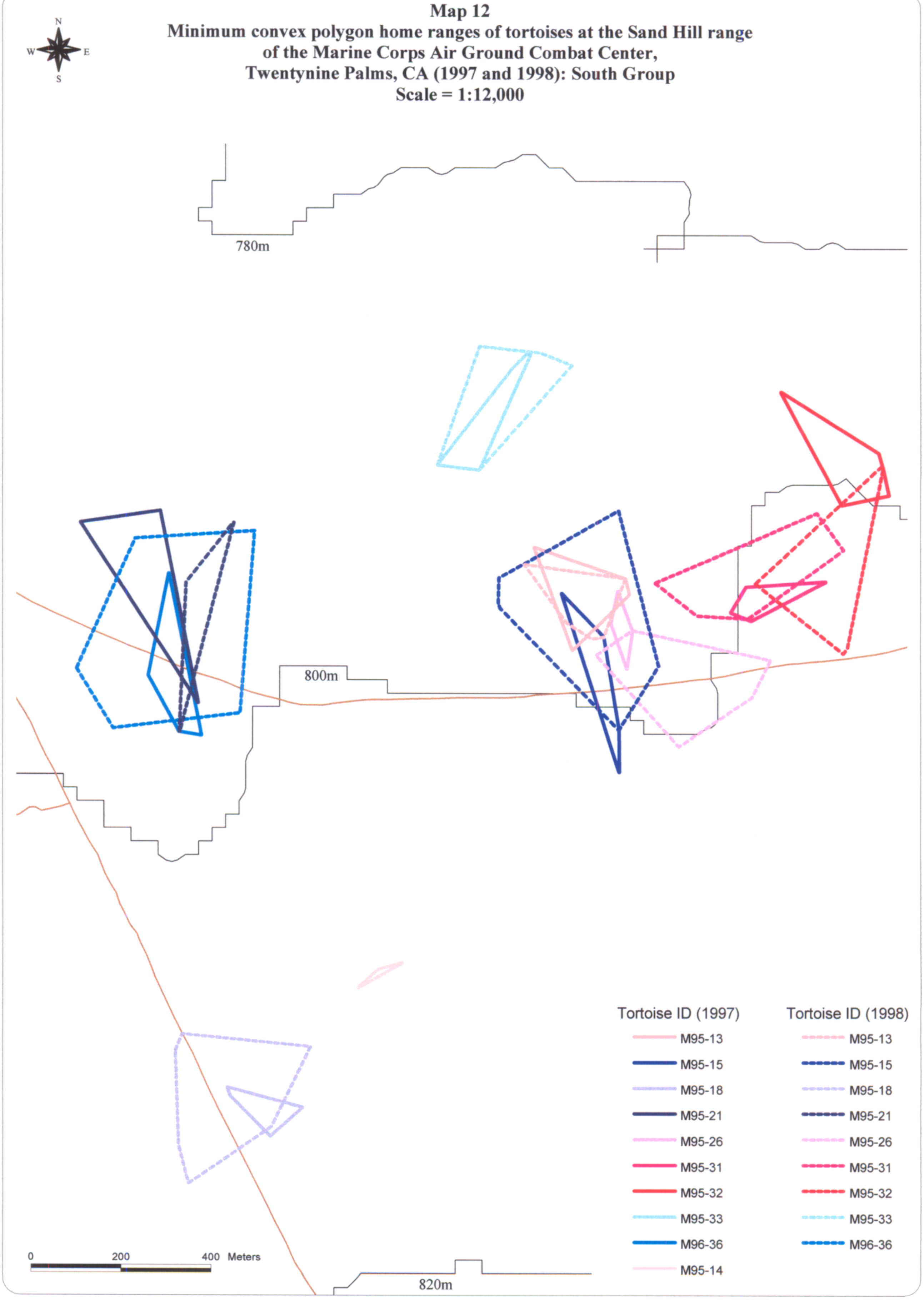
Map 10
Minimum convex polygon home ranges of tortoises at the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 and 1998)
Scale = 1:12,000



Map 11
Minimum convex polygon home ranges of tortoises at the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 and 1998): North Group
Scale = 1:7,500



Map 12
Minimum convex polygon home ranges of tortoises at the Sand Hill range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA (1997 and 1998): South Group
Scale = 1:12,000



APPENDIX 2: NON-TELEMETRY TORTOISES

Table A2.1. —Female tortoises marked at the Marine Corps Logistics Base, Barstow, CA during the 1998 field season. Linear measurements are millimeters: weights are grams. Coordinates are UTM, zone 11.

Tortoise	Date	Sex	MCL	Width	Weight	Girth	Easting	Northing
B06	4/16/98	F	221.5	167.0	2050	447.0	507586	3856352
	7/7/98						507849	3856782
B08	4/16/98	F	247.0	187.0	2588	494.0	507931	3856681
B11	4/21/98	F	231.0	183.0	2280	465.0	507687	3857155
B13	4/22/98	F	187.0	148.0	1260	388.0	507903	3855907
B15	4/30/98	F	215.0	163.0	1950	439.0	507900	3855655
B16	5/5/98	F	199.0	151.5	1420	406.0	507423	3857173
	5/22/98						507423	3857173
B17	5/22/98	F	200.0	144.5	1660	397.0	507203	3856808
	7/29/98						507174	3856927
	8/20/98						506991	3856648
B19	6/4/98	F	233.0	178.0	2540	473.0	507834	3856972
B22	6/12/98	F	239.0	181.0	2640	475.0	508024	3856608
B23	6/18/98	F	203.0	155.0	1760	419.0	508021	3855936
B24	7/1/98	F	213.0	161.0	1910	435.0	507223	3856785
B26	7/23/98	F	219.0	158.0	1900	418.0	507917	3855859
	7/29/98						508049	3855663
	8/9/98						508049	3855663
B31	8/10/98	F	203.0	149.0	1560	395.0	507335	3856507
B32	9/3/98	F	219.5	177.5	1970	453.0	508016	3855882
B33	9/4/98	F	196.5	145.0	1460	385.0	506985	3856006

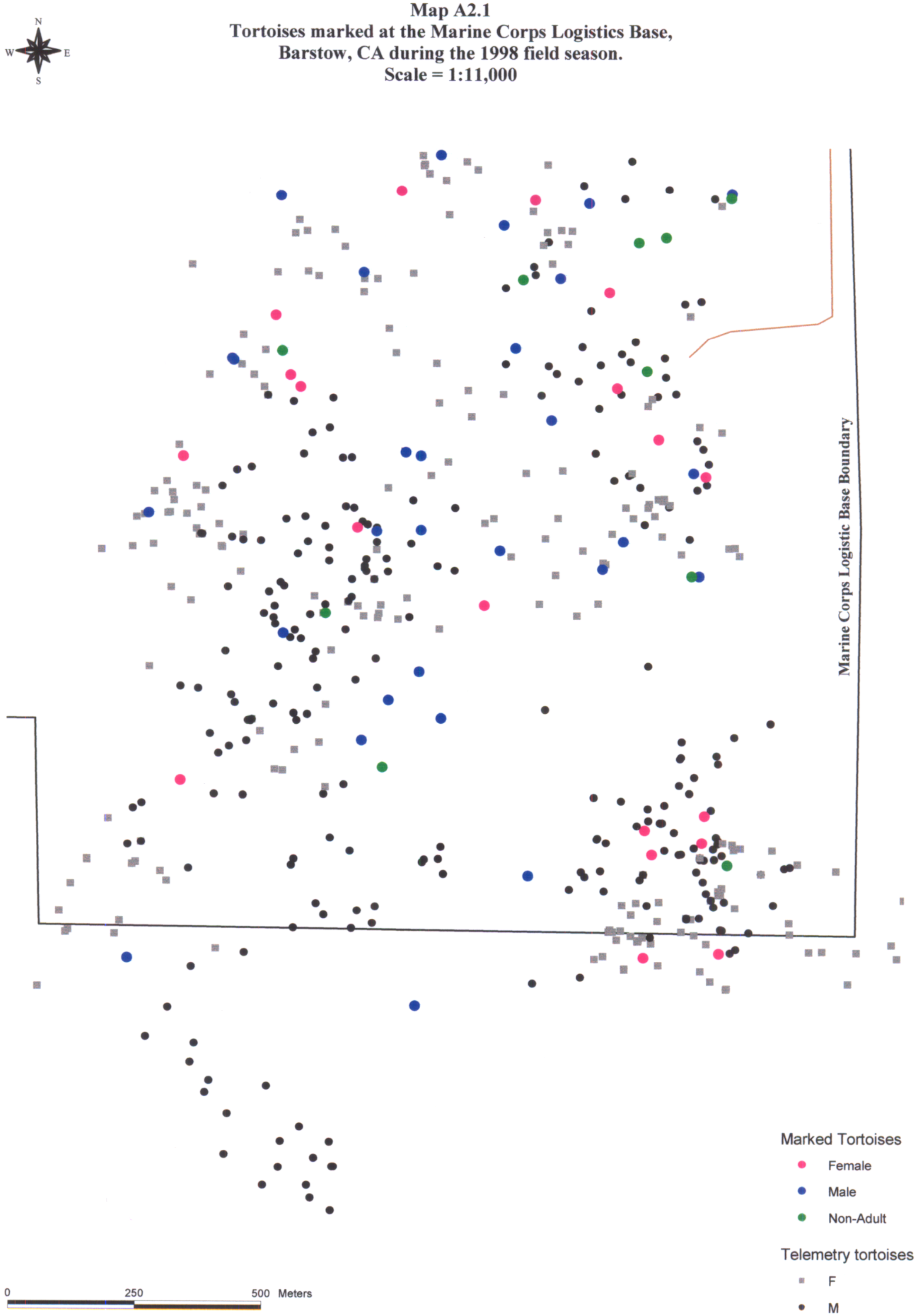
Table A2.2. —Male tortoises marked at the Marine Corps Logistics Base, Barstow, CA during the 1998 field season. Linear measurements are millimeters: weights are grams. Coordinates are UTM, zone 11.

Tortoise	Date	Sex	MCL	Width	Weight	Girth	Easting	Northing
B01	4/15/98	M	263.0	209.5	3600	554.0	507794	3857149
	6/11/98						508076	3857168
B02	4/15/98	M	255.0	190.0	3320	504.0	507625	3857105
	6/12/98						507737	3857000
B02	7/1/98	M	255.0	190.0	3320	504.0	507501	3857244
B03	4/15/98	M	257.5	193.0	3380	519.0	507719	3856719
	8/10/98						508000	3856615
B04	4/16/98	M	252.0	185.5	3120	494.0	507457	3856221
	9/11/98						507617	3856461
B05	4/16/98	M	272.0	213.0	3740	545.0	507457	3856221
B07	4/16/98	M	242.0	190.0	2860	504.0	507820	3856424
B09	4/20/98	M	257.0	202.0	3480	534.0	507461	3856649
	4/29/98						507461	3856502
B10	4/20/98	M	279.0	206.0	3550	543.0	507188	3856297
	9/11/98						507343	3856086
B12	4/22/98	M	255.0	189.0	3040	501.0	507672	3855817
	5/22/98						507861	3856479
B14	4/22/98	M	211.0	150.0	1870	415.0	508011	3856410
B18	5/28/98	M	210.0	158.0	1680	416.0	507348	3857012
B20	6/11/98	M	212.0	168.0	2150	441.0	507185	3857164
B21	6/12/98	M	285.0	207.0	4400	553.0	507648	3856861
	6/25/98						507648	3856861
B25	7/6/98	M	255.0	198.0	3470	524.0	507396	3856165
B27	7/29/98	M	254.0	193.0	3160	511.0	507091	3856838
	9/16/98						507088	3856841
B28	8/5/98	M	275.0	207.0	3720	544.0	506923	3856536
B29	8/9/98	M	288.0	217.0	4280	573.0	506879	3855654
B30	8/9/98	M	265.0	205.0	3440	540.0	507448	3855560
B34	9/4/98	M	263.0	193.0	3550	511.0	507500	3856129
B35	9/25/98	M	267.0	196.0	3460	523.0	507431	3856656
B36	9/25/98	M	217.5	165.5	2050	446.5	507373	3856500

Table A2.3. —Tortoises marked at the southern boundary of the Fort Irwin National Training Center, CA and the Lava range of the Marine Corps Air Ground Combat Center, Twentynine Palms, CA during the 1998 field season. Linear measurements are millimeters: weights are grams. Coordinates are UTM, zone 11.

ID	Date	Sex	MCL	Width	Weight	Girth	Easting	Northing
TC07	9/2/97	M					528274	3888235
TC10	6/17/98	M	232.0	170.0	2360	454.0	528554	3888771
TC11	6/23/98	M	233.0	182.0	2610	479.0	529209	3888342
TC12	7/28/98	F	225.0	167.0	2070	444.0	529029	3887926
TC13	8/08/98	F	187.0	139.0	1190	378.5	528997	3888331
TC14	9/23/98				1650	437.5	527931	3888195
LV09	8/21/98	F	257.0	198.0	3140	519.0	588907	3811169

Map A2.1
Tortoises marked at the Marine Corps Logistics Base, Barstow, CA during the 1998 field season.
Scale = 1:11,000

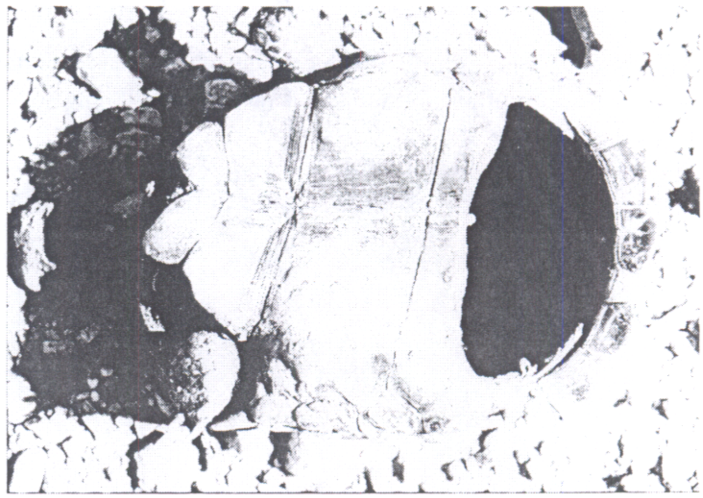


APPENDIX 3: MORTALITY

This appendix contains a chronological listing of all study tortoise deaths that occurred from late March 1997 to late September 1998. Circumstances surrounding these deaths are discussed to the extent of our knowledge. No actual deaths were observed during the study, nor were any causes of death proven.

Six mortalities were confirmed during this study. One animal (Sand Hill, M95-25, female) suspected to have been predated in 1997 was found alive in 1998. Two other animals at Sand Hill apparently had transmitters removed by predators. No carcasses were found, and both individuals were large males (M95-2, 331 mm MCL and M95-21, 312 mm MCL). Rhys Evans and Curtis Bjurlin (Personal Communication) observed M95-2 alive in 1999. We assume that M95-21 also survived.

Figure A3.1. —Photograph of the carcass of MB01 taken on April 23, 1997, East of the rifle range of the Marine Corps Logistics Base, Barstow, CA

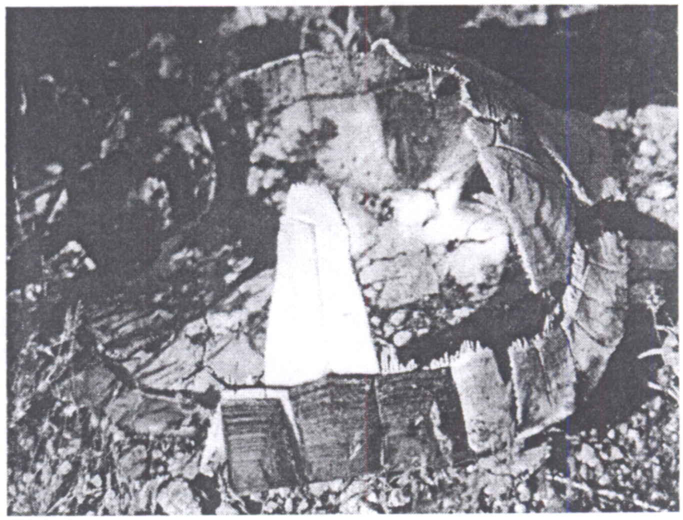


On April 23, 1997 the transmitter for tortoise **MB01** was found nearly 400m from the last location (April 12, 1997). The transmitter had been damaged (casing cracked on the side, no chew marks or antenna damage). The carcass was found around 15m from the transmitter (Figure A3.1). The carcass had been damaged (a portion of the plastron, including the gular process and 3-5 cm posterior to the gular, was removed and not located). Although the inside had been cleaned out, the rear legs had not been damaged. The head and forelimbs were not located. It is suspected that humans took this animal. It is hypothesized that the shell was not taken due to a large crack on the first vertebral and first and second right costal scutes.

On June 17, 1997 the transmitter for tortoise **LV05** was found damaged near cover site # LV05-13APR97. The transmitter was cracked and had a small, round pit (possible bite mark) where the crack began. Found nearby were blood spots and a portion of crushed bone, indicating a predation related mortality. This carcass was never found, although the surrounding area was searched and numerous visits were made to the site since this discovery. Hairs collected at this site were analyzed at USU and the USFWS Forensics Laboratory, Ashland, OR. Results were not positive, but suggested that the predator was a Mountain Lion (*Felis concolor*).

On September 21, 1997 tortoise **TC06** was found dead. The animal was approximately 56 m from its last location (September 14, 1997). The transmitter was on the animal, and the animal, while largely cleaned out inside, appeared undamaged on the shell surface. The animal had appeared healthy the previous week, however a large white ball (~2.5in diameter) was found inside the carcass. This ball is assumed to be impacted calcium from eggs that failed to develop or be reabsorbed by the body.

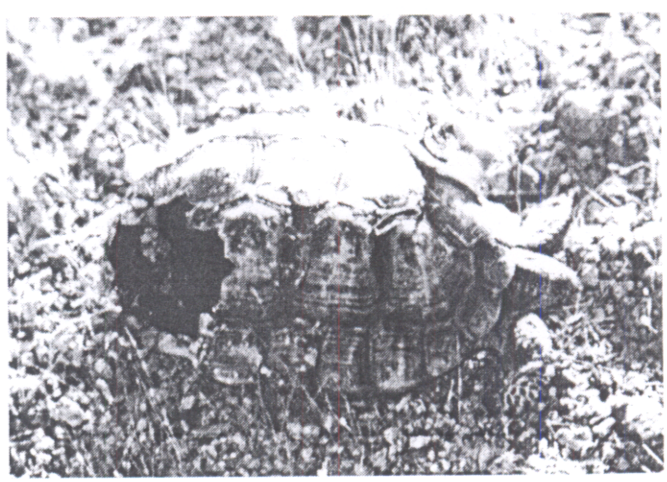
Figure A3.2. —Photograph of the carcass of TC04 taken on May 1, 1998 at the southern boundary of the Fort Irwin National Training Center, CA



The remains of **TC04** (Figure A3.2) were located on May 1, 1998, the first day we visited this site in 1998. Although this animal had been seen alive on September 21, 1997, the carcass appeared greatly aged, and was highly fragmented. Additionally, the transmitter was damaged; however it is not known if this was a predation event or scavenging.

The carcass of **MB22** was found in a shallow burrow/pallet on July 29, 1998. This animal had been found with a *Bromus madritensis rubens* seed in its left eye on June 10, 1998. Its eyes were swollen shut and its mouth appeared swollen, particularly the tongue. The seed was removed and the eyes were cleared with water. The animal was placed in a cover site, 3 meters away, which it had occupied previously. The animal appeared lethargic and continued to exhibit signs of infection (swelling) until it appeared to be recovering when located on July 23, 1998. When located, the carcass was severely desiccated, but had not yet been scavenged by vertebrates.

Figure A3.3. —Photograph of the carcass of MB19 taken on August 4, 1998, at the rifle range of the Marine Corps Logistics Base, Barstow, CA



The female tortoise **MB19** was found dead on August 4, 1998 (Figure A3.3). The head and front limbs appeared undamaged. There was an opening in the right posterior quarter of the carapace, with the 4th and 5th vertebral scutes and the 3rd and 4th

right costal scutes partially or wholly missing. There appeared to be tooth marks (canine) on the transmitter and around the margins of the opening. Canine scat and tortoise shell fragments were found approximately ten meters away, near what appeared to be the desiccated remains of the tortoise's lower intestine.

APPENDIX 4: GOVERNMENT COMMENTS ON THE DRAFT FINAL REPORT:

The Occupation of Steep Slopes by Desert Tortoises in the Western Mojave Desert: A Description of Occupied Habitats, Habitat Use, and Desert Tortoise Density

Gardner Comments

3 November 1999

Rhys M. Evans, NREA Division, MCAGCC, 29 Palms, CA

Page	Paragraph	Comment
Cover	(address)	Change "Code" from "231-WF" (William Fisher) to code specified by SWDiv (probably T. Cutler).
2		Add Contract Number
2		Add Recommended Citation???
6	Barret	agassizii (or is it written agassizi in the reference?); Same comment for Rainboth (page 8).
6	Boarman	Goodlett
6	Chambers	Alvord Slope, San Bernardino
8 10	O'Connor 1	Underline sci. name, also abstract
6		Add citation for Duda and Krzysik
14		Paragraph or spacing problem. "...habitat. To ensure..."
17		(second to last line) Erodium
18	2	*Hymenoclea salsola* not italicized
18	3	...surrounded by rocky washes... ??
20	2	...side of a wash, the slope of the wash...
All		You seem to interchangeably use "Sand Hill" and "Sandhill." Please pick one and use it consistently (I prefer "Sand Hill").
27	1	Minor typo, wherein the parenthesis ")" appears to be underlined. (Ephedra californica)
34	1	"...a poor choice..."
35	2,3	Krzysik is misspelled (twice, in two different ways!)
All		*Ephedra californica* may be misidentified *Ephedra nevadensis*. Though both are known here, *nevadensis* is much more common in the areas you studied. Please confirm with Mark Elvin, (760) 591-7962.
37	(1)	Insert space between "... 27.1 tortoises..."

Gardner Comments (continued)

3 November 1999

Rhys M. Evans, NREA Division, MCAGCC, 29 Palms, CA

Page	Paragraph	Comment
38	2	Parenthetic comment is not closed.
38	2 (2nd to last line)	Tortoises at Barstow…
38	2	"… in the relatively cool, wet year of 1998…" ???
37	What types…	Move to next page, not leaving this one line at bottom of page
39	1	…decreased movements…" Or other grammar fix possible.
39		Move management recommendations to new page.
41	Lava	You might want to add that we have named the Lava study site an "environmentally sensitive area," which does not limit training, but advises that increased use of that area may in the future require additional restrictions. If you want to add this, contact me for better text. Our objective is to casually monitor your tortoises over the next several years, with an attempt to relocate many of them in about 2003.
		Why no mention of mortality that occurred during your study? Other problems, too, such as transmitter failure should, in my opinion, be mentioned.
A2.2	Figure 2	Shows China Lake (south range) as part of Ft. Irwin. A pull-out map of all of Southern California may be helpful (I have several to select from).
A2.16	Figure 12	I would suggest changing the caption to read "Two males in combat" followed by further information. Though it may be more proper, "two males (…) in combat (…)" is awkward to read…
		When will we have access to Appendices 5, 6 and 7??
		GREAT WORK!!!

7 December 1999

TO: Ty Gardner and Dr. Edmund Brodie, Jr., Department of Biology, Utah State University.
FR: Tricia Cutler, Natural Resources Management Specialist, Southwest Division Naval Facilities Engineering Command, San Diego, CA. TLC
RE: Comments on the Draft Final Report "The occupation of steep slopes by desert tortoises in the western Mojave Desert" (Contract N68711-96-LT-60038).

Thank you for doing such an excellent job. These comments range from minor to a few more substantial points. My only substantial concern is your use of the term "preference" (please see comments 35, 40, and 41).

These comments correspond with numbers in the text:

1. Please indicate that this is the Final Report. I also modified our SWDIV address.
2. Omit acronyms on this page.
3. Add contract #N68711-96-LT-60038.
4. Move this info. to an Acknowledgments section placed after the Introduction or Abstract.
5. Add recommended literature citation for your report to the bottom of the page.
6. Capitalize heading.
7. Move "Literature Cited" to after "Conclusions", and add "Appendices" after Literature Cited.
8. These titles should appear word-for-word as they do on the actual tables, figures, appendices.
9. I would prefer tables and figures integrated throughout text, but if Art & Mickey are ok with this format then it's fine w/ me.
10. Move the Literature Cited to appear after the Discussion section, and before Appendices. Please cross-check all citations between your report text and Lit. Cit.... some mentioned in the text are missing in Lit. Cit.
11. Please cite "U. S. Fish and Wildlife Service" instead of "Fish and Wildlife Service".
12. Italicize.
13. I suggest adding a sentence from your Conclusions section here, about the implications of your results. E.g., that tortoise habitat should be reevaluated throughout the Mojave.
14. Use "were" (past tense) instead of "have been" when referring to other studies.
15. These 2 sentences conflict.
16. E. Jaeger discussed tortoises inhabiting steep slopes in the Mojave. You should probably cite this in your report.... I'll e-mail the citation to you. need to find
17. Do you have only 1 citation to support this? If so, not a very strong argument that tortoises were thought only to occur in these areas. Prior to this sentence, you provide lots of citations that tortoises occupy rocky areas and hillsides. need to find
18. Additionally, tortoises on hillsides would also be exposed to less human activity (vehicles), and possibly to fewer predators (such as feral dogs).

19. I suggest not using the term "critical habitat" unless you're specifically talking about USFWS designated Critical Habitat. You could delete "critical".
20. Please standardize "Sand Hill" throughout.
21. Tortoises ate chinchweed at our house in 29P like it was going out of style. Did you expect them to eat it but they didn't? Why didn't they? (was other forage abundant?).
22. Please add a few sentences on capture methods. How and when were tortoises captured? Was this done non-randomly?
23. Why did you modify this method? Did your placement work better?
24. Is this effectively an estimate of minimum tortoise density?
25. This citation not in Lit. Cit. (need to put in)
26. Multiple locations of an individual tortoise would not be independent if a tortoise has a propensity for using certain cover types. Can you take a stab at addressing this?
27. You explained that you tried 2 methods, but not why you selected the latter method. I suggest that you either explain why, or don't tell the reader that you tried 2 methods.
28. You already presented this abbreviation in the previous page. Present all abbreviations only once the first time used in the text, and then refer to the abbreviation thereafter (with the exception of the Abstract, Tables, Figures, and Appendices where they must be presented independently if used).
29. (nevermind – I deleted this comment)
30. Standardize the date format?
31. There's no need to repeat the stat. methods you used in Results... this should be covered in Methods.
32. Many people consider $p < 0.10$ biologically significant.
33. I suggest that you refer to these tables, but you don't need to explain their contents here.
34. Say how many. (need to look)
35. Be careful when using the word "preference". The general rule is not to use it unless you studied and quantified habitat availability and use, and used stat. methods that specifically address preference. I would just state that you often observed them eating legumes.
36. In this section, you're using the passive voice ("...was observed") rather than the active ("We observed...") which is the proper usage.
37. Don't use acronyms unless you use the acronym at least twice thereafter in the text.
38. Did you ever define "steep"? I suggest doing this somewhere in the paper.
39. You would expect these substrates to be different because of the erosional process in deserts. Rock particle size decreases predictably from mountaintops to bajadas to flats to playas. This process occurs in both deserts. Couldn't this alone explain your differences in substrate in areas occupied by tortoises between different study sites?
40. It's misleading to use the term "preference" here. To draw conclusions about preference, you would have to quantify the availability and use of cover-site types at each study site, and then see if use was significantly different from availability. What you have done here is summarized the types of burrows used by tortoises you monitored. I suspect that your results can be explained by use of cover-site types in proportion to availability at each site, which isn't preference. When you state that tortoises used burrows almost exclusively at Sand Hill, you should probably qualify

that is consistent with what you'd expect since burrows are the predominant cover site type available in Sand Hill.

41. Again, it's misleading to make statements about preference unless you studied availability vs. use.
42. I'd say "sandy to coarse surface substrates".
43. I would think of it a little differently (backwards)... that tortoise activity was in response to more lush vegetation. The end result is heavier tortoises (improved physical condition).
44. You mentioned signs of disease... would you recommend monitoring the population for effects of disease on a periodic basis? E.g., monitor the population size and health of animals. Or, do you think this isn't necessary?
45. Are tortoise densities low here due to natural or unnatural causes? (I'm not familiar with this particular area). I see that you mentioned prolonged drought, but do you think this is the primary reason for low tortoise densities? The presence of numerous inactive burrows and carcasses is interesting, and seems to indicate that the tortoise population hasn't always been low. Maybe you could discuss this a little more.
46. I would add to the end of the 3rd sentence "... where off-road vehicle operation is difficult." You might qualify the last statement by saying something like "We feel this population is already protected, and therefore make no special management recommendations."
47. I suggest adding "from off-road vehicle use" to the end of the 2nd sentence. I also suggest recommending the continued protection of the current restricted area.
48. In this and other tables, leave blank spaces (rather than "x") for missing data – this is consistent w/ most journals.
49. In this and other tables, use small-case superscript letters for table footnotes – this is consistent w/ most journals.
50. All tables, figures, and appendices should be able to stand alone if separated from the report. Therefore, "desert tortoise", city & state, and even the range of study years should appear in each title.
51. You can present "$P < 0.0001$" instead of the exact p value.
52. Consider presenting this table in landscape.
53. Please label countries, at least, and maybe states?
54. Please label CA & NV.
55. Spell out MCLB throughout. The title should read something like "Map A3.1. Tortoise locations at Nebo, Marine Corps Logistics Base, Barstow, California. 1997-1998."
56. This map is hard to read. Please replace file names in legend with appropriate titles. What's the difference between the black & colored dots?
57. Please mark this boundary... I can't tell which side is in or out of MCLB.
58. See my corrections on the title page for our address.

Other Comments:

Electronic Appendices: I'm not sure what your plans are for submitting these, so I'll make some suggestions: For each electronic Appendix, include a page that states the file name(s), and that the file was submitted on a CD ROM deposited at each installation and at SW Division (include a mailing address for each). On each CD, provide a database key (explanation of each data field) with each data file on the CD. Also provide the report text on the CD. Then, submit one to each of us with the Final Report. I'd like to have a chance to review and comment on the CD ROM before you submit it, as well.

Original field data: Make copies for yourself and submit all original field notes and data sheets to each installation (none to me). You don't need to include data sheets in each report... this is too cumbersome.

Add Appendix 8: Government comments on the Draft Final Report: "The occupation of steep slopes by desert tortoises in the western Mojave Desert". In this appendix please provide photocopies of all government comments submitted to you on the Draft Report.

Ty J. Gardner

From: Cutler, Patricia L [CutlerPL@efdsw.navfac.navy.mil]
Sent: Wednesday, November 17, 1999 1:29 PM
To: 'Ty Gardner '
Cc: 'MR RHYS M EVANS '; 'Art Gleason '; 'Quillman, Mickey '
Subject: RE: USFWS Report

Ty,

I haven't been able to read the entire report yet, but I reviewed your management recommendations and I think they're thoughtful and appropriate. Some questions/comments:

Barstow:
- You mentioned signs of disease... would you recommend monitoring the population for effects of disease on a periodic basis? E.g., monitor the population size and health of animals. Or, do you think this isn't necessary?

Irwin:
- Are tortoise densities low here due to natural or unnatural causes? (I'm not familiar with this particular area). I see that you mentioned prolonged drought, but do you think this is the primary reason for low tortoise densities? The presence of numerous inactive burrows and carcasses is interesting, and seems to indicate that the tortoise population hasn't always been low. Maybe you could discuss this a little more.

Lava:
I would add to the end of the 3rd sentence "... where off-road vehicle operation is difficult." You might qualify the last statement by saying something like "We feel this population is already protected, and therefore make no special management recommendations."

Sandhill:
I suggest adding "from off-road vehicle use" to the end of the 2nd sentence. I also suggest recommending the continued protection of the current restricted area.

I appreciate receiving the draft report double-spaced and in a 3-ring binder... that makes it so easy to review. I'll get back to you w/ comments on the rest of the report by approx. 3 December. Are you still planning to defend in December?

Trish

-----Original Message-----
From: Ty Gardner
To: MR RHYS M EVANS; Art Gleason; Quillman, Mickey; Cutler, Patricia L
Sent: 11/12/99 2:09 PM
Subject: USFWS Report

Hello all,
In addition to finishing my report to you (GIS, raw data sheet copies, G0), I am completing the final report to the USFW Service required by our permit. I would specifically like comments from all of you about the recommendations section I provided in your report. The report to the USFWS is similar but less detailed, however the recommendation section will probably be the same. This is scheduled to be mailed off early next week so if you could give me comments on just the recommendations section on Monday I would appreciate it. I will be working the remaining portion of this weekend on items for all of you. If you have any other concerns about info to be provided to the service please let me know.

Gardner Comments – Final Report

8 March 2000

Rhys M. Evans, NREA Division, MCAGCC, 29 Palms, CA

Page	Paragraph	Comment
v, vi		Remove solo lines from top / bottom of page
xi		Move Art Gleason up a notch or two in acknowledgements, after Jesse probably most appropriate
xi		I think (perhaps check with Art) you can shorten the first line by saying "…funded by the U.S. Marine Corps Logistics Base, Barstow, CA
5	2	You use "we sought to determine" four times in one paragraph. Suggest some word tweaking.
6	Fig 2	Perhaps a darker line for state boundaries? Otherwise, remove county boundaries, as this map could be confusing to people unfamiliar with the area
7	1	Spell out Highway or put a period at the end (i.e. Hwy.)
7	1	Erodium, not Erodum
9	2	Didn't we agree to replace Ephedra californica with Ephedra spp.? No big deal.
11	2	"…female tortoises tortoise…"
11	3	Include model and make of receiver??? (AVM LA-12 Q)
19	Table 1d caption	Fix indent error (MS Word is the pits!)
36	Fig 11 caption	Doesn't include abbrev. for FINTC
40	Tab 11d caption	…is double spaced
41	1	Replace "sites" with "site"
52	2	"… resident, rather than migratory populations" seems better than "…resident, rather than migratory, populations"
52	3, 4	Two misspellings of "Krzysik" slipped through. Suggest search of entire doc to see if any slipped by ME.
56	1	Perhaps another sentence describing the details of the 86.39 ha MCP? Wasn't this the result of just one very long foray?
56	MCLB	Diskeratosis not diskeritosis (though I'm also finding references to "dyskeratosis" – perhaps you should take the easy out and use "shell disease."
60	Bailey	No year on the cite
61	USFWS	Cite is double spaced; Woodbury not indented.

Prepared by
Ty J. Gardner and Dr. Edmund D. Brodie, Jr.
Department of Biology
Utah State University

Prepared for
Marine Corps Logistics Base, Barstow, CA
Fort Irwin National Training Center, CA
Marine Corps Air Ground Combat Center, Twentynine Palms, CA
Southwest Division, Naval Facilities Engineering Command

Recommended Literature Citation

Gardner, T.J. and E.D. Brodie, Jr. 2000. The Occupation of Steep Slopes by Desert Tortoises (*Gopherus agassizii*) in the Western Mojave Desert: A Description of Occupied Habitats, Habitat Use, and Desert Tortoise Density. Final Report.