SPATIAL ECOLOGY AND DEMOGRAPHY OF THE ORNATE BOX TURTLE IN A SEASONALLY BURNED SAND PRAIRIE MATRIX

by

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Abstract

Box turtles (*Terrapene* spp.) are declining throughout their range, but there is a lack of information on general ecology and the influence of common land management practices on populations of these terrestrial turtles. Because of these inadequacies, I initiated the first phase of a long-term ornate box turtle (*Terrapene ornata*) research project at Matador Wildlife Management Area in Cottle County, Texas. To examine spatial ecology, a 273-ha primary study site dominated by sand sagebrush (*Artemisia filifolia*) grasslands was divided into 15 ~18-ha plots (5 blocks x 3 plots). Within each block, there were randomly assigned burning treatments: winter burn, summer burn, and unburned. Thirty-one turtles were captured within the plots and outfitted with radiotransmitters and followed from June 2007 to April 2010. Using GIS, I assigned treatments to radiolocations and calculated minimum convex polygon (100%, 95%), fixed kernel (95%), and bivariate normal (95%) home ranges. I compared male and female total, annual, monthly, seasonal, and average daily activity using analysis of variance. I used second and third order compositional analysis to evaluate habitat selection based on treatment. Turtle movement was significantly less in April than in May, June, July, June, August, and September. Whereas males and females had similar home range sizes, males had greater daily movement. Turtles did not appear to have a preference for burn treatment. Thus, in the short term, box turtles did not appear to be influenced by burning regime in this habitat. I also examined data from 477 ornate box turtles captured at Matador Wildlife Management Area from 2004 – 2010 to assess the demography of this population. The population of ornate box turtles was significantly female biased at 1.65:1. Adult female turtles were heavier than males but no difference was detected in turtle carapace length or body condition. Based upon regression of age against both mass and carapace length, growth was basically linear. Both Kaplan-Meier and ln(frequency) regression methods produced annual survival estimates near 80%, but adult female survival was higher than that of adult males. Ornate box turtles at Matador Wildlife Management Area had a staggered entry into hibernation beginning in October with all turtles underground by the end of December. However, turtles displayed rather synchronous emergence from hibernation in mid-April. Ornate box turtles demonstrated reproductive activity throughout the active season, but such activity was most pronounced in September. The overall pattern of relatively high survival, high capture rates, linear growth, and small home ranges suggests that the ornate box turtle population at Matador Wildlife Management Area is very robust.

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CHAPTER I

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LITERATURE REVIEW

The ornate box turtle (*Terrapene ornata*) was first described by Louis Agassiz in 1857 (Dodd 2001). First recognized as *Cistudo ornata* it was changed to its current genus in 1891. The ornate box turtle is classified as a member of the Kingdom Animalia, Phylum Chordata, Class Reptilia, Order Testudines, Suborder Cryptodira, and Family Emydidae (Legler 1960). Within the Genus *Terrapene* there are 4 recognized species: eastern box turtle (*T. carolina*), Coahuilan box turtle (*T. coahuila*), spotted box turtle (*T. nelsoni*), and *T. ornata* (Dodd, 2001). Within *T. ornata* there are 2 recognized subspecies: ornate box turtle (*T. o. ornata*) and the desert box turtle (*T. o. luteola*; Legler 1960).

The carapace of the ornate box turtle is broad and oval, domed, and flat at the top (Dodd 2001). Mean carapace length of females and males was indistinguishable within a population in Nebraska (female mean = 110.42 mm, males mean = 110.44 mm; Converse et al. 2002). Adult males typically have a red iris, whereas females have a yellow-brown iris. Adult males have a long tail whereas females have a short tail. Coloration of the carapace is dark with yellow radiating lines on the scutes of the carapace. There is a linear relationship between shell mass and body mass, with shell mass accounting for approximately 30% of the entire body mass (Millar and Birchard 2005). Ornate box turtle also have 4 claws on the hind feet the first toe of which is widened, thickened, and turned inward in males (Legler 1960).

Karyotype for the ornate box turtle is $2n = 50$ (Bickham 1981, Ernst and Lovich 2009). In the ornate box turtle there are 26 macrochromosomes with 16 being metacentric, 6 submetacentric, and 4 telocentric (Ernst and Lovich 2009). There are 24 microchromosomes (Ernst and Lovich 2009).

The oldest fossil records for the ornate box turtle have been found in deposits that date to the Barstovian-Clarendonian time period of the Miocene era (9-15.5 Mya) in Kansas and Nebraska (Parmley 1992). Mid-Pliocene (2.5-5.3 Mya) records have been collected in Arizona, Kansas, and Oklahoma (Hibbard 1958, Milstead 1967, Moodie and Van Devender 1978). While numerous other specimens dating to the Pleistocene (0.01-2.5 Mya) have been found in Arizona, Arkansas, Kansas, Missouri, New Mexico, Oklahoma, Texas, and Sonora, Mexico (Ernst and Lovitch 2009).

The current geographic range of the ornate box turtle has extended as far east as northwest Indiana and southern Wisconsin (Grant 1935, List 1951, Legler 1960, Dodd 2001). The ornate box turtle can be found throughout the prairies of Kansas and Texas and as far west into Colorado and southeastern Arizona (Legler 1960, Dodd 2001). The northern part of its range is found in Colorado to south-central South Dakota with a few documented records in Iowa (Dodd 2001).

The majority of the geographic area in which the ornate box turtle occurs is semiarid or arid. The average precipitation during the active season (April through September) varies from approximately 63.5 cm in the northeast to approximately 25.4 cm in the southwest (Legler 1960). The prairies of Kansas, Nebraska, Oklahoma, and northern Texas provide the best habitat for the ornate box turtle (Legler 1960, Dodd 2001). Found in mesic forest and woodlands to the short and tall-grass prairies of the Great Plains the ornate box turtle can be observed in many habitats, but they tend to favor prairie grasslands which are characterized by a wide diversity of grasses such as bluestem (*Andropogon* spp.), wheatgrass (*Agropyron* spp.), grama (*Bouteloua* spp.), rescuegrass (*Bromus* spp.), panicum (*Pancium* spp.), indiangrass (*Sorghastrum nutans*), and buffalograss (*Buchloe dactyloides*) (Dodd 2001). In the northern portion of the ornate box turtles range within the sandhills of Nebraska, yucca (*Yucca* spp.) is an important component of the habitat as it serves as important thermoregulatory refugia for inactive turtles during periods of high temperature (Converse et al. 2002). The 3 primary limiting factors for the distribution of the ornate box turtle appear to be: 1) Presence of a substrate too hard to permit digging of nests, 2) Temperatures cold enough to cause the ground to freeze deep enough to kill turtles hibernating, 3) Lack of wet periods during a warm season (Legler 1960).

The body temperature in the ornate box turtle ranges from 12.0-35.9 °C with a mean or preferred temperature of 28 °C (Brattstrom 1965). Ornate box turtles exhibit a bimodal activity pattern, in which turtles are active in the morning and afternoon and inactive during midday and night. During the hottest portions of the summer, a negative relationship between activity level and midday ambient temperatures results in increasing lengths of the in daily inactive period (Legler 1960). Ornate box turtle are most active from 0600 – 1000 h and 1600 – 1800 h, with the highest activity levels documented between the hours of 0800 – 1000 h (Converse et al. 2002).

The initiation of overwintering behavior most likely occurs sometime after the first of October and lasts until the beginning of April. No communal wintering sites have been observed. Ornate box turtles overwinter individually and all of the winter sites used by a turtle are located inside of the activity area used by a turtle during summer months (Converse et al. 2002). The emergence from the hibernation period is associated with increased subsurface soil temperatures (Grobman 1990).

Mating may take place throughout the active season (April-October) but is most common in the spring (Legler 1960). The earliest record of copulation is 5 April and the latest recorded was 13 October (Blair 1976). Females may be gravid from May through August, while most females have laid their eggs by late July (Nieuwolt-Daganay 1997). In Nebraska, nests were documented exclusively on upland prairie sites with an average clutch size of 2.6 eggs (Converse et. al. 2002). Clutch sizes range from 1 – 4 throughout the entire distribution of the ornate box turtle with a mean clutch sizes of 2.68. Clutch size does not appear to vary from year to year, and there is no evidence to indicate that ornate box turtles lay more than one clutch per year (Nieuwolt-Daganay 1997).

Ornate box turtles are omnivorous and have been observed feeding on a wide variety of plant and animal materials; however, their diet primarily consists of insects (Legler 1960, Blair 1976, Claussen et. al. 1997). Despite a primarily insectivorous diet ornate box turtles have been documented eating a black rat (*Rattus rattus*), land snails

(*Placostylus* spp.), and fruit, including Texas persimmon (*Diospyros texana*), prickly-pear cactus (*Opuntia lindheimeri*), and red mulberries (*Morus rubra*; Blair 1976).

There have been very few first hand observations of predation on the ornate box turtle (Legler 1960). Among the few predators observed are: prairie moles (*Scalopus aquaticus machrinus*), Chihuahuan raven (*Corvus cryptoleucus*), coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), American badger (*Taxidea taxus*), and the raccoon (*Procyon lotor*; Legler 1960, Doroff and Keith 1990). Although natural factors can affect populations of the ornate box turtle, human forces have the greatest impact. One study of a marked population during a 10 year period observed that the only cause of mortality in adult populations was a result of anthropogenic forces such as automobiles, farm machinery, and lawn mowers (Doroff and Keith 1990). In a degraded or disturbed area annual survival of adult female ornate box turtles was 0.816 (95% CI 0.69-0.94) and survival of adult males was 0.813 (0.70-0.93). In an undisturbed area annual survival was 0.932 (SE = 0.014) and 0.882 (SE = 0.022) for females and males respectively (Bowen et al. 2004).

In 1994, concern over population levels of all box turtle species in North America led to the listing of this species under Appendix II of the Convention on International Trade of Endangered Species of Wild Fauna and Flora (U.S. Fish and Wildlife Service 1995). Urban sprawl and habitat fragmentation have destroyed many areas where box turtles were once abundant. Habitat fragmentation threatens box turtles in several ways, including loss of forage, inability to find mates, edge effects, changes in environmental conditions, and increased predation. The best method for long-term conservation of box turtles is protection of the remaining natural habitat (Dodd 2001).

Because of the long lived and late maturing demographic life style of ornate box turtles it is predicted that fragmentation would increase their susceptibility to the threat of population declines. Between 1990 and 1993, the U.S. Fish and Wildlife Service documented that more than 81,233 box turtles at an estimated worth $494,845 were exported to Europe, Japan, and Hong Kong (Dodd 2001). These figures are believed to be an underestimate and the actual number exported is thought to be well over 100,000 (Dodd 2001). Although the 1994 CITES listing may have limited the commercialization and trade of box turtles within the United States the practice still continues (Dodd 2001). Such removals, compounded with habitat fragmentation, road mortality, and other human related factors such as mowing and road mortality, are thought to have had a major impact on box turtle populations especially in grasslands where ornate box turtles reside (Dodd 2001). Along with pressure from commercialization, habitat fragmentation within the Great Plains has resulted in ornate box turtles occupying less than 5% of their historic range (Lomolino and Smith 2003).

There are few long-term data related to ornate box turtles. Dodd (2001) states flatly that "there is a critical need for long-term studies on these long-lived chelonians." Though studies have examined various aspects of the ornate box turtles demography and movement (Legler 1960, Blair 1976, Doroff and Keith 1990, Claussen et. al. 1997, Nieuwolt-Daganay 1997, Converse et. al. 2002) little is published on populations located within sand prairie ecosystems. Furthermore, Nieuwolt-Daganay (1997) suggested that to assist in effective management of the ornate box turtles future research must focus on spatial ecology and habitat management.

INTRODUCTION

The largest vegetative province in North America is the native prairie. A significant portion of this province, the Great Plains Ecosystem, once extended from Canada to the Mexican border and from the foothills of the Rocky Mountains to western Indiana and Wisconsin (Samson and Knopf 1994). The prairies of the North American Great Plains are considered among the most endangered ecosystems on the continent (Samson et. al 2004). Prior to European settlement and agricultural development, approximately 162 million ha of prairie covered the Great Plains (Samson and Knopf 1994). The North American Prairie is composed of 3 main vegetation systems: tallgrass, mixed-grass, and shortgrass (Samson et. al 2004). With declines estimated at 82-99% since 1830, tallgrass prairie loss exceeds that of any other major ecosystem in North America, including remnant old-growth forest in the Pacific northwest, temperate rainforest in British Columbia and southeast Alaska, and bottomland hardwoods in the south-central United States (Samson and Knopf 1994). Declines in mixed-grass prairie have ranged from 30% in Texas to 99% in Manitoba and short grass prairies have decreased ranging from 20% in Wyoming to 85% in Saskatchewan (Samson and Knopf 1994).

Woody vegetation encroachment, defined as the establishment, development and spread of tree or shrub species, is considered among the leading causes of decline in grassland ecosystems (Huges et al. 2006). The use of land management practices such as fire suppression, enhanced seed distribution via livestock, and overgrazing have perpetuated the increase of woody legumes, such as honey mesquite (*Prosopis glandulosa*), in the twentieth century in the southern Great Plains (Archer 1990, Wright et. al 1976, Ansley et al 2001, Asner et al. 2003, Ansley and Castellano 2006). Among these practices, fire suppression has had a disturbing effect on the development and persistence processes of grassland ecosystems (Brockway et al. 2002). In the Great Plains, fire is a naturally reoccurring event often taking place annually in tallgrass prairies, every 3-5 years in mixed-grass prairies, and is considered an ecological driver for short grass prairies (Samson et al. 2004). In these ecosystems, periodic burning favors grasses by reducing woody species and discouraging the invasion of non-native plant species (Brockway et al. 2002). In the past 150 years, fire frequency and size have decreased within semiarid grasslands while the size and density of woody plants has increased leading to a reduction in grass biomass (Van Auken 2000).

With the extreme loss of prairie there is serious concern regarding decline of grassland specialists. There are 55 grassland species in the United States listed as threatened or endangered, and another 728 are candidates for listing (Samson and Knopf 1994). In an effort to restore grassland ecosystems and reduce woody vegetation encroachment recent land management practices have included the use of herbicides, mechanical manipulation, and the use of prescribed fire (Ansley and Catellano 2006). The use of prescribed fire increases plant species diversity and reduces standing biomass of herbaceous plants (Ford and McPherson 1996, Brockway et al 2002). Arthropod and vertebrate species have a diverse array of responses to prescribed fire and further research is needed (Ford and McPherson 1996).

Among the species of concern are North American turtles. Gibbons et al. (2000) considered the approximate global number of turtles to be 260, with 14% classified as endangered or threatened. In the Convention on the International Trade in Endangered

Species (CITES) 25 turtles species are listed in Appendix I , 49 turtle species are in Appendix II, and 6 turtle species are in Appendix III (Gibbons et al. 2000). Among the Appendix II listing is ornate box turtle (*Terrapene ornata ornata*; Dodd 2001). The majority of the ornate box turtle's known distribution is within the Great Plains Ecosystem, but there is a lack of information on the effects of fire on this species.

To better understand the relationship between fire and the ornate box turtle I examined the microhabitat use, habitat selection, and spatial ecology of the ornate box turtle within a prescribed fire matrix. My specific objectives were to (1) determine if ornate box turtles prefer or avoid habitat based on seasonally prescribed fire, (2) determine if male and female ornate box turtles exhibit the same spatial ecology, and (3) determine if canopy or cover influences microhabitat use by ornate box turtles.

STUDY AREA

The Rolling Plains eco-region extends north from the Edwards Plateau in Texas to western Oklahoma. Adapted to seasonal fire, the flat to rolling landscape of the Rolling Plains has native vegetation typical of mixed-grass plains, short-grass high plains, shinnery oak (*Quercus havardii*) grasslands, and mesquite grasslands. The 11,410 ha Matador Wildlife Management Area (WMA) lies within the central Rolling Plains (figure 1). Matador WMA was purchased by the state in 1959 with Pittman-Roberson funds by the Wildlife Division of Texas Parks and Wildlife Department for the purposes of wildlife research, wildlife management, and public use. The area is dominated by mesquite uplands, shinnery oak rangeland and gravelly hills consisting of red berry juniper (*Juniperus coahuilensis*) and honey mesquite (Becker et al. 2009). Common species of wildlife found on Matador WMA include northern bobwhite (*Colinus virginianus*), scissor-tailed flycatchers (*Tyrannus forficatus*), Mississippi kites (*Ictinia mississippiensis*), western diamondback rattlesnakes (*Crotalus atrox*), western coachwhip (*Masticophis flagellum*), western hognose snakes (*Heterodon nasicus*), Texas horned lizards (*Phrynosoma cornutum*), six-lined racerunners (*Cnemidophorus sexlineatus*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*Odocoileus virginianus*). Annual rainfall for Matador WMA varies from 55.9 – 76.2 cm with the greatest precipitation in late spring and fall (Figure I.2). Average maximum summer temperature is 36°C and average winter minimum temperature is -2°C (Becker et al. 2009).

METHODS

Burning and Experimental Design

My specific study site consisted of 273 ha dominated by sand sagebrush (*Artemisia filifolia*) - honey mesquite grasslands that were divided into 15 ~18-ha study plots (Figure I.1). Using a random block design, within each block 1 of 3 treatments (dormant season burning [winter], growing season burning [summer], and unburned) was assigned (Figure I.3). This resulted in 5 replicated blocks of 3 study plots. Initial burn treatments were conducted in February 2005 for dormant season plots and August 2005 for growing season plots. A second round of burning was conducted in August 2008 for growing season plots and January 2009 for dormant season plots.

Vegetation Sampling

To help examine any habitat differences among the study plots that resulted from burning treatments I conducted herbaceous and woody vegetation surveys. Herbaceous vegetation was sampled twice a year: in the late spring (May – June) and late summer/early fall (September – October) from May 2007 – October 2009, by using 100 randomly selected 50 x 20-cm quadrats within each of the 15 plots (Daubenmire and Daubenmire 1968). To sample each plot I started at the center of each plot and used the second hand of an analog watch to indicate the direction and the number of paces to be taken. After the direction and number of paces were determined and I reached the destination point, I blindly tossed the quadrat over my shoulder and then recorded cover and frequency. Canopy cover (%) was estimated for forbs, grasses, bare ground and litter. I repeated these steps (each having a new direction and distance) 100 times per plot per spring and fall sampling period. I used analysis of variance to compare differences in canopy cover (% bare ground, litter, grass, forbs) with season, treatment, and year as main effects and also examined season*treatment, season*year, treatment*year, and season*treatment*year interactions.

To sample woody vegetation I estimated horizontal woody canopy cover in each study plot using the line intercept method (Chambers and Brown 1983). Within each plot, 3 evenly distributed 200-m north and south running parallel main transects were established. On each 200-m transect a 30-m line was placed perpendicular to the north-south running transect every 40-m for a total of 6 lines per transect. Originating direction of each line was determined randomly by flipping a coin (heads = east, tails = west; Figure I.4). Woody canopy cover was then recorded as the number of centimeters of tape along the 6 30-m line (180 meters total) that intersected woody stems for each species. Thus, canopy was estimated as the cumulative (cm) cover averaged across the 3 transects within each plot. I used analysis of variance to compare differences in canopy cover for sandsage, honey mesquite, yucca (*Yucca glauca*), and shinnery oak with treatment and year as the main effect for woody vegetation.

Capture and Radio Telemetry

As part of an ongoing mark/recapture program initiated by Texas Parks and Wildlife Department ornate box turtles were captured within the study area by road cruising or fortuitous encounters. Once captured the turtles were sexed by tail length and iris, weighed (g), measured (mm), and given a unique notch code on its marginal scutes so that the turtle could then be individually identified. At each turtle capture site a GPS (Global Positioning System) point was taken using a Garmin Etrex GPS unit (Garmin International, Olathe, KS, USA). Turtles captured within the prescribed fire matrix were outfitted with radio transmitters (Holohil Systems, Carp, Ontario, Canada). In 2007 (June-September) transmitters used were 2 – year – old, 0.95 g, 45 day transmitters. In late September of 2007, monitored turtles were recaptured and outfitted with RI 2-B, 14.3 g, 24 month transmitters. Turtles captured and monitored after September 2007 where equipped with RI 2-B transmitters. RI 2-B transmitters were flat on the bottom and elliptical in shape. Using silicone, the transmitters were affixed to the carapace of the turtle and covered with local soil to aid in camouflaging the transmitter then released at the point of capture (Kazmaier et al. 2002). During the primary active season (May-

August) turtles were relocated daily and for the remainder of the year (September-April) turtles were relocated weekly and a GPS point recorded at each location.

Habitat Selection

To assess the habitat selection of ornate box turtles in relation to seasonality fire, radiolocations were loaded into a geographic information system (Arcview ver. 3.3; ESRI, Redlands, CA, USA) to assign a treatment (winter burn, summer burn, unburned) to each location. I used compositional analysis to determine if treatment influenced space use by ornate box turtles (Aebischer et al. 1993). Home range size was determined using 100% minimum convex polygons (MCP; Kie et al. 1994). Calculations were then made to determine the amount of area used in each treatment within the 100% MCP and the entire study area. The study area was defined as the smallest rectangle that contained all relocation points. Using 2nd Order compositional analysis I compared use (= proportion of each 100% MCP within each treatment) versus availability (= proportion of the total study area within each treatment; Johnson 1980). Then using 3rd Order compositional analysis I compared use (= proportion of each turtles radiolocations within each treatment) verses availability (= proportion of each 100% MCP within each treatment; Johnson 1980). For this and all subsequent comparisons $\alpha = 0.05$.

Microhabitat Use

To evaluate microhabitat use, at each radiolocation event the percent cover (= herbaceous vegetation) and percent canopy (= woody vegetation) was estimated immediately above the turtle. Dominant species responsible for cover and canopy was also recorded. The top five dominant species for cover and canopy were individually averaged for each turtle and then averaged among all turtles to determine use. To document if turtles made use of existing holes or burrows a yes or no was recorded at each relocation event. The total number of radiolocations involving use of a hole or burrow was divided by the total number of radiolocations for each individual, and the percentage of each turtles use of hole/burrow was then averaged among all turtles.

Activity

To examine variation in activity at different temporal scales, I calculated spatial statistics at 4 time scales: cumulative (= entire study duration), annual, seasonal, and monthly. Seasons were defined as Spring = 16 February – 15 May, Summer = 16 May – 15 August, Fall = 16 August – 15 November, and Winter 16 November – 15 February. I calculated cumulative home ranges using 100% minimum convex polygons (MCP), 95% MCP, 95% bivariate normal ellipses, and 95% fixed kernels (Mohr 1947, Jennrich and Turner 1969, Worton 1989) using the animal movement program within Arcview 3.3 (ESRI, Redlands, CA, USA; Hooge et al. 1999). Similarly, I calculated annual home ranges using 100% MCP, 95% MCP, 95% bivariate ellipses, and monthly and seasonal activity ranges using 100% MCP and 95% bivariate ellipses. To examine movement patterns, I calculated total distance (movement between all relocation points from first to last), maximum distance (largest individual movement between two relocations), and speed (average daily distance moved; Kie et al. 1996) within a GIS at all four time scales. I set a minimum number of radiolocations required to calculate spatial statistics as 113 for cumulative, 50 for annual, 20 for seasonal, and 8 for monthly time scales. I used analysis of variance to compare differences in home ranges and activity with sex as a main effect for cumulative, sex and year as main effects for annual, sex and season as main effects for seasonal, and sex, month, and year as main effects for monthly calculations.

To examine daily turtle activity patterns I recorded at each relocation event the time and each turtle's activity (active or inactive). An "active" turtle was described as traveling, feeding, etc. An "inactive" turtle was observed sleeping or in a hole. Locations were then grouped by hour (i.e., 0800-859, 0900-0959, etc.) and the number of active turtle locations were divided by the total number of locations for that hour. To identify hourly activity patterns I examined all relocation points throughout the study, cumulative monthly relocation points for the active season (April-October), and yearly (2007, 2008, 2009) average daily activity.

Bootstrapping and Site Fidelity

Within the Animal Movemment Extension within ArcView 3.3 I used Boot-strapping determine the number of radiolocations needed to characterize "a stable" 100% MCP home range size (Hooge et al. 1999) for each turtle . Site Fidelity Tests within the Animal Movement Extension were used to determine if each turtle exhibited movement that was random, more constrained than random, or less constrained than random (Hooge et al. 1999). I assumed that any turtle that exhibited a movement pattern that was more constrained than random was exhibiting site fidelity.

Survival

I used the Kaplan-Meier staggered entry procedure to estimate annual survival rates from radiotelemetry data adjusted to a single year (Pollock et al. 1989, Kazmaier et al. 2001). I compared annual survival and shapes of the survival curves between females and males with SAS code from White and Garrott (1990). I assumed all censored individuals were dead to derive minimum survival estimates and all censored individual were alive to derive maximum survival estimates. I compared annual survival and shapes of the survival curves between censored = live and censored = dead groups with SAS code from White and Garrott (1990).

RESULTS

Vegetation

Cover by bare ground or litter did not differ between spring and summer ($p \geq 0.666$, Table I.1). Grass cover was higher in summer (mean = 73.5%, SE 2.1) than in spring (mean = 67.6%, SE 2.2; $p \leq 0.001$). Forb cover was higher in spring (mean = 59.6%, SE 2.7) than in summer (mean = 30.3%, SE 1.9; $p \leq 0.001$; Table I.1). All measures of herbaceous vegetation cover (bare ground, litter, grass, forbs) varied by year ($p \leq 0.019$; Table I.2). Bare ground was significantly ($p \leq 0.001$) higher in summer burned treatments (mean = 10.0%, SE 1.5) than winter burned treatments (mean = 5.9%, SE 0.8; Table I.3). However, bare ground in unburned treatments (mean = 2.3 %, SE 0.7) was significantly ($p \leq 0.001$) lower than both summer burn (mean = 10.0%, SE 1.5) and winter burn treatments (mean = 5.9%, SE 0.8; Table I.3). Litter cover was significantly

($p \leq 0.001$) higher in unburned treatments (mean = 97.5, SE 89.9) than in both summer (mean 89.9, SE 1.5) and winter treatments (mean = 93.6 %, SE 0.9; Table I.3). Litter cover was higher in winter burn treatments (mean = 93.6 %, SE 0.9) than summer burn treatments (mean 89.9, SE 1.5; $p \leq 0.001$; Table I.3). Similarly, grass cover was higher in unburned treatments (mean = 76.9, SE 2.4) than in winter burned (mean = 70.9, SE 2.3) and summer burned treatments (mean = 63.9, SE 2.9; $p \leq 0.001$; Table I.3). Grass cover was higher in winter burned treatments (mean = 70.9, SE 2.3) than summer burned treatments (mean = 63.9, SE 2.9; $p \leq 0.001$; Table I.3). Forb cover did not differ by treatment ($p = 0.102$; Table I.3).

Woody vegetation did not vary by year ($p \geq 0.504$) for honey mesquite, yucca, or shinnery oak (Table I.4). Sandsage was higher in higher in 2007 (mean = 3109 cm, SE 360) than in 2008 (mean = 1775 cm, SE 187) and 2009 (mean = 1587 cm, SE 235; $p \leq 0.001$). Sandsage was significantly ($p = 0.005$) lower in summer burn treatments (mean = 1584 cm, SE 195) than in unburned (mean = 2570 cm, SE 346) and winter burn treatments (mean = 2318 cm, SE 350; $p = 0.005$). Honey mesquite was significantly ($p \leq 0.001$) lower in both winter burn (mean = 216 cm, SE 44) and summer burn treatments (mean = 252 cm, SE 84) than unburned treatments (mean = 772 cm, SE 115). No difference ($p = 0.279$) was detected in treatment for yucca and shinnery oak was only approaching significance ($p = 0.060$; Table I.5).

Habitat selection

I recorded 5,337 relocations from 31 ornate box turtles (females: n =15, radiolocations = 3004; males: n = 12, radiolocations = 2201; juveniles: n =4, radiolocations = 132) from 21 June 2007 – 22 April 2010. In 2nd order compositional analysis no selection was detected ($\lambda = 0.9926$, $X^2 = 0.2301$, $p = 0.891$). Likewise, in 3rd order compositional analysis there was no selection based on treatment ($\lambda = 0.9625$, $X^2 = 1.1849$, $p = 0.553$).

Microhabitat Use

The 31 ornate box turtles monitored from 21 June 2007 – 22 April 2010 used preexisting holes 35.94% of the time. Dominant cover use was represented by more than 50 different species of herbaceous vegetation. The principal use by ornate box turtles for cover (herbaceous vegetation) was either no cover (22.5%) or litter (19.6%; Figure I.5). The three types of living vegetation most often used were Texas blue grass (*Poa arachnifera*; 11.7%), Western ragweed (*Ambrosia psilostachya*; 9.48%), and sleepy daisy (*Xanthisma texanum*; 7.97%; Figure I.5). Canopy use was dominated primarily by honey mesquite (*Prosopis glandulosa*; 33.5%), no cover used (31.8%), or Sand sagebrush (*Artemisia filifolia*; 31.6%; Figure I.6).

Activity

Cumulative--The number of days monitored and the number of radiolocations was not significantly different between males and females ($p \geq 0.534$; Table I.6). Home range size among individual ornate box turtles did vary greatly (Figure I.7). For cumulative home ranges, males had slightly larger home ranges than females (Table I.6). Males had an average 100% MCP cumulative home range of 6.34 ha (SE = 1.25) and females averaged 5.29 ha (SE = 1.34) but this difference was not significant ($p = 0.584$). There was also no significant difference ($p \geq 0.245$) in 95% bivariate ellipse size between males (mean = 7.52 ha, SE = 1.44) and females (mean = 4.9 ha, SE = 1.54; $p = 0.245$). Likewise there was no significant difference in 95% fixed kernel home range size between males (mean = 2.84 ha, SE = 0.56) and females (mean= 2.54 ha, SE = 1.04; $p = 0.814$).

Maximum distance moved between locations did not differ between males (mean = 297 m, SE = 36.4) and females (mean = 270 m, SE = 45.6; $p = 0.669$). The total distanced moved tended to be higher for males (mean = 9819 m, SE = 1048) than females (mean 7182 m, SE = 801; $p = 0.055$). Average daily distance moved was higher for males (mean = 14 m/day, SE = 1.3) than females (mean 9.8 m/day, SE = 0.9; $p = 0.015$).

Annual--The number of days monitored and the number of radiolocations did not differ between the sexes ($p \geq 0.315$; Table I.7). However number of days monitored and the number of radiolocations did vary by year ($p \leq 0.001$) with 2007 having less effort than 2008 and 2009 (Table I.8). Annual home range did not differ between the sexes ($p \geq 0.142$; Table I.7). However, 100% MCP home ranges did differ by year ($p = 0.034$) with home ranges in 2007 being much smaller than home ranges in 2009 (Table I.8). Neither 95% MCP home ranges nor 95% bivariate normal ellipse home ranges differed by year ($p \geq 0.264$; Table I.8). There were no sex*year interactions for any annual home range estimate ($p \geq 0.315$; Table I.9).

There was no significant difference ($p \geq 0.175$) between the sexes in speed or maximum distance (Table I.7). Males (4484 m, SE = 391) had a significantly ($p = 0.033$) larger total distance moved than females (3203 m, SE = 242). When comparing the movement of all turtles by year there was significant difference ($p \leq 0.022$) in total distance, speed, and maximum distance (Table I.8). For the annual two-way interaction of sex and year there was no significant differences ($p \geq 0.330$) in maximum distance or speed, although total distance was approaching significance ($p = 0.079$; Table I.9).

Monthly--Cumulative monthly days monitored and radiolocations did not vary ($p \geq 0.157$) by sex (Table I.10), but did vary ($p \leq 0.001$) by month (Table I.11). In 2008 and 2009 there was no significant difference ($p = 0.660$) in monthly days monitored but there was a significant difference ($p = 0.001$) in number of radiolocations (Table I.12). There was no difference ($p \geq 0.288$) in days monitored or radiolocations for monthly two-way interaction of sex*month (Table I.13) or sex*year (Table I.14). For the three-way interaction of sex*month*year there was a difference ($p = 0.001$) in both days monitored and radiolocations (Table I.15).

There was a significant difference in monthly home ranges by ($p \leq 0.009$) sex (Table I.10) and year (Table I.12). When all turtle home ranges were compared by month there was a significant difference in 95% bivariate ellipse size ($p = 0.035$) however it was only approaching significance in 100% MCP ($p = 0.051$; Table I.11). For the two-way interaction of sex*month home range it was approaching significance for 100% MCP ($p = 0.097$) but not significant ($p = 0.100$) for 95% bivariate ellipse (Table I.13). No significant difference ($p \geq 0.484$) was found when comparing the two-way interaction of sex*year (Table I.14) or the three-way interaction of sex*month*year (Table I.15) home ranges.

All forms of measured movement (total distance, speed, maximum distance) were significant ($p \leq 0.042$): cumulative monthly movement by sex (Table I.10), month (Table I.11), and month*year (Table I.12), and sex*month (Table I.13). However, no significant ($p \geq 0.147$) movement was observed for the two-way interaction of sex* year (Table I.14) or the three-way interaction of sex*month*year (Table I.15).

Seasonal--The cumulative season days monitored and radiolocations did not differ significantly ($p \geq 0.187$) for sex (Table I.16) or the two-way interaction of sex*season (Table I.18). Days monitored and radiolocations did differ significantly ($p = 0.001$) by season (Table I.17). For seasonal home ranges there was a significant difference ($p \leq 0.028$) in both sex (Table I.16) and season (Table I. 18). But there was no observed significance ($p \geq 0.298$) in the two-way interaction of sex*season (Table I.18). Seasonal movement for all effects (sex, Table I.16; season, Table I.17; sex*season, Table I.18) were significant ($p \leq 0.026$).

Daily-- Daily activity of ornate box turtles was bimodal with the greatest activity occurring in the morning and late afternoon (Figure I.8-I.10). Based on individual months ornate box turtle activity was highest between 0800-0859 in June, July, and August, 0900-0959 in May, September, and October, and 1200-1259 in April (Figure I.9). Ornate box turtles had the highest activity between the hours of 0900-0959 in 2007, and 0800-0859 in 2008 and 2009 (Figure I.10).

Bootstrapping and Site Fidelity

The number of radio relocations required to characterize the home range of the ornate box turtle averaged 104 ($\sigma = 49$, $n = 12$) for females and 96 ($\sigma = 27$, $n = 10$) for males. Twelve of 13 female turtles had observed movement classified as more constrained than random ($p \leq 0.017$). The observed movement in one female turtle was considered random ($p = 0.092$; Figure III.13). All male turtles had movements that were more constrained than random ($p < 0.05$).

Survival

Female vs. Male Survival--Seventeen female ornate box turtles were radiotracked for 8,826 radio-days (1 radio-day is one radiotransmitter on one ornate box turtle). Four female turtles were censored (= unknown fate) and 1 died in the prescribed fire conducted on 12 August 2008. Kaplan-Meier annual survival for female turtles in which censored individuals considered dead was 0.84 and survival with censored individual considered alive was 0.97. Thirteen male ornate box turtles were tracked for 6,774 radio-days. Three male turtles were censored and I recovered 2 presumably avian predation related mortalities. Annual survival for male turtles was 0.65 (censored = dead) or 0.75 (censored = live). Annual survival tended to be higher for females than males when censored individuals were considered dead ($p = 0.059$). Curve shapes did not differ between females and males ($X^2 = 1.78$, $p = 0.182$ when censored = live; $X^2 = 0.10$, $p = 0.749$ when censored = dead).

Overall Survival—Regardless of sex, annual survival of turtles was 0.75 when censored individuals were considered dead and 0.87 when censored turtles were considered alive. These differences approached significance ($p = 0.066$). Curve shapes did not differ whether censored individuals were considered alive or dead ($X^2 = 2.641$, $p = 0.104$).

DISCUSSION

Habitat Selection

I detected no selection of habitat by ornate box turtles based on treatment type. One possible explanation of these results is that prescribed fire has no effect on ornate box turtle habitat selection. Ornate box turtles have a large and extensive geographic range that includes many different types of habitats from semiarid or arid sandy plains to oak-walnut woodlands (Ernst and Lovich 2009). Within these habitats the ornate box turtle often displays a remarkable versatility for occupying microhabitats that differ significantly in food supply, temperature, moisture, and soil type (Legler 1960, Doroff and Keith 1990). Because of this wide use of microhabitats, ornate box turtles may be unaffected by the changes produced by prescribed fire in a sand prairie ecosystem.

Conversely, it is possible that the treatments have not undergone enough burn cycles to facilitate a large enough change in habitat variables important to the ornate box turtle. The effect of prescribed fire on grassland production varies from one habitat to another (Heirman and Wright 1973). Often repeated fires are needed to reduce woody vegetation and alter the habitat (Heirman and Wright 1973, Trlica and Schuster 1969). While I observed that honey mesquite coverage was lower in both the summer and winter burned treatments from the unburned treatments and that sand sage coverage was lower within summer treatments, the difference may not be enough to affect the microhabitat of ornate box turtles. Therefore to test this hypothesis it would benefit to replicate this study after 4-5 burn cycles (burn cycle = every 4-5 years).

Microhabitat Use

Ornate box turtles at Matador WMA frequently used pre-existing holes. My research supported previously published data that ornate box turtles uses holes, limestone shelves, or small mammal burrows for hibernacula or for shelter (Metcalf and Metcalf 1979, Franklin 2003). Box turtles frequently used Texas bluegrass in my study. This is most likely because Texas bluegrass often in grows in association with sandsage brush, which was commonly used as canopy cover (Pitman and Read 2007). Moreover, Texas bluegrass is a cool season grass and during the summer months will die and then be considered litter, the dominant cover used by turtles. It is reasonable to conclude that its high use was because of its association with sand sagebrush for these. Sand sagebrush was the third most dominant canopy closely behind honey mesquite and no cover. In the sandhills of Nebraska nearly all shrubs used by ornate box turtles were of yucca (*Yucca glauca*; Converse and Savidge 2004), which was the fourth most common cover type used in my study. However, Converse and Savidge (2004) stated that this is probably because of availability. In my study area the 2 most dominant woody species are honey mesquite and sand sagebrush. Therefore ornate box turtle use of these 2 species for cover is most likely because of their availability.

Activity

Home Range--In Wisconsin ornate box turtle annual home ranges calculated using 100% harmonic means (Dixon and Chapman 1980) were slightly larger than those in my study, with average female home ranges of 12.0 ha in 1986 (n = 17) and 6.90 ha (n = 12) in 1987 (Doroff and Keith 1990). Males at the same site averaged 8.20 ha (n = 13) in 1986 and 3.4 ha in 1987 (n = 5; Doroff and Keith 1990). My turtles also exhibited year to year variability. While in neither study was the home range significantly different between females and males, females in Wisconsin had a larger home range than males, while in my study males were observed to have a larger home range (Doroff and Keith 1990). At Matador WMA average annual female home range size was 1.92 ha in 2007, 2.49 ha in 2008, and 5.27 ha in 2009. Likewise male home ranges were 2.77 ha in 2007, 3.77 ha in 2008, and 5.52 ha in 2009. One of the difficulties in comparing my study to others is that the methods and styles of reporting home ranges varied in the literature. Moreover, the duration for which home ranges were calculated differed. None the less my results agree with other studies conducted in Iowa and Texas that reported larger home ranges for male ornate box turtles than females (Blair 1976, Bernstein et al 2007).

In my study monthly activity ranges where larger for males than females. This is in contrast to Bernstein et al. (2007) who in Iowa found no difference between the sexes in monthly MCP, but did find a difference in annual home ranges. Bernstein et al. (2007) also found ornate box turtles to be the most active in May and June. Turtles at Matador WMA were most active in June and August (Figure I.12). Although it was found not to be significant males had much larger home range activity than females in August and

September. Females had a larger home range activity than males in the month of June. This female movement is most likely because the primary nesting period for an ornate box turtle is in June (Legler 1960). Male movement in August and September is likely tied to courtship. In the ornate box turtle the female ovarian cycle begins in July soon after ovulation (Ernst and Lovich 2009).

When comparing 100% MCP seasonal home range movements averaged from June 2007 – April 2010, males used significantly larger area than females. However, no overall interaction between sex*season was detected. Male turtles did move significantly more than females in the fall of 2008 and 2009. No detection in movement rates between the sexes in the fall of 2007 is likely to the small sample size of males (n = 2). This difference in fall movement is again likely tied to reproduction (Ernst and Lovich 2009). At Matador WMA there was a significant difference in seasonal home ranges among all turtles. This is primarily because of large home ranges in the summer of 2009. In the summer of 2009 the mean home range for all turtles was more than double the size for the fall of 2007, fall 2008, fall 2009, and summer 2008. It was nearly 4.5 times larger than the spring of 2009, and nearly 7.5 times larger than the spring of 2008.

These large differences in seasonal activity ranges may be related to weather. In the summer of 2008 turtles appeared to go into estivation for several days especially around the end of July to mid August because of high daily temperatures (> 37°C). Turtle #205 did not move from 31 July-16 August and turtle # 209 did not move from 31 July-11 August. The overall turtle home range size for the summer of 2008 was half that observed in 2009. Conversely milder temperatures in 2009 suggest that box turtle movement is strongly influenced by temperature.

Movement--In nearly all forms of movement (total distance, mean distance, speed, etc) and all home range analyses (cumulative, annual, monthly, etc.) males exhibited or tended to exhibit greater activity than females. The only noticeable exception to this pattern is during the month of July, where females tended to have larger total distances moved and mean speed. This pattern was consistent for 2008 and 2009. Legler (1960) also reported that males on average had larger daily movements than females. However average daily movement for Legler's (1960) turtles in Kansas were 110.64 m for gravid females, 68.88 m for non-gravid females in June. This is much larger than those observed at Matador WMA where the mean speed for females was 22.94 m. Legler (1960) reported an average daily movement of 88.08 m for males, whereas daily movement of my male turtles averaged only 28 m. The daily movement differences reported by Legler (1960) in Kansas and the movements I observed at Matador may be attributed to regional variation or they may be attributed to the differences in techniques used. Legler (1960) tracked daily movement by using thread trailing (Claussen et al 1997). For our study information was calculated through point data using radio relocations. In radio telemetry daily movement is calculated in a straight line from one relocation point to another. Whereas thread trailing actually documents the precise pathway used by a turtle. Thus, thread-trailing will always give longer estimates of activity than radiotelemetry, but comparative studies of the 2 techniques are lacking.

Of the 5,334 radio relocations observed at Matador WMA from 21 June 2007-22 April 2010 ornate box turtles were classified as inactive for 79% of my observations. This is similar to a study in Nebraska which reported that 80% of all turtles observed where inactive (Converse et al 2002). The daily activity patterns of ornate box turtles at

Matador WMA where similar to those found in other studies (Legler 1960, Converse et al 2002). Turtle's activity was bimodal to coincide with average daily temperatures. Turtles became less active and sought refuge from the heat as the day progressed with the lowest level of activity during the hottest part of the day from 1400-1600. Though the bimodal pattern remained constant through the ornate box turtles active season (April-September) there was hourly variation throughout the months (Figure I.9). This is most likely attributed to daily maximum temperature averages that vary by month.

Survival

Ornate box turtle survival at Matador WMA differed considerably depending on whether censored individuals were considered alive or dead. When censored individuals were considered alive at Matador WMA, female survival closely resembled that of a study in Illinois (survival = 0.99; Bowen et al 2004). However estimated annual survival of male turtles in Illinois (0.90) was much higher than that observed at Matador WMA. When censored individuals are considered dead, then annual survival is considerably lower at Matador WMA compared to the population in Illinois. Annual survival at Matador WMA more closely resembled annual survival of a mark/recapture population in Wisconsin which averaged 0.81 for both sexes over a 10 year period (Doroff and Keith 1990). However, during the 10 year study annual survival showed considerable variation and ranged from 0.51 – 1.00. Doroff and Keith (1990) radio-tagged individuals and annual survival was 0.96 in 1986 (4,126 radio-days) and 0.91 in 1987 (3,315 radio-days).

During the course of my study 7 adult box turtles (4 female, 3 male) were classified as censored (unknown fate). Six of these cases can possibly be explained by transmitter failure. In the summer of 2007 six of the censored turtles were tracked using 45 day, 0.95 g Holohil transmitters. Because of their small size and age, transmitter signals became undetectable between 21-30 days. No signal failure was observed for any of the new Holohil Systems RI 2-B, 14.3 gram, 24 month transmitters. Only the transmitter of the remaining censored turtles was found on the morning of 29 July 2008. The transmitter had bite marks on the antenna and was found in a shelterbelt east of the burn plots. This could be the possible result of raccoon (*Procyon lotor*) predation, but after an intensive search of the area no carcass was found. In 2 studies conducted in Kansas the following species were observed as predators of the ornate box turtle: raccoons, striped skunks (*Mephitis mephitis*), American badger (*Taxidea taxus*), and the coyote (*Canis latrans*) all of which have been documented on Matador WMA (Legler 1960, Metcalf and Metcalf 1979).

Three turtles were found dead (1 female, 2 males). The female died as a direct result of the summer prescribed fire conducted on 12 August 2008. Of the prescribed fires conducted on August 12, 13, and 21 this was the only fatality out of a possible ten turtles using summer burn plots during the prescribed fires. The two male mortalities were the result of predation. Both turtle #213 (18 June 2009) and #115 (22 June 2009) were found in unburned plot 2 (Figure I.3). For both turtles only the shell was found and the inside of the turtle stripped. In the case of turtle #213 there was still fresh blood on the shell when it was relocated on 18 June 2009. The two predations appear to be avian and red-tail hawks (*Buteo jamaicensis*), which are known predators on box turtles (Ernst and Lovich 2009), are common in the vicinity.

Summary

The ornate box turtles I studied at Matador WMA showed similar spatial ecology to other studies conducted throughout their known distribution. As reported in Wisconsin (Doroff and Keith 1990) and Iowa (Bernstein et al. 2007) ornate box turtles at Matador WMA displayed annual and monthly variation in home range size and activity. As observed in populations found in Iowa (Bernstein et al. 2007) and Texas (Blair 1976) male ornate box turtles at Matador WMA had slightly larger home ranges than females. Male ornate box turtles were observed to have significantly larger monthly and seasonal home range movement activity and greater daily movements. Bernstein et al. (2007) reported that ornate box turtles in Iowa were the most active in May and June, this is in contrast to ornate box turtles at Matador WMA where activity was highest in the months of June and August.

Similar to observations in Nebraska (Converse and Savidge 2004) ornate box turtles showed a daily bimodal activity pattern with highest activity occurring in the early morning and late evening. As reported in Kansas, Nebraska, Iowa, Wisconsin, and Texas ornate box turtles made use of pre-existing burrows and holes generated by other animals. Litter and Texas bluegrass were important cover refuge for ornate box turtles at Matador WMA while sandsage and honey mesquite provided the dominant canopy.

I found that annual survival for Matador WMA box turtles to be lower than those reported in populations observed in Illinois and Nebraska. Further investigation is needed to determine what variables affect ornate box turtle survival at Matador WMA. The early stages of a seasonal prescribed fire burn regime appear to have minimal affects on ornate box turtles. My study resulted with only a single observed mortality directly associated with summer prescribed fire and no mortalities connected to winter prescribed fires. After 2 burn cycles (4-5 years) I failed to detect an effect on habitat preference or avoidance by ornate box turtles for summer or winter prescribed fires in a sand prairie ecosystem.

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Table I.1: Seasonal differences in percent cover of bare ground, forbs, grasses, and litter from 100 0.1-m^2 quadrats per plot per season at Matador Wildlife Management Area, Cottle County, Texas, 2007 – 2009.

	Spring		Summer		
	Mean	SE	Mean	SE	P-Value
Bare ground	6.2	0.9	5.9	1.1	0.666
Litter	93.5	1.0	93.8	1.1	0.788
Grass	67.6	2.2	73.5	2.1	<0.001
Forbs	59.6	2.7	30.3	1.9	<0.001

Table I.2: Annual differences in percent cover of bare ground, forbs, grasses, and litter from 100 0.1-m^2 quadrats per plot per season at Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at $\alpha = 0.05$.

	2007		2008		2009		
	Mean	SE	Mean	SE	Mean	SE	P-Value
Bare ground	4.3a	0.9	6.7b	1.4	7.3b	1.1	0.004
Litter	95.4a	1.1	93.3ab	1.4	92.3b	1.2	0.019
Grass	70.6ab	3.1	67.5a	2.7	73.6b	2.2	0.005
Forbs	59.5a	3.5	30.5b	2.3	44.8c	3.7	<0.001

Table I.3: The influences of seasonality of burning on percent cover of bare ground, forbs, grasses, and litter from 100 0.1-m^2 quadrats per plot per season at Matador Wildlife Management Area, Cottle County, Texas, 2007 – 2009. Within a row, means followed by the same letter are not different at $\alpha = 0.05$.

	Unburned		Summer Burned		Winter Burned		
	Mean	SE	Mean	SE	Mean	SE	P-Value
Bare ground	2.3a	0.7	10.0b	1.5	5.9c	0.8	<0.001
Litter	97.5a	0.9	89.9b	1.5	93.6c	0.9	<0.001
Grass	76.9a	2.4	63.9b	2.9	70.9c	2.3	<0.001
Forbs	47.4	4.5	44.9	3.7	42.5	3.5	0.102

Table I.4: Canopy cover (cm) for common woody species collected from the line intercept method (180 m total) at Matador Wildlife Management Area, Cottle County, Texas, 2007 – 2009. Within a row, means followed by the same letter are not different at $\alpha = 0.05$.

	2007		2008		2009		
	Mean	SE	Mean	SE	Mean	SE	P-Value
Sand sage	3109.7a	359.9	1775.4b	186.9	1587.4b	234.6	<0.001
Honey mesquite	409.9a	101.9	442.8a	110.9	387.7a	114.8	0.861
Yucca	94.7a	25.5	71.5a	15.8	70.9a	18.0	0.504
Shinnery oak	102.4a	81.8	50.1a	44.7	142.7a	127.8	0.699

Table I.5: Canopy cover (cm) for common woody species from the line intercept method (180 m total) at Matador Wildlife Management Area, Cottle County, Texas, 2007 – 2009. Within a row, means followed by the same letter are not different at α = 0.05.

	Unburned		Summer Burned		Winter Burned		
	Mean	SE	Mean	SE	Mean	SE	P-Value
Sand sage	2570.0a	346.2	1584.0b	195.1	2318.3a	350.0	0.005
Honey mesquite	772.3a	114.8	252.4b	83.8	215.6b	43.7	<0.001
Yucca	65.0a	14.5	100.3a	19.8	71.9a	24.5	0.279
Shinnery oak	0.0a	0.0	253.0b	148.4	42.2ab	35.7	0.060

Table I.6: Cumulative days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% fixed kernels (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female (*n* = 12) and male (*n* = 9) ornate box turtles with a minimum of 113 relocation points monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas.

	Female		Male		
	Mean	SE	Mean	SE	P-Value
Days monitored	728.3	41.7	695.7	20.4	0.534
Radiolocations	240.3	17.1	227.2	14.5	0.583
100% MCP	5.29	1.34	6.34	1.25	0.584
95% MCP	4.04	1.41	8.30	3.78	0.256
95% Fixed kernels	2.54	1.04	2.84	0.56	0.814
Bivariate ellipse	4.90	1.54	7.52	1.44	0.245
Total distance	7182	802	9819	1048	0.056
Speed	9.8	0.9	14.0	1.3	0.015
Maximum distance	270.0	45.6	296.7	36.4	0.670

Table I.7: Annual days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female (*n* = 26) and male (*n* = 19) ornate box turtles with a minimum of 50 relocation points per year monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas.

	Female		Male		
	Mean	SE	Mean	SE	P-Value
Days monitored	268.5	16.5	273.9	19.4	0.914
Radiolocations	104.1	4.7	101.7	6.0	0.315
100% MCP	3.58	0.67	4.40	0.61	0.464
95% MCP	2.09	0.45	3.46	4.78	0.142
Bivariate ellipse	4.34	0.90	6.76	1.04	0.212
Total distance	3203	242	4484	391	0.033
Speed	13.0	1.3	16.9	1.2	0.175
Maximum distance	221.5	25.6	251.2	22.9	0.634

Table I.8: Annual days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha) home ranges, total distance (m), speed (m), and maximum distance (m) moved ornate box turtles with a minimum of 50 relocation points per year monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	2007 (*n* = 6)		2008 (*n* = 20)		2009 (*n* = 19)		
	Mean	SE	Mean	SE	Mean	SE	P-Value
Days monitored	137.2a	10.5	259.9b	17.1	324.5c	8.8	<0.001
Radiolocations	70.3a	5.3	100.7b	6.1	115.9c	2.2	<0.001
100% MCP	2.20a	0.56	3.06a	0.52	5.38b	0.96	0.034
95% MCP	1.63a	0.43	2.43a	0.46	3.25a	0.62	0.264
Bivariate ellipse	3.16a	0.90	4.93a	1.04	6.50a	1.17	0.302
Total distance	2812a	408	3136a	234	4677b	395	<0.001
Speed	21.5a	4.2	12.9b	1.2	14.3b	1.2	0.022
Maximum distance	165.6a	27.0	198.4a	18.7	293.3b	31.5	0.015

Table I.9: Annual days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female (2007, *n* = 4; 2008, *n* = 11; 2009, *n* = 11) and male (2007, *n* = 2; 2008, *n* = 9; 2009, *n* = 9) ornate box turtles with a minimum of 50 relocation points per year monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	2007				2008				2009				
	Female		Male		Female		Male		Female		Male		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*p*
Days monitored	140.3a	16.1	131.0a	6.0	262.9a	23.5	256.1a	26.4	320.7a	12.2	329.8a	13.3	0.905
Radiolocations	76.8a	4.9	57.5a	4.5	102.0a	8.6	99.1a	9.2	116.1a	3.3	115.8a	2.9	0.640
100% MCP	1.92a	0.40	2.77a	1.79	2.49a	0.65	3.77a	0.81	5.27a	1.32	5.52a	0.97	0.865
95% MCP	1.36a	0.29	2.16a	1.38	1.93a	0.67	3.04a	0.59	2.51a	0.85	4.26a	0.84	0.868
Bivariate ellipse	2.70a	0.73	4.10a	2.75	3.73a	1.36	6.41a	1.53	5.54a	1.61	7.82a	1.69	0.960
Total distance	2875a	487	2684a	1026	2760a	282	3596a	346	3766a	431	5932b	447	0.079
Speed	22.2a	6.0	20.2a	6.9	11.1a	1.3	15.2a	2.0	11.6a	1.2	18.03a	1.4	0.330
Maximum distance	168.6a	33.5	159.8a	64.2	177.8a	18.1	223.6a	34.6	284.6a	52.2	305.2a	25.7	0.864

Table I.10: Monthly days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female (*n* = 120) and male (*n* = 94) ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas.

	Female		Male		
	Mean	SE	Mean	SE	P-Value
Days monitored	27.1	0.3	27.0	0.3	0.827
Radiolocations	15.7	0.6	15.2	0.6	0.157
100% MCP	0.88	0.14	1.36	0.12	0.009
Bivariate ellipse	2.45	0.38	4.00	0.38	0.005
Total distance	519	31	706	39	<0.001
Speed	18.8	1.1	26.1	1.4	<0.001
Maximum distance	125.6	8.3	159.5	8.2	0.002

Table I.11: Monthly days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	April (*n* = 25)		May (*n* = 29)		June (*n* =39)	
	Mean	SE	Mean	SE	Mean	SE
Days monitored	23.4a	0.2	24.9b	0.3	27.2c	0.5
Radiolocations	8.6a	0.2	14.7b	1.3	15.7c	0.5
100% MCP	0.37a	0.15	1.19ab	0.24	1.57bc	0.38
Bivariate ellipse	1.60a	0.55	3.67abc	0.79	4.55bc	1.06
Total distance	217a	53	614b	54	679b	61
Speed	9.1a	2.2	24.9b	2.2	25.1b	2.3
Maximum distance	92.2a	15.9	146.2b	16.4	164.9b	19.2

Table I.11 Continued: Monthly days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at $\alpha = 0.05$.

	July (n = 40)		August (n = 41)		September (n = 40)		
	Mean	SE	Mean	SE	Mean	SE	P-Value
Days monitored	30.0d	0.0	27.4c	0.5	27.63c	0.2	<0.001
Radiolocations	24.0d	0.6	16.3c	0.4	10.6e	1.4	<0.001
100% MCP	0.97abc	0.12	1.11bc	0.16	1.10bc	0.18	0.051
Bivariate ellipse	2.09ab	0.30	2.89abc	0.45	3.60bc	0.52	0.035
Total distance	704b	55	650b	57	604b	52	<0.001
Speed	23.5b	1.9	23.5b	2.0	21.9b	1.9	<0.001
Maximum distance	135.0b	10.6	136.6b	9.9	152.4b	13.5	0.011

Table I.12: Annual differences in average monthly days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas.

	2008 (n = 96)		2009 (n = 118)		
	Mean	SE	Mean	SE	P=Value
Days monitored	27.3	0.3	26.9	0.2	0.660
Radiolocations	17.0	0.6	14.2	0.5	<0.001
100% MCP	0.84	0.08	1.30	0.16	0.006
Bivariate ellipse	2.33	0.22	3.78	0.46	0.004
Total distance	547	33	645	36	<0.001
Speed	19.8	1.2	23.8	1.3	<0.001
Maximum distance	123.0	6.8	154.7	9.1	<0.001

Table I.13: Sex*month interactions for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	Female					
	April (*n* = 14)		May (*n* = 16)		June (*n* = 22)	
	Mean	SE	Mean	SE	Mean	SE
Days monitored	23.4a	0.3	24.9a	0.5	27.8a	0.4
Radiolocations	8.6a	0.3	14.9a	1.7	16.0a	0.7
100% MCP	0.11a	0.04	1.14a	0.34	1.77a	0.63
Bivariate ellipse	0.54a	0.19	3.49a	1.16	5.00a	1.68
Total distance	102ag	20	527bcefghi	47	639bcdhjk	31
Speed	4.3ag	0.8	21.5bcdefghj	2.1	22.9bcdehijk	2.5
Maximum distance	54.1ba	9.5	151.4bcdefghijk	24.4	175.0bcdghijkl	31.4

Table I.13 Continued: Sex*month interactions for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	Female					
	July (*n* = 23)		August (*n* = 23)		September (*n* = 22)	
	Mean	SE	Mean	SE	Mean	SE
Days monitored	30.0a	0.0	27.0a	0.78	27.5a	0.3
Radiolocations	24.1a	0.8	16.3a	0.7	10.8a	0.4
100% MCP	0.82a	0.14	0.65a	0.12	0.59a	0.12
Bivariate ellipse	1.81a	0.39	1.51a	0.23	2.00a	0.40
Total distance	739cdhijk	82	533bcefgijl	66	413befgh	35
Speed	24.6bcdeijkl	2.7	19.4bcdefgj	2.3	15.1befgj	1.3
Maximum distance	130.4bcdefghijk	14.0	110.0bdefghij	10.0	114.2bedfghij	12.0

Table I.13 Continued: Sex*month interactions for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	Male					
	April (*n* = 11)		May (*n* = 13)		June (*n* = 17)	
	Mean	SE	Mean	SE	Mean	SE
Days monitored	23.5a	0.3	24.8a	0.5	26.5a	0.9
Radiolocations	8.5a	0.3	14.5a	1.9	15.3a	2.1
100% MCP	0.71a	0.31	1.25a	0.33	1.30a	0.33
Bivariate ellipse	2.95a	1.11	3.89a	1.06	3.96a	1.13
Total distance	365abefg	103	720bcdehjk	101	730cdehijkl	106
Speed	15.3abefg	4.3	29.1cdhijkl	4.0	27.8cdhijkl	4.0
Maximum distance	140.6bcdefghijk	28.6	139.7bcdefghijkl	21.8	151.8bcdefghijkl	17.8

Table I.13 Continued: Sex*month interactions for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	Male						
	July (*n* = 17)		August (*n* = 18)		September (*n* = 18)		
	Mean	SE	Mean	SE	Mean	SE	P-Value
Days monitored	29.94a	0.1	27.8a	0.4	27.7a	0.1	0.288
Radiolocations	23.8a	0.9	16.3a	0.5	10.39a	0.4	0.966
100% MCP	1.17a	0.20	1.71a	0.29	1.73a	0.31	0.097
Bivariate ellipse	2.47a	0.44	4.64a	0.82	5.55a	0.87	0.100
Total distance	656bcdehijkl	69	799cdhijkl	90	837dhijkl	79	0.012
Speed	21.9bcdefghijk	2.3	28.8cdhijkl	3.2	30.2dhikl	2.8	0.022
Maximum distance	141.1bcdefghijk	16.5	170.6bcdghijkl	15.6	199.2bchikl	21.9	0.042

Table I.14: Sex*year interactions for days monitored for number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female (2008, *n* = 53; 2009, *n* = 67 and male (2008, *n* = 43; 2009, *n* = 51) ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas.

	2008				2009				
	Female		Male		Female		Male		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	P-Value
Days monitored	27.3	0.5	27.4	0.4	27.0	0.3	26.7	0.4	0.652
Radiolocations	17.2	0.8	16.7	0.9	14.5	0.7	13.9	1.5	0.669
100% MCP	0.61	0.08	1.13	0.14	1.09	0.23	1.56	0.19	0.962
Bivariate ellipse	1.53	0.16	3.32	0.40	3.18	0.66	4.57	0.60	0.880
Total distance	495	44	610	48	538	43	787	57	0.202
Speed	17.7	1.5	22.3	1.8	19.6	1.5	29.3	2.1	0.187
Maximum distance	107.5	7.9	142.2	11.2	140.0	13.2	174.1	11.6	0.880

Table I.15: Sex*month*year interactions for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female and male ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	April							
	2008				2009			
	Female (*n* = 4)		Male (*n* = 3)		Female (*n* = 67)		Male (*n* = 8)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Days monitored	22a	0	22a	0	24ab	0	24ab	0
Radiolocations	10abdklmnpwx	0	8abdklmnpwx	0	8abmnw	0	8abmnw	0
100% MCP	0.02a	0.02	0.13a	0.09	0.14a	0.05	0.93a	0.40
Bivariate ellipse	0.08a	0.07	0.67a	0.51	0.73a	0.25	3.81a	1.42
Total distance	48a	27	128a	43	123a	24	65a	129
Speed	2.2a	1.2	5.8a	2.0	5.1a	1.0	18.9a	5.4
Maximum distance	25.5a	13.0	62.3a	12.1	65.6a	10.5	170.0a	33.7

Table I.15 Continued: Sex*month*year interactions for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female and male ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	May							
	2008				2009			
	Female (*n* = 4)		Male (*n* = 3)		Female (*n* = 12)		Male (*n* = 10)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Days monitored	28.0bc	0.0	28.0bc	0	23.9ab	0.1	23.8ab	0.1
Radiolocations	26.3chot	0.3	26.7chot	0.3	11.1adklmpwx	0.26	10.9adklmpwx	0.3
100% MCP	0.43a	0.15	1.41a	0.74	1.37a	0.44	1.21a	0.38
Bivariate ellipse	1.10a	0.39	3.87a	2.50	4.28a	1.49	3.89a	1.24
Total distance	374a	72	790a	266	578a	51	700a	112
Speed	13.4a	2.6	28.2a	9.5	24.2a	2.2	29.4a	4.7
Maximum distance	87.8a	23.7	135.7a	40.5	172.7a	29.4	140.9a	26.7

Table I.15 Continued: Sex*month*year interactions for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female and male ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	June							
	2008				2009			
	Female (*n* = 10)		Male (*n* = 8)		Female (*n* = 12)		Male (*n* = 9)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Days monitored	26.9bc	0.7	25.4bc	1.5	28.5bc	0.5	27.6bc	1.0
Radiolocations	18.8ejq	0.5	17.5ejquv	1.1	13.8fir	0.6	13.3firx	0.6
100% MCP	0.80a	0.22	0.91a	0.26	2.58a	1.10	1.65a	0.58
Bivariate ellipse	2.13a	0.56	2.43a	0.49	7.39a	2.92	5.33a	2.03
Total distance	508a	82	560a	69	749a	104	880a	180
Speed	19.4a	3.5	23.1a	3.6	25.9a	3.5	32.0a	6.7
Maximum distance	110.6a	15.7	136.1a	16.8	228.7a	52.0	165.7a	30.5

Table I.15 Continued: Sex*month*year interactions for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female and male ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	July							
	2008				2009			
	Female (*n* = 12)		Male (*n* = 9)		Female (*n* = 11)		Male (*n* = 8)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Days monitored	30.0c	0.0	30.0b	0.0	30.0c	0.0	29.88c	0.4
Radiolocations	23.0gst	0.4	22.9gst	0.5	25.4chot	1.5	24.8cghost	1.8
100% MCP	0.87a	0.20	0.91a	0.31	0.77a	0.20	1.45a	0.23
Bivariate ellipse	1.70a	0.34	2.19a	0.66	1.93a	0.75	2.79a	0.61
Total distance	757a	111	548a	108	720a	127	778a	64
Speed	25.2a	3.7	18.3a	3.6	24.0a	4.2	26.1a	2.2
Maximum distance	134.4a	20.6	107.8a	17.0	126.1a	19.7	178.5a	24.1

Table I.15 Continued: Sex*month*year interactions for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female and male ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at $\alpha = 0.05$.

	August							
	2008				2009			
	Female (*n* = 12)		Male (*n* = 10)		Female (*n* = 11)		Male (*n* = 8)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Days monitored	26.5bc	1.5	28.0bc	0.7	27.6bc	0.2	27.6bc	0.2
Radiolocations	15.2firuv	1.1	16.4ijquv	0.7	17.6ejquv	0.7	16.3ijquv	0.8
100% MCP	0.57a	0.14	1.32a	0.22	0.73a	0.19	2.19a	0.56
Bivariate ellipse	1.43a	0.26	3.76a	0.62	1.61a	0.40	5.73a	1.66
Total distance	503a	87	653a	94	566a	103	981a	146
Speed	18.3a	2.8	23.4a	0.7	20.6a	3.8	35.5a	5.2
Maximum distance	110.2a	15.8	144.8a	13.0	109.7a	12.9	202.9a	28.0

Table I.15 Continued: Sex*month*year interactions for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female and male ornate box turtles with a minimum of 8 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	September								
	2008				2009				
	Female (*n* = 11)		Male (*n* = 10)		Female (*n* = 11)		Male (*n* = 8)		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	P-Value
Days monitored	27.1bc	0.5	27.5bc	0.2	28.0bc	0.0	28.0bc	0.0	<0.001
Radiolocations	10.7dklmpwx	0.7	9.8abdklmnpwx	0.6	10.9dklmpwx	0.2	11.1adklmprwx	0.5	<0.001
100% MCP	0.46a	0.05	1.51a	0.33	0.71a	0.23	2.01a	0.58	0.557
Bivariate ellipse	1.59a	0.22	5.25a	1.00	2.41a	0.76	5.92a	1.59	0.485
Total distance	396a	34	756a	95	431a	64	939a	131	0.783
Speed	14.7a	1.3	27.6a	3.4	15.4a	2.3	33.6a	4.7	0.892
Maximum distance	109.2a	10.8	201.5a	32.8	119.2a	21.9	196.3a	29.7	0.147

Table I.16: Seasonal days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for female (*n* = 66) and male (*n* = 49) ornate box turtles with a minimum of 20 relocation points per month monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas.

	Female		Male		
	Mean	SE	Mean	SE	P-Value
Days monitored	81.7	1.5	83.8	1.3	0.187
Radiolocations	37.1	1.9	37.2	2.2	0.450
100% MCP	1.59	0.30	2.56	0.28	0.028
Bivariate ellipse	2.71	0.47	4.86	5.41	0.009
Total distance	1176	112	1726	141	<0.001
Speed	14.7	1.4	20.5	1.6	<0.001
Maximum distance	141.6	12.8	196.3	12.8	0.011

Table I.17: Seasonal days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 20 relocation points per season monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	Fall 2007(*n* = 6)		Fall 2008 (*n* = 22)		Fall 2009 (*n* = 18)	
	Mean	SE	Mean	SE	Mean	SE
Days monitored	80.7abcdefg	8.3	89.0abdeg	1.0	77.03acdef	3.7
Radiolocations	39.3a	0.17	29.8b	1.0	28.3bcd	1.2
100% MCP	1.91a	0.51	1.93a	0.38	1.68a	0.34
Bivariate ellipse	3.52abce	0.96	4.02ab	0.85	3.30abc	0.60
Total distance	1705a	266	1504a	166	1416a	199
Speed	22.6ac	4.1	89.0a	1.8	18.1a	2.2
Maximum distance	163.3abcaefg	26.0	170.7abcef	19.6	175.5abcfg	23.3

Table I.17 Continued: Seasonal days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 20 relocation points per season monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at $\alpha = 0.05$.

	Spr 2008 (n = 7)		Spr 2009(n = 22)		Sum 2008(n = 21)		Sum 2009(n = 19)		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	P-Value
Days monitored	85.0abcdg	0.0	83.7abcdeg	0.2	75.0acf	3.1	87.16abdfg	0.09	<0.001
Radiolocations	24.0 cde	0.0	22.3 de	0.2	53.5f	2.6	57.4f	1.5	<0.001
100% MCP	0.52a	0.27	0.87a	0.25	1.97a	0.39	4.33b	0.85	<0.001
Bivariate ellipse	1.42abc	0.69	1.75abc	0.48	3.50abc	0.82	6.63ace	1.30	0.002
Total distance	297b	79	496b	97	1458a	130	2618c	210	<0.001
Speed	3.5b	0.9	5.9b	1.2	19.8a	1.7	30.0c	2.4	<0.001
Maximum distance	80.4adef	24.8	125.7abdef	20.1	149.2abcdef	11.2	242.3abcg	31.3	<0.001

Table I.18: Sex*season interaction for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 20 relocation points per season monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	Female					
	Fall 2007 (n = 4)		Fall 2008 (n = 12)		Fall 2009 (n = 11)	
	Mean	SE	Mean	SE	Mean	SE
Days monitored	76.5a	12.5	88.21a	1.8	74.2a	5.3
Radiolocations	37.0a	5.0	29.6a	1.7	27.4a	1.6
100% MCP	1.59a	0.38	0.86a	0.14	0.92a	0.24
Bivariate ellipse	3.22a	1.02	1.69a	0.26	2.02a	0.47
Total distance	1423.68abcfim	154.13	998.18abcklm	104.58	935.07bcklm	142.65
Speed	21.18acfhijm	5.53	11.34bckl	1.15	12.88abcklm	1.88
Maximum distance	168.59abcdefghjklmn	33.46	123.94acdefhklm	15.38	125.41abcdefhklm	22.09

Table I.18 Continued: Sex*season interaction for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 20 relocation points per season monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	Female							
	Spr 2008 (n = 3)		Spr 2009(n = 10)		Sum 2008 (n = 12)		Sum 2009(n = 11)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Days monitored	85.0a	0.0	84.13a	0.2	75.2a	4.2	87.0a	0.0
Radiolocations	24.0a	0.0	22.5a	0.2	53.4a	3.3	58.2a	2.08
100% MCP	0.15a	0.09	0.39a	0.9	1.87a	0.57	4.58a	1.34
Bivariate ellipse	0.42a	0.23	0.88a	0.22	3.29a	1.23	6.53a	1.99
Total distance	182dekl	68	276dekl	41	1536afhm	196	2470ghijn	295
Speed	2.1dekl	0.8	3.3dekl	0.5	20.7afhijm	2.4	28.4aghijn	3.4
Maximum distance	52.3abcdefhklm	19.4	73.8abcdehkm	8.6	153.1abcfhklm	17.9	260.9aghijln	51.5

Table I.18 Continued: Sex*season interaction for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 20 relocation points per season monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	Male					
	Fall 2007 (n = 2)		Fall 2008 (n = 10)		Fall 2009 (n = 7)	
	Mean	SE	Mean	SE	Mean	SE
Days monitored	89.04a	0.0	90.04a	0.0	81.5a	4.9
Radiolocations	44.0a	0.0	30.10a	0.9	29.9a	1.8
100% MCP	2.54a	1.56	3.21a	0.61	2.88a	0.55
Bivariate ellipse	4.13a	2.65	6.83a	1.42	5.32a	0.98
Total distance	2266afghijmn	946	2111aghij	224	2173aghij	281
Speed	25.5afghijmn	7.5	23.45afghijm	2.5	26.3afghijn	2.6
Maximum distance	152.8abcdefghijklmn	57.3	226.73aghijkln	31.3	254.3aghijln	31.6

Table I.18 Continued: Sex*season interaction for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 20 relocation points per season monitored from 21 June 2007 – 22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at $\alpha = 0.05$.

	Male			
	Spr 2008 (n = 3)		Spr 2009(n = 10)	
	Mean	SE	Mean	SE
Days monitored	85.0a	0.0	83.3a	0.4
Radiolocations	24.0a	0.0	22.1a	0.3
100% MCP	1.00a	0.52	1.45a	0.48
Bivariate ellipse	2.77a	1.30	2.79a	0.94
Total distance	451bcdekl	116	761abcdeklm	178
Speed	5.3bcdekl	1.4	9.1bcdekl	2.1
Maximum distance	118.0abcdefhiklmn	48.3	188.0abcfghijklmn	34.3

Table I.18 Continued: Sex*season interaction for days monitored, number of radiolocations, 100% minimum convex polygons (MCP) home range (ha), 95% MCP (ha), 95% bivariate ellipse (ha), total distance (m), speed (m), and maximum distance (m) for ornate box turtles with a minimum of 20 relocation points per season monitored from 21 June 2007-22 April 2010 on Matador Wildlife Management Area, Cottle County, Texas. Within a row, means followed by the same letter are not different at α = 0.05.

	Male				
	Sum 2008(n = 9)		Sum 2009 (n = 8)		
	Mean	SE	Mean	SE	P-Value
Days monitored	74.8a	5.0	87.4a	0.2	0.749
Radiolocations	53.6a	4.3	56.4a	2.4	0.897
100% MCP	2.09a	0.55	3.98a	0.9	0.298
Bivariate ellipse	3.77a	1.04	6.77a	1.62	0.314
Total distance	1355abcfhlm	160	2822ghn	297	0.012
Speed	18.6acfhim	2.4	32.3ghjn	3.4	0.026
Maximum distance	144.0abcdefhklmn	11.6	216.7abfghijklmn	24.7	0.012

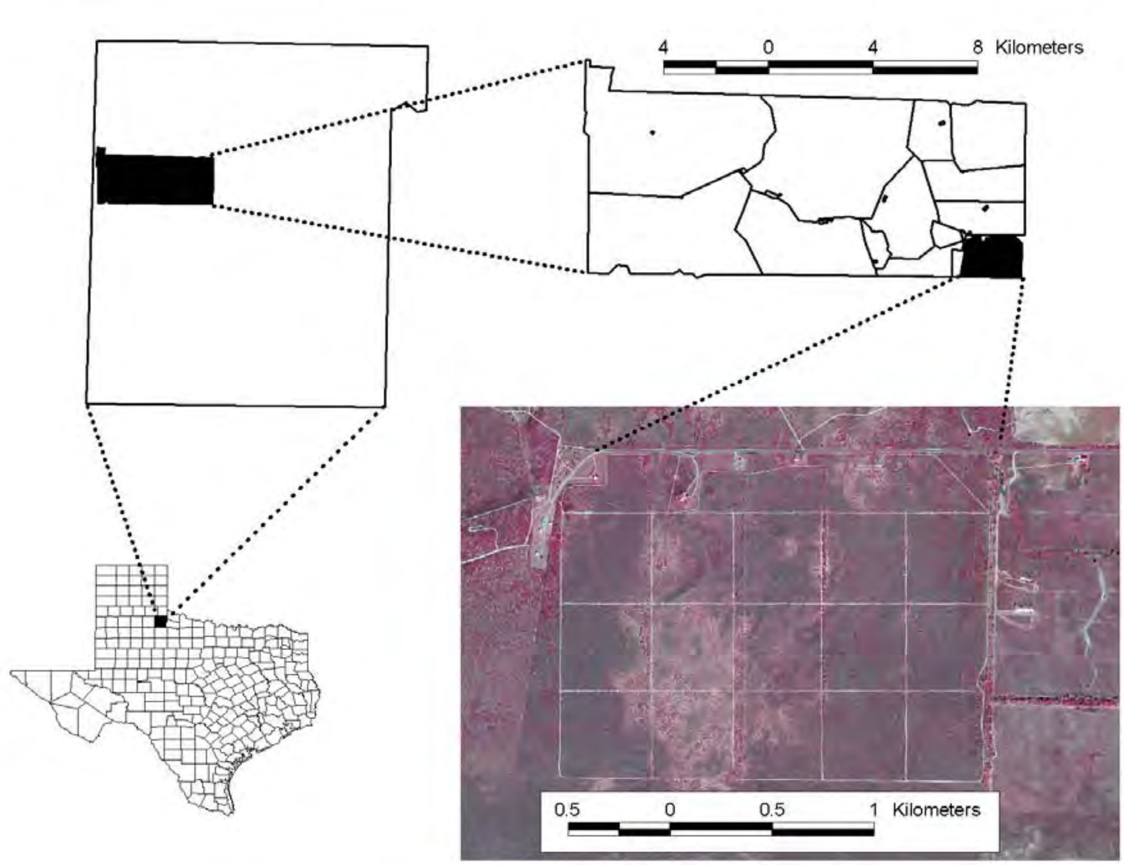

Figure I.1: The location of Cottle County within Texas, Matador Wildlife Management Area within Cottle County, Headquarters Pasture within Matador WMA, and the prescribed burn matrix within Headquarters Pasture that was used as my specific study site to explore the spatial ecology of ornate box turtles, 2007 - 2010.

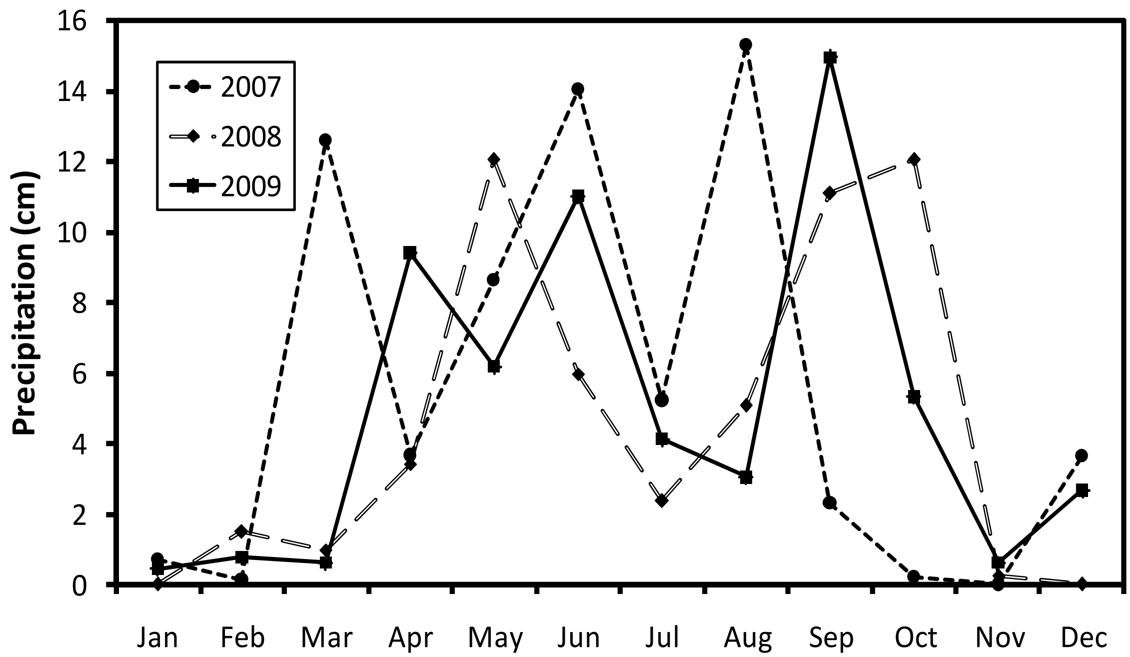

Figure I.2: Monthly precipitation (cm) for 2007, 2008, and 2009 recorded from the National Weather Service Cooperative Observer station in Paducah located ~13km south-southeast of my specific study plots.

Blocks

1	2	3	4	5
U	W	W	U	S
S	U	S	W	U
W	S	U	S	W

Figure I.3: Diagrammatic representation of my specific study plots within Headquarters Pasture at Matador WMA in Cottle County, Texas. Headquarters Pasture was divided into 5 blocks, each consisting of 3 18-ha plots. Each of the 3 plots within a block was randomly assigned one of 3 treatments: unburned (U), winter burning (W), summer burning (S).

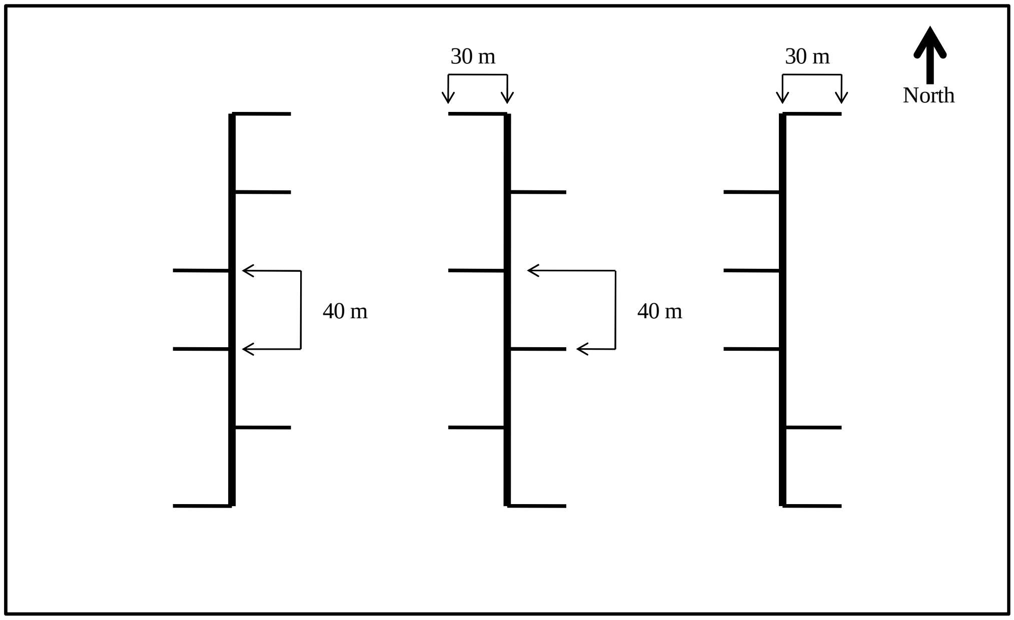

Figure I.4: Diagrammatic representation of transect sampling regime for measuring canopy cover of woody vegetation within each plot. Three 200-m north and south parallel transects approximately 100-m apart. Perpendicular to each north and south running transect are 6 30-m east or west lines spaced at 40-m along the main transect, and randomized as to direction (east or west). Woody canopy cover and frequency were measure along these 30-m lines at Matador Wildlife Management Area in Cottle County, Texas in 2007, 2008, 2009.

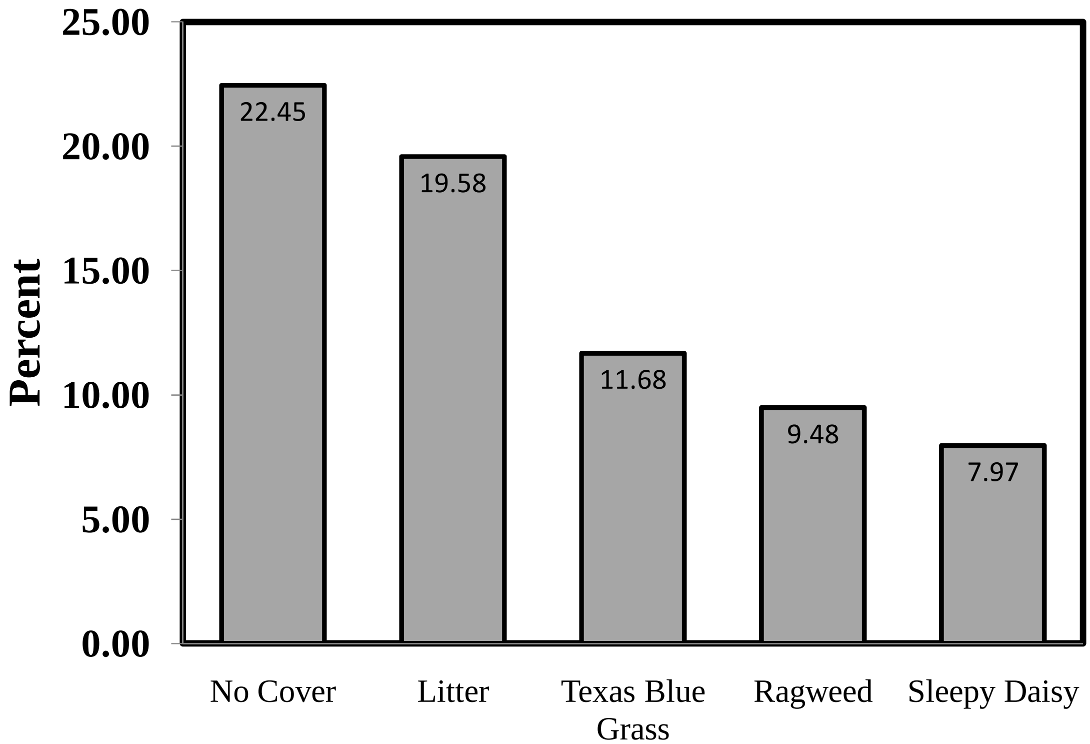

Figure I.5: Top 5 average cover use by 31ornate box turtles based on 3261 radiolocations monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007 – 22 April 2010.

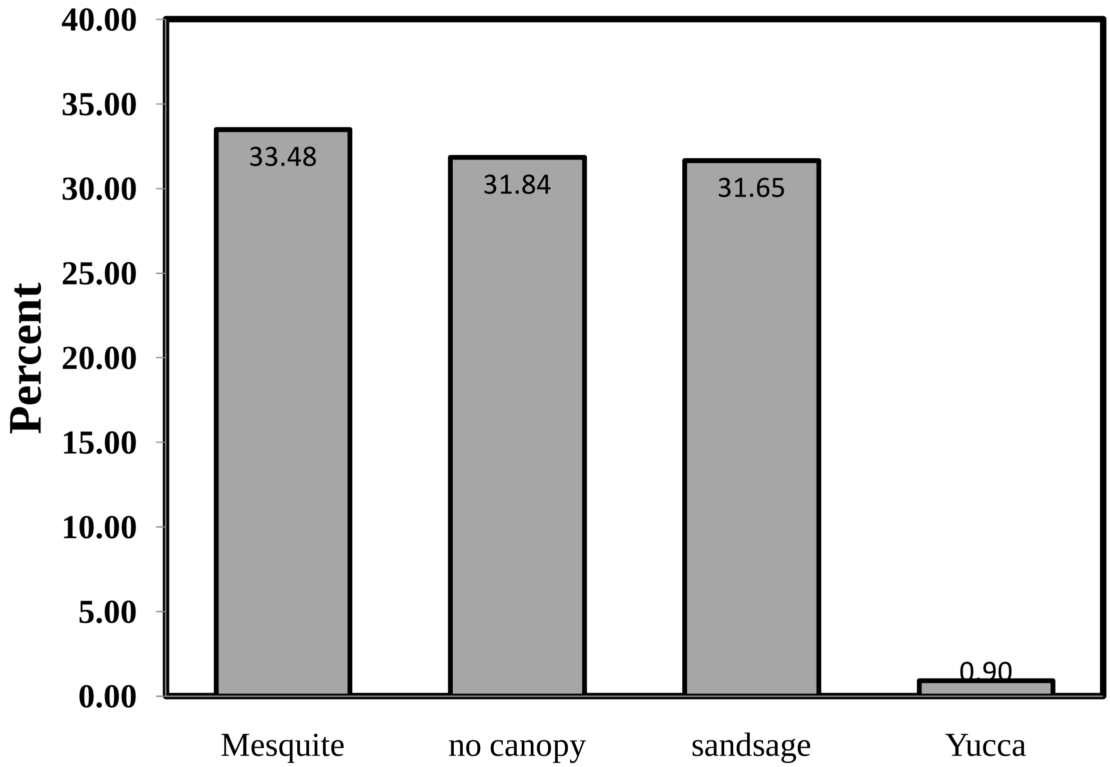

Figure I.6: Top four average canopy use by 31 ornate box turtles based on 3261 relocations monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007 – 22 April 2010.

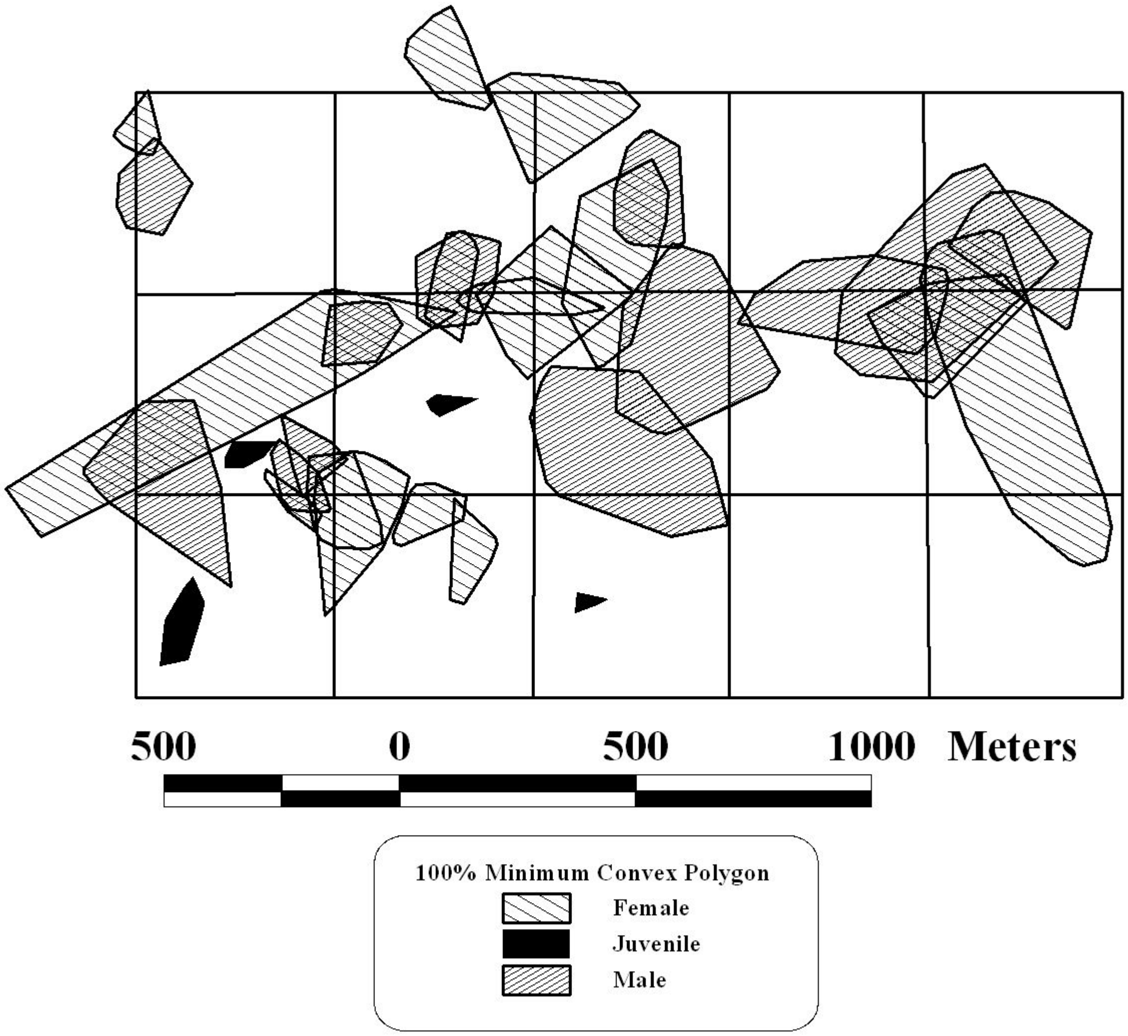

Figure I.7: 100% Minimum Convex Polygon for female, male, and juvenile ornate box turtles monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007 – 22 April 2010.

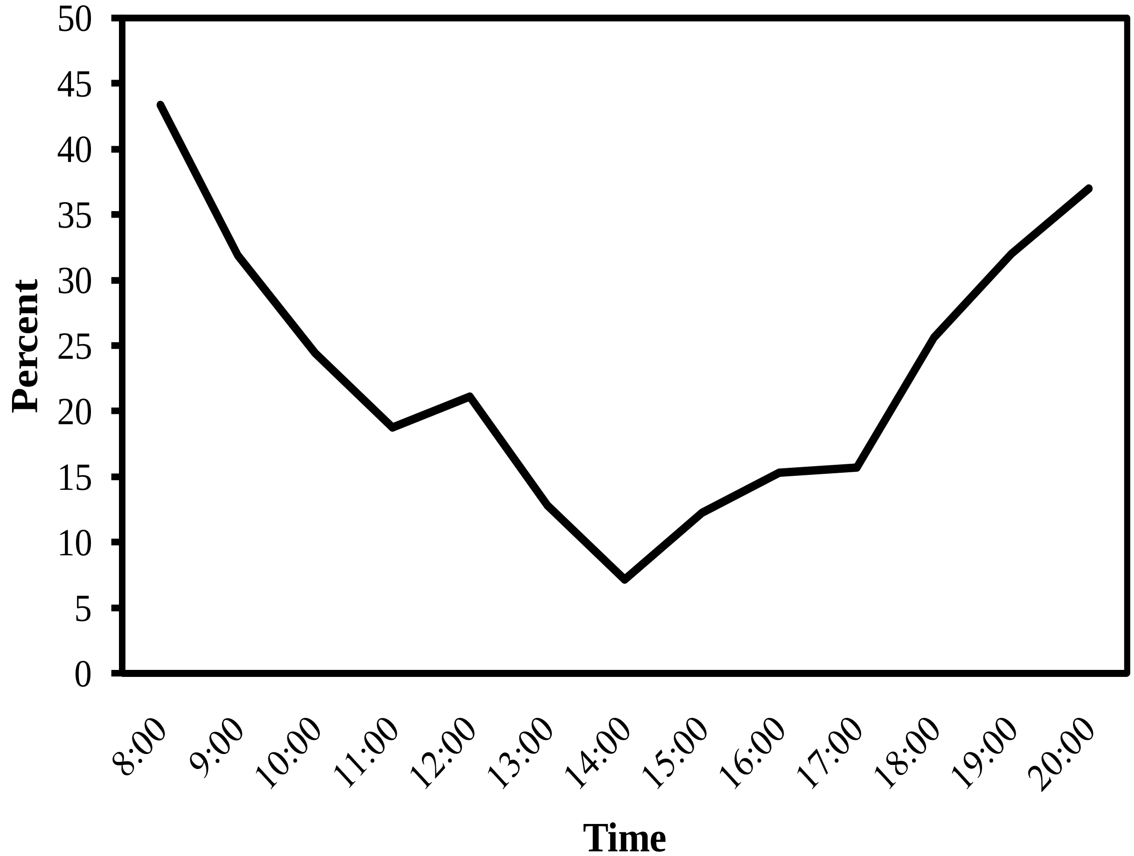

Figure I.8: Total hourly percent of active ornate box turtles based on 5269 locations with a minimum of 200 location points per hour monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007 – 22 April 2010.

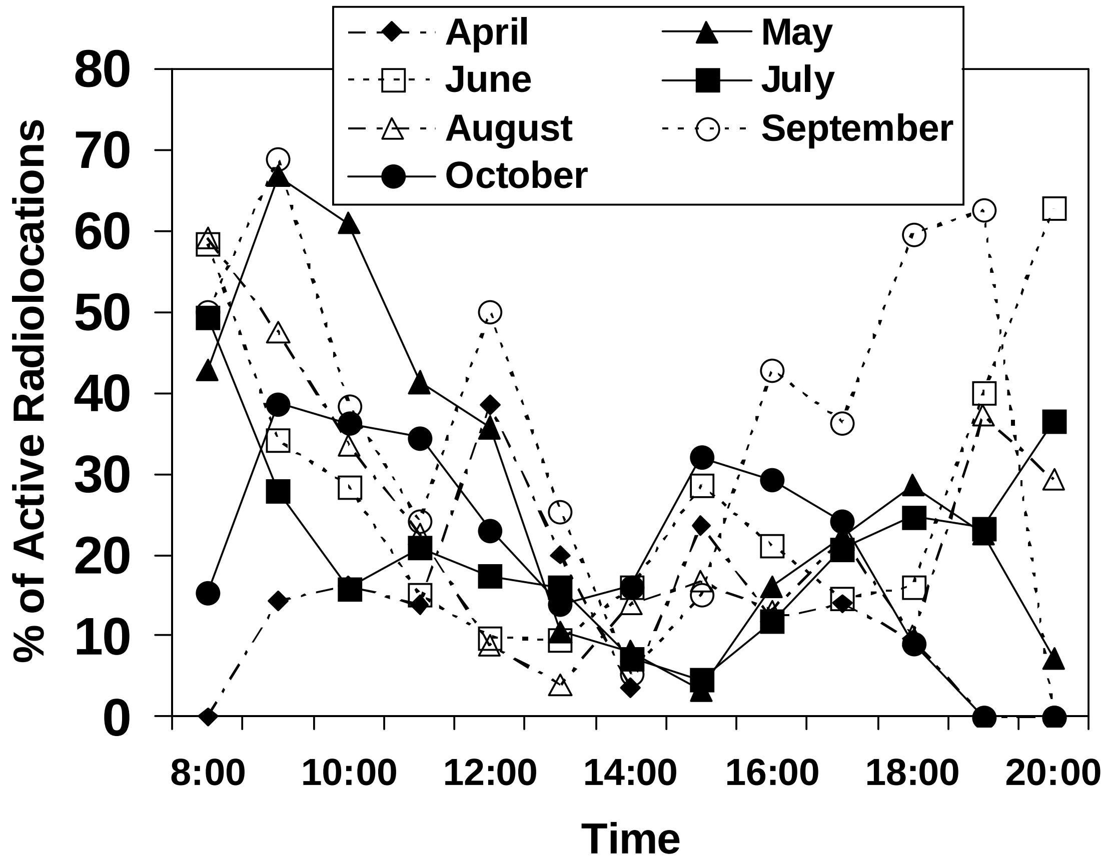

Figure I.9: Hourly monthly percent active turtles based on 5269 locations monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007 – 22 April 2010.

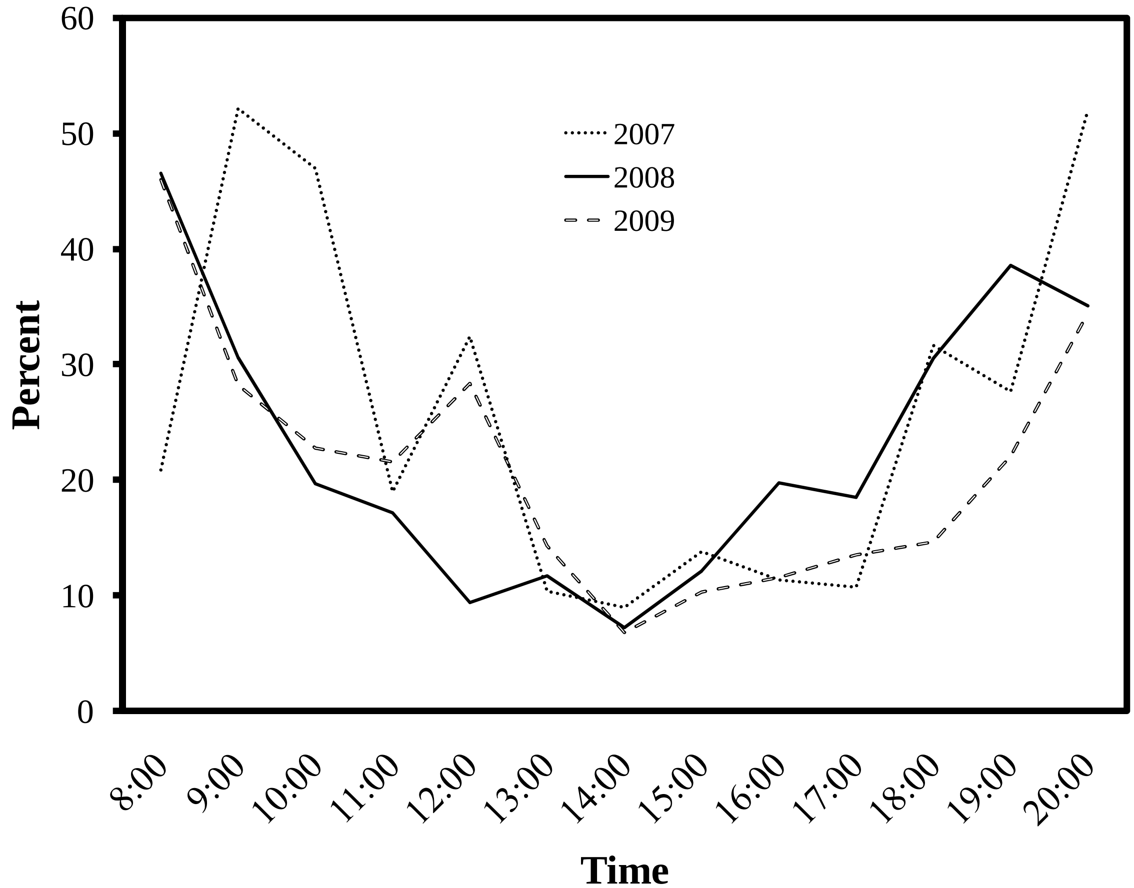

Figure I.10: Hourly percent active turtles based on 5111 locations monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007 – 31 December 2009.

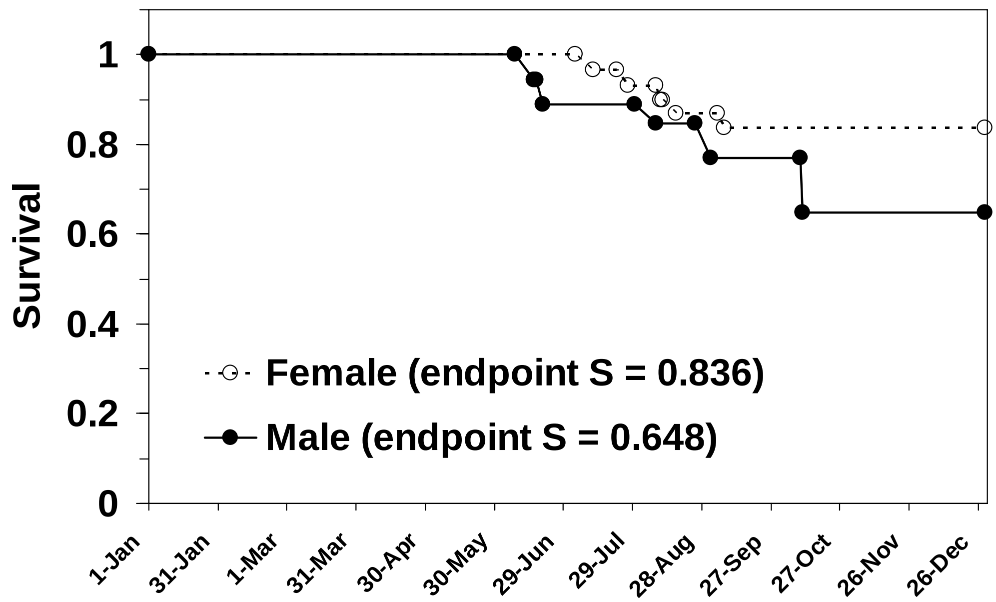

Figure I.11: Annual Kaplin-Meier survival estimate of male versus female ornate box turtles (censored individuals = dead) monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007 - 22 April 2010.

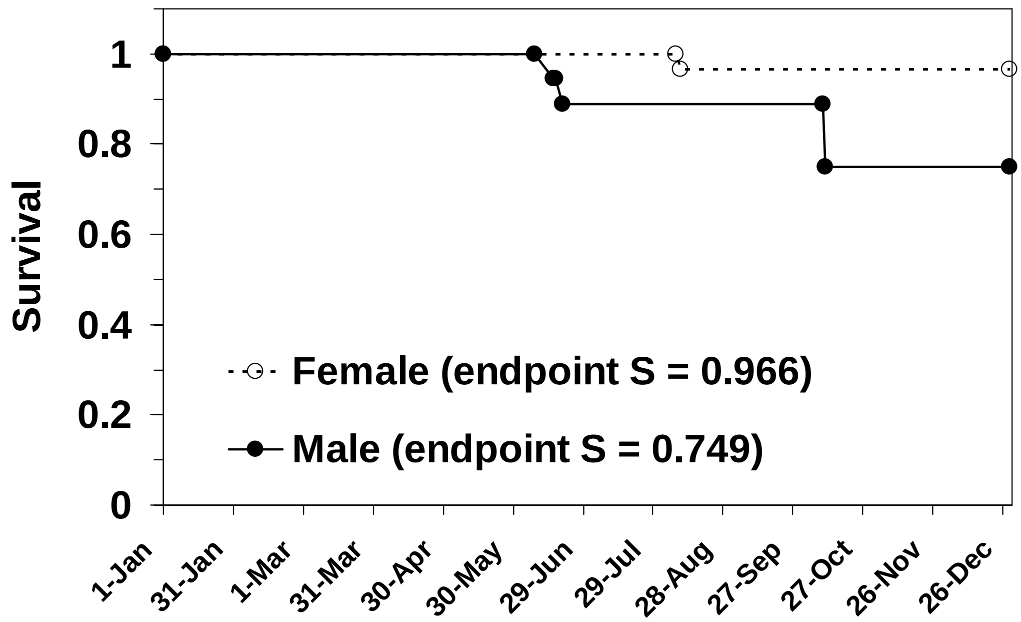

Figure I.12: Annual Kaplin-Meier survival estimate of male versus female ornate box turtles (censored individuals = live) monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007 – 22 April 2010.

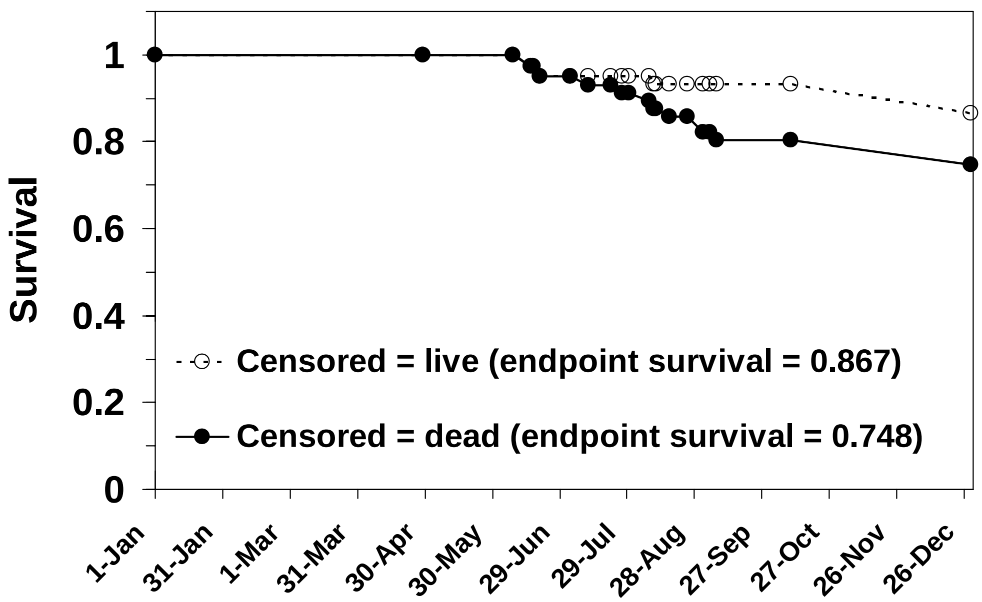

Figure I.13: Annual Kaplin-Meier survival estimate of censored live versus censored dead ornate box turtles (censored individuals = live) monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007 – 22 April 2010.

CHAPTER II

DEMOGRAPHY OF THE ORNATE BOX TURTLE IN A SAND PRAIRIE ECOSYSTEM

INTRODUCTION

The ornate box turtle (*Terrapene ornata*) is a small, largely terrestrial emydid that inhabits a variety of prairie, plains, and xeric shrubland habitats from southern Wisconsin and Western Indiana to southeastern Arizona and the Lower Rio Grande Valley of Texas (Figure II.1; Grant 1935, List 1951, Legler 1960, Dodd 2001, Ernst and Lovich 2009). In recent years, many herpetologists have observed an apparent decline in box turtle populations (Dodd 2001). This concern over population levels of all box turtle species in North America led to an Appendix II listing with the Convention on International Trade of Endangered Species of Wild Fauna and Flora (U.S. Fish and Wildlife Service 1995). Urban sprawl and habitat fragmentation have destroyed many areas where box turtles were once abundant. Habitat fragmentation threatens box turtles in several ways including loss of forage, inability to find mates, edge effects, change in environmental conditions, and increased predation.

The long lived (>25 years) and late maturing (8-10 years for sexual maturity) demographic life style of the ornate box turtle predisposes this species to the threat of population declines. Removals, such as for international food markets or the domestic pet trade, compounded with habitat fragmentation, road mortality, and various human related factors, such as mowing, are expected to have a major impact on box turtle populations especially, in grasslands where ornate box turtles reside (Dodd 2001). As a result of habitat loss and fragmentation, grassland ecosystems within the Great Plains now occupy less than 5% of their historic extent (Lomolino and Smith 2003).

Many turtles have been identified as excellent models for the study of life histories of long-lived vertebrates (Mitchell 1988, Congdon and Gibbons 1990, Heppell 1998, Hellgren et al. 2000). Though some studies have regarded various aspects of the ornate box turtles life history and demography (Legler 1960, Blair 1976, Metcalf and Metcalf 1979, Doroff and Keith 1990, Claussen et. al. 1997, Nieuwolt-Daganay 1997, Converse et. al. 2002) little is published on populations located within sand prairie ecosystems. There is an even greater need for information regarding long-term studies of ornate box turtles (Dodd 2001). To address these concerns the first phase of a long-term research project examining various aspects of the ornate box turtle demography at Matador WMA, Cottle County, Texas, was initiated in 2004. To that end, my objective was to characterize the life history and demography of ornate box turtles at this site to help clarify the regional variation found in this species.

STUDY AREA

The Rolling Plains eco-region extends north from the Edwards Plateau in Texas to western Oklahoma. Adapted to seasonal fire, the flat to rolling landscape of the Rolling Plains has native vegetation of mixed-grass plains, short-grass prairies, shinnery oak

(*Quercus havardii*) grasslands, and mesquite (*Prosopsis glandulosis*) grasslands. Within the central Rolling Plains is my study site, the Matador Wildlife Management Area (WMA). Located in Cottle County, Texas, (Figure II.2) the 11,410 ha Matador WMA was purchased by the state in 1959 with Pittman-Roberson funds by the Wildlife Division of Texas Parks and Wildlife Department for the purposes of wildlife research, wildlife management, and public use. Major habitat types on Matador WMA include shinnery oak rangeland, gravelly hills consisting of red berry juniper (*Juniperus coahuilensis*), ephemeral riparian areas dominated by cottonwood (*Populus deltoides*) and salt cedar (*Tamarix sp.*), and sandsage (*Artemisia filifolia*) savannahs (Becker et al 2009).

Common species of wildlife found on Matador WMA include northern bobwhite (*Colinus virginianus*), scissor-tailed flycatchers (*Tyrannus forficatus*), Mississippi kites (*Ictinia mississippiensis*), western diamondback rattlesnakes (*Crotalus atrox*), western coachwhip (*Masticophis flagellum*), western hognose snakes (*Heterodon nasicus*), Texas horned lizards (*Phrynosoma cornutum*), six-lined racerunners (*Cnemidophorus sexlineatus*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*Odocoileus virginianus*). Annual rainfall for Matador WMA varies from 55.9 – 76.2 cm with the greatest precipitation in late spring and fall (Figure II. 3; Figure II.4). Average maximum summer temperature is 36°C and average winter minimum temperature is -2°C (Becker et al. 2009).

METHODS

Capture, Marking, and Aging

In 2004, a long term mark/recapture program for ornate box turtles was initiated at Matador WMA, Cottle County, Texas. From May 2004 – September 2010, ornate box turtles were captured within the study area by road cruising or fortuitous encounters. Upon capture Global Positioning System (GPS) coordinates were taken for each turtle to indicate position using a Etrex GPS unit (Garmin International, Olathe, KS, USA). Once captured the turtles were sexed by tail length and iris color, weighed (g), measured (straight-line carapace length [SCL]), and given a unique notch code on its marginal scutes so that the turtle could then be individually identified upon recapture (Cagle 1939, Ernst and Lovich 2009). I then summarized the number of individuals captured by month and year. I compared the number of captured individuals, number of adult females, number of adult males, and number of juveniles to average annual (2004 – 2010) and monthly (April - November) precipitation using linear regressions. To determine if there was sex or age-based differences in activity as a result of rainfall, I compared the annual proportion of females and juveniles captured with annual precipitation (2004 – 2010) using linear regressions.

From May 2007 to October 2009 turtle molds were made of captured turtles using dental alginate and dental stone (Galbraith and Brooks 1987a). After morphological measurements were taken, dental alginate was mixed and applied to the plastron and carapace of each ornate box turtle to generate a temporary impression. At a later date the temporary mold was surrounded by clay and filled with dental stone creating a permanent positive impression. Age was estimated by counting scute annuli on the gular, humeral, pectoral, abdominal, femoral, and anal scutes on the plastron and the costal and vertebral scutes on the carapace. The modal count of all scutes for each turtle was used to indicate age (Legler 1960, Blair 1976, Germano 1988, Zugg 1991).

Sex and Age Structured Survival

I compared sex frequency distributions using chi-square tests of homogeneity to determine if adult sex ratio differed from 1:1 (Kazmaier et al. 2001). For this and all other comparisons, $\alpha = 0.05$. If individuals were encountered more than once, captures were randomly chosen for inclusion in the analyses such that each individual was represented only once (cumulative and annual analysis). Survival rates were calculated for individuals aged from 2007 to 2009 using ln frequency regression for ages 9 – 19 (Kazmaier et al. 2001). The antilog of the slope of these lines represented average annual survival for the age interval (9-19).

Size and Body Condition

Using analysis of variance (ANOVA) I compared the mean straight line carapace length (SCL) and mass between adult males and females. I divided SCL by mass to create a condition index whereby small values indicated heavier (and presumably better conditioned) turtles. I compared body condition among juveniles, adult females, and adult males and then among years using ANOVA. I used both ANOVA and linear regression to compare annual precipitation to body condition of adult females, adult males, juveniles, and all turtles pooled.

Growth

Growth curves were developed by plotting straight-line carapace length and mass versus age (i.e., number of annuli) for individuals 0-16 using simple linear regression and a power function. Because of a lack of individuals or small sample size, hatchlings (age = 0) and age classes higher than 16 were not used for analysis.

Reproduction

From 21 June 2007 – 22 April 2010 ornate box turtles were observed using radio telemetry. Thirty-one ornate box turtles were outfitted with radio transmitters (Holohil Systems, Carp, Ontario, Canada). In 2007 (June-September) transmitters used were 2 year old 0.95 g, 45 day, transmitters. In late September of 2007 monitored turtles were recaptured and outfitted Holohil Systems RI 2-B, 14.3 g, 24 month transmitters. Turtles captured and monitored after September 2007 where equipped with RI 2-B transmitters. RI 2-B transmitters were flat on the bottom and elliptical in shape. Using silicone, the transmitters were affixed to the carapace of the turtle and covered with local soil to aid in camouflaging the transmitter then released at the point of capture (Kazmaier et al 2002). During the summer season (May-August) turtles were relocated daily and for the remainder of the year (September-April) turtles were relocated weekly and a GPS point recorded at each location.

To determine the reproductive behavior of ornate box turtles at Matador Wildlife Management Area all reproductive activity was documented at the time of capture or observed during radio telemetry and separated by months (Cahn and Conder 1932, Legler 1960, Nieuwolt-Dagany 1997). When presented with the opportunity, adult female turtles where x-rayed in 2008 and 2009 to determine gravidity and clutch size (Hinton et al. 1997).

Hibernation

Using telemetry, we examined the hibernation activity of ornate box turtles at Matador WMA, Cottle County, Texas. By subtracting X and Y axes from each successive radiolocation, I used geometry ($a^2 + b^2 = c^2$) to calculate the linear distance between each successive location. I standardized all locations collected from June 2007 to April 2010 into a single year. I plotted each movement distance versus date to visualize when activity ceased to indicate when turtles entered winter hibernation and engaged in spring emergence.

RESULTS

Captures

From 7 May 2004 to 24 September 2010 individual box turtle captures totaled 477 (258 females, 156 males, 63 juveniles). Annual captures yielded similar sex and age structure, with the highest total captures in 2007 (Figure II.5). Monthly captures varied considerably with the highest number of captures occurring in June (Figure II.6). There was no relationship between the number of females, males, or juvenile box turtles captured and annual (females $F = 0.767$, $df = 5$, $p = 0.431$; males $F = 0.029$, $df = 5$, $p = 0.872$; juveniles $F = 0.708$, $df = 5$, $p = 0.863$) or monthly (females $F = 0.281$, $df = 7$, $p = 0.615$; males $F = 3.338$, $df = 7$, $p = 0.117$; juveniles $F = 0.342$, $df = 7$, $p = 0.580$) precipitation (Figure II.7). There was also no significant relationship between the proportion of juveniles ($F = 0.085$, $df = 5$, $p = 0.785$; Figure II.8) or proportion of adult females (females $F = 2.286$, $df = 6$, $p = 0.191$; Figure II.9) captured and rainfall.

Sex Ratio and Survival

Adult sex ratio was significantly female biased at 1.65:1 ($X^2 = 25.13$, $p < 0.001$). From 2007 – 2009, 117 turtles were aged from dental stone impressions (69 females, 30 males, 18 Juveniles; Figure II.10). The annual survival rate determined from age distributions of box turtles (ages 9-19) was 0.80 (Figure II.11).

Size and Body Condition

Female SCL (mean = 111.76 mm, SE = 0.57, $n = 242$) did not differ significantly ($p = 0.754$) from males (mean = 112.03 mm, SE = 0.57, $n = 151$). However females (mean = 324.40 g, SE = 4.98, $n = 242$) were significantly ($p = 0.010$) heavier than males (mean = 306.02 g; SE = 4.20, $n = 151$). Although the mean difference between female (0.347) and male (0.369) body condition was approaching significance ($p = 0.089$) there was a significant difference ($p < 0.001$) between adults and juveniles (0.770). The mean body condition was poorer in 2006 (0.553, $p \leq 0.005$) than in 2004 (0.469), 2005 (0.461), 2007 (0.489), and 2008 (0.460). Ornate box turtles also had poorer body condition in 2009 (0.529; $p \leq 0.036$) relative to 2004 (0.469), 2005 (0.461), and 2008 (0.460). For all years observed (2004 – 2010) juvenile body condition was significantly ($p < 0.001$) poorer than that of adult females and males. Among juvenile ornate box turtles, body condition in 2006 (0.929) was significantly ($p \leq 0.047$) worse than in 2004 (0.749), 2005

(0.689), 2007 (0.750), 2008 (0.642), and 2010 (0.785). Juvenile ornate box turtle body condition in 2009 (0.848) was significantly worse than 2005 (0.689), 2007 (0.750), and 2008 (0.642). There were only 2 significant differences between annual adult body conditions. Adult males in 2006 (0.386) and 2009 (0.391) were significantly ($p = \leq$ 0.032) lower than female body condition in 2004 (0.315). Annual precipitation had no direct significant effect on body condition (females $F = 2.628$, $df = 5$, $p = 0.180$; males $F = 0.176$, $df = 5$, $p = 0.696$; juveniles $F = 0.067$, $df = 5$, $p = 0.808$; Figure II.12).

Growth

There were strong linear relationships between age and mass ($F_{15} = 242.08$, $p = <0.001$, $r^2 = 0.945$; Figure II.13) and between age and carapace length ($F_{15} = 171.99$, $p = <0.001$, $r^2 = 0.925$; Figure II.15). Turtles age 1 – 16 grew on average 22.6 g and 39 mm per year. Power functions did not greatly increase explanatory power ($r^2 = 0.938$ for power vs. $r^2 = 0.945$ for linear regression of mass; Figure II.14; $r^2 = 0.934$ for power vs. $r^2 = 0.925$ for linear regression of carapace length; Figure II.16).

Reproduction

From May 2004 to September 2010 ornate box turtles were observed mating 18 times (6 from turtle captures, 12 from radio telemetry). The highest amount of observed mating occurred in the month of September (Figure II.17). In 2008, 7 individual adult female ornate box turtles were x-rayed to determine gravidity (1 on 27 May; 1 on 18 June; 6 on 16 July). One gravid female was carrying 5 eggs on 27 May and not gravid when x-rayed again on 16 July. On 23 June 2009, 4 females were x-rayed, and 1 turtle contained 3 eggs and the remaining turtles were not gravid.

Hibernation

No overwintering mortality was observed for the duration of this study (summer 2007 –spring 2010). However at the time data collection ceased on 20 April 2010, 2 turtles had still not emerged from hibernation. While slight movement was observed in March, ornate box turtles at Matador WMA primarily emerged from hibernation in early to mid-April (Figure II.18). Turtles began entering hibernation in mid-October and by late December all turtles were underground (Figure II.19). The earliest observed hibernation occurred on 20 October 2007 the latest observed was the 30 December 2008. Most turtles entered hibernation during the Month of November. In 2008, 5 turtles entered hibernation in October, 15 turtles entered hibernation in November, and 3 in December. The earliest emergence from hibernation was briefly by turtle a male turtle on 26 January 2009, but it returned underground and full emergence occurred on 9 April 2009. Apart from this movement the earliest turtle emergence was 19 March 09 and the latest was the 2 turtles that had not emerged by 21 April 2010.

DISCUSSION

The total number of individuals in a population of ornate box turtles studied by Legler in Kansas over 4 years was estimated to be 286 (Legler 1960, Ernst and Lovich 2009). Though the sample size of turtles at Matador WMA is larger than those observed in Kansas the capture proportions of females, males, and juveniles are similar. In Legler's population, females represented 53%, males 31%, and juveniles 16% (n = 194; Legler 1960). Ornate box turtles at Matador WMA had similar proportion with females representing 54%, males 33%, and juveniles 13% of individuals (n = 477). In a population studied in Wisconsin the sex ratio of females to males was 1.56:1 (n = 102; Doroff and Keith 1990), ornate box turtles at Matador WMA had a slightly higher ratio of 1.65:1 (n = 414). The female bias in sex ratio in ornate box turtles observed at Matador WMA appears to be consistent with other studies conducted throughout their known distribution (Legler 1960, Blair 1976, Doroff and Keith 1990, Bowen et al. 2004).

Although it has been documented that the activity of ornate box turtles seemed largely controlled by rainfall (Ernst and Lovich 2009), I found no relationship between monthly and annual rainfall and activity as represented by the number of captures. This is likely a result of scale. Turtles could have responded to daily rainfall events in a pattern that was obscured by pooling across month and year. However, I lacked sufficient data to examine relationships between captures and precipitation at a finer scale.

The oldest individual aged at Matador WMA was 19 (Figure II.10). This is considerably lower than another population studied in Texas in which the oldest turtles were 2 males at 31 and a female at 32 years old (Blair 1976). In another population studied within Kansas the oldest observed turtle was 28 years old and average of 59 females was 22.5 years, and for 56 males was 21.8 years (Metcalf and Metcalf 1985). There are 3 explanations why no turtles were observed older than 19 years of age at Matador WMA. The first is that the technique of aging annuli could be invalid. However, this is highly unlikely because many studies have addressed age and annuli on the surface of plastral or carapacial scutes in turtles (Galbraith and Brooks 1987b, Galbraith and Brooks 1989, Germano 1998, Bury and Germano 1998, Germano and Bury 1998, Helgren et al. 2000). The use of age annuli have also been verified by comparisons with growth rings in the bones of turtles (Hammer 1969, MacCulloch and Secoy 1983). The second possible explanation is that the observed sample size is too small. From 2007 to 2009, I assessed age from 117 individuals. The third possible explanation is low survival.

The overall annual survival of ornate box turtles at Matador WMA for turtles aged 9-19 was 0.801. This statistic appears to corroborate the radiotelemetry based estimates of survival for this population of 0.748 – 0.867 (Chapter I). These survival estimates of ornate box turtles appear to be lower than in other studies. Survival of a population studied in Illinois was 0.97 for females and 0.90 for males with an overall mean survival of 0.97 (Bowen et al. 2004). Annual survival for another population studied from 1981 – 2000 in Nebraska averaged 0.932 for females and 0.883 for males though the annual survival ranged from 0.810 – 0.965 for females and 0.723 – 0.944 for males (Converse et al. 2005).

For the duration of this study the annual survival at Matador WMA appears to more closely resemble the survival of a marked population in Wisconsin, which during a 10-year period averaged 0.81 for both sexes (Doroff and Keith 1990). Though in this population of marked ornate box turtles annual survival ranged from 0.51-1.00 during the 10-year period. In 1986 and 1987, Doroff and Keith (1990) radio-tagged individuals and annual survival was 0.96 (4126 radio-days, *n* = 5) in 1986; in 1987 survival was 0.91 (3,315 radio-days, *n* = 26). Nebraska ornate box turtles had a considerable range in survival from year to year in 19 years of observation (Converse et al 2005), turtles at Matador WMA may yield similar variations and further monitoring of this population beyond the 3 years of my study seems warranted to help clarify variation in survival rates.

The mean straight line carapace length observed in turtles found at Matador WMA is similar to those observed in other populations studied (Legler 1960, Blair 1976, Converse et al. 2002). Legler (1960) reported that females in Kansas grew larger than males while there was no difference between the sexes in Nebraska and Texas (Blair 1976, Converse et al. 2002). My observations at Matador WMA suggested no difference between male and female carapace length. In Legler's (1960) and Blair's (1976) study growth appeared to plateau between the ages of 13 and 15. Turtles at Matador WMA had continual growth with age and growth did not plateau. However given my predicted age structure, turtles at Matador WMA are just reaching the age where growth begins to plateau in other populations. Thus, the pattern of growth in my population might be heavily constrained by its age structure. In Oklahoma, St. Clair (1998) studied a captive population of ornate box turtles and mean adult size was 135.3 mm for females (*n* = 35) and 122.8 mm for males (*n* = 11; 1998). Similar to turtles observed at Matador WMA, St. Clair (1998) failed to detect any difference in body size between the sexes. St. Clair (1998) did observe a plateau in captive ornate box turtles growth at carapace lengths >120.0 mm. Therefore, the discrepancy between the plateau found in Legler's (1960) and Blair's (1976) wild populations and those at Matador WMA may be because of resource availability and annual survival. The study area and wild populations of ornate box turtles examined previously in Kansas and Texas were considerably smaller than those found at Matador WMA (Legler 1960, Blair 1976). The habitat and resource availability may be high enough at Matador WMA to encourage continual growth later than ages 13 – 15 as observed by Legler (1960) and Blair (1976). High resource availability at Matador WMA is supported by the small home ranges of turtles found there (Chapter I).

There is very little reported on the mass of ornate box turtles. Legler (1960) flatly states that "Absolute weights have little significance since weight is affected to a large extent by the amount of fluid in the body." However, although body mass may be a reflection of shell size, when used in conjunction with straight-line carapace length it can be an indicator of body condition (Miller and Birchard 2005). Condition indices such as SCL/Mass have been used to describe the "health" of turtles (Miller and Birchard 2005). In my population, females had slightly better body condition than males. Juveniles had poorer body condition across all effects measured than both adult females and males. This is most likely attributed to excess energy being dedicated to shell growth as this provides advantages for survival and competition (Legler 1960). However, comparisons of body condition between juveniles and adults may not be warranted, because of the ontology of shell formation. Because juveniles do not have a fully ossified shell, values of condition derived in this way may have more to do with extent of shell ossification than turtle health.

Turtles had significantly poorer body condition in 2006 and 2009 than any of the other years of the study (2004 – 2010). Although there was no direct relationship to body condition and annual precipitation, further investigation is needed. One possible explanation is that in the 2 years preceding the poor body condition, precipitation was either below average or timing of precipitation fell outside prime growing peaks. Daily high temperatures were also above average in 2006 and 2009, suggesting that these patterns were weather driven. Another possible explanation is that an unmeasured effect related to hibernation impacted body condition. Further investigation is needed to better explain these patterns in body condition.

Most reproductive activity at Matador WMA occurred in September followed by a secondary peak in May. This closely resembled the pattern found in a population studied in Wisconsin, where 50% of reproductive activity occurred late in the year (August-September) and 38% of reproductive activity occurred early in the year (May-June; Doroff and Keith 1990). However, in Kansas Legler (1960) found mating to be most common in the spring soon after emergence from hibernation. The clutch sizes observed in box turtles at Matador WMA resemble those observed in other populations throughout its known range (Legler 1960, Doroff and Keith 1990, Nieuwolt-Dacanay

1997). Ornate box turtles in Kansas had an average clutch size of 4.7 eggs (Legler 1960). While in Wisconsin clutch size averaged 3.5 eggs (Doroff and Keith 1990). In a New Mexico population of ornate box turtles the average clutch was 2.7 eggs.

Hibernating activity by ornate box turtles at Matador WMA was similar to observations in other studies conducted throughout their know distribution (Legler 1960, Blair 1976, Doroff and Keith 1990, Bernstein and Black 2005). In Iowa and Wisconsin turtles began hibernating in September; while in Kansas and Texas turtles began entering hibernation in October and by the end of November most turtles were underground (Legler 1960, Blair 1976, Doroff and Keith 1990, Bernstein and Black 2005). In my population, ornate box turtles had a staggered entry into hibernation beginning in October with all turtles underground by the end of December. At Matador WMA ornate box turtles appeared to synchronize spring emergence with some type of environmental factor. Legler (1960) observed that emergence of ornate box turtles was stimulated by temperature and humidity in Kansas.

The ornate box turtles I studied at Matador WMA shared a variety of characteristics reported in other demographic studies conducted throughout their known distribution. The female sex bias, adult body size, mating, clutch size, and hibernation activity of ornate box turtles recorded at Matador WMA supported previous observations found in Wisconsin, Kansas, Iowa, Nebraska, and southern Texas. I found annual survival for Matador WMA box turtles to be lower than those reported in populations observed in Illinois and Nebraska. Further investigation is needed to determine the variables that affect ornate box turtle survival at Matador WMA. Although survival was determined to be low it is important to note that in 6 years the sample size I observed at Matador WMA was much larger than those reported by studies conducted in Kansas over a 5 year period (Legler 1960), in Wisconsin over a 10 year period (Doroff and Keith 1990), and in Nebraska over a 20 year period (Converse et al. 2005). This suggests that mortality may be higher at Matador WMA, but the habitat is favorable and supports a large population of ornate box turtles.

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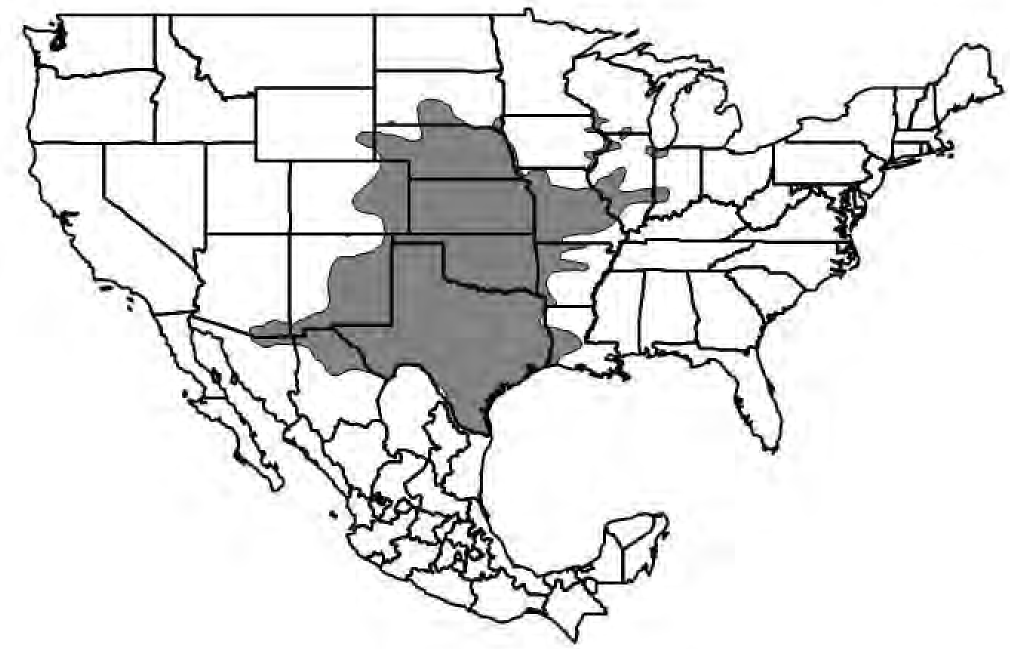

Figure II.1: Geographic distribution of the ornate box turtle in North America (modified from Ernst and Lovich [2009] and Iverson [1992]).

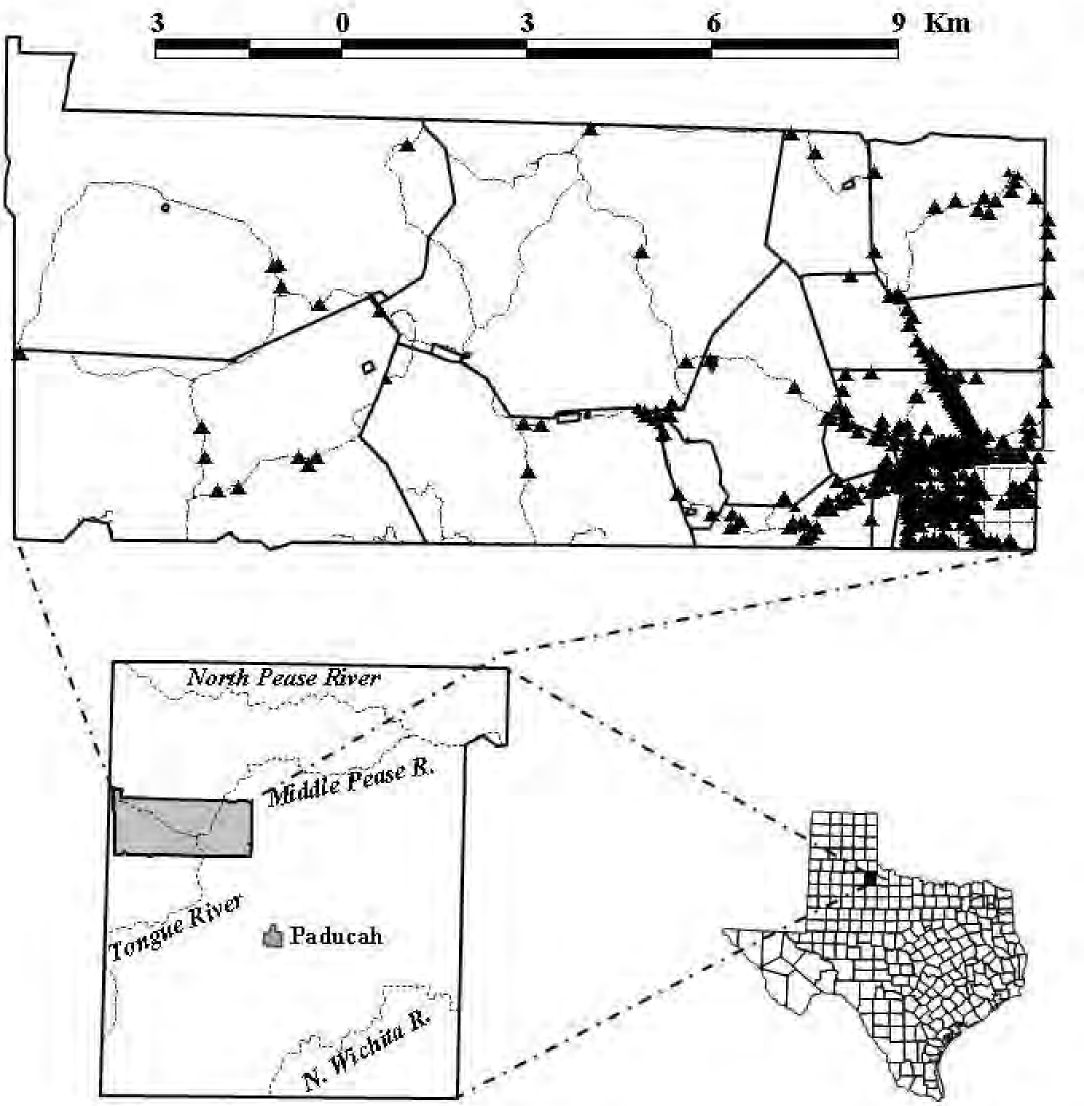

Figure II.2: The location of Cottle County within Texas (lower right), Matador Wildlife Management Area within Cottle County in relation to major river drainages and the town of Paducah (lower left), and ornate box turtle captures (triangles) within Matador Wildlife Management Area (upper) from 7 May 2004 – 24 September 2010. Within the figure of Matador Wildlife Management Area, dashed lines represent roads and solid lines represent fences.

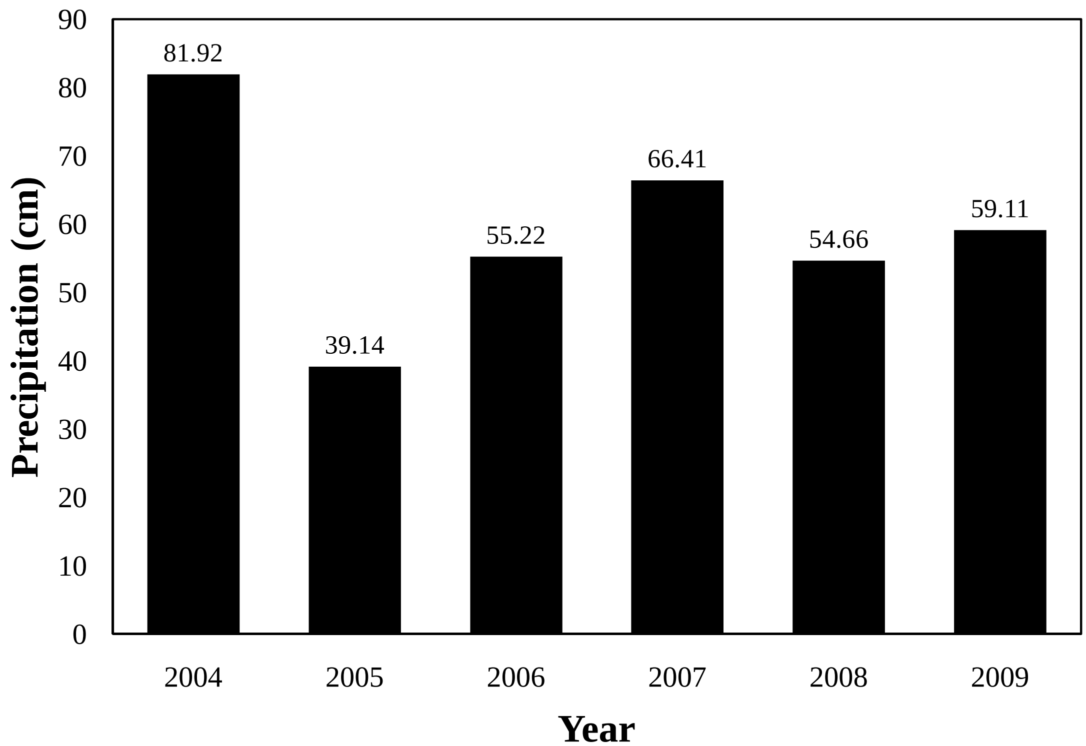

Figure II.3: Annual precipitation (cm) recorded from the National Weather Service Cooperative Observer station in the town of Paducah located ~13 km south-southeast of Matador Wildlife Management Area, Cottle County, Texas.

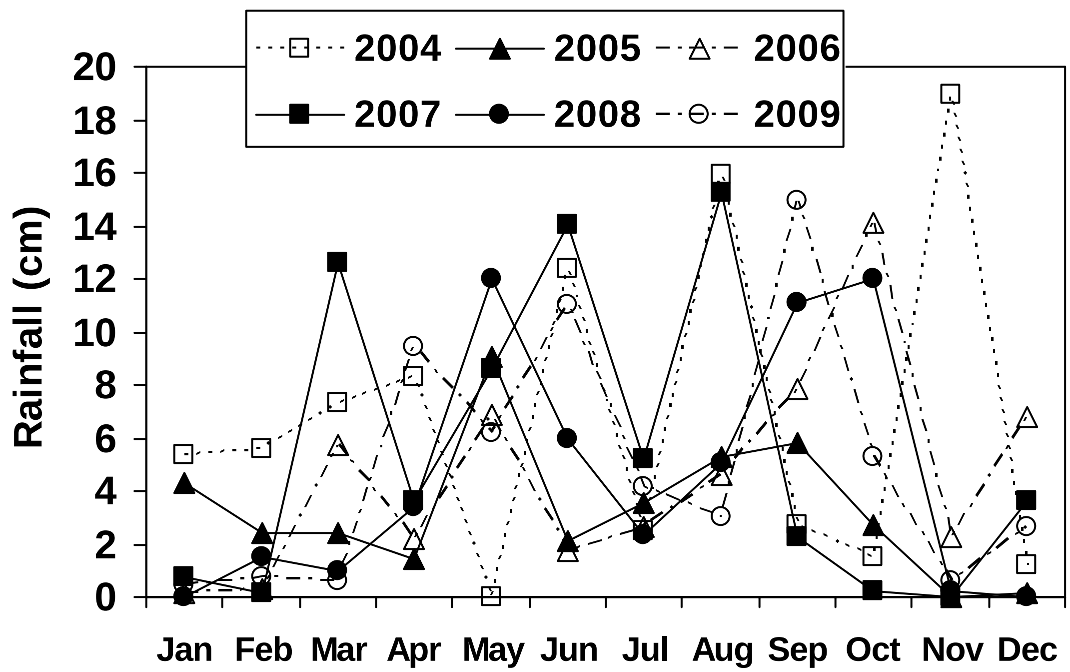

Figure II.4: Monthly precipitation (cm) recorded from the National Weather Service Cooperative Observer station in the town of Paducah located ~13 km south-southeast of Matador Wildlife Management Area, Cottle County, Texas.

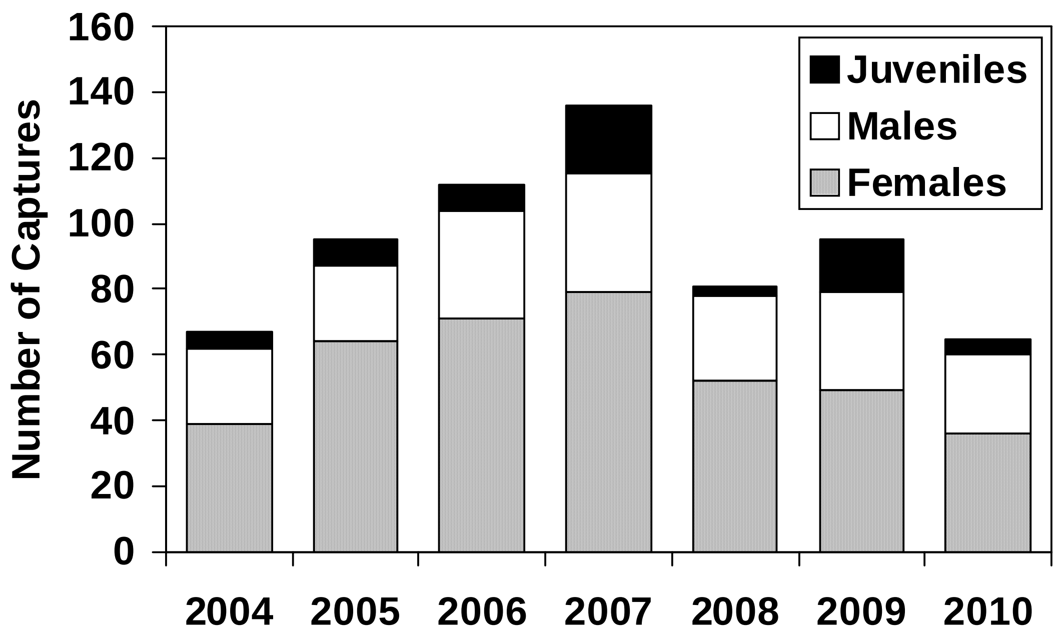

Figure II.5: Annual number of individual female, male, and juvenile ornate box turtles captured at Matador Wildlife Management Area, Cottle County, Texas, from May 2004 – September 2010.

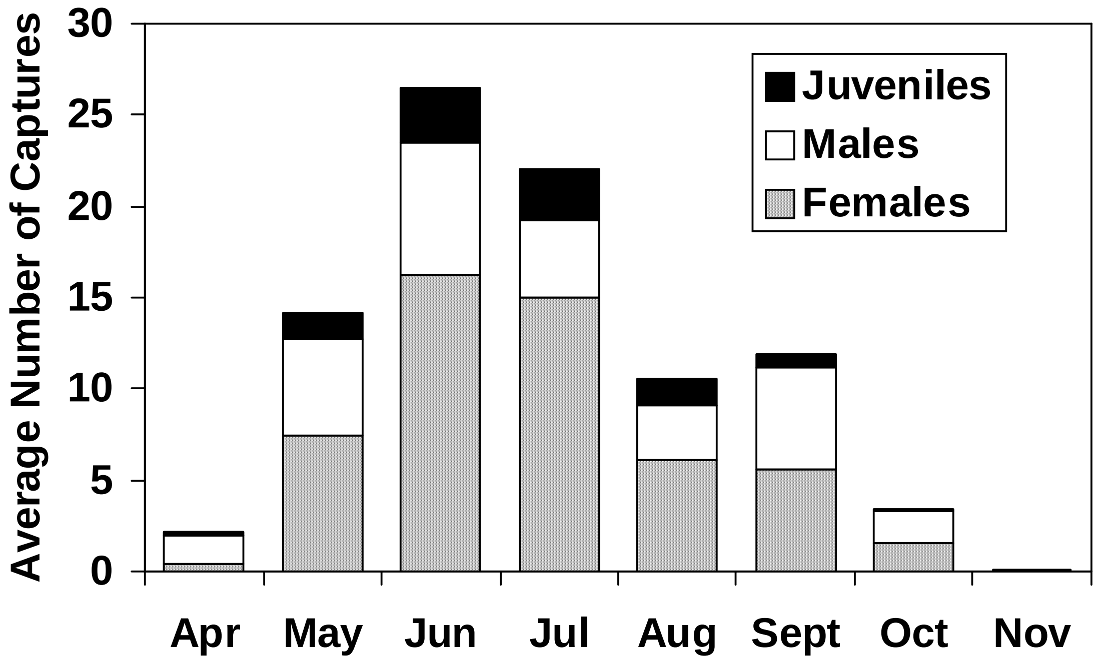

Figure II.6: Average monthly number of individual female, male, and juvenile ornate box turtles captured at Matador Wildlife Management Area, Cottle County, Texas, from May 2004 – September 2010.

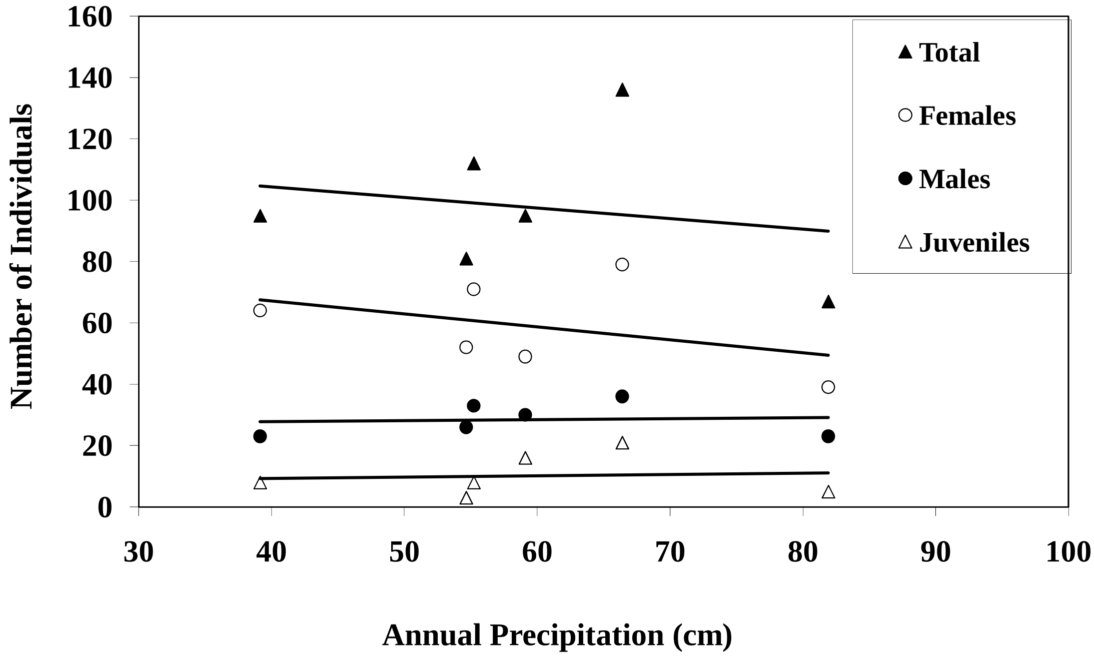

Figure II.7: Simple linear regressions for comparing the annual numbers of individual adult female, adult male, and juvenile, and total ornate box turtles ($p > 0.117$) captured with annual precipitation (cm) captured at Matador Wildlife Management Area, Cottle County, Texas, May 2004 to September 2010.

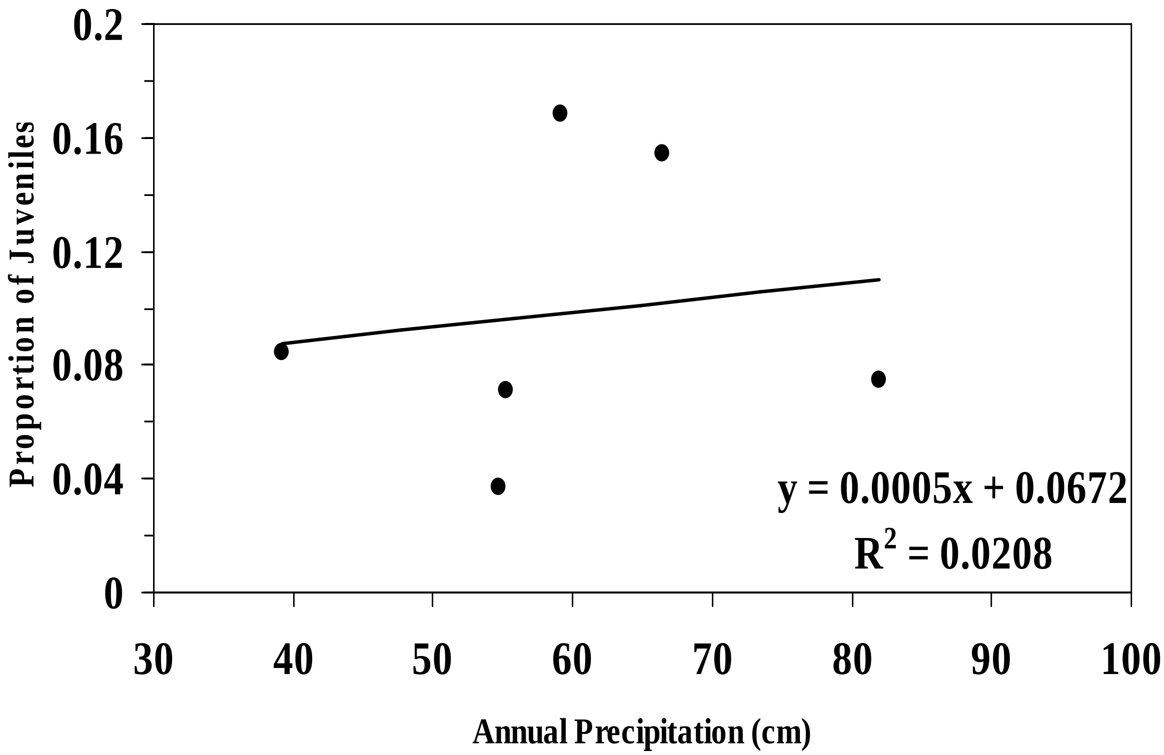

Figure II.8: Relationship between precipitation (cm) and proportion of juvenile ornate box turtles (p = 0.785) captured at Matador Wildlife Management Area, Cottle County, Texas, May 2004 – September 2010.

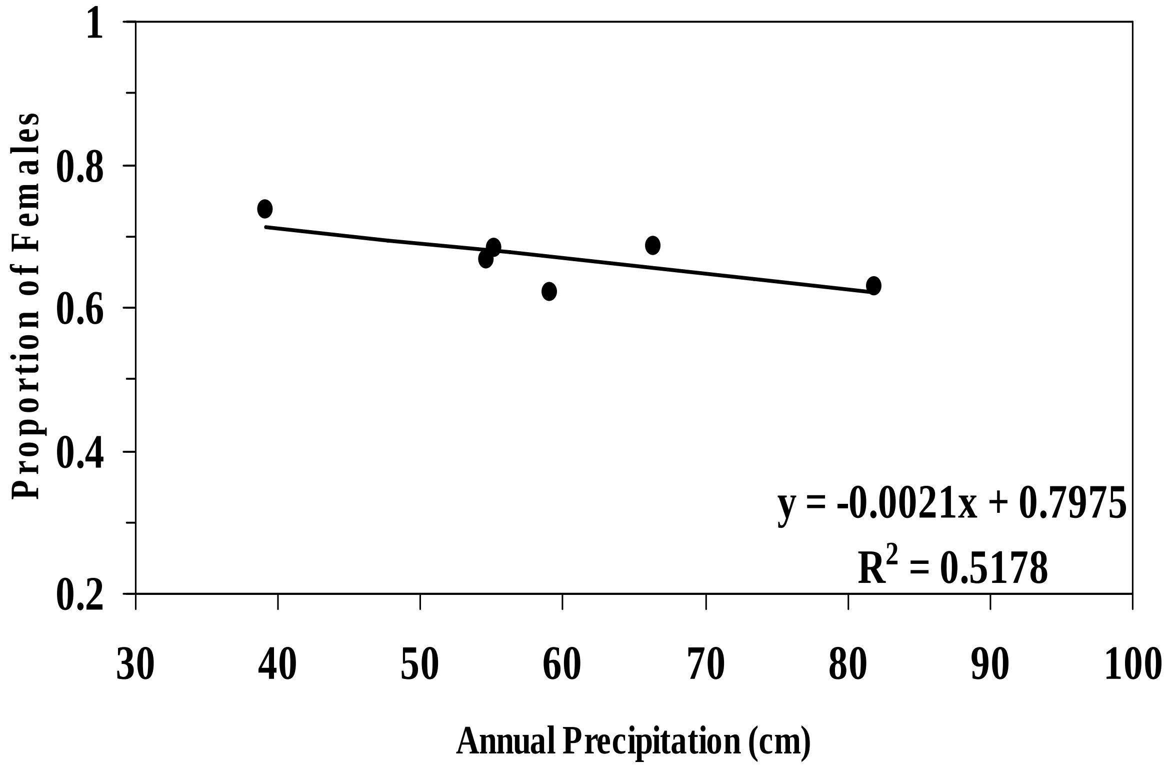

Figure II.9: Relationship between precipitation (cm) and proportion of adult female ornate box turtles (p = 0.191) captured at Matador Wildlife Management Area, Cottle County, Texas, May 2004 – September 2010.

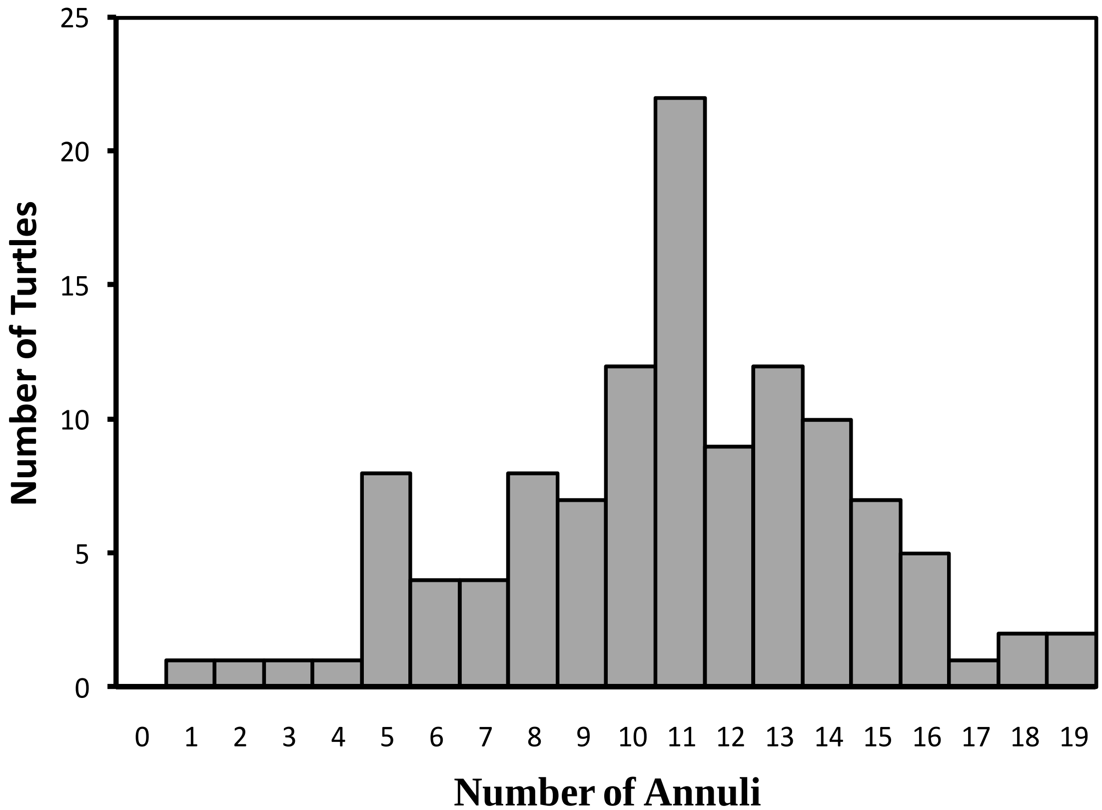

Figure II.10: Age distribution for ornate box turtles (n = 117) captured at Matador Wildlife Management Area, Cottle County, Texas, 2007 – 2009.

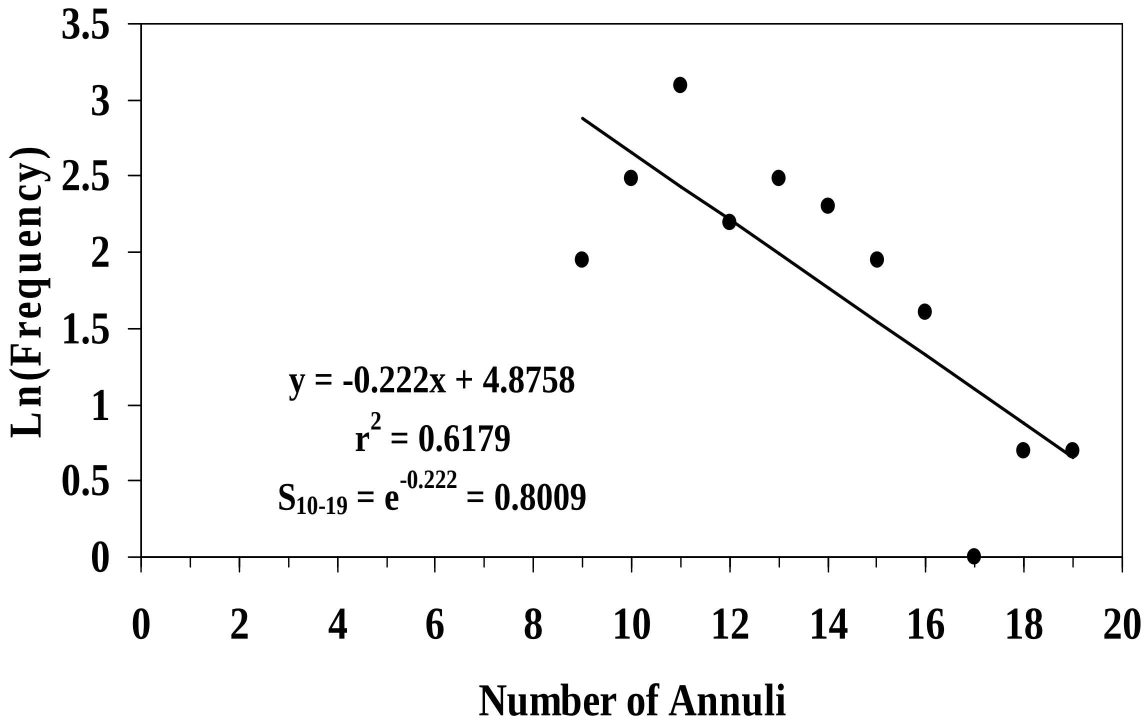

Figure II.11: Natural log (frequency) age distribution for calculation of annual survival of adult ornate box turtles (ages 9-19, *n* = 89) from Matador Wildlife Management Area, Cottle County, Texas, 2007 – 2009).

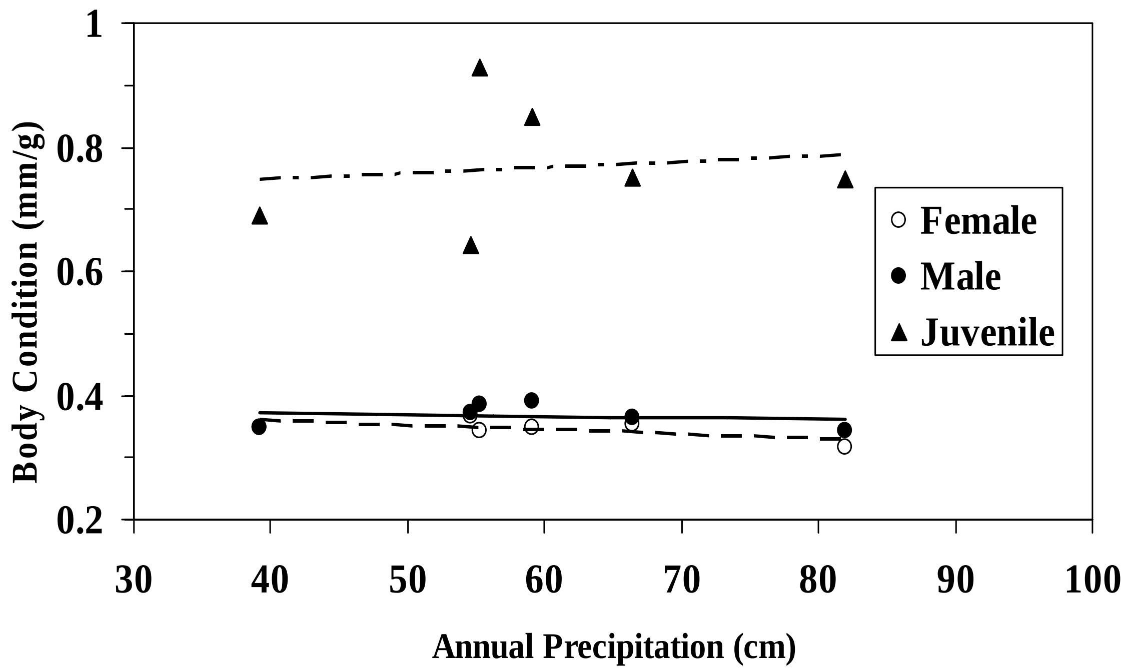

Figure II.12: Relationship of annual precipitation to body condition for adult female, adult male and juvenile ornate box turtles from Matador Wildlife Management Area, Cottle County, Texas, from May 2004 – September 2010.

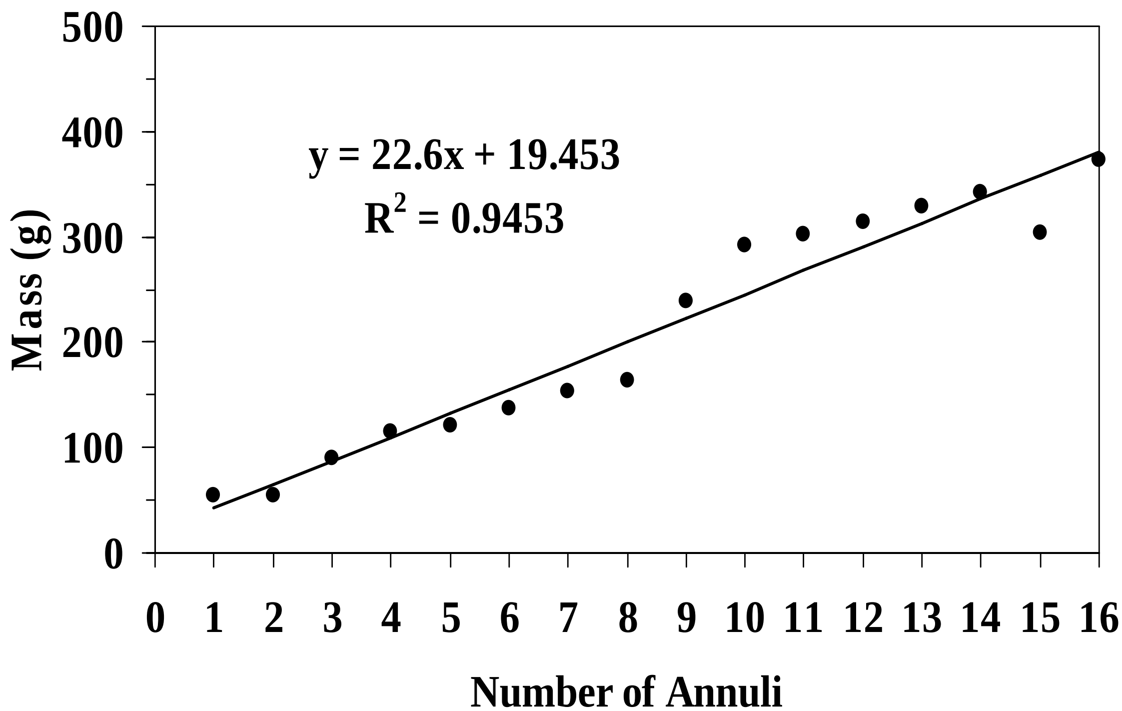

Figure II.13: Linear regression between age and mass for ornate box turtles (*n* = 112) on the Matador Wildlife Management Area, Cottle County, Texas, from 2007 – 2009.

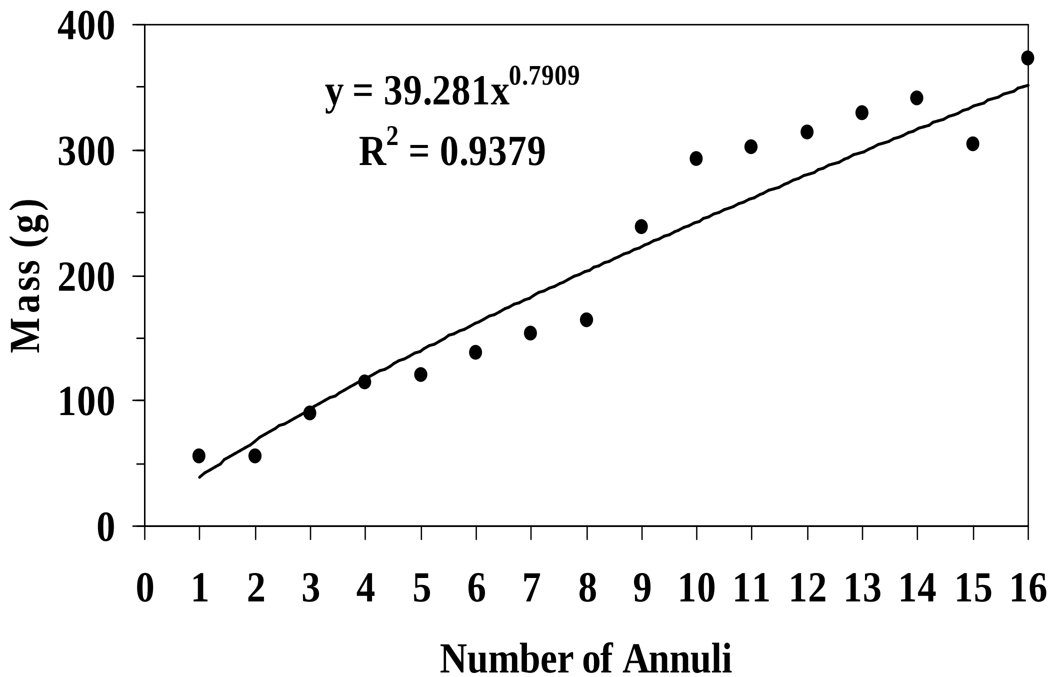

Figure II.14: Power function between age and mass for ornate box turtles (n = 112) on the Matador Wildlife Management Area, Cottle County, Texas, from 2007 – 2009.

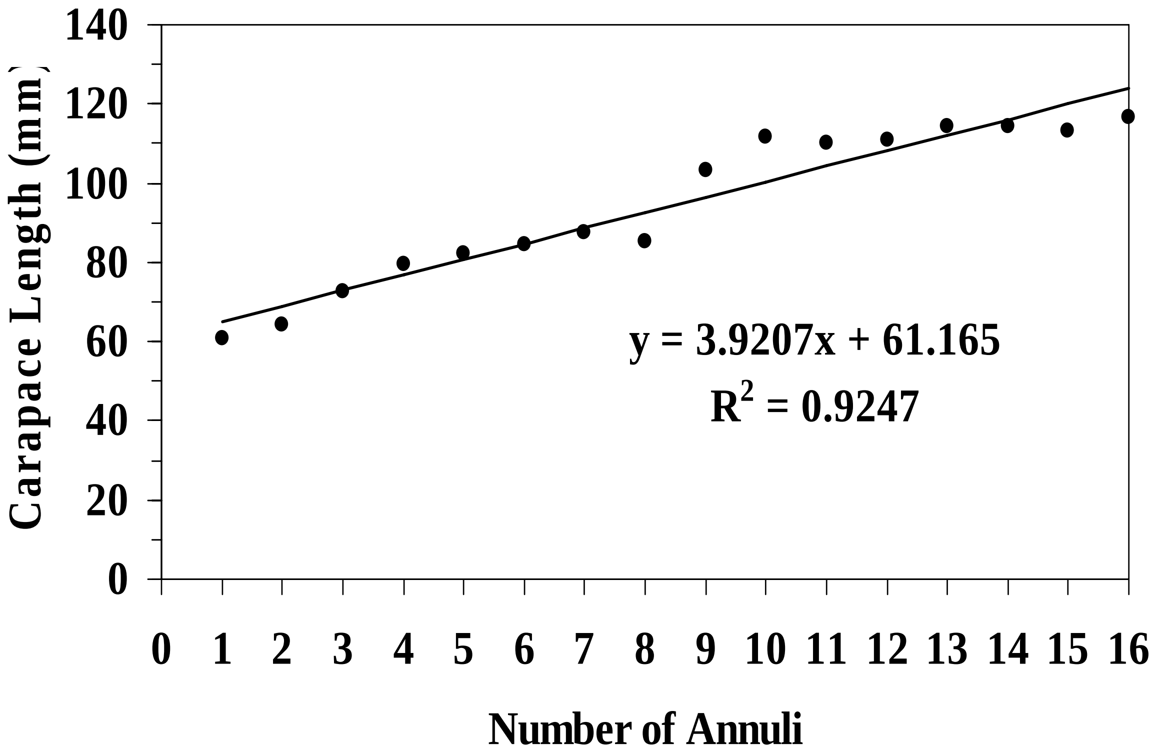

Figure II.15: Linear regression between age and straight line carapace length for ornate box turtles (*n* = 112) on the Matador Wildlife Management Area, Cottle County, Texas, from 2007 – 2009.

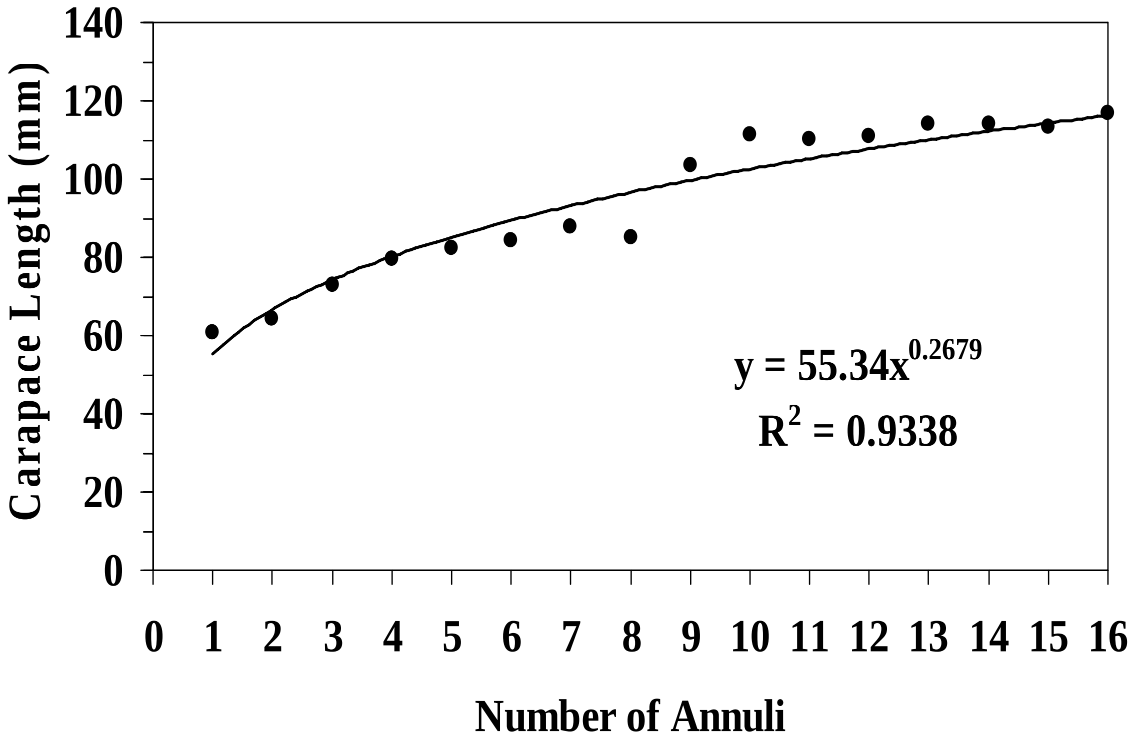

Figure II.16: Power function between age and straight line carapace length for ornate box turtles (*n* = 112) on the Matador Wildlife Management Area, Cottle County, Texas, from 2007 – 2009.

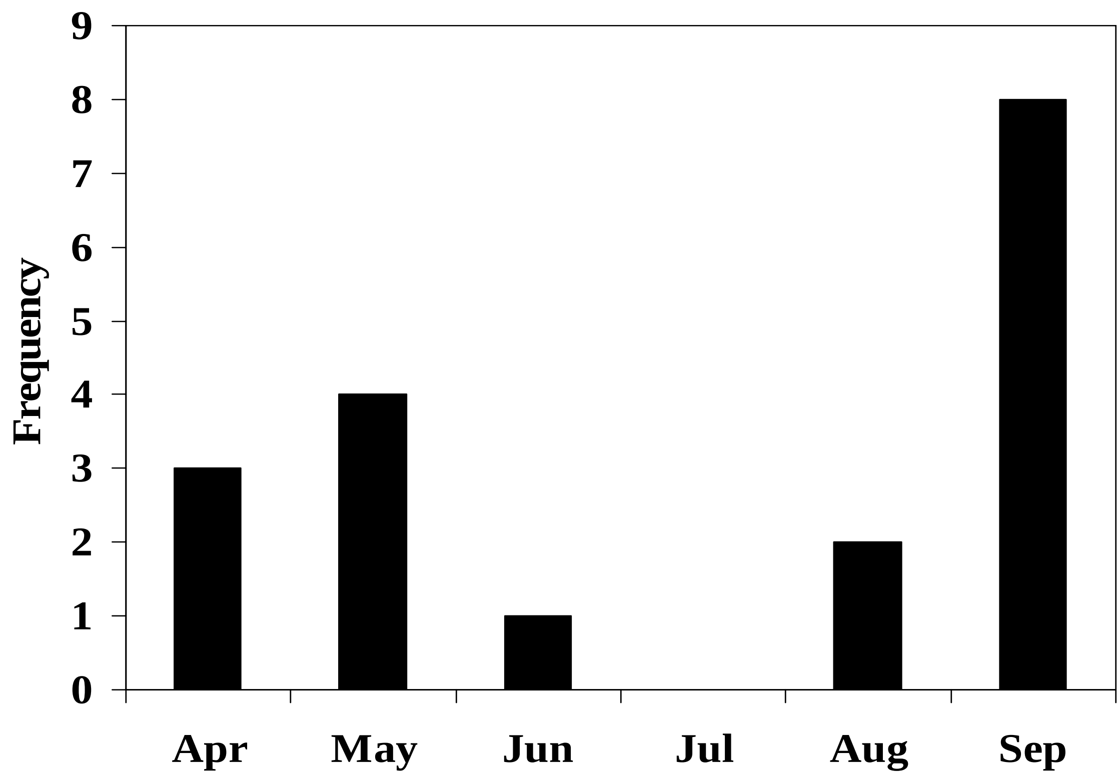

Figure II.17: Frequency of mating observations for ornate box turtles at Matador Wildlife Management Area, Cottle County, Texas, from May 2004 – September 2010.

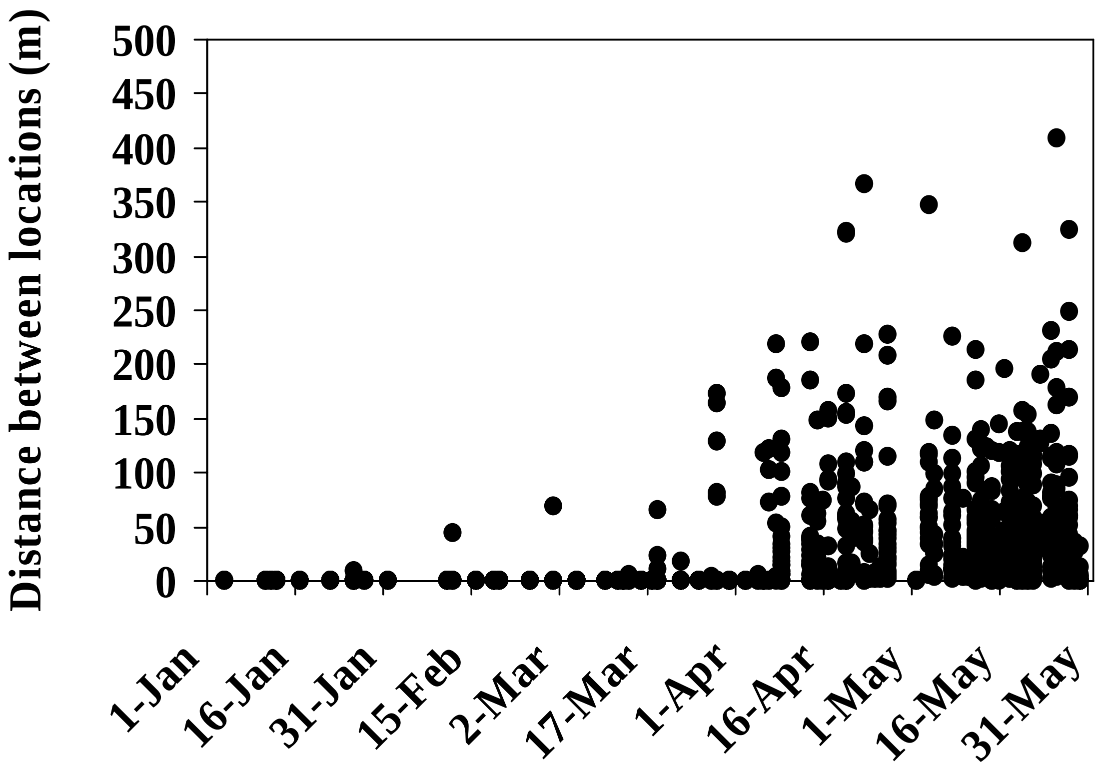

Figure II.18: Temporal variation in activity as expressed as distance between consecutive locations for ornate box turtles (n = 24) monitored during the early active season at Matador Wildlife Management Area, Cottle County, Texas from 21 June 2007 to 22 April 2010.

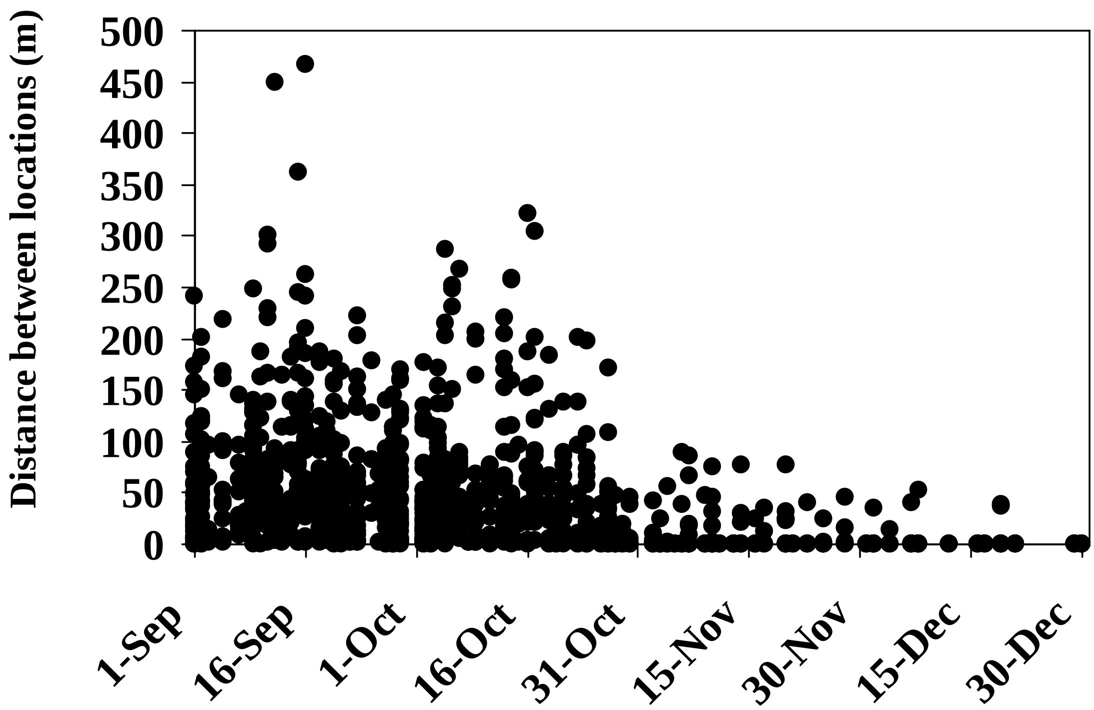

Figure II.19: Temporal variation in activity as expressed as distance between consecutive locations for ornate box turtles (*n* = 24) monitored during the late active season at Matador Wildlife Management Area, Cottle County, Texas from 21 June 2007 to 22 April 2010.

CHAPTER III

APPENDIX

Table III.1: Average percentage of radiolocations within each herbaceous cover type and average canopy cover of that cover type when used by ornate box turtles (n = 31) monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007-22 April 2010.

Type of Cover	Scientific Name	% Radio-locations	Average % Cover
No Cover		22.5	
Litter		19.6	77.7
Texas Blue Grass	*Poa arachnifera*	11.7	88.0
Western Ragweed	*Ambrosia psilostachya*	9.48	78.0
Sleepy Daisy	*Xanthisma texanum*	7.97	70.8
Sand Dropseed	*Sporobolus cryptandrus*	5.68	50.1
Purple Three-awn	*Aristida purpurea*	4.19	82.8
Indian Blanket	*Gaillardia pulchella*	2.9	79.7
Blue Gramma	*Bouteloua gracilis*	2.71	46.4
Fringed Signal Grass	*Brachiaria ciliatissima*	1.87	53.8

Table III.2: Average percentage of radiolocations within each woody cover type and average canopy cover of that cover type when used by ornate box turtles (n = 31) monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007-22 April 2010.

Type of Canopy	Scientific Name	% Radio-locations	Average % Canopy
Honey Mesquite	*Prosopis glandulosa*	33.5	98.9
No Canopy		31.8	
Sandsage	*Artemisia filifolia*	31.6	94.7
Yucca	*Yucca glauca*	0.9	89.2
Unknown		0.87	100.0
Silk Tree	*Albizia julibrissin*	0.39	100.0
Netleaf Hackberry	*Celtis reticulata*	0.32	100.0
Shinnery Oak	*Quercus havardii*	0.19	76.2
Sand Plum	*Prunus angustifolia*	0.16	100.0
Litter		0.13	85.0

Table III.3: Total radio relocation points, 100% minimum convex polygon home range (ha), 95% bivariate ellipse (ha), and 95% fixed kernel (ha) for female turtles (*n* = 15) monitored from 21 June 2007-22 April 2010.

Turtle ID	# of Points	100% MCP	Bivariate Ellipse	95% Fixed Kernel
100	41	0.75	1.28	0.64
101	245	14.95	7.35	2.50
102	343	2.46	2.72	1.09
105	40	1.33	1.92	1.25
106	311	1.67	2.05	1.50
112	298	14.17	21.09	13.73
116	267	1.26	1.47	0.84
201	210	4.34	3.79	1.02
203	118	2.21	2.81	1.35
204	230	4.21	3.61	1.52
205	227	1.61	1.44	0.60
206	227	5.52	4.59	2.85
207	202	6.29	3.46	1.34
211	206	4.82	4.48	2.15
212	39	0.54	0.93	0.81

Table III.4: Total radio relocation points, 100% minimum convex polygon home range (ha), 95% bivariate ellipse (ha), and 95% fixed kernel (ha) for male turtles (*n* = 12) monitored from 21 June 2007-22 April 2010.

Turtle ID	# of Points	100% MCP	Bivariate Ellipse	95% Fixed Kernel
109	18	1.14	3.35	2.11
110	29	1.12	2.24	1.84
111	297	12.47	11.25	2.62
113	304	2.09	1.66	0.50
115	195	1.75	1.84	0.71
200	226	6.48	8.62	3.11
202	219	10.17	13.73	5.02
208	206	9.20	1.16	6.03
209	216	5.13	8.39	3.90
210	197	2.98	4.22	2.49
213	109	2.88	3.59	1.44
215	185	6.81	6.39	2.59

Table III.5: Cumulative radio relocation points, total distance (m), maximum distance (m), and mean speed (m) for female (*n* = 15) turtles monitored from 21 June 2007-22 April 2010.

Turtle ID	# of Points	Total Distance	Max Distance	Mean Speed
100	41	914.7	131.6	39.8
101	245	9138.9	682.9	8.8
102	343	6395.0	137.3	7.7
105	40	986.6	189.6	34.2
106	311	9542.5	197.3	11.6
112	298	11880.6	367.5	14.8
116	267	4375.3	100.4	6.0
201	210	6135.6	222.8	8.9
203	118	2864.2	122.9	6.9
204	230	6897.5	222.3	10.0
205	227	3517.3	248.6	5.1
206	227	10549.8	301.4	15.4
207	202	7674.2	391.6	11.2
211	206	7217.7	245.1	10.8
212	39	883.1	71.7	18.0

Table III.6: Cumulative radio relocation points, total distance (m), maximum distance (m), and mean speed (m) for male turtles (n = 12) monitored from 21 June 2007-22 April 2010.

Turtle ID	# of Points	Total Distance	Maximum Distance	Mean Speed
109	18	667.6	123.9	30.4
110	29	1238.6	106.2	31.0
111	297	15063.9	337.9	18.9
113	304	7850.7	142.7	10.0
115	195	3756.1	134.5	6.0
200	226	9408.0	309.1	13.6
202	219	12446.3	466.8	18.0
208	206	10549.8	301.4	15.4
209	216	9857.7	321.9	14.4
210	197	9174.3	228.7	13.5
213	109	4381.6	156.2	12.4
215	185	9232.8	366.6	14.8

Table III.7: Carapace length (mm), mass (g), cumulative radio relocation points, total distance (m), maximum distance(m), mean speed (m), 100% minimum convex polygon home range (ha), 95% bivariate ellipse (ha), and 95% fixed kernel (ha) for juvenile turtles monitored from 29 June 2007-2 October 2007.

Turtle ID	Carapace Length	Mass	# of Points	Total distance	Max distance	Mean speed	100% MCP	Bivariate ellipse	95% Fixed kernel
103	68.10	70	28	986.6	103.8	39.5	1.01	1.58	1.30
104	79.60	115	27	838.4	70.2	34.9	0.43	0.86	0.62
107	57.50	40	58	934.8	96.0	10.9	0.27	0.27	0.14
108	64.20	55	19	436.1	56.4	21.8	0.15	0.39	0.27

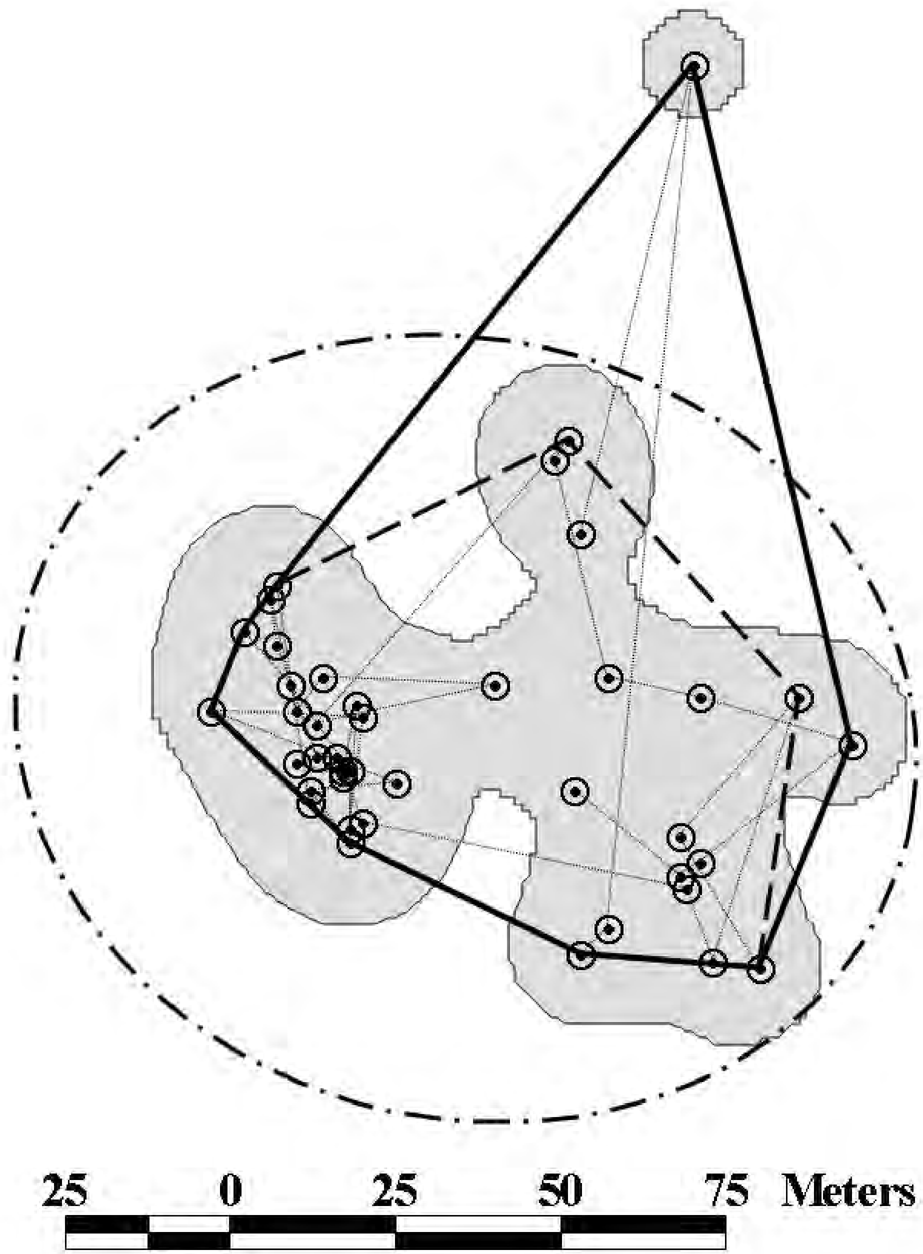

Figure III.1: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 100 monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007-14 July 2007.

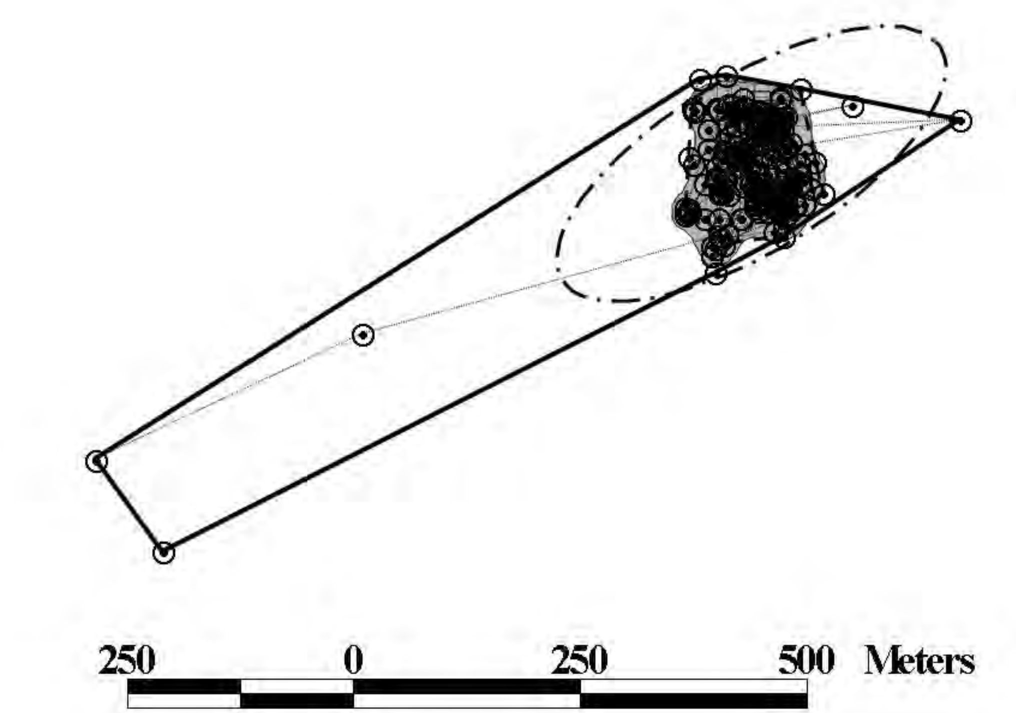

Figure III.2: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 101 monitored at Matador Wildlife Management Area in Cottle County, Texas from 21 June 2007-22 April 2010.

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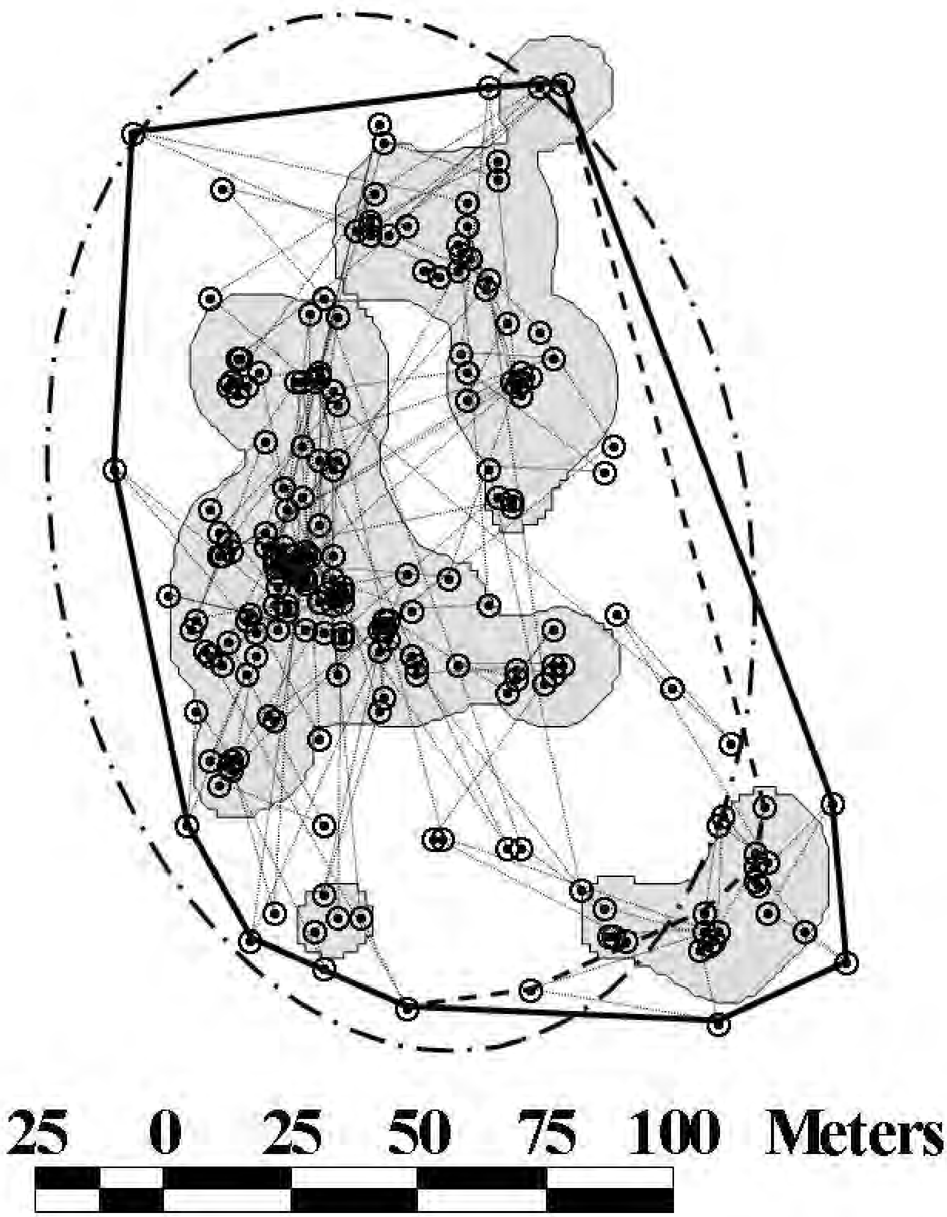

Figure III.3: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 102 monitored at Matador Wildlife Management Area in Cottle County, Texas from 4 July 2007-9 October 2009.

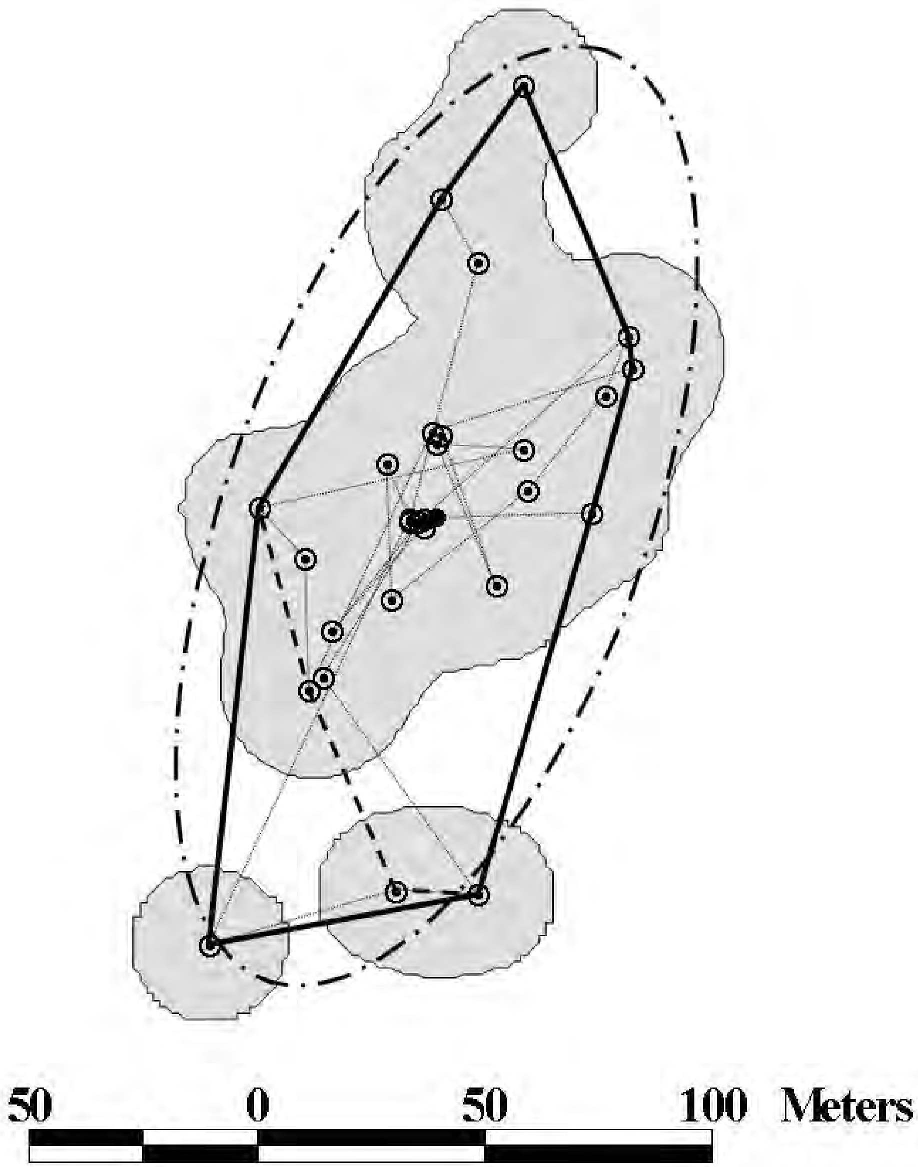

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Figure III.4: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for juvenile ornate box turtle number 103 monitored at Matador Wildlife Management Area in Cottle County, Texas from 29 June 2007-25 July 2007.

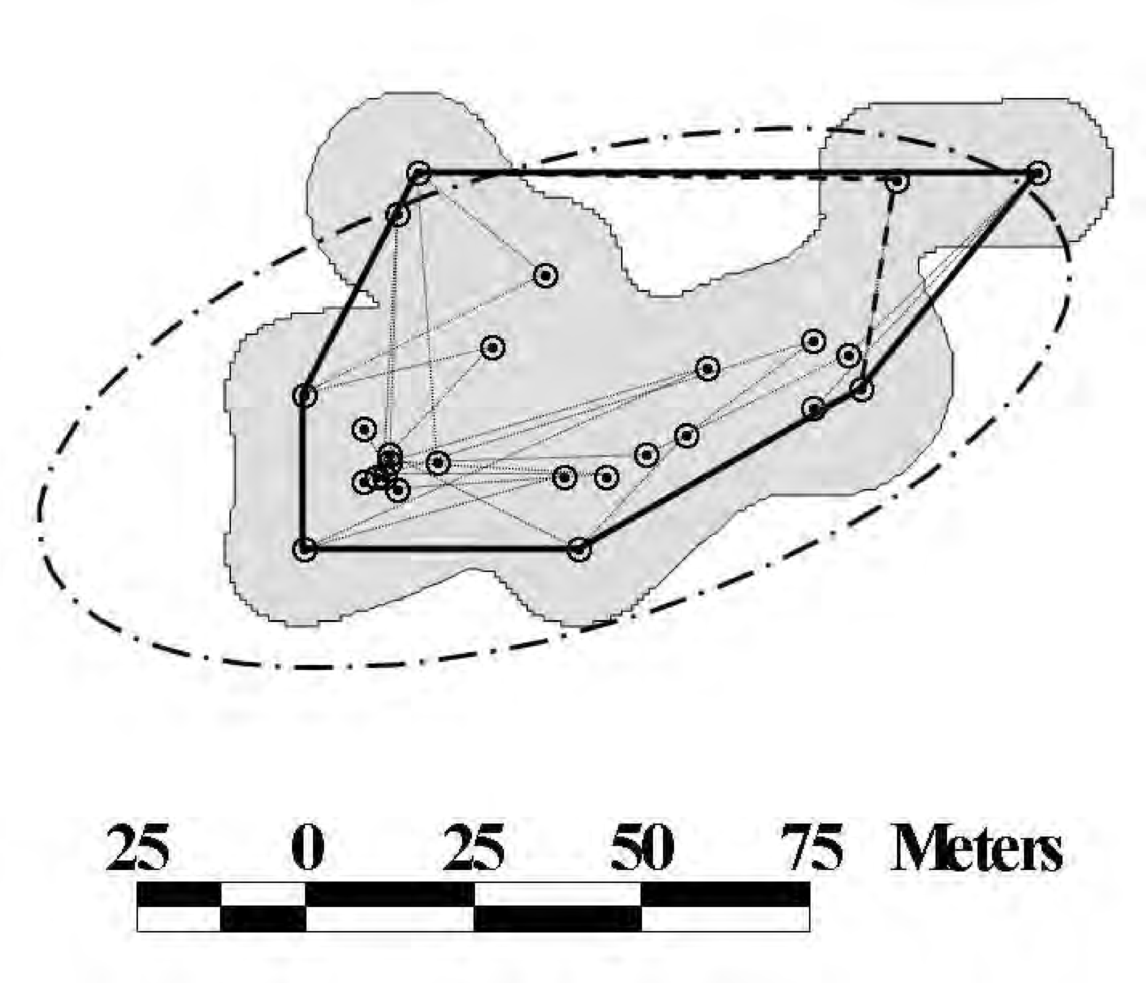

Figure III.5: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for juvenile ornate box turtle number 104 monitored at Matador Wildlife Management Area in Cottle County, Texas from 29 June 2007-25 July 2007.

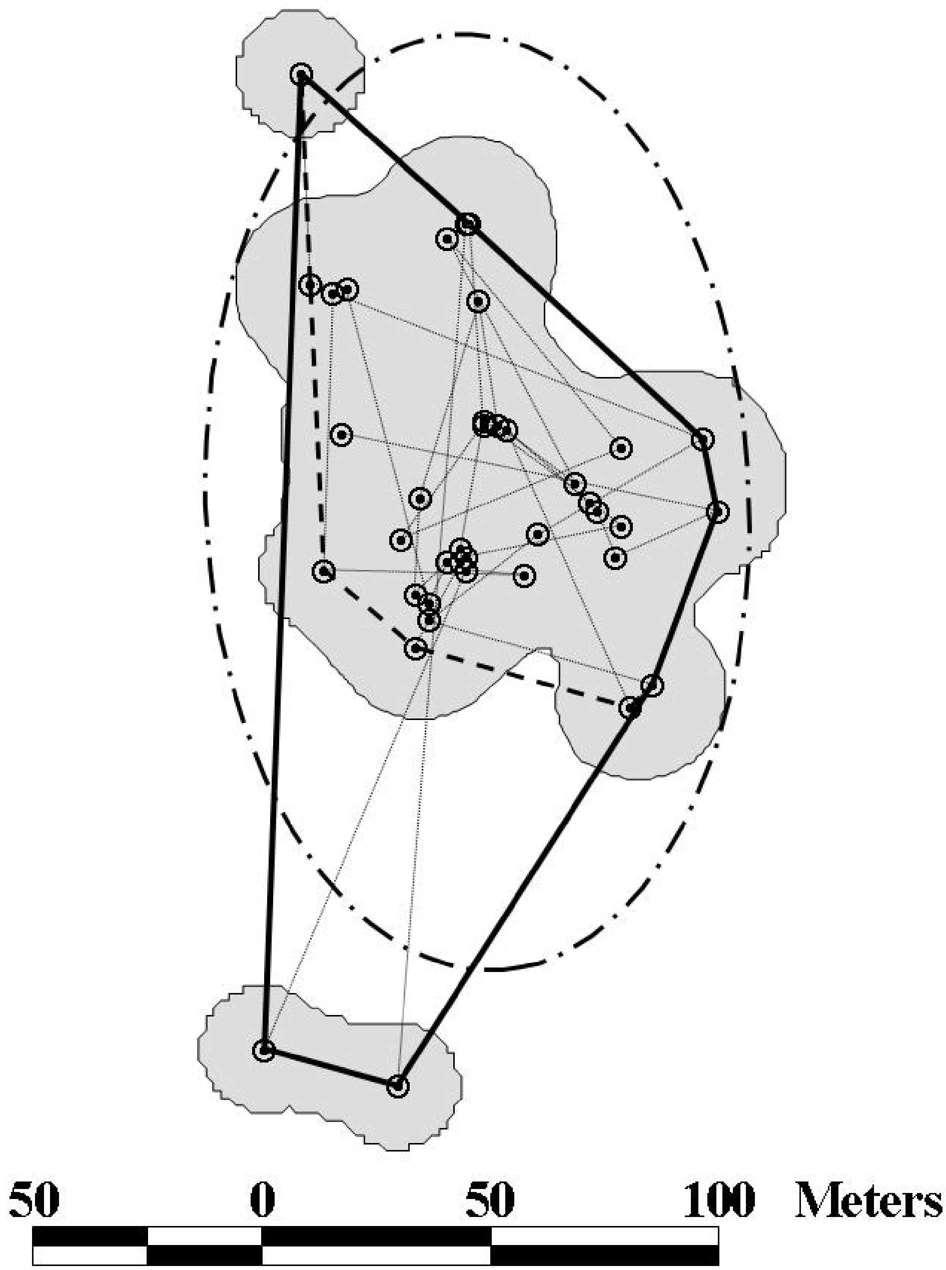

Figure III.6: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 105 monitored at Matador Wildlife Management Area in Cottle County, Texas from 4 July 2007-19 August 2007.

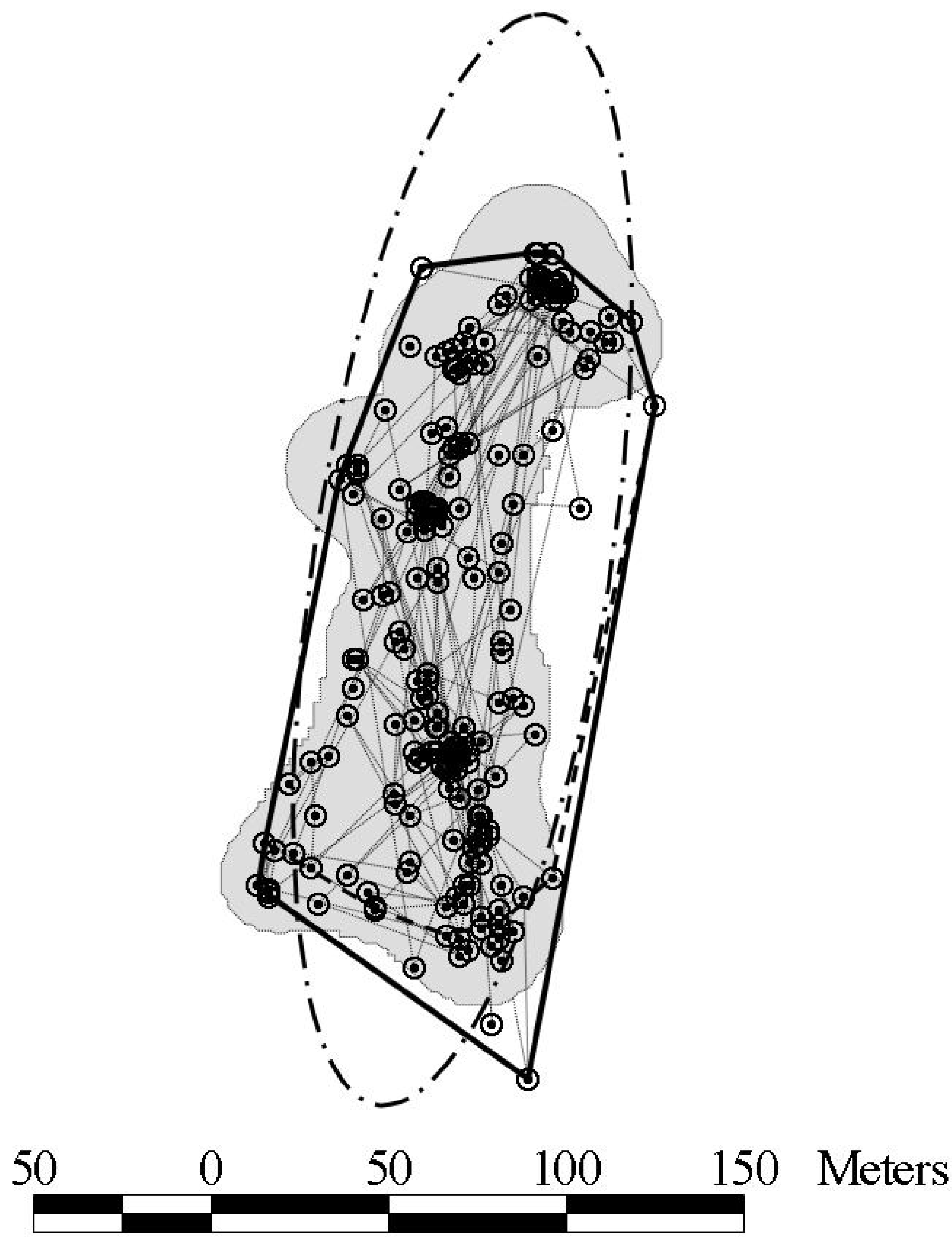

Figure III.7: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 106 monitored at Matador Wildlife Management Area in Cottle County, Texas from 6 July 2007-9 October 2009.

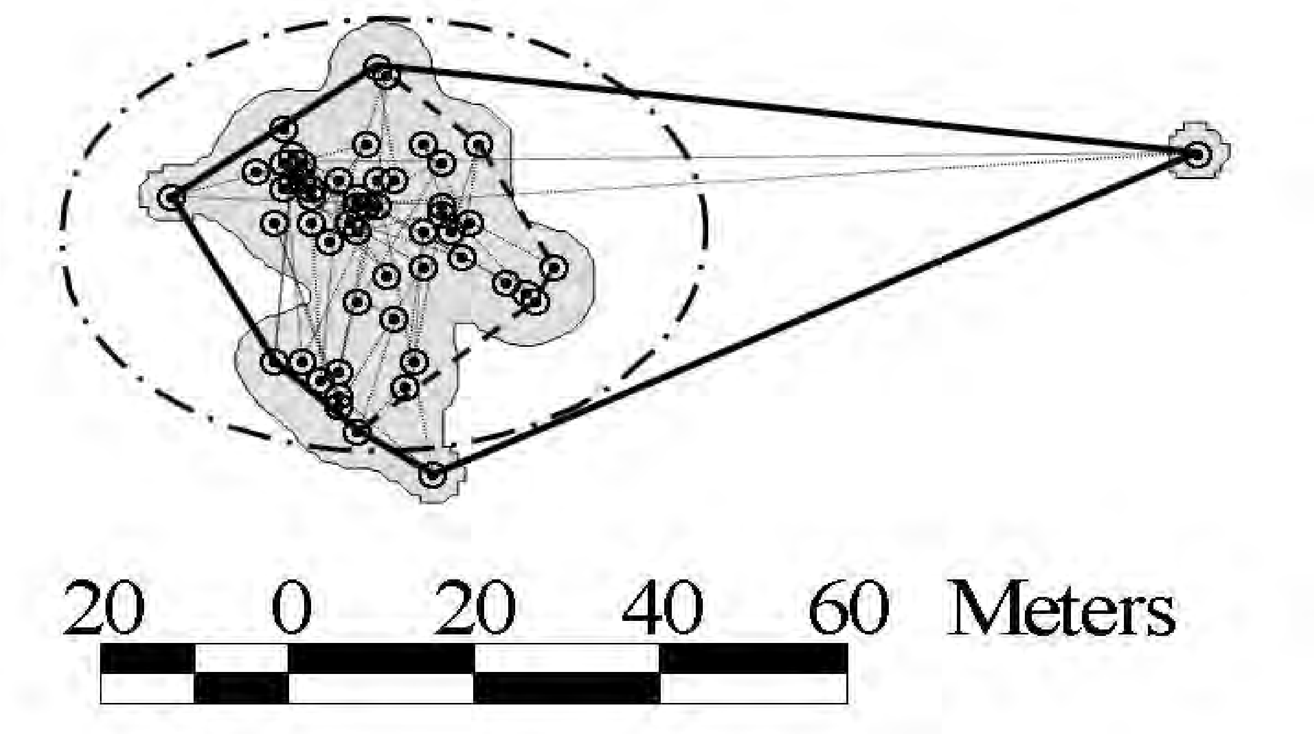

Figure III.8: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for juvenile ornate box turtle number 107 monitored at Matador Wildlife Management Area in Cottle County, Texas from 6 July 2007-2 October 2007.

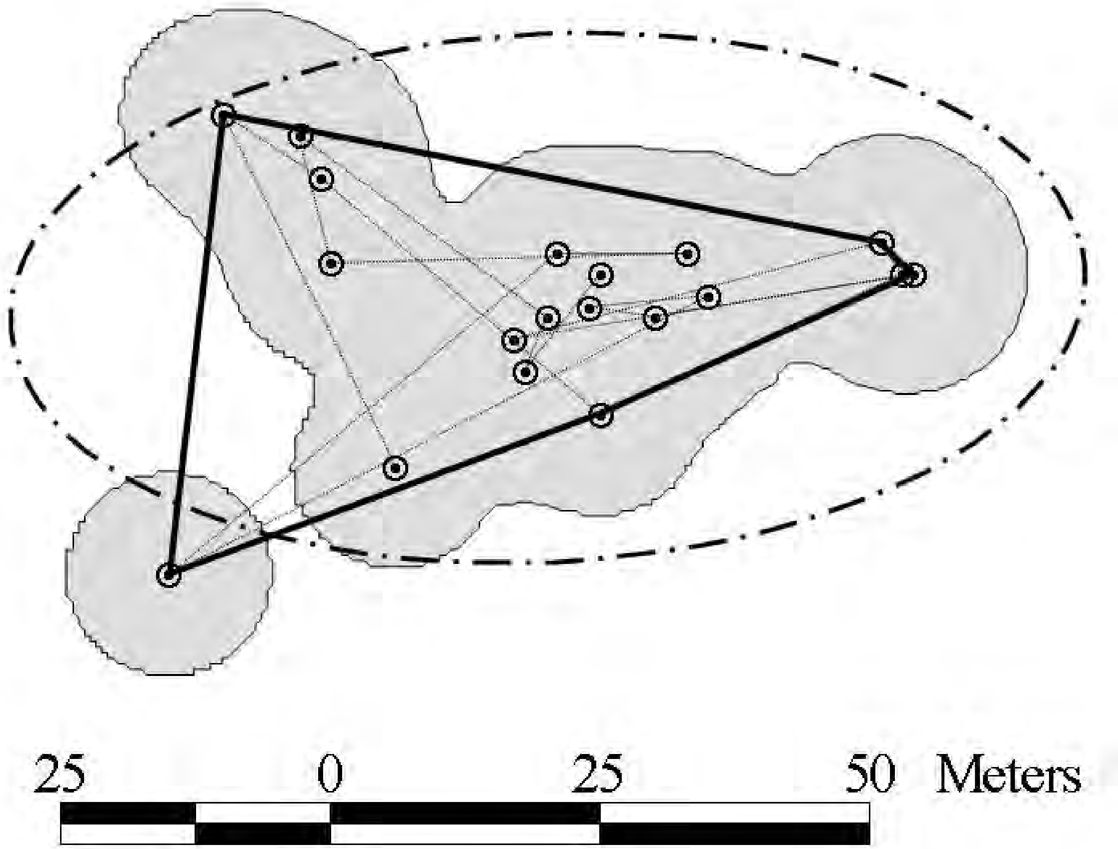

Figure III.9: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for juvenile ornate box turtle number 108 monitored at Matador Wildlife Management Area in Cottle County, Texas from 6 July 2007-27 July 2007.

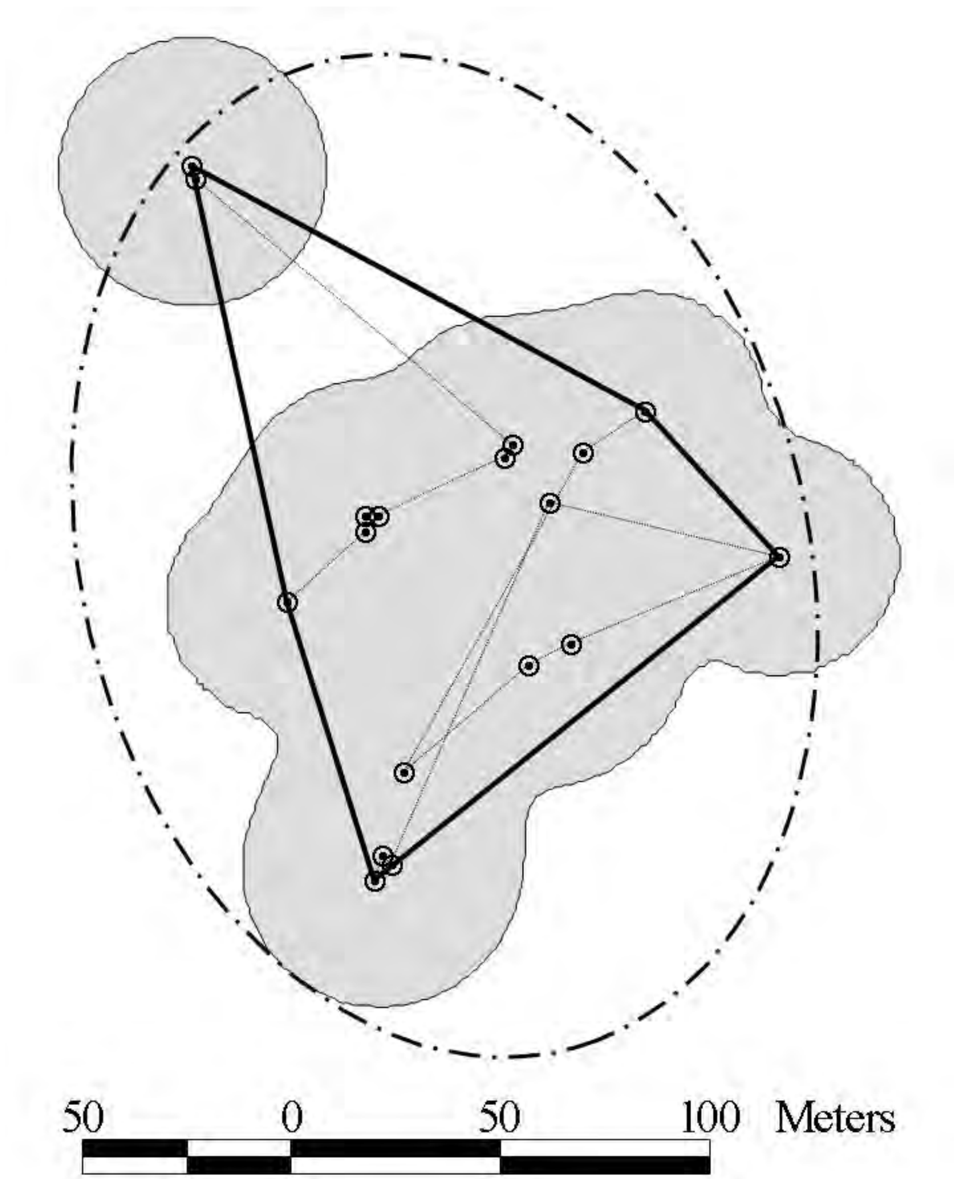

Figure III.10: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for male ornate box turtle number 109 monitored at Matador Wildlife Management Area in Cottle County, Texas from 18 July 2007-10 August 2007.

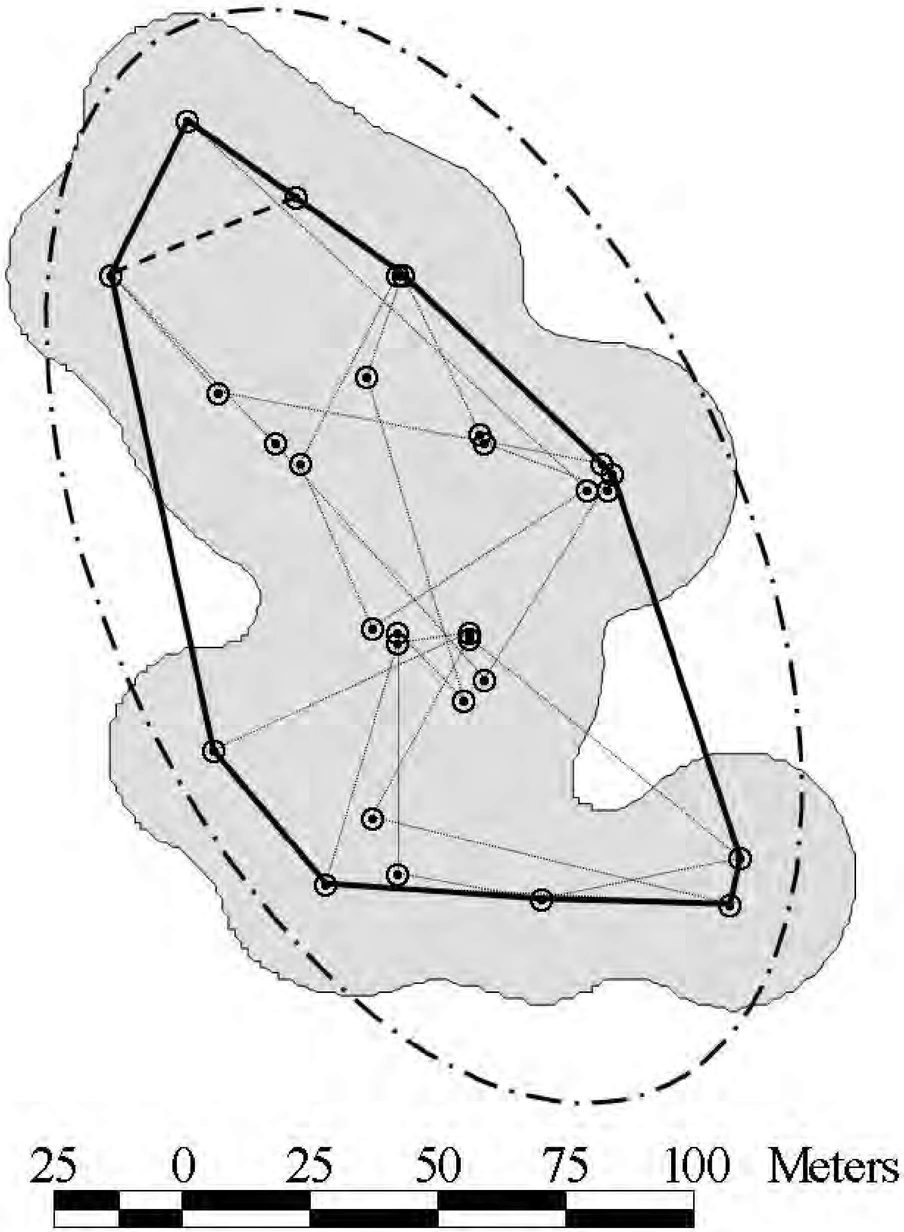

Figure III.11: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for male ornate box turtle number 110 monitored at Matador Wildlife Management Area in Cottle County, Texas from 24 July 2007-3 September 2007.

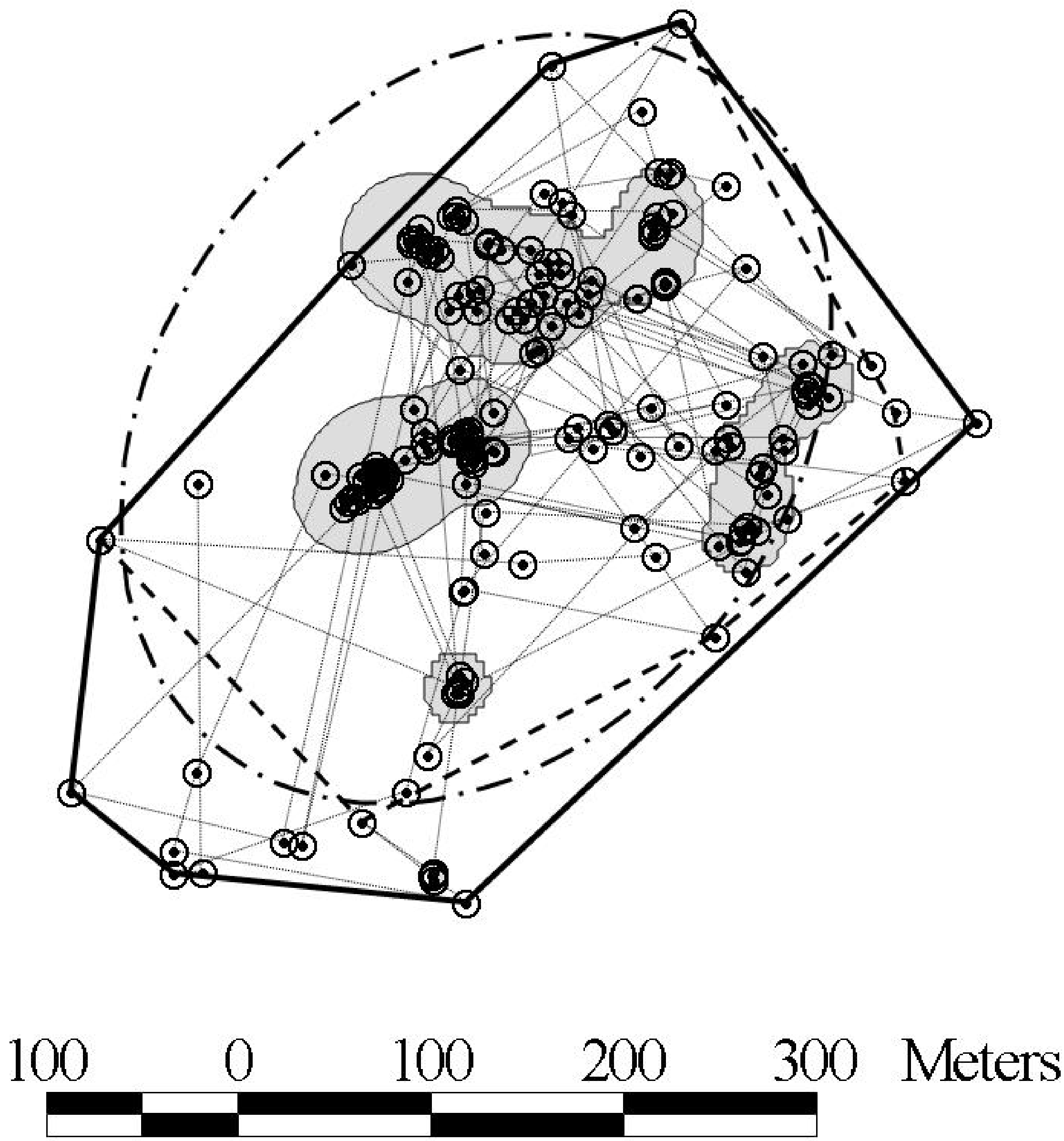

Figure III.12: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for male ornate box turtle number 111 monitored at Matador Wildlife Management Area in Cottle County, Texas from 1 August 2007-9 October 2009.

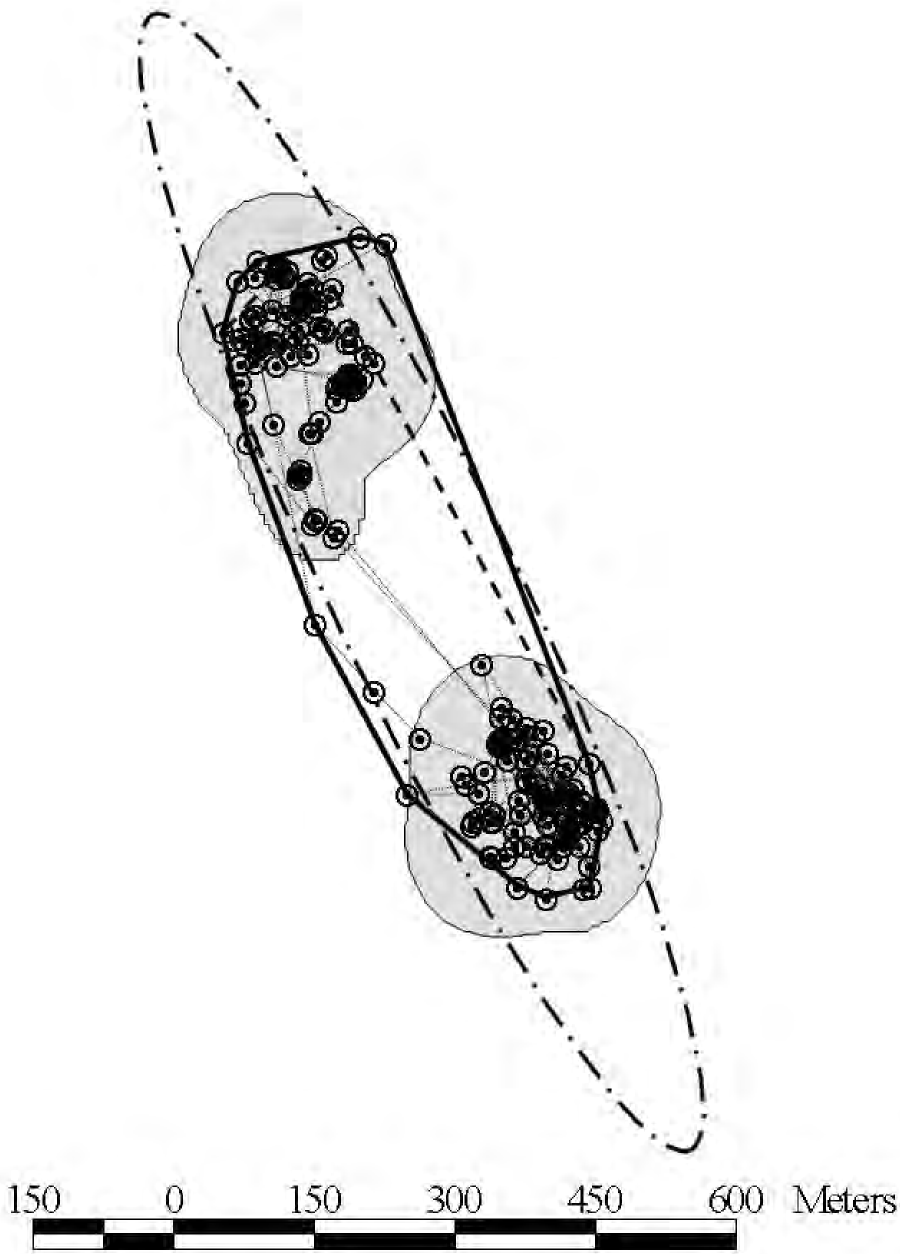

Figure III.13: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 112 monitored at Matador Wildlife Management Area in Cottle County, Texas from 1 August 2007-12 October 2009.

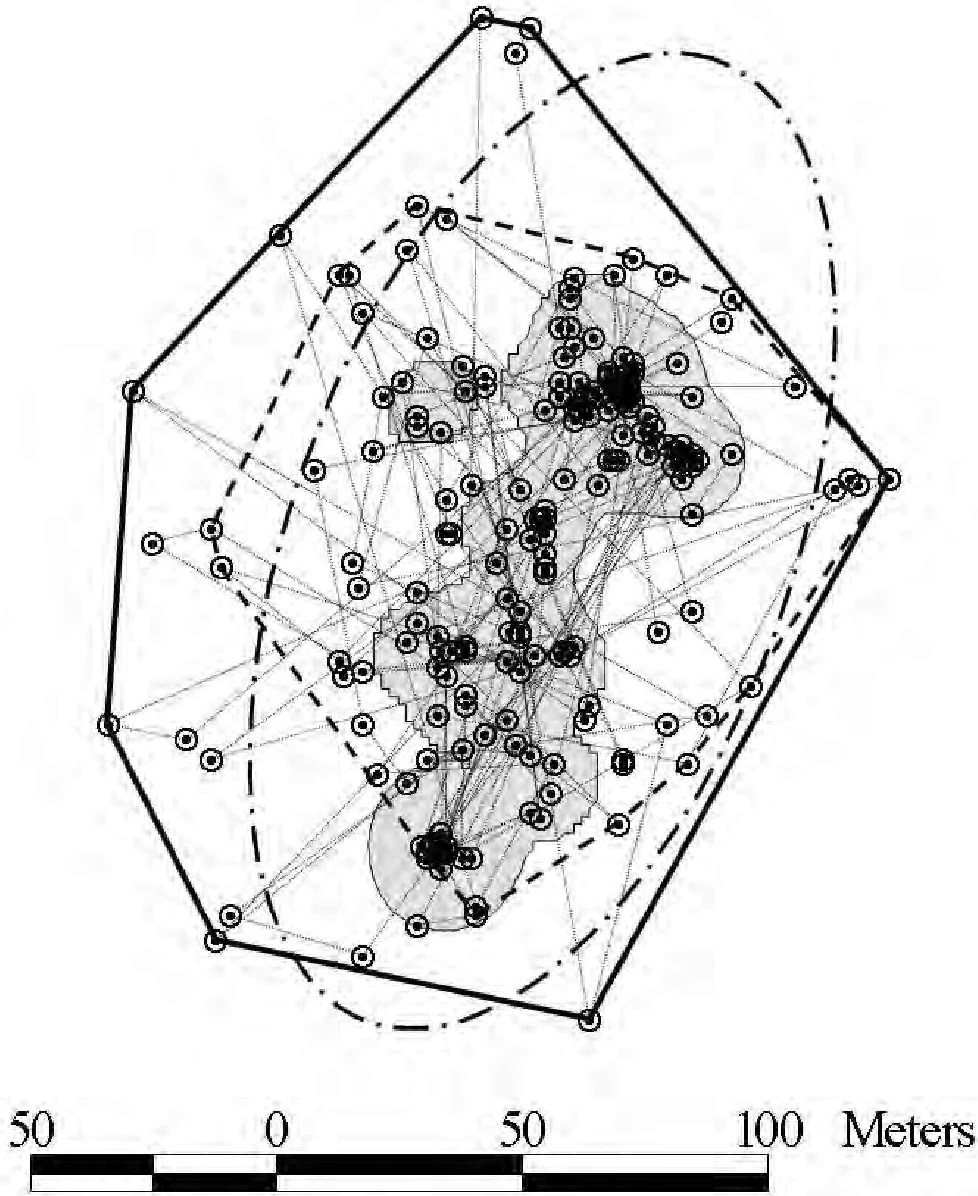

Figure III.14: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for male ornate box turtle number 113 monitored at Matador Wildlife Management Area in Cottle County, Texas from 13 August 2007-9 October 2009.

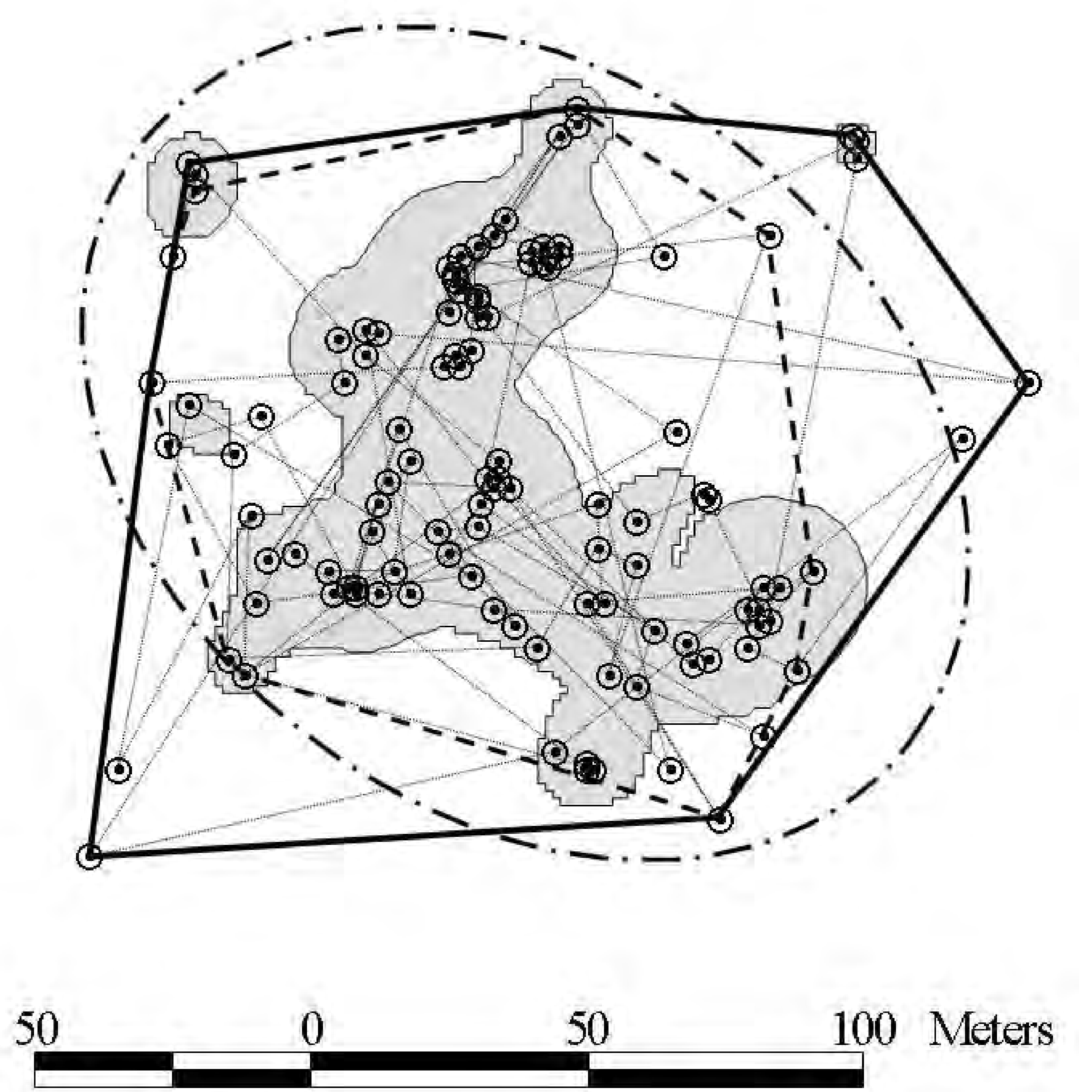

Figure III.15: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for male ornate box turtle number 115 monitored at Matador Wildlife Management Area in Cottle County, Texas from 6 October 2007-22 June 2009.

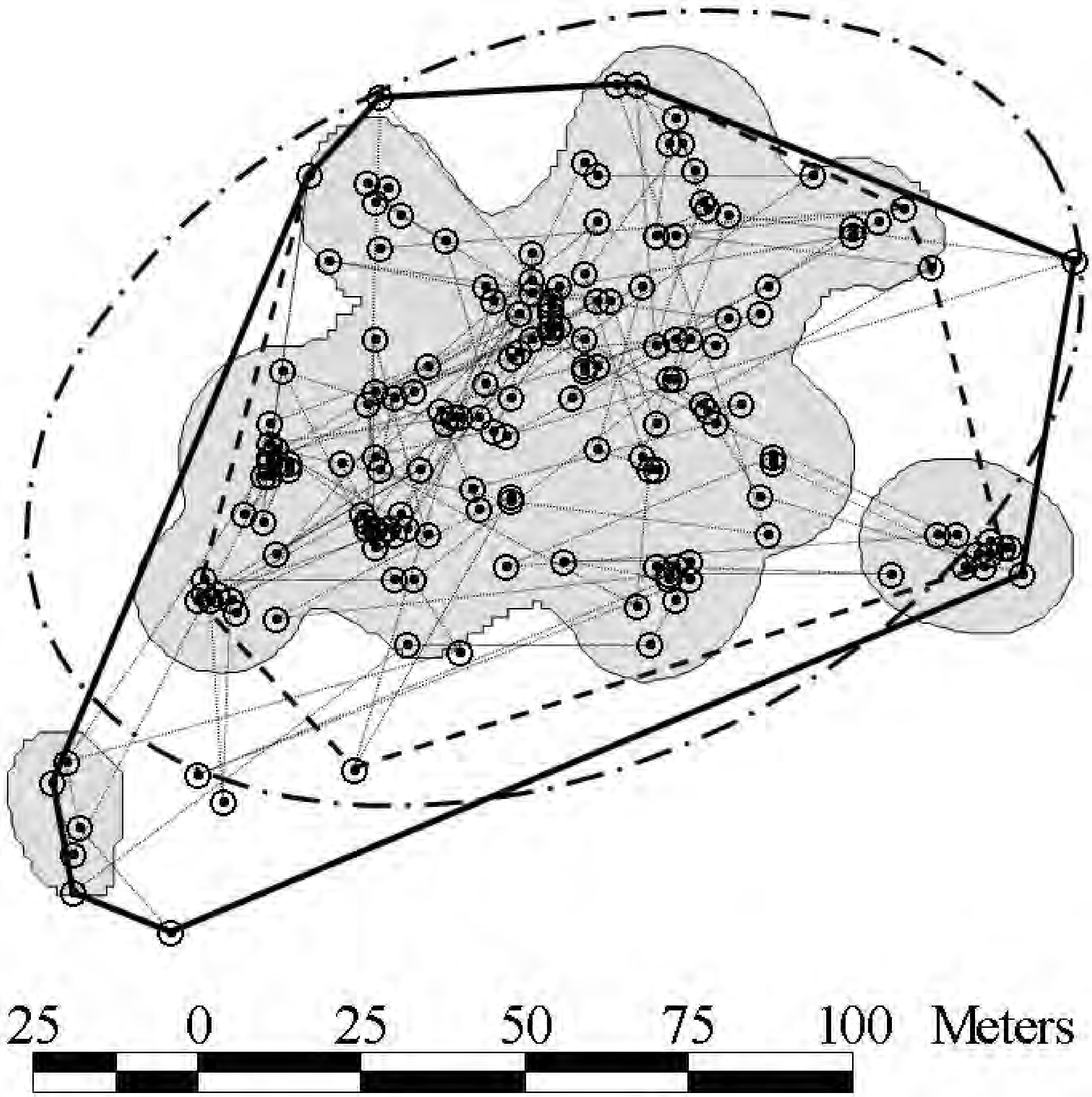

Figure III.16: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 116 monitored at Matador Wildlife Management Area in Cottle County, Texas from 6 October 2007-22 April 2010.

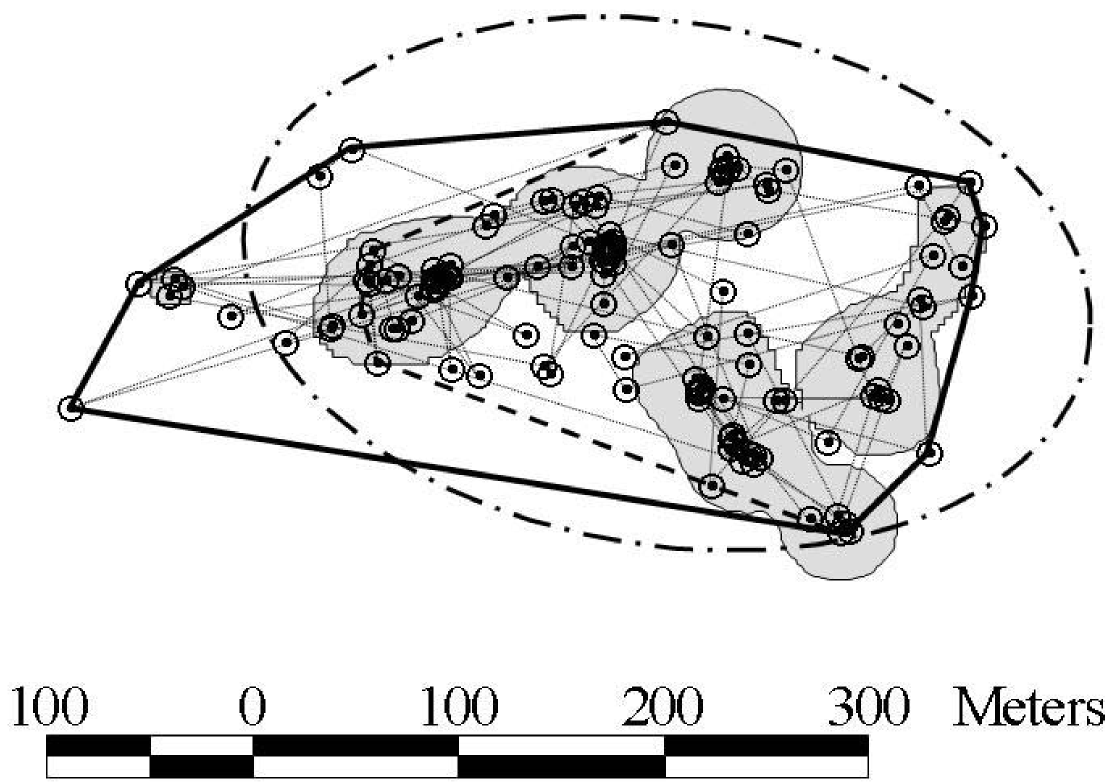

Figure III.17: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for male ornate box turtle number 200 monitored at Matador Wildlife Management Area in Cottle County, Texas from 28 May 2008-22 April 2010.

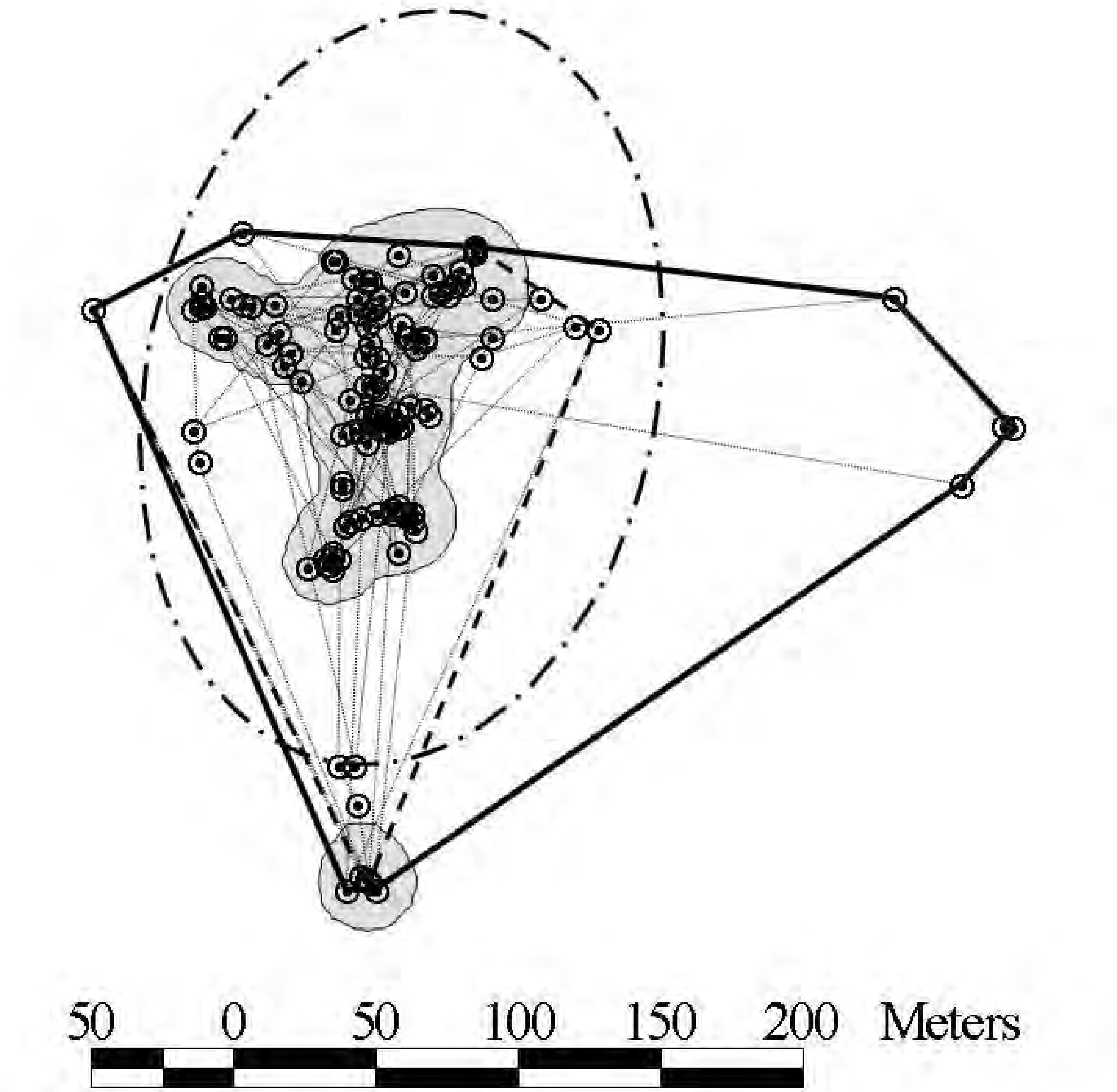

Figure III.18: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 201 monitored at Matador Wildlife Management Area in Cottle County, Texas from 28 May 2008-22 April 2010.

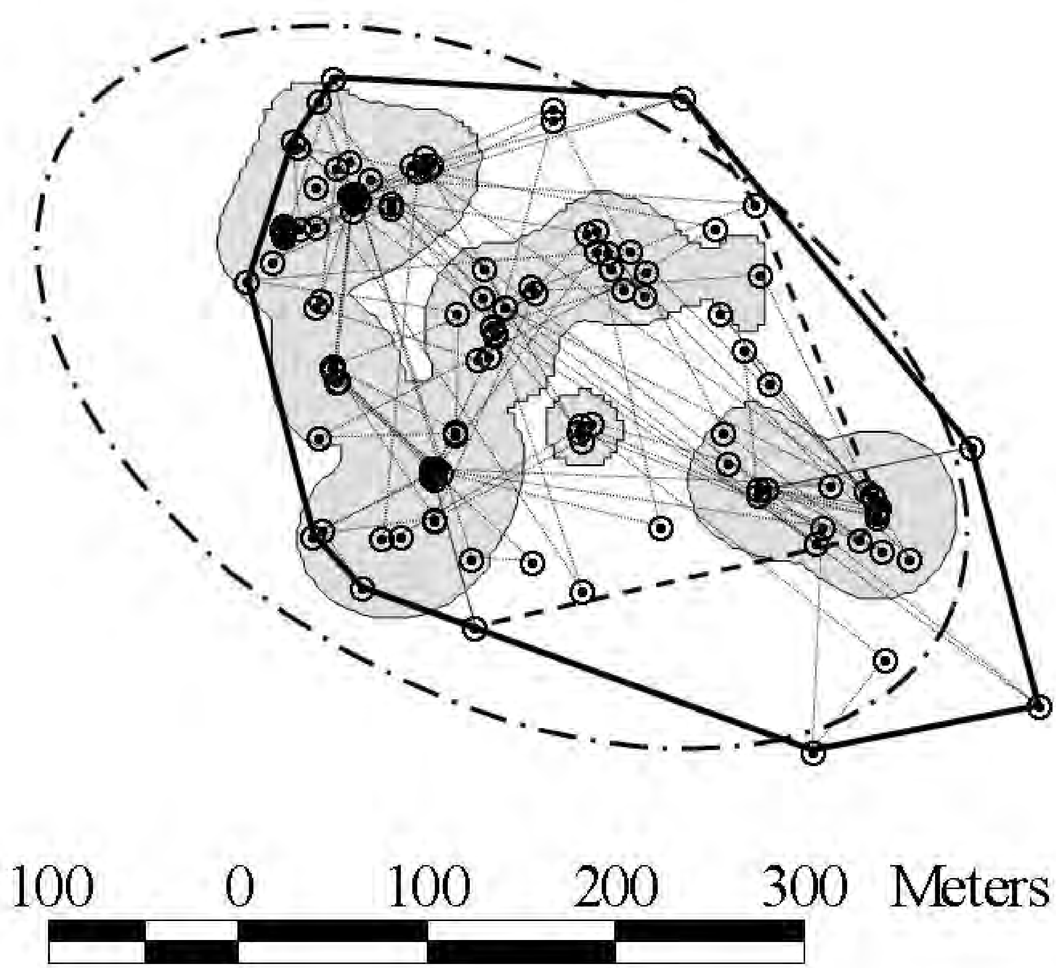

Figure III.19: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for male ornate box turtle number 202 monitored at Matador Wildlife Management Area in Cottle County, Texas from 30 May 2008-22 April 2010.

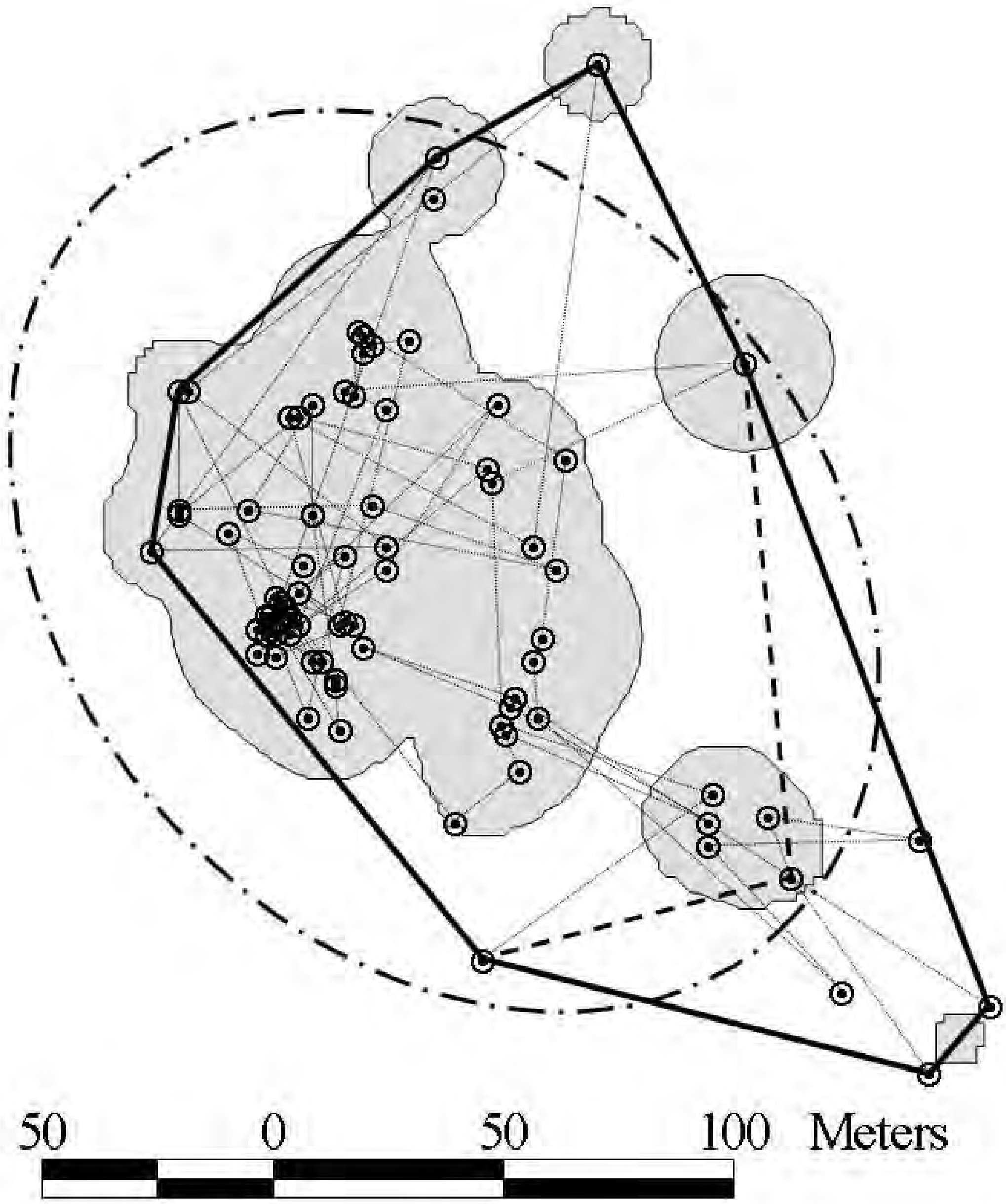

Figure III.20: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 203 monitored at Matador Wildlife Management Area in Cottle County, Texas from 30 May 2008-27 August 2009.

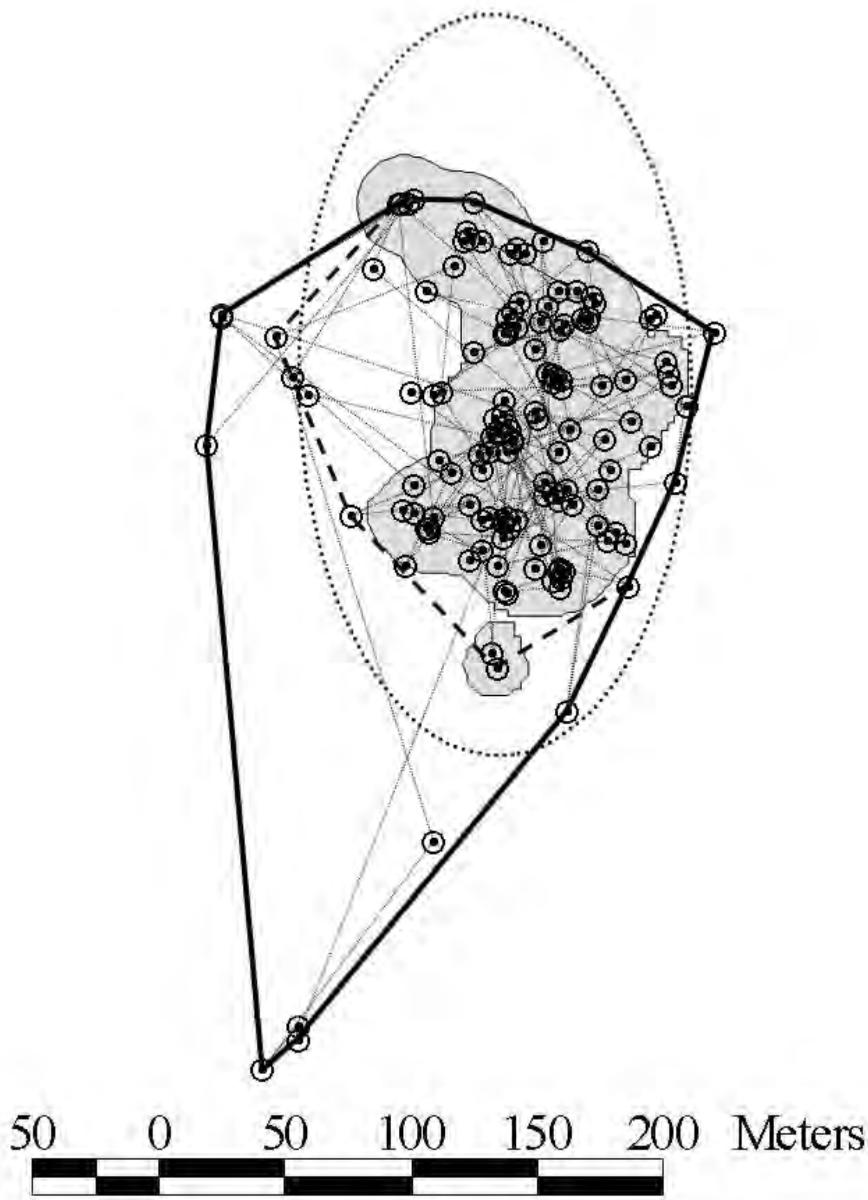

Figure III.21 Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 204 monitored at Matador Wildlife Management Area in Cottle County, Texas from 2 June 2008-22 April 2010.

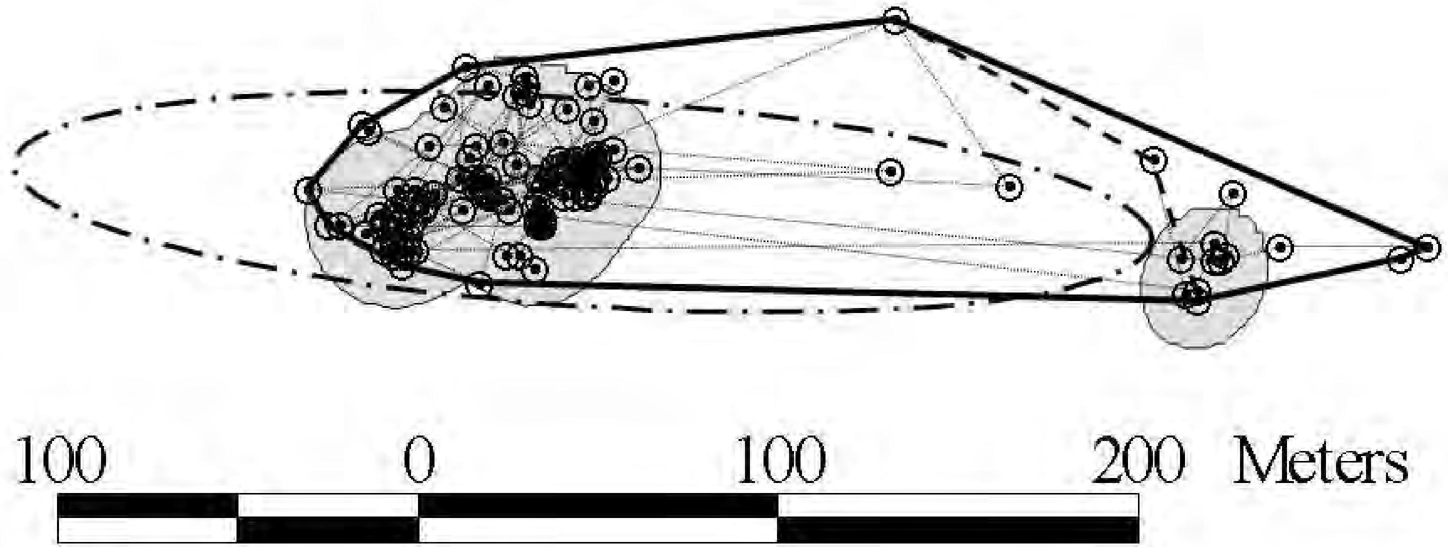

Figure III.22: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 205 monitored at Matador Wildlife Management Area in Cottle County, Texas from 2 June 2008-22 April 2010.

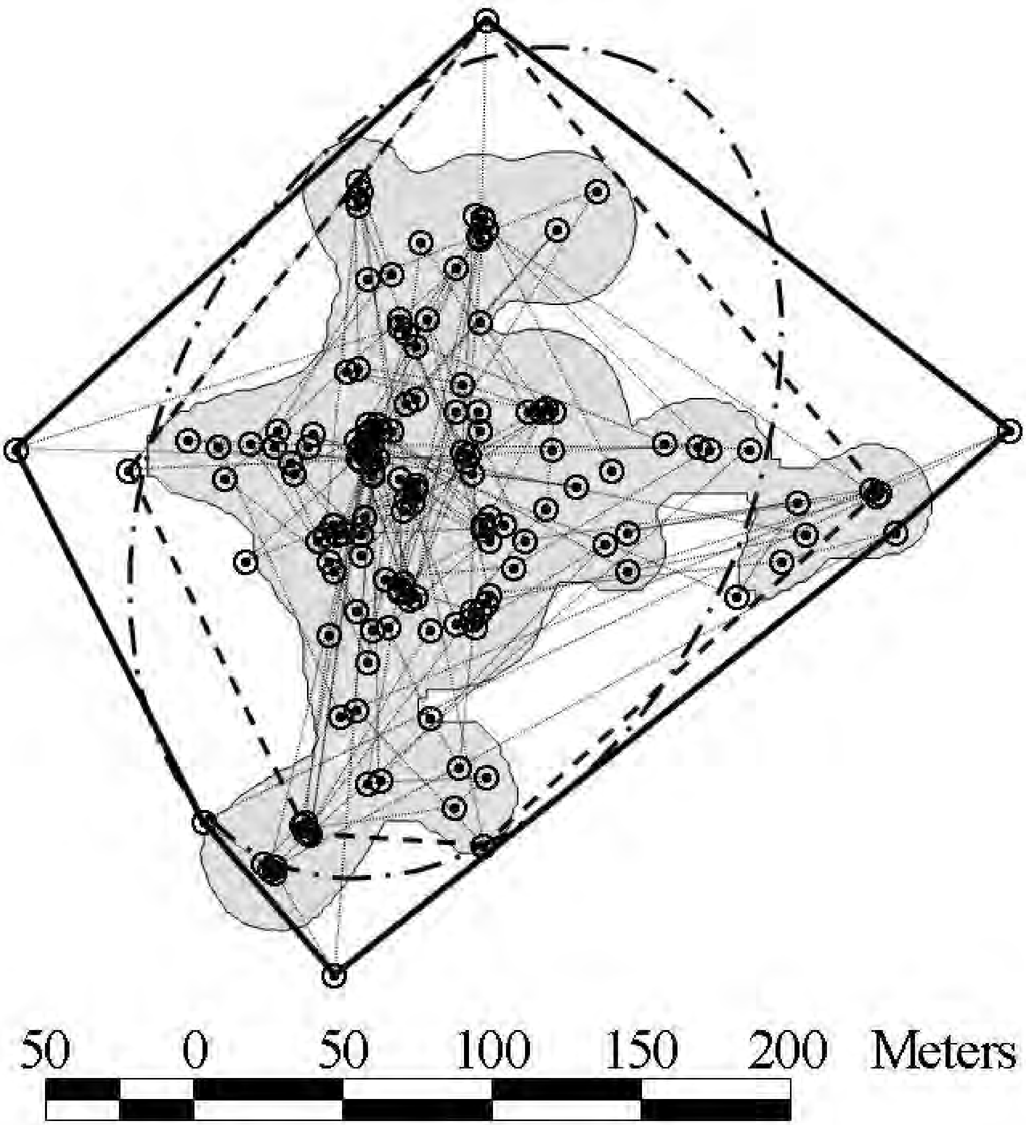

Figure III.23: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 206 monitored at Matador Wildlife Management Area in Cottle County, Texas from 5 June 2008-22 April 2010.

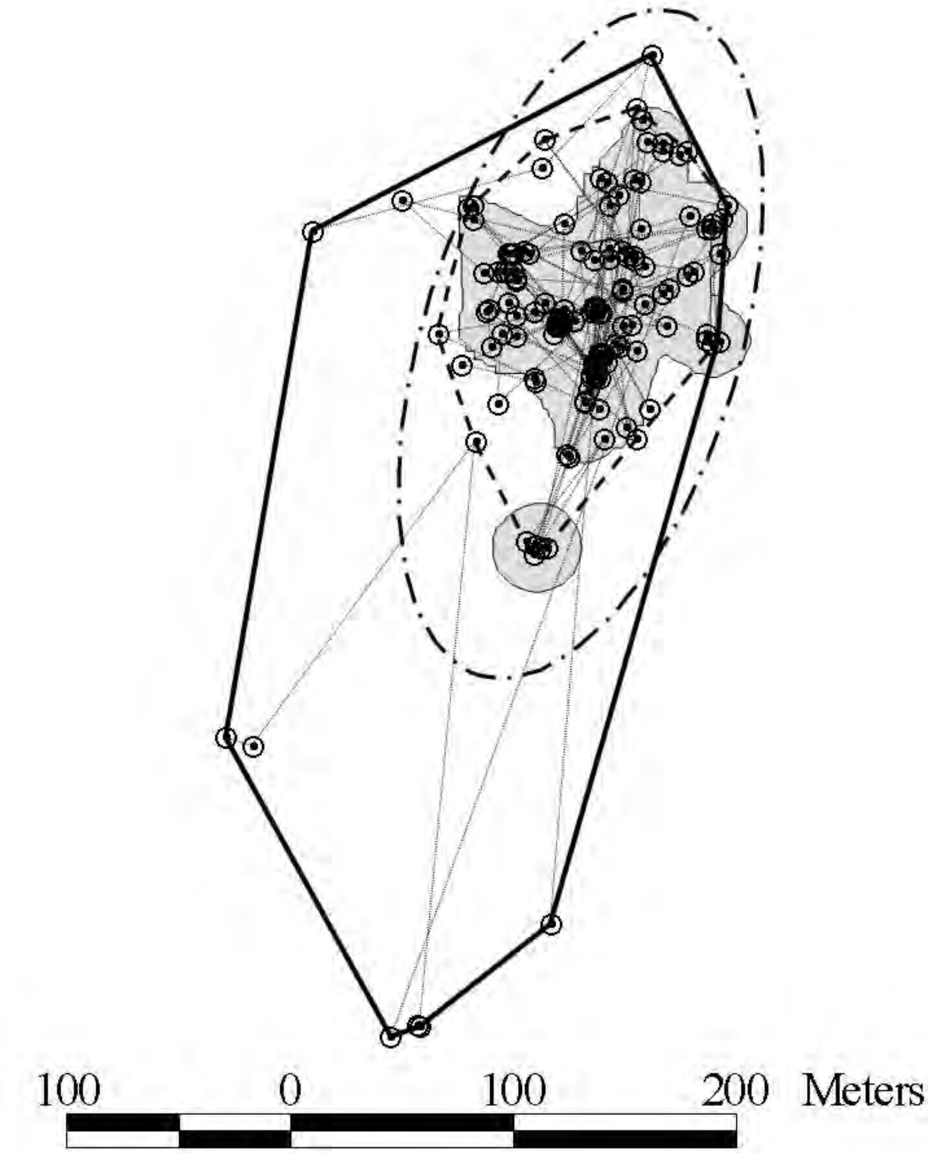

Figure III.24: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 207 monitored at Matador Wildlife Management Area in Cottle County, Texas from 5 June 2008-22 April 2010.

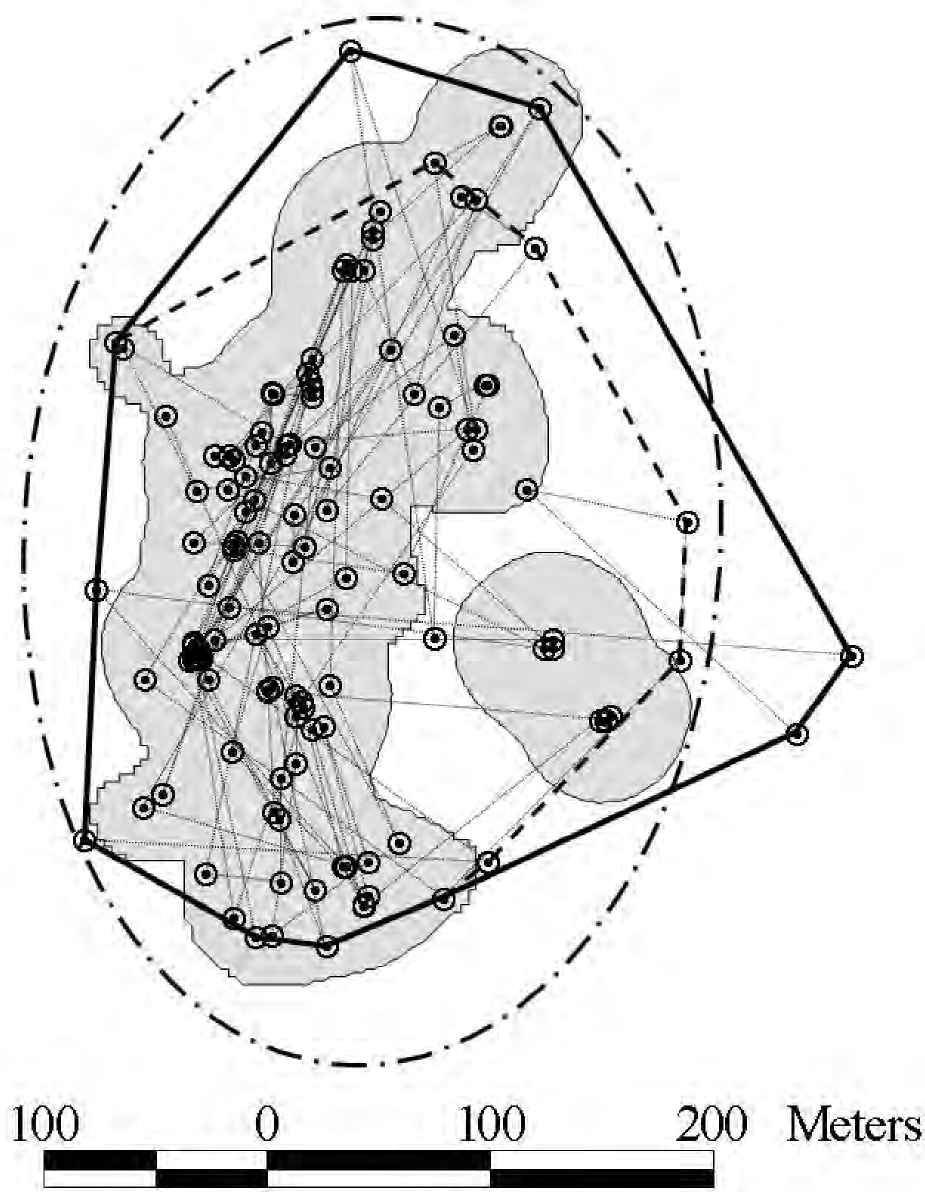

Figure III.25: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for male ornate box turtle number 208 monitored at Matador Wildlife Management Area in Cottle County, Texas from 7 June 2008-22 April 2010.

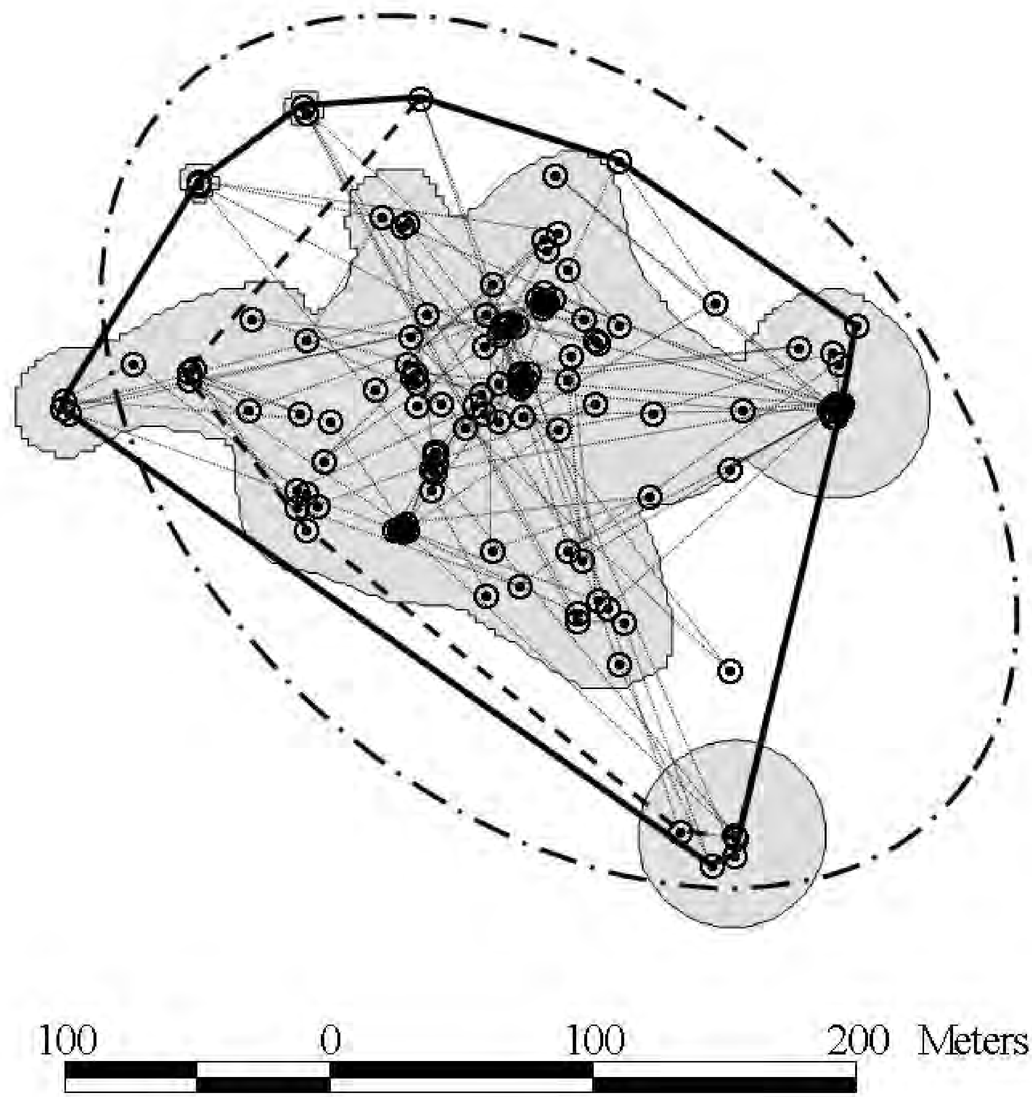

Figure III.26: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for male ornate box turtle number 209 monitored at Matador Wildlife Management Area in Cottle County, Texas from 7 June 2008-22 April 2010.

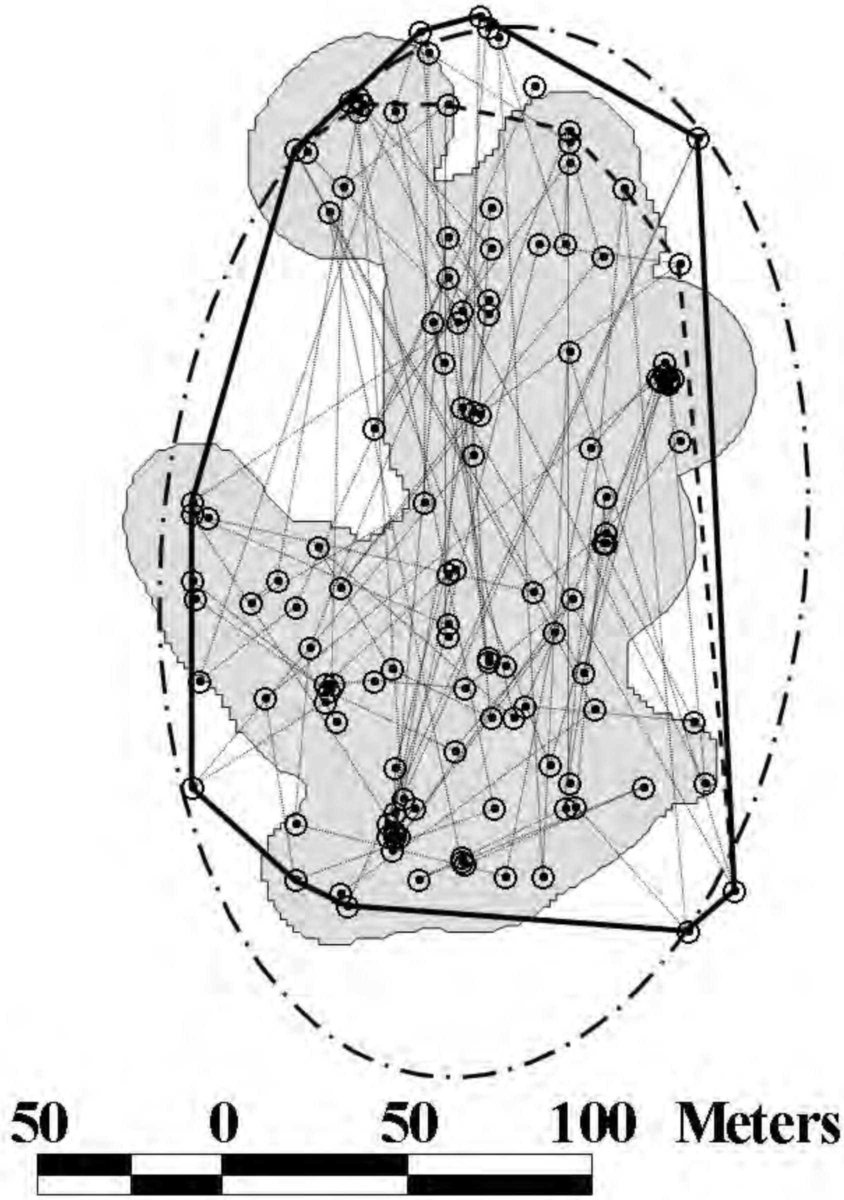

Figure III.27: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for male ornate box turtle number 210 monitored at Matador Wildlife Management Area in Cottle County, Texas from 10 June 2008-22 April 2010.

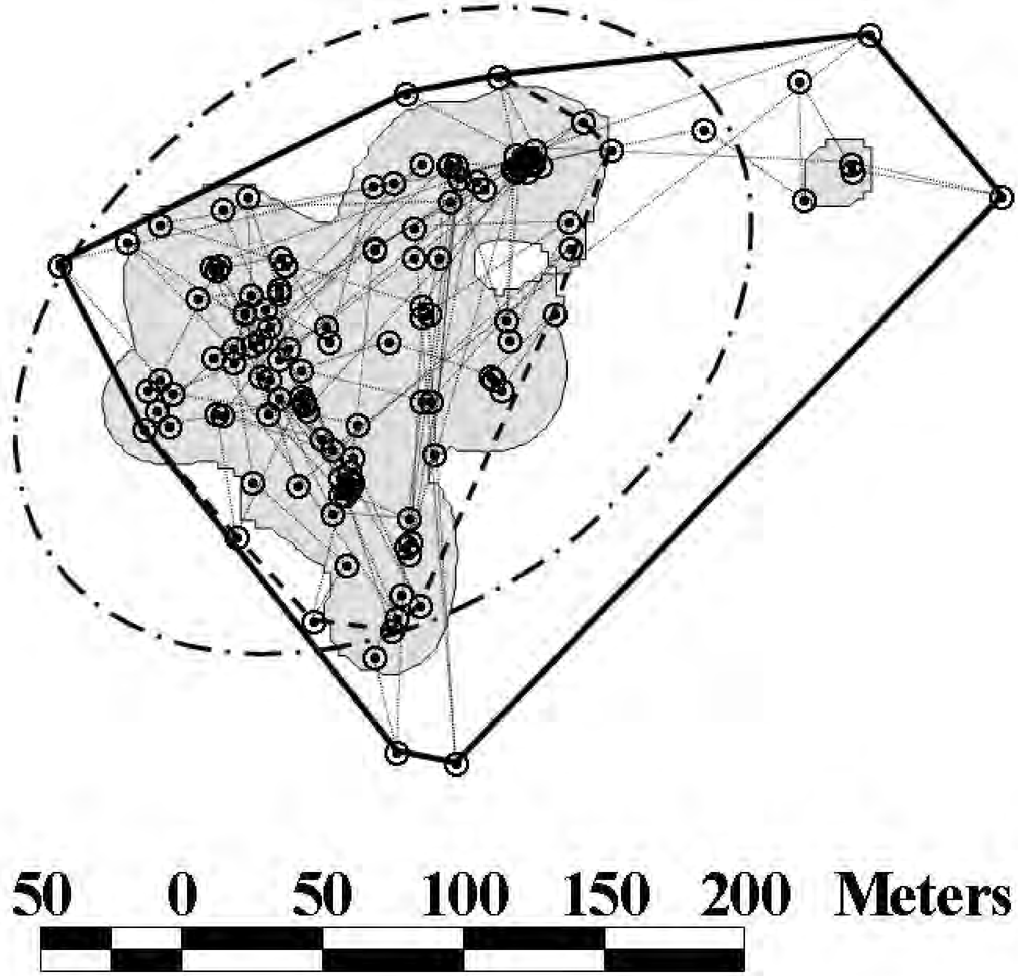

Figure III.28: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 211 monitored at Matador Wildlife Management Area in Cottle County, Texas from 23 June 2008-22 April 2010.

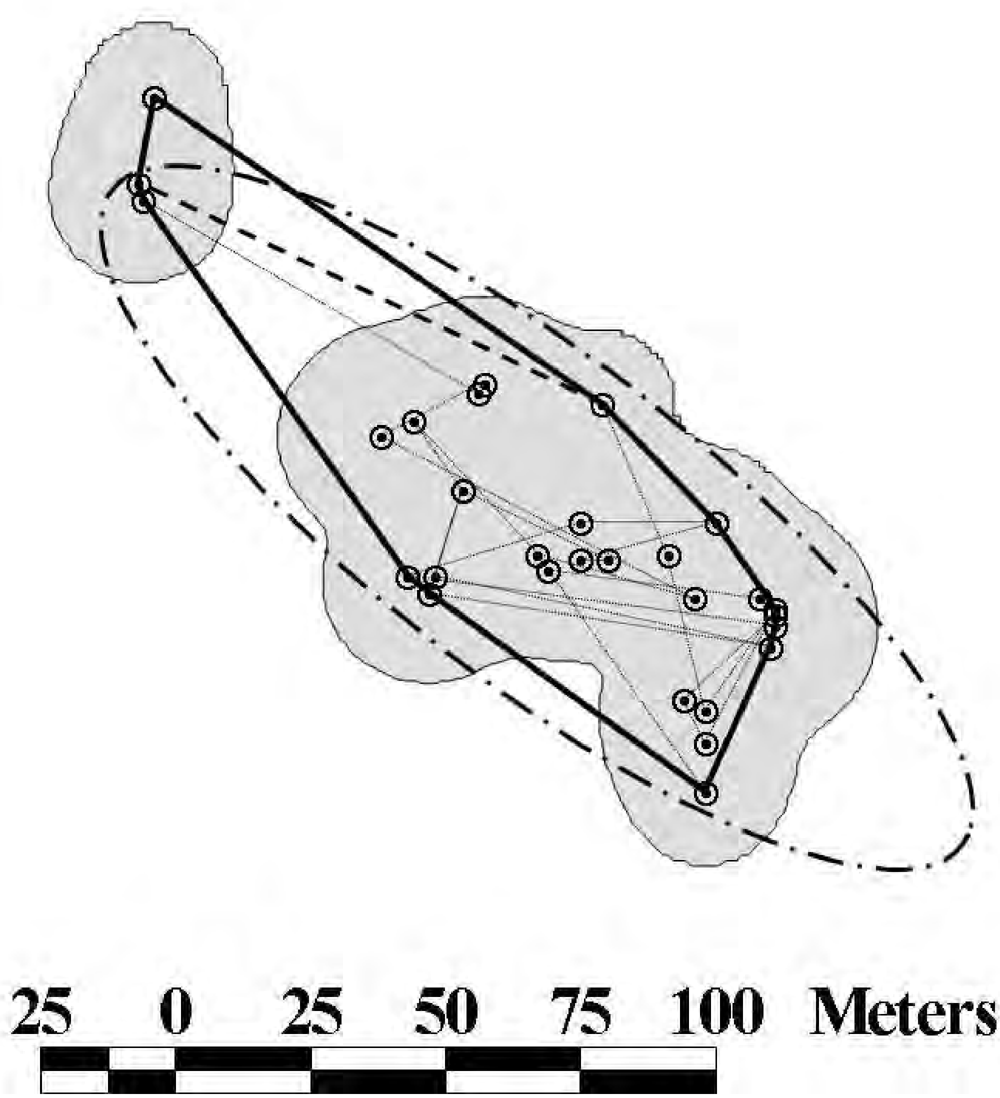

Figure III.29: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 212 monitored at Matador Wildlife Management Area in Cottle County, Texas from 23June 2008-12 August 2008.

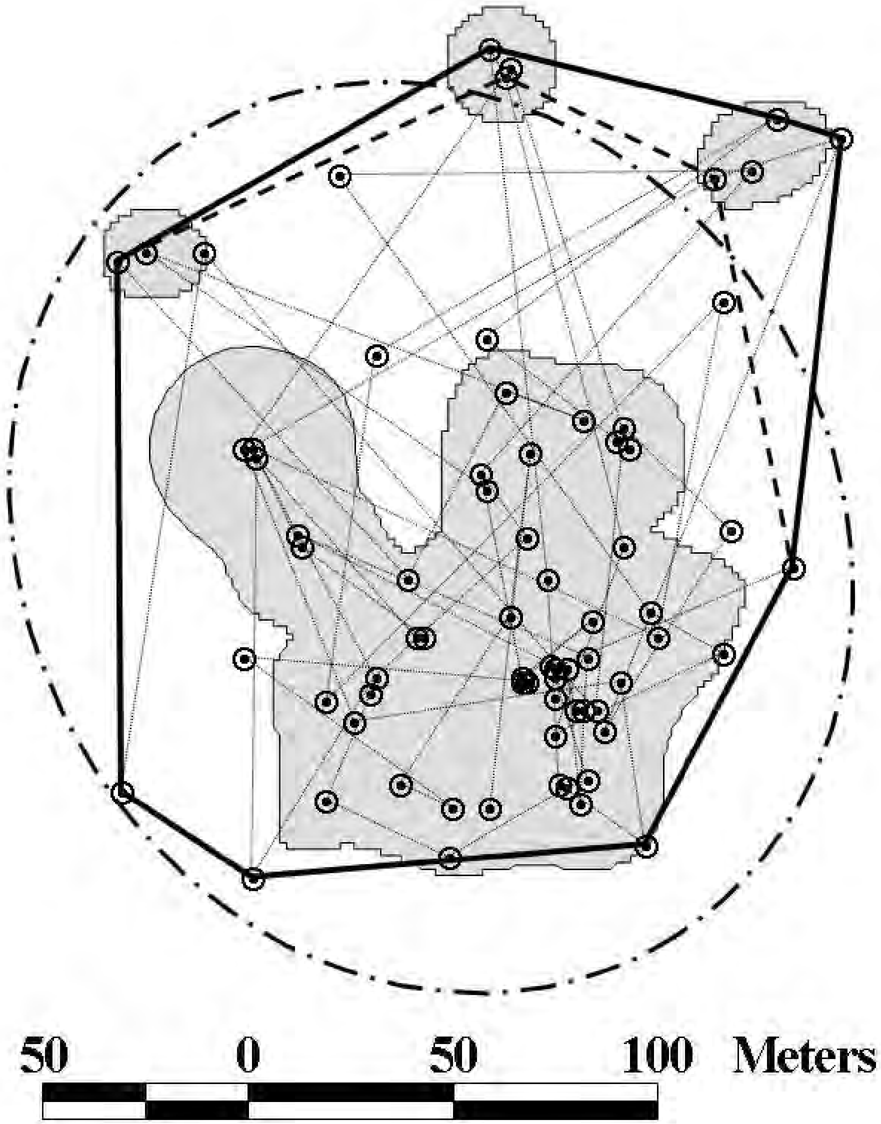

Figure III.30: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for male ornate box turtle number 213 monitored at Matador Wildlife Management Area in Cottle County, Texas from 25 June 2008-18 June 2009.

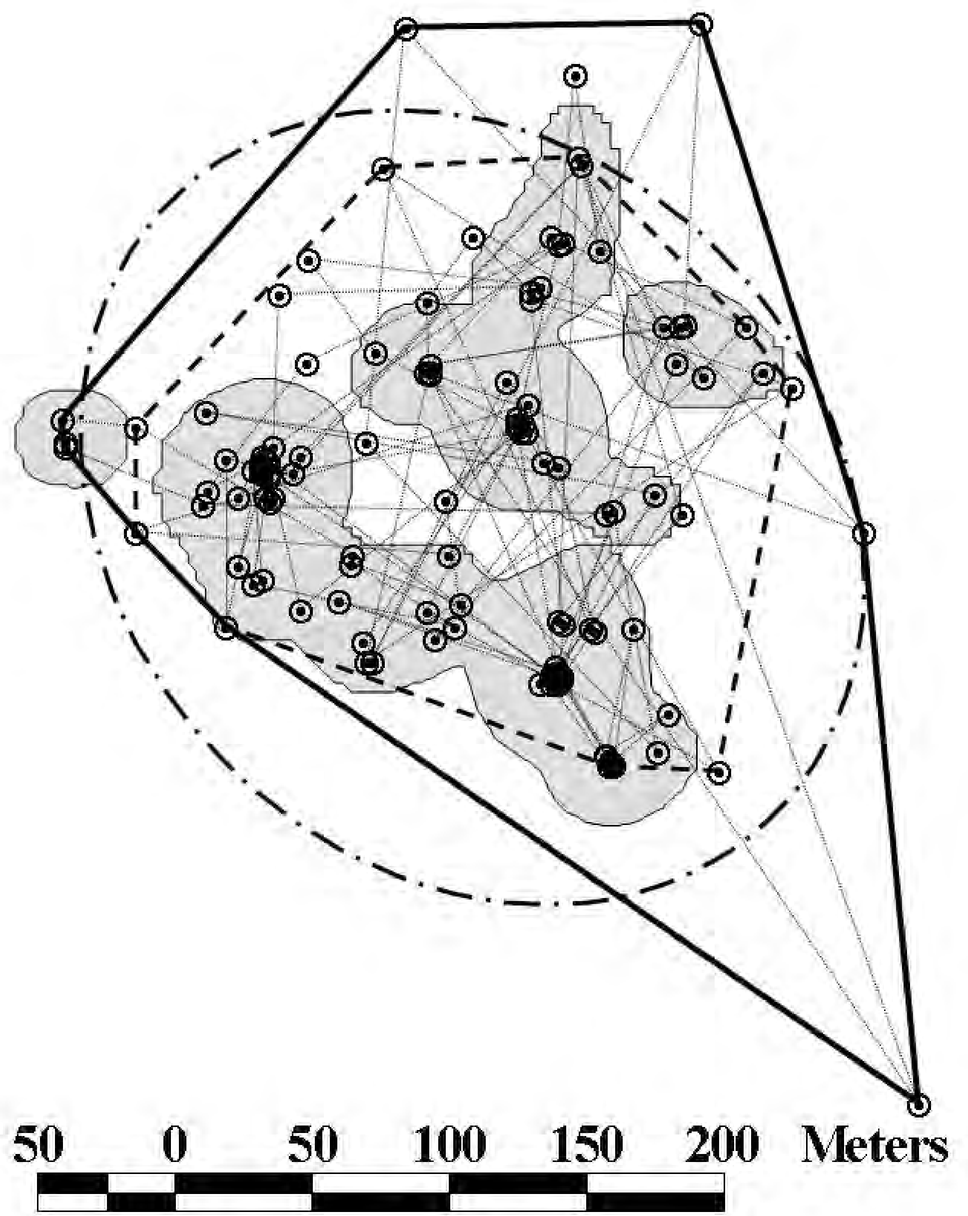

Figure III.31: Radiolocation points, movement between points (solid gray line), 100% minimum convex polygon (thick solid line), 95% minimum convex polygon (dashed line), 95% bivariate normal ellipse (dot-dash line), and 95% fixed kernel (gray filled) for female ornate box turtle number 215 monitored at Matador Wildlife Management Area in Cottle County, Texas from 23 July 2008-22 April 2010.