SPATIAL ECOLOGY OF BOBCATS IN A TEXAS HIGH PLAINS ECOSYSTEM

by

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ABSTRACT

I studied bobcats on and around the 7,289 ha Pantex Plant in Carson County, Texas. This region of the Southern High Plains is primarily shortgrass prairie and agricultural lands with minor topographic relief and little natural structure or vertical cover. I captured 23 individual bobcats a total of 34 times. Eleven of these individuals were females (8 adults) and 12 of the individuals were males (10 adults). Adults (age > 1 year) were fitted with a GPS-GSM collar. Radiotelemetry efforts resulted in 17,478 viable locations for the 13 bobcats used in home range and habitat selection analyses. Female 100% minimum convex polygon (MCP) home ranges ranged from 5,496 - 20,406 ha. Male home ranges ranged from 6,969 - 40,748 ha. There was no statistical difference between seasonal home range sizes ($P = 0.779$). I used compositional analysis to evaluate habitat selection at 2 spatial scales. For second-order selection, use was defined as the habitat within 100% MCPs generated around each bobcat's radiolocations. Availability was defined as habitat within the study area which was an MCP that included all bobcat radiolocations. For third-order selection, use was defined by the habitat composition at each bobcat's radiolocations and availability was defined as the habitat within each bobcat's 100% MCP. I also investigated both second and third-order habitat selection for proximity to defined habitat types by calculating buffer increments for each habitat. For second-order selection, use was defined as the buffer increments within each bobcat's

100% MCP while the habitat available was defined as the buffer increments within the study area. For third-order, use was defined as the proportion of relocations within each buffer increment while the buffer increments within the 100% MCP served as the habitat available. Bobcats demonstrated high preference for anthropogenically-impacted areas in third-order selection and high preference for prairie dog towns in second-order selection. They exhibited avoidance of roads and railroads in both second and third-order selection. Preference for anthropogenic areas is likely a response to the lack of natural structure in the area. The selection preferences for artificial habitat features and relatively large home range sizes may indicate a lower quality habitat for bobcats.

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CHAPTER I

HOME RANGE AND SEASONAL MOVEMENT OF BOBCATS IN A FRAGMENTED SHORTGRASS PRAIRIE ECOSYSTEM

INTRODUCTION

The bobcat (*Lynx rufus*) is one of North America's most adaptable and widely distributed native felids (Anderson 1987, Anderson and Lovallo 2003). Bobcats can be differentiated from other felids by their short tails, tufted ears, prominent facial ruffs and absence of the second upper premolars which leaves them with 28 teeth rather than the usual 30 (Anderson 1987). Their geographic range extends from central British Columbia to Oaxaca, Mexico and from the Atlantic coast to Pacific coast in the United States. Historically, they occupied all 48 contiguous states (Young 1958). However, because of extensive agricultural practices and unrelenting persecution by humans during the 20th century, populations were heavily reduced in the Midwest (Erickson 1981, Anderson 1987). Despite this, bobcats now appear to be expanding across most of their geographic range (Roberts and Crimmins 2010). Conservative estimates for the United States population suggest their numbers are at a minimum of 1.4 million (Roberts and Crimmins 2010) and they are not considered to be under any special concern for conservation purposes. Bobcats are distributed across Texas and are common in a variety of habitats (Anderson 1987, Anderson and Lovallo 2003) but prefer rough, rocky terrain interspersed with dense cover (Young 1958, Anderson 1987) that produces abundant prey and allows hunting by ambush or stalking (Anderson and Lovallo 2003).

Bobcats are an integral part of many ecosystems and are considered to be a top predator in some parts of their geographic range (Conner et al. 2001). They play a major role in controlling a variety of small mammal populations (Anderson 1987, Anderson and Lovallo 2003). Major prey composition for bobcats include the hispid cotton rat (*Sigmodon hispidus*; Beasom and Moore 1977, Miller and Speake 1979), rabbits (*Sylvilagus* spp.), hares (*Lepus* spp.; Parker and Smith 1983), and woodrats (*Neotoma* sp.; Anderson and Lovallo 2003); all of which occur in my study area (McCaffrey et al. 2009, Pruett et al. 2010). In some areas of their geographic range they are considered to be a significant source of predation on white-tailed deer (*Odocoileus virginianus*; Anderson and Lovallo 2003) and pronghorn fawns (*Antilocapra americana*; Beale and Smith 1973). In addition to their ecological role, their economic significance as a furbearer is a motivating factor for research on and management of this species (Woolf and Hubert 1998, Roberts and Crimmins 2010). To successfully manage for bobcats we must first understand their natural history requirements. Factors such as home range size, habitat preferences, diet, and social organization are all crucial management considerations for any species. Additionally, carnivores are considered to be prophetic indicators of the relative health and functioning of ecosystems because of their top-level trophic position (Crooks et al. 2010, Ordeñana et al. 2010).

Home range, for the purpose of this study, is best defined as the amount of area required by an animal to perform its normal activities over a definitive length of time (Harris et al. 1990). An animal's home range is sometimes confused with its territory which is an area within the animals' home range that is defended against other individuals of the same species (Krausman 1999); however, not all animals maintain territories. Home range sizes vary widely within and among studies because of the number of locations used, seasonality, sample sizes, and the method of home range size estimation (Aebischer et al. 1993, Anderson and Lovallo 2003). Bobcat home ranges are affected by a number of other factors such geographic area, population densities, prey abundance, time-in residence (Conner et al. 1999), age, gender, habitat quality (Rucker et al. 1989), and social status (Anderson and Lovallo 2003). Typically, northern populations of bobcats have larger home ranges than their southern counterparts (Anderson and Lovallo 2003). This is thought to be because of their larger body size as well as increased thermal demands and the generally lower prey abundance (Anderson and Lovallo 2003).

Male home ranges are typically 2 to 3 times larger than female home ranges though increases up to 4 and 5 times have been documented (Major 1983, Witmer and DeCalesta 1986, Cochrane et al. 2006, Lynch et al. 2008). It has been suggested that females may maintain typically smaller home ranges than males, at least in part, because of the higher energetic requirements imposed by lactation and kitten-rearing (Anderson and Lovallo 2003). Females need to remain relatively close to kittens in the den and have been documented to hunt their ranges more intensively than males (Anderson 1987). Female home range size is suggested to be dependent on prey availability while male home range sizes seem to be based on female home range size and maximizing mating opportunities (Anderson and Lovallo 2003, Cochrane et al. 2006, Ferguson et al. 2009).

Seasonal variations among home range sizes have been reported by a number of studies (Anderson and Lovallo 2003, Cochrane et al. 2006). Some studies have reported that female home ranges have been documented as smallest during nursing (spring) and largest during gestation (late winter; Kitchings and Story 1984, Anderson 1987, Litvaitis et al. 1987, Cochrane et al. 2006). Males in Maine had a similar pattern in that home ranges are smallest during spring and largest during winter (Litvaitis et al. 1987) though several studies have documented the largest male home ranges occurring in spring so as to procure mating opportunities (Anderson 1987, Anderson and Lovallo 2003).

Intraspecific home range overlap is extremely variable among bobcats. Typically, adult female home ranges are exclusive of each other while male home ranges overlap not only each other but several females as well (Anderson and Lovallo 2003). However, there are numerous reports of females with overlapping home ranges and males that exclude each other (Kitchings and Story 1984, Lynch et al. 2008). Spatial exclusivity, regardless of sex, is suggested to be highest when prey abundance is moderate, but exclusivity may be abandoned when prey becomes overabundant or rare (Cochrane et al. 2006, Lynch et al. 2008).

There are many methods available for calculating home ranges from radiotelemetry data (Swihart and Slade 1985, Aebischer et al. 1993). The minimum convex polygon (MCP) is a widely-used method (Mohr 1947). This technique involves a simple polygon that is generated by connecting the outermost relocations for each individual (Mohr 1947, Aebischer et al. 1993). This is one of the least complicated methods used to calculate home ranges and is considered among the most useful for comparison among studies and between home-range programs because it is always generated the same way (Lawson and Rodgers 1997). The MCP method is not based on a mathematical distribution (Swihart and Slade 1985). Therefore, locations used to calculate an MCP do not need to be independent of each other as in the probabilistic home range methods (Swihart and Slade 1985). A 100% MCP is one that includes all location points for that animal for the duration specified (Kenward 1987, Lawson and Rodgers 1997). Likewise, the researcher can utilize 95% MCPs and other percentages that exclude outlying relocations if desired (Lawson and Rodgers 1997). The purpose behind using varying percentages is to determine regions with the highest density of relocations (Kenward 1987) which often signify core areas. These are areas of concentrated use within an animal's home range (Kaufmann 1962) and usually contain important resources such as den sites or quality foraging areas (Burt 1943, Ewer 1968). It is important to note that the term "core area" is not synonymous with territory (Burt 1943, Kaufman 1962, Krausman 1999).

There are several drawbacks to using the MCP home range method. First, it invariably incorporates quite a bit of empty or what is considered to be "unused" space (Burt 1943, Aebischer et al. 1993). Next, the overall size of the home range generally increases as more location data are obtained. Therefore, comparing home range sizes between individuals with widely varying numbers of relocations is tenuous (Aebischer et al. 1993). Likewise, comparing home range sizes between individuals that were monitored in different years may not be possible (Samuel and Fuller 1996).

A major consideration for any home range method should be the stability of the size estimate with increasing numbers of relocations (Aebischer et al. 1993). It is possible to determine the number of relocations necessary to achieve this stability by plotting the number of relocations against the home range area (Kenward 1982, Harris et al. 1990) which is referred to as a bootstrap analysis. This method is useful because it indicates whether enough information has been obtained to adequately characterize that animal's home range. The duration of time of study is more important than the number of relocations (Aebischer et al. 1993). It should be noted that no home range method should be considered infallible or a completely accurate representation of the habitat used by, or even available to, an animal (Aebischer et al. 1993).

Human interference, both direct and indirect, is the most common cause of mortality in bobcat populations (Anderson and Lovallo 2003, Ordeñana et al. 2010). Mortalities among males are higher than females especially during the first few adult years (Parker et al. 1983, Quinn and Thompson 1987). This is considered to be because of the greater risks associated with their larger home ranges and higher level of daily movements (Anderson and Lovallo 2003, Ordeñana et al. 2010). Bobcats have largely been studied in wooded or at least semi-wooded landscapes (Cain et al. 2003, Cochrane et al. 2006, Lynch et al. 2008, Ruell et al. 2009, Ordeñana et al. 2010). Home range studies in grasslands areas appear to be limited. The comparative lack of natural vertical structure, including both topography and vegetation, on the Southern High Plains may present challenges to bobcat survival.

I utilized location data collected from 2009 to 2013 and conducted a Global Positioning System (GPS) and Global System for Mobile Communications (GSM) based telemetry study to describe cumulative home range sizes for adult bobcats. I characterized seasonal home ranges in this fragmented shortgrass prairie ecosystem. I also examined seasonal daily movement of bobcats.

METHODS

Study Area

My study site is located on the Llano Estacado (Choate 1997, Texas Almanac 2014) within the Southern High Plains in the Texas Panhandle. The Llano Estacado is one of the largest mesas in the world and encompasses approximately 51,800 km^2 (Lotspeich and Coover 1962, Choate 1997). Elevations on the Llano Estacado range from 762 m to 1,524 m (Lotspeich and Everhart 1962).

The Southern High Plains is a shortgrass prairie ecosystem (Kuykendall and Keller 2011). The nearly flat surface of this area is dominated by gramas (*Bouteloua* spp.) and buffalo grass (*Buchloë dactyloides*; Wright 1979). Prickly pear (*Opuntia* sp.) and forbs such as silver-leaf nightshade (*Solanum elaeagnifolium*) are also common. Cultivated farm lands primarily produce sorghum (*Sorghum bicolor*), wheat (*Triticum* sp.), and cotton (*Gossypium* sp.; Kuykendall and Keller 2011). All plant taxonomy follows Barkley (1986).

Black-tailed prairie dog (*Cynomys ludovicianus*) towns are frequently encountered and are comprised of various short grasses and forbs interspersed with patches of bare ground which are created by the rodents around their burrows (Russell and Detling 2003, Bangert and Slobodchikoff 2004).

The semi-arid climate of the Texas Panhandle is characterized by high variability. All months can exhibit large diurnal temperature variations (Lotspeich and Everhart 1962, Choate 1997). Rainfall in this area is also variable though mean annual rainfall is generally less than 50.8 cm (Texas Almanac 2014). Winds are a factor and blow almost continuously (Choate 1997) with gusts in excess of 96.56 kph being commonplace in weather stations across the Panhandle (Lotspeich and Everhart 1962).

Natural structures and vertical cover is limited. Agricultural practices, ranching and areas of concentrated human activity have resulted in a mosaic of habitat types in this area. Some lands within the study area have been incorporated into the Conservation Reserve Program (CRP) which provides monetary incentives to farmers who utilize approved conservation methods on environmentally-sensitive lands (United States Department of Agriculture 2014). The criteria for CRP land designates the land must be agriculturally-based or must border a river so that it will act as a buffer zone for water quality (United States Department of Agriculture 2014). The state of Texas did not mandate these grasslands be returned to a native-only state so many CRP lands in this area were planted with exotic grass species such as bluestems (*Andropogon* spp.; (R. T. Kazmaier, West Texas A&M University, personal communication).

My study area was a 100% MCP generated by inclusion of all bobcat locations generated during the course of this study. The study area polygon encompassed 93,413 ha and included all of the Pantex Plant, outlying areas such as Pantex Lake, the town of Panhandle, TX, and large amounts of private land. The study area is bisected by 2 major highways (United States Highway 60 and Interstate 40) as well as the Panhandle Northern Railroad. The Pantex Plant is 32 km northeast of Amarillo in Carson County, Texas (Figure I.1.). Pantex is a 7,289 ha facility owned by the United States Department of Energy (DOE) and National Nuclear Security Administration (NNSA). The plant is managed by Consolidated Nuclear Security, LLC (CNS). It is the primary nuclear weapons assembly and disassembly facility in the United States (J. D. Ray, Consolidated Nuclear Security, LLC, personal communication). Part of the Pantex Plant site is the Texas Tech University Research Farm which is used for agricultural production (Texas Tech University 2014).

Capture

Bobcats were targeted across all seasons from spring 2009 through winter 2013, although trapping efforts were sporadic between spring 2009 and fall 2011. Bobcats were captured in wire live-capture traps (size 106.7 cm x 38.1 cm x 50.8 cm; Tomahawk Trap Co., Tomahawk, Wisconsin, USA). These were used in conjunction with live roosters housed in separate wire cages to act as lures. Traps were covered with vegetation to provide both cover and shade as well as funnel animals to the opening of the trap. Trap arrays were placed in areas where bobcats had been previously seen or where the habitat was considered favorable. This included tree rows, along drainages, roadway culverts, near or adjacent to abandoned buildings and near debris piles. I frequently utilized a double-trap system wherein a rooster was placed between 2 traps to maximize trapping success. Trap arrays were usually situated in an L-shape although some linear arrays were also utilized depending on site accessibility and existing structure configuration. Trap nights were defined as 1 trap open for 1 night. I also utilized motion-triggered game cameras including the Reconyx HC500 Hyperfire and Reconyx HC600 Covert (RECONYX Inc, Holmen, WI, USA) to assess prospective locations for bobcat activity and monitor established trap sites for continued bobcat presence. Trap sets were checked each morning before 1100 hr to reduce the risk of distressing the animal.

I anesthetized bobcats with an intramuscular injection of aqueous Telazol (Tiletamine HCL and Zolazepam HCL; 5 mg/kg body weight; Fort Dodge Animal Health, Fort Dodge, Iowa, USA) into the caudal thigh muscle via a pole syringe. Under sedation, I recorded standard morphological measurements and marked each bobcat with color-coded combinations of ear tags for primary identification. As a precaution, each bobcat also had a passive integrated transponder (PIT tag; Biomark, Boise, Idaho, USA) inserted for secondary identification in case one or both ear tags were lost. Age was determined based on tooth eruption, staining and overall body size following Crowe (1975). Adults (age > 1 year) were fitted with a 250 g Tellus GPS-GSM collar (Followit Lindsberg AB, Sweden). The collars did not exceed 3% of each animal's body weight except for 1 individual in which it did not exceed 3.6% of its body weight. All collars were equipped with an internal antenna, mortality sensor, remote-drop switch and activity sensors. I then returned the bobcats to the trap and released them after full recovery from the dissociative effects of the sedative (≥ 4 hours). All animal housing and handling procedures were approved by the West Texas A&M University Animal Care and Use Committee (protocol 04-12-12).

Radiotelemetry

To determine home range sizes of bobcats, I programmed the GPS-GSM collars to record a GPS location using Universal Transverse Mercator (UTM) coordinates every 6 hrs. During 2009 through spring 2011 the collars were programmed to obtain a location every 2 hrs. This was found to reduce battery life ahead of schedule so all subsequent collars were programmed for 4 locations per day. This was considered to be an acceptable compromise between extending battery life and obtaining an adequate portrayal of daily movements. Frequencies were maintained at 148 MHz. Location data were downloaded from the Tellus website (http://tellus.televilt.se/) and from collars themselves by use of a 4-element RCD-04 handheld unit (Followit Lindsberg AB, Sweden).

All location points with a horizontal dilution of precision (HDOP) value greater than 5 were discarded because of their questionable accuracy. This was only done for the 8 collars (out of 22) that recorded HDOP values. Additionally, all bobcat datasets were reduced to serial locations ≥ 6 hours apart to correct for the differing time intervals between collar programming schedules. I imported the relocations into a Geographic Information System (GIS) using ArcView version 3.3 (Environmental Systems Research Institute, Redlands, California, USA) and calculated bobcat home ranges by use of the Animal Movement Extension (Hooge et al. 1999) within that GIS. Cumulative home ranges were calculated for each bobcat at the 100%, 95%, 75% and 50% level using the MCP method (Mohr 1947, Lawson and Rodgers 1997). I also performed a bootstrap analysis on each cumulative dataset to determine if I had adequately characterized each animal's home range (Kenward 1982, Harris et al. 1990).

Seasonal home ranges were analyzed by grouping the calendar months into seasons, assigning relocations as necessary, and calculating a home range for each season. Each season was comprised of 3 months: fall (September, October, November), winter (December, January, February), spring (March, April, May), and summer (June, July, August). I excluded all relocations that started or ended partway through a given season to ensure that each bobcat had adequate representation for that season. Low sample size precluded separating bobcats by sex and year for seasonal home range analyses. I performed Analysis of Variance (ANOVA) in Statistical Package for the Social Sciences (SPSS; IBM SPSS Version 19.0., Armonk, NY, USA) to compare seasonal home ranges and mean distance traveled between relocations among seasons. I used the Kolmogrov-Smirnov test for normality for home range and movement analyses. The critical value for all analyses was $\alpha = 0.05$.

RESULTS

Eighteen adult bobcats were captured 34 times from March 2009 through February 2013. Radiotelemetry effort yielded over 17,400 GPS relocations after position time-outs and locations with high HDOPs were removed. The mean number of viable relocations per collar were 794 ± 588 (mean ± 1 STD; range = 35-1,999 relocations, n = 22). Some individuals were successfully recaptured and wore multiple collars throughout the study. Because of premature mortalities and collar malfunctions, 5 males were unable to be included in cumulative home range analyses because of lack of sufficient relocations.

I monitored 13 bobcats (8F:5M) for sufficient time to describe cumulative home ranges. Some of these individuals wore several successive collars while others were not recaptured so collar duration for home range analyses was variable with a mean of 8 ± 4 months (range = 4-20 months, n = 13). One male, bobcat 13, was excluded from the cumulative home range analysis because of a lack of sufficient relocations (n = 309) (Figure I.2), but was able to be included in seasonal home range analyses because of his adequate representation for the fall season. Therefore, seasonal home range analyses include 14 bobcats (8F:6M). Variations in available habitat were found to be minimal (<0.01%) across study years so I compared seasonal home ranges of bobcats monitored throughout the duration of the study. The bootstrap analysis determined cumulative home range sizes stabilized for females at a mean of 1,012 ± 955 locations (range = 375-3,300 relocations, n = 8; Figure I.3) while the males stabilized at 480 ± 96 locations (range = 400-645 relocations, n = 5; Figure I.4).

Cumulative bobcat home range sizes were highly variable (Table I.1). Female home ranges at the 100% MCP level ranged from 5,496 to 20,406 ha. Male 100% MCP home ranges ranged from 6,969 to 40,748 ha.

Seasonal home ranges were calculated using a 100% MCP for each season. The data were not normally distributed (D = 0.186, df = 30, P = 0.01) but were log-normally distributed (D = 0.128, df = 30, P = 0.20). ANOVA results on log-transformed data indicated no statistical significance for differences in mean home range sizes among seasons (*F* = 0.396, df = 3, *P* = 0.76; Table I.2).

Mean distance traveled between relocations was similar across seasons. The data were normally distributed (*D* = 0.122, df = 30, *P* = 0.20) although ANOVA results indicated no difference in mean distance traveled between seasons (*F* = 0.685, df = 3, *P* = 0.57; Table.I.3).

DISCUSSION

All mammals can be said to have a home range, whether stationary or shifting (Burt 1943). Bobcat home range sizes are extremely variable across their geographic range and are influenced by a variety of factors as previously discussed. Habitat quality or prey abundance is often used to explain this variation (Anderson 1987, Knick 1990, Conner et al. 2001). A primary indicator of the suitability of any habitat is its ability to support prey populations (Boyle and Fendley 1987). Habitats more suitable for abundant prey densities are more likely to be included in bobcat home ranges and high quality habitat should result in smaller home ranges (Knick 1990).

Reproductive success of solitary carnivore females is suggested to be closely associated with the ability to exploit resources so movement and spacing patterns should be largely determined by food abundance and distribution (Prange et al. 2004). In urban-associated areas, artificial resources may result in smaller and more stable home ranges (Prange et al. 2004). Conner et al. (1999) also suggested that more experienced bobcats are more successful and efficient hunters which will lead to a decrease in home range size. It has been suggested that experienced females will often share space with other females (Chamberlain and Leopold 2001, Diefenbach et al. 2006). Additionally, genetic relatedness may contribute to females sharing space with each other (Cochrane et al. 2006).

This may have been the case in my study population. Resident females with home ranges located entirely or at least mostly within Pantex Plant boundaries generally had the smallest home ranges and frequented anthropogenic areas such as buildings to a greater extent than did females located off-site. This could also be because Pantex Plant is speculated to offer a more hospitable environment than the surrounding private lands. The bobcats are popular with Pantex employees and there are no programs in place to control or remove them as is often the case in the surrounding area.

Variations in home range sizes can be explained both biologically as well as analytically. The method used for home range estimation is influential on both the size and configuration of the home range generated (Burt 1943, Swihart and Slade 1985, Aebischer et al. 1993). The main drawback to using the MCP method is that it overestimates the size of the home range by incorporating empty space (Burt 1943, Kenward 1987, Aebischer et al. 1993). I contend that the animal may use at least some degree of that space as a travel conduit to other areas of its home range as represented by outlying relocations. Also, animals do not move in a straight line (Aebischer et al. 1993). It is possible that the animal utilizes other areas (i.e. this “unused” space) of its home range between timing of relocations.

As previously stated, comparisons of home ranges across studies can be misleading for a variety of reasons. The method of home range estimation and program used to calculate ranges have a large influence on the size reported (Swihart and Slade 1985, Lindstedt et al. 1986, Kenward 1987, Aebischer et al. 1993, Lawson and Rodgers 1997). Also, the number of relocations, sample sizes (Aebischer et al. 1993), duration of study, seasonality and geographic area (Anderson and Lovallo 2003) can confound comparisons. However, it is possible to mitigate some of these risks by comparing results generated by the same home range method, in this case the 100% MCP, and reporting all known factors such as sample size and geographic area. When compared to other studies, it appears that bobcats in my study area have considerably larger mean home range sizes (Table I.4). This could suggest a generally lower-quality habitat for bobcats in my study area.

Bobcats in this area of the Texas Panhandle have not been well-studied. Population densities and overall abundances are unknown. It could be speculated that a lack of natural structure, local persecution by humans including annual organized predator harvests, and persistent drought are factors that could limit bobcat abundance in this area. Drought conditions are known to greatly reduce small mammal populations (Yahner 1992, Pruett et al. 2009). Further research would be necessary to investigate bobcat population densities in this area as well as the relationship with small mammal abundances.

Bobcats are known to exhibit a high degree of long-term site fidelity in their land-tenure system (Litvaitis et al. 1987, Poole 1994, Benson et al. 2004). Adults readily shift their ranges in response to death or emigration of neighboring residents (Bailey 1974, Anderson 1988). Vacant home ranges are quickly filled in by neighboring residents or transients (Bailey 1974, Anderson 1988, Benson et al. 2004). Some studies have documented the new occupants exhibiting a high degree of overlap with the former residents' home range and point locations (Benson et al. 2004). This is suggested to validate the concept of a land tenure system based on prior rights in bobcats and suggests that vacant home ranges are filled by members of the same sex (Benson et al. 2004) as seemed to be the case in my study area. Bobcats will occasionally investigate areas outside of their normal home range (Burt 1943) which allows them to capitalize on resources that become available in case of area vacancies (Lovallo and Anderson 1995). These reconnaissance trips familiarize them with the surrounding landscape which allows the bobcat to relocate to areas with better resources should they become available (Lovallo and Anderson 1995, Conner et al. 1999). This shifting of ranges suggests that bobcats are aware of a hierarchy of quality in home ranges (Anderson and Lovallo 2003) and that social organization in bobcats is more complex than previously suggested (Benson et al. 2004).

There was no statistical difference between seasonal home range sizes in my study. I initially expected spring home ranges to be the largest because of their coincidence with the breeding season. Although breeding in bobcats can occur at any time of the year, the majority of copulations occur in February or March (Young 1958, Crowe 1975). The fact that the spring home ranges were unremarkable could be explained by the fact that 3 of the 6 cats represented in the spring season were females; their home ranges ranged from 1,916 ha to 2,978 ha. The 3 male home ranges in spring ranged from 6,327 ha to 11,931 ha. It was suggested by Lynch et al. (2008) that females may restrict their home range sizes during the breeding season to increase their chances of being encountered by neighboring males. Small sample sizes generally increase variance and reduce the likelihood of detecting differences (Otis and White 1999). Unfortunately, my small sample sizes for each season also precluded separating bobcats by sex and year so statistical sensitivity was lost by pooling data when the majority of male mammals are suggested to have larger home ranges than females (Burt 1943, Lindstedt et al. 1986). In the case of bobcats, male home ranges are often considerably larger (Major 1983, Witmer and DeCalesta 1986, Cochrane et al. 2006, Lynch et al. 2008).

The lack of statistical differences between seasonal home ranges could also be explained by a relative continuity in habitat quality in my study area. In many respects, habitat quality for bobcats in this area of the Southern High Plains may not vary considerably between seasons. For example, snowfalls were mild to moderate during my study (NOAA 2014) and while temperatures between seasons are variable, each season undergoes significant fluctuations in diurnal and nocturnal temperatures (Choate 1997, NOAA 2014). The majority of the study duration was also influenced by a prolonged drought (NOAA 2014). Drought conditions are known to greatly reduce small mammal populations (Yahner 1992, Pruett et al. 2009). As previously stated, vegetation is sparse and available cover is often limited in this area. These factors could contribute to poor hunting success (Anderson 1987). Interestingly, the majority of my study population relied heavily on anthropogenically-impacted areas such as buildings, abandoned houses, and barns within their respective home ranges (see Chapter 2). The consistently high selection attributed to these areas suggests that bobcats in this area rely on them to meet important resource requirements. Because they were so reliant on these anthropogenic areas, bobcats may not exhibit marked variation in seasonal home range sizes. The pressure of a relatively atypical habitat may have made them dependent on alternative habitat attributes that bobcats in more natural areas would likely avoid (Riley et al. 2003, Riley 2006) such as western populations that utilize caves and rock piles year-round for shelter, dens and resting sites (Boyle and Fendley 1987). These are considered to be critical habitat features for bobcats in these areas (Bailey 1974, Boyle and Fendley 1987).

Movement between relocations did not differ between seasons. Although the data were normally distributed they may have been skewed by a few individuals. Thus, seasonality seems to have no effect on distances traveled between relocations for bobcats in my study area.

The literature suggests that much of the difference in distances moved can be attributed to differing home range sizes between sexes (Anderson and Lovallo 2003). This implies that males and females traverse their respective home ranges in a comparable amount of time (Anderson and Lovallo 2003). Therefore, movement patterns and home range sizes are best interpreted when assessed in relation to both short and long-term population trends (Lynch et al. 2008). A few studies have detected a difference in movements between relocations between sexes (Anderson 1987, Cain et al. 2003). In these cases, slower movements by females are suggested to indicate their more intensive hunting for smaller prey items than males which is supported by documentation of sex-related feeding habits (Anderson 1987, Anderson and Lovallo 2003). As previously stated, I was unable to analyze each sex independently. I suspect the lack of observed differences in seasonal home ranges may have biological relevance obscured by small sample sizes and influences from sex-related, study year or individual biases could have been a factor in these results. Future research should investigate distances traveled and home ranges, both cumulative and seasonal, to ascertain whether these results can be extrapolated. It could be that these results are typical of bobcats in this area given the atypical habitat.

The greatest challenges to this study were technology-based. The GPS-GSM collars had a manufacturer-estimated battery life of 1.5-2 years for our area. The maximum amount of time attained by a single collar was 10 months. The majority only reached 6-8 months before they had to be dropped because of low battery signals. Home range analyses are best done on individuals with a minimum of 1 year of data. This helps alleviate influences from seasonal variations, environmental factors and individual biases. Although my original purpose for this study was to collect ≥ 12 months of data for each bobcat, the technology I relied on did not make this possible. Also, mortalities in the form of vehicular collisions and hunter harvest reduced my sample size (Anderson and Lovallo 2003, Cain et al. 2003, Riley et al. 2003). One study in southern California attributed 50% of all mortalities within their study population to vehicular collisions (Tigas et al. 2002).

Bobcats are known to modify certain behaviors and activity patterns in response to anthropogenic activity and residential areas (Tigas et al. 2002, Riley et al. 2003, Riley 2006). Despite their suggested resilience to urban association; human-caused mortalities, both direct and indirect, are responsible for the majority of mortalities in many bobcat study populations (Anderson and Lovallo 2003, Cain et al. 2003, Riley et al. 2003). Bobcats in habitats similar to my study area may establish similar home ranges and movement patterns because of exposure to comparable habitat features. Further research should be done in comparable habitats to investigate short-term and long-term population trends as well as their correlation with home range, movement and activity patterns. Bobcats are both ecologically and economically significant (Roberts and Crimmins 2010). Proper management decisions are imperative to ensure their continued presence in our ecosystems.

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Table I.1. Sex, approximate collar durations (radio-days), number of relocations, and MCP home ranges (ha) of 13 bobcats monitored within March 2009-October 2013 in Carson and Potter counties, Texas.

Bobcat	Sex	Radio-days	Relocations	100% MCP	95% MCP	75% MCP	50% MCP
1	F	600	2,089	6,187	2,806	1,568	516
2	F	180	1,724	14,491	7,831	2,903	1,250
4	M	150	1,243	6,969	5,527	3,481	1,205
5	F	150	880	10,468	7,525	4,823	2,096
6	F	390	1,067	9,292	4,678	1,887	767
7	F	180	538	7,157	4,537	3,045	1,571
8	F	180	718	20,406	3,015	1,542	385
11	M	210	718	40,748	35,474	22,701	10,703
12	F	300	986	5,496	2,375	1,138	329
14	F	150	616	15,491	10,396	8,018	2,123
16	M	300	1,045	20,053	17,577	7,893	2,538
17	M	270	912	11,628	6,142	1,752	1,249
18	M	240	972	17,976	13,400	7,608	3,453

Table I.2. Summary statistics for comparison among seasonal home range sizes (ha) of bobcats monitored within March 2009-October 2013 in Carson and Potter counties, Texas.

Season	Median	Mean	SD	*n*
Fall	7,391	11,516	13123	6
Spring	4,653	5,972	4363	6
Summer	7,326	9,560	8041	9
Winter	10,482	10,749	6618	6

Table I.3. Summary statistics for comparison of movement between relocations (m) among seasons for bobcats monitored within March 2009-October 2013 in Carson and Potter counties, Texas.

Season	Mean	SD	*n*
Fall	1,171	569	6
Spring	1,408	264	6
Summer	1,488	479	9
Winter	1,365	336	6

Table I.4. Average home range size (km^2) of bobcat populations with reported sample sizes and geographic area. All home ranges calculated with 100% minimum convex polygon (MCP; Mohr 1947) home range method unless otherwise noted[a].

	Male		Female		
Location	*n*	MCP	*n*	MCP	Reference
Maine	9	138.6	1	27.5	Major 1983
Alabama	6	2.6	6	1.1	Miller and Speake 1979
Idaho	4	42.1	8	19.3	Bailey 1974
Idaho	3	20.4	5	11.6	Knick 1990
Idaho	2	123	2	69.7	Knick 1990
Oregon	1	11	5	2	Witmer and DeCalesta 1986
Texas	8	9.94[a]	4	7.1[a]	Mock 2004
Texas	5	195	8	111	Present study
Texas	5	156[a]	8	54[a]	Present study

NOTE: [a]95% MCP home range estimator

Figure I.1. The spatial relationship among my radiotelemetry study area (stippled polygon), the property boundaries of Pantex (black polygons), and the neighboring urban areas of Amarillo and Panhandle (grey polygons) within Carson and Potter counties, Texas.

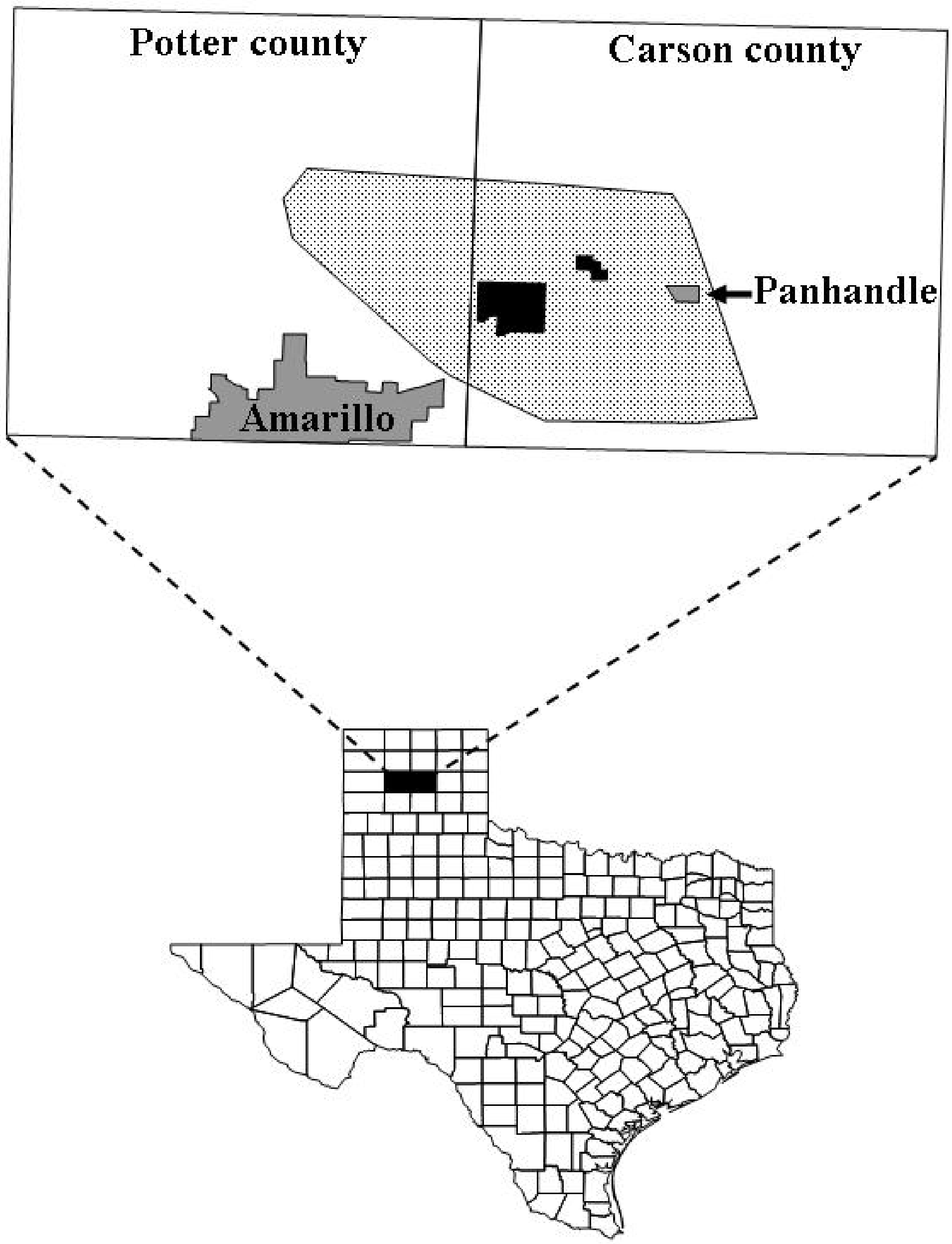


Figure I.2. Bootstrap analysis of bobcat 13 (male) depicting no home range size stabilization (slope of line does not approach zero) throughout duration of monitoring period of 30 August 2012 through 23 November 2012. This suggests failure to adequately characterize cumulative home range of this individual and resulted in exclusion from most home range analyses.

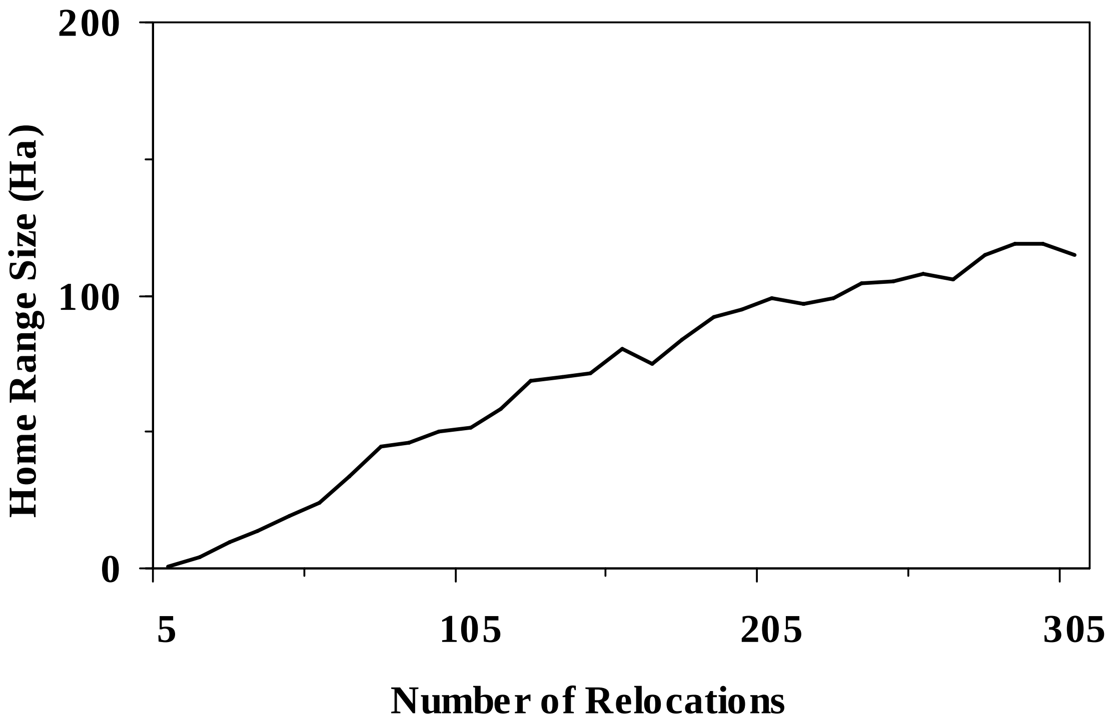


Figure I.3. Bootstrap analysis of bobcat 2 (female) depicting home range size stabilization (slope of line approaches zero) at approximately 900 relocations. This suggests successful characterization of this individuals' home range and supports inclusion in subsequent home range analyses.

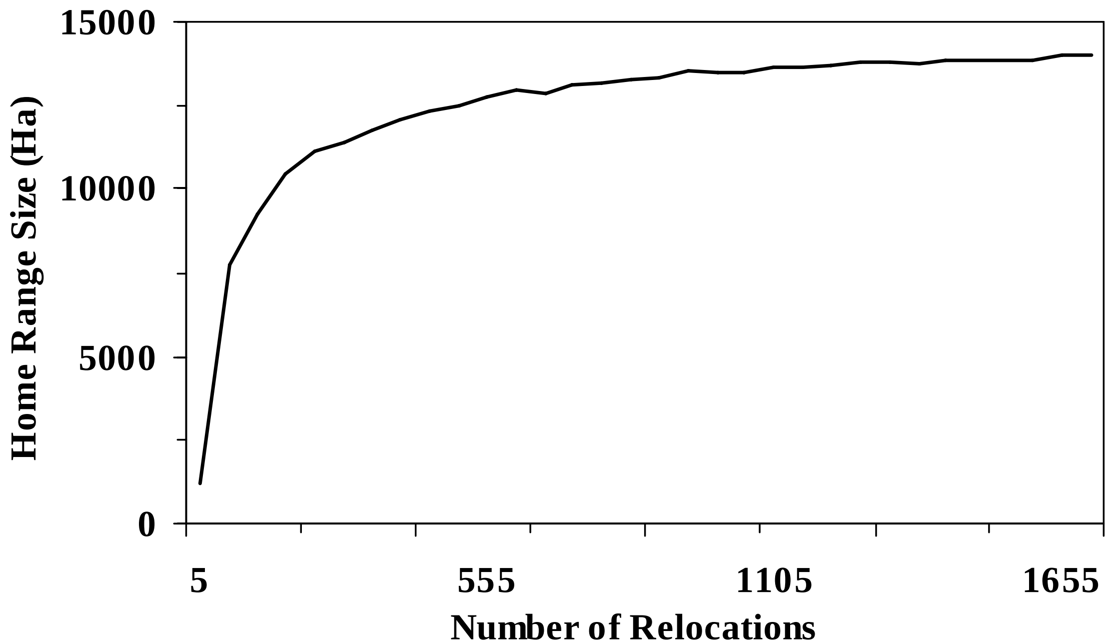
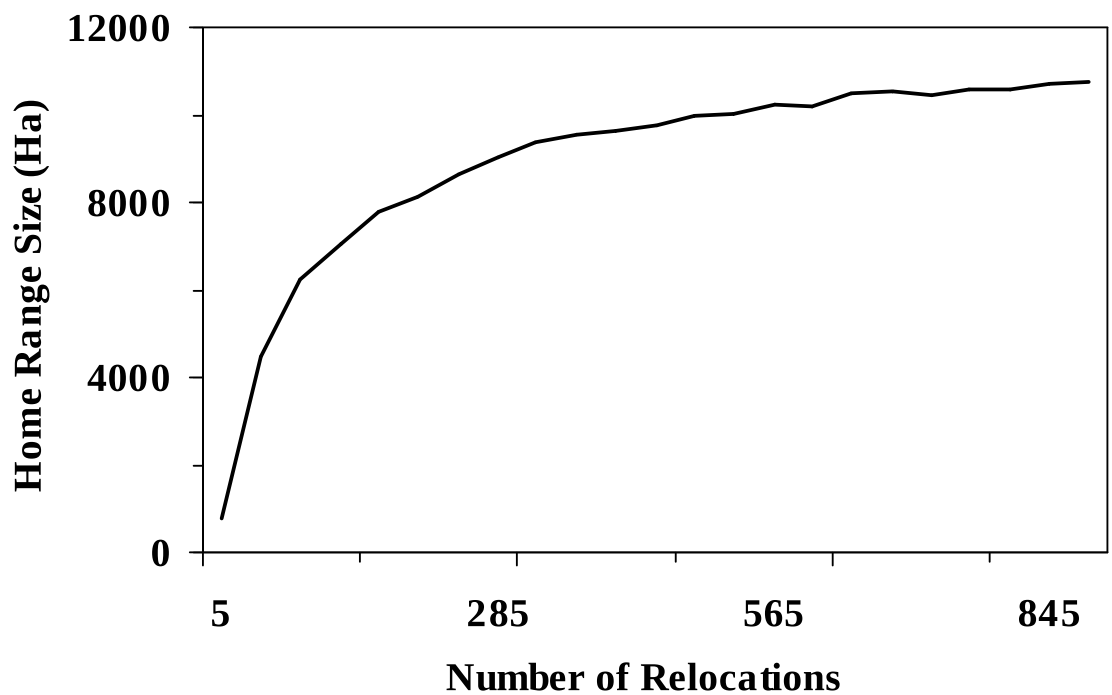


Figure I.4. Bootstrap analysis of bobcat 17 (male) depicting home range size stabilization (slope of line approaches zero) at approximately 645 relocations. This suggests successful characterization of this individuals' home range and supports inclusion in home range analyses.



CHAPTER II

HABITAT SELECTION OF BOBCATS IN A FRAGMENTED SHORTGRASS PRAIRIE ECOSYSTEM

INTRODUCTION

The bobcat (*Lynx rufus*) is one of the most adaptable and widely distributed carnivores in North America (Anderson 1987). Their geographic range extends from central British Columbia to southern Mexico and from the Atlantic to Pacific coasts within the United States (Anderson and Lovallo 2003). Bobcat distribution is limited in some areas by the presence of other predators such as Canada lynx (*Felis canadensis*), mountain lion (*Puma concolor*), coyote (*Canis latrans*), and grey wolf (*Canis lupus*; Anderson and Lovallo 2003). Additionally, they have faced persecution from humans across most of their geographic range (Anderson and Lovallo 2003, Roberts and Crimmins 2010). Despite this, they have not only succeeded but flourished, by being adaptive generalists (Anderson and Lovallo 2003) and are considered to be expanding across much of their geographic range (Roberts and Crimmins 2010).

Bobcats are an integral part of many ecosystems and are considered to be a top predator in some systems (Conner et al. 2001). They are instrumental in controlling small mammal populations and they themselves serve as a prey item for several apex predators

(Anderson and Lovallo 2003). Aside from their ecological role, their economic significance as a furbearer is a motivating factor for research and management of this species (Woolf and Hubert 1998, Roberts and Crimmins 2010). To successfully manage for bobcats we must first understand their natural history requirements. Considerations such as home range size, habitat preferences, diet and social organization all have crucial management implications.

The rate of habitat fragmentation and conversion of native habitats into cropland and human settlements is increasing (Cain et al. 2003, Ruell et al. 2009). Mass extinctions of native species and ecological degradation can be linked to direct and indirect effects of human land use practices (Sala et al. 2000). It is vital that we understand how these changes impact important species such as the bobcat. Fragmentation results when contiguous habitat is divided into smaller isolated patches of land that are used in different ways (Kuykendall and Keller 2011). This creates a patchwork or mosaic-type landscape which presents challenges to a multitude of species (Kuykendall and Keller 2011). Fahrig (2003) describes 4 effects of habitat fragmentation that can affect wildlife at the species level. First and foremost is an overall loss in the amount of total habitat. Also, the number of habitat patches increases. It then follows that these patches generally decrease in size. Last, the habitat patches become increasingly isolated or separated from each other (Fahrig 2003).

In a fragmented landscape, species that are edge-adapted will benefit over those that depend on core or interior habitats (Krausman 1999, Kuykendall and Keller 2011). These area-sensitive species are negatively affected by habitat edges and may decline over time which then impacts the total ecosystem, including the edge-adapted species, in a variety of ways (Yahner and Smith 1990). Human activity has significantly contributed to habitat fragmentation through agricultural land practices, residential development, power line right-of-ways, and construction of roads and railroads (Fleishman and Mac Nally 2007, Kuykendall and Keller 2011). Agriculturally-based land management practices such as cattle grazing, tilling, and use of center pivot irrigation have a huge impact on vegetative communities and, by extension, the ecosystem. The center-pivot irrigation practice leaves 4 unfarmed corners where the irrigation does not reach (Kuykendall and Keller 2011). These corners are often used for cultivation of a different crop such as winter wheat (*Triticum aestivum*) or are enrolled in the Conservation Reserve Program (CRP; Kuykendall and Keller 2011). The species richness of small mammals in these unfarmed corners can be relatively high (Kuykendall and Keller 2011) and this resource could potentially provide an important prey source for edge-adapted species, such as the bobcat, in a changing landscape.

The term habitat denotes more than just vegetative structure. It is the sum of resources needed by an organism (Krausman 1999). These resources include food, water, cover, and a variety of special factors that contribute to survival and reproductive success (Leopold 1933). This includes migration and dispersal corridors as well as land used during breeding and nonbreeding seasons (Krausman 1999). Obviously the term habitat can be loosely applied and some habitats will be better or more ideal for a given species than another.

Habitat use is defined as the way an animal uses the physical and biological resources in a habitat (Krausman 1999). A certain type of habitat may be used for denning, cover, foraging, etc. These categories rely upon different resources, but may overlap, and are not necessarily mutually exclusive (Krausman 1999). Therefore, an area used for denning may possess the same physical characteristics as an area used for foraging (Krausman 1999).

Habitat selection is an active behavioral process involving both innate and behavioral decisions about which habitat to use (Krausman 1999). This process results in disproportionate use of some habitats over others which is the basis for selection (Aebischer et al. 1993, Krausman 1999). Habitat selection can be further classified as either preference or avoidance, depending upon the proportion of use. Habitat selection is determined by comparing the habitat used to the habitat available (Aebischer et al. 1993, Siegel and Collins 1993). Habitat availability must take into account not only what features are available in the habitat, but what are actually accessible and procurable by the animal (Krausman 1999). Although a habitat is theoretically accessible, its actual use by the animal may be precluded by a variety of factors such as intraspecific or interspecific competition, habitat fragmentation, urbanization, etc. Therefore, determining habitat selection requires significantly more intensive behavioral observations than merely documenting habitat use (Siegel and Collins 1993).

Habitat is scale dependent and is often further delineated into micro and macrohabitat (Krausman 1999). Macrohabitat use refers to large, landscape-scale features while microhabitat is much more fine-scaled and pertains to how features of a habitat are used (Krausman 1999). Johnson (1980) summarized a natural hierarchy of orders for the habitat selection process. First-order selection is very broad and explains how a species selects a geographical range (Johnson 1980, Krausman 1999). Most studies define the geographic range as the habitat used while the continent or larger geographic area is the habitat available (Johnson 1980). Second–order selection is often defined in studies as the home range is the habitat used and the study area is the habitat available. Third-order selection relates to specific areas or components the animal uses within its home range (Johnson 1980). In short, the habitat composition within location points is the habitat used while the home range itself serves as the habitat available (Johnson 1980, Krausman 1999). It is useful to investigate more than 1 spatial scale when investigating habitat selection to gain a more comprehensive understanding of selection patterns (Johnson 1980, Krausman 1999). Also, the orders of habitat selection are by definition different and therefore provide insight for fundamentally different questions (Johnson 1980). By understanding habitat requirements for species of interest, land managers are better equipped to make informed management decisions (Burt 1943). This process, if done correctly, leads to better ecosystem management so that a number of species will benefit rather than a select few.

Bobcats have largely been studied in wooded or at least semi-wooded landscapes (Cain et al. 2003, Cochrane et al. 2006, Lynch et al. 2008, Ruell et al. 2009). Habitat selection studies in strictly grassland areas are limited. The comparative lack of native vertical structure on the Southern High Plains may present significant challenges to bobcat survival. I conducted a Global Positioning System (GPS) and Global System for

Mobile Communications (GSM) based telemetry study from August 2009 to October 2013 at a site in the Texas Panhandle to investigate second and third-order habitat selection by bobcats.

METHODS

Study Area

My study site is located in the Southern High Plains on the Llano Estacado (Lotspeich and Coover 1962, Texas Almanac 2014). The Southern High Plains is a shortgrass prairie ecosystem (Kuykendall and Keller 2011) and the nearly flat surface of this area is dominated by gramas (*Bouteloua* spp.) and buffalo grass (*Buchloë dactyloides*; Wright 1979). Prickly pear (*Opuntia* sp.) and forbs such as silver-leaf nightshade (*Solanum elaeagnifolium*) are also commonly encountered. Agricultural lands primarily produce sorghum (*Sorghum bicolor*), wheat (*Triticum* sp.), and cotton (*Gossypium* sp.; Wright 1979, Kuykendall and Keller 2011). All vegetative taxonomy follows Barkley (1986).

Black-tailed prairie dog (*Cynomys ludovicianus*) towns are regularly encountered and are comprised of various short grasses and forbs with large patches of bare ground (Russell and Detling 2003, Bangert and Slobodchikoff 2004). Playa lakes are a feature on the Southern High Plains as well. These shallow, circular depressions generally fill only with precipitation or agricultural irrigation runoff but are completely dry during droughts (Smith 2003).

The semi-arid climate of the Texas Panhandle is characterized by high variability. Significant diurnal and nocturnal temperature fluctuations are common throughout the year (Lotspeich and Everhart 1962). Rainfall is also highly variable though annual mean rainfall is typically less than 50.8 cm (Lotspeich and Everhart 1962). Some lands within the study area have been incorporated into the CRP which promotes returning agricultural lands to a grassland state for purposes of improving water quality, providing erosion control and reducing loss of habitat for wildlife (United States Department of Agriculture 2014). Unfortunately, Texas did not mandate these CRP lands be returned to an only native grassland state so many areas were planted with exotic grass species such as bluestems (*Andropogon* spp.; (R. T. Kazmaier, West Texas A&M University, personal communication). Natural structures and vertical cover in the study area is limited. Since the Llano Estacado was settled late in the 19th century, nearly all lands have been altered by agricultural production or overgrazing (Choate 1997).

My study area was a 100% minimum convex polygon (MCP) which included all bobcat location points. This area was comprised of 93,413 ha and encompassed all of Pantex Plant, outlying areas such as Pantex Lake, the town of Panhandle and large amounts of private land in both Carson and Potter counties, Texas (Figure II.1). The study area is bisected by 2 major highways (United States Highway 60 and Interstate 40) as well as the Panhandle Northern Railroad.

The Pantex Plant is 32 km northeast of Amarillo in Carson County. Pantex is a 7,289 ha facility owned by the United States Department of Energy (DOE) and National Nuclear Security Administration (NNSA). The plant site is managed by Consolidated Nuclear Security, LLC (CNS). It is the primary nuclear weapons assembly and disassembly facility in the United States (J. D. Ray, Consolidated Nuclear Security, LLC, personal communication) and includes varying types of industrial buildings and roadways. Part of the Pantex Plant site is the Texas Tech University Research Farm which is used for agricultural production (Texas Tech University 2014). The agricultural practices and areas of concentrated human activity have resulted in a mosaic-type landscape.

Capture

Bobcats were targeted across all seasons from spring 2009 through winter 2013, although trapping efforts were sporadic between spring 2009 and fall 2011. I used wire live-capture traps (size 106.7 cm x 38.1 cm x 50.8 cm; Tomahawk Trap Co., Tomahawk, Wisconsin, USA) in conjunction with live roosters housed in separate wire cages to act as lures. Traps were covered with vegetation to provide both cover and shade as well as funnel animals to the entrance of the trap. I frequently utilized a double-trap system wherein a rooster was placed between 2 traps to maximize trapping success. Trap arrays were usually situated in an L-shape although some linear arrays were also utilized depending upon site accessibility and existing structure configuration. Trap arrays were placed in areas where bobcats had been previously seen or where the habitat was considered favorable. This included tree rows, along drainages, roadway culverts, near or adjacent to abandoned buildings and near debris piles. I also utilized motion-triggered game cameras including the Reconyx HC500 Hyperfire and Reconyx HC600 Covert (RECONYX Inc, Holmen, WI, USA) to assess prospective locations for bobcat activity and monitor established trap sites for continued presence. Trap nights were defined as 1 trap open for 1 night. Trap sets were checked each morning before 1100 hr to reduce the risk of distress for captured animals.

I anesthetized bobcats with an intramuscular injection of aqueous Telazol (Tiletamine HCL and Zolazepam HCL; 5 mg/kg body weight; Fort Dodge Animal Health, Fort Dodge, Iowa, USA) into the caudal thigh muscle via a 1 m pole syringe. While the animal was under sedation, I recorded standard morphological measurements and marked each bobcat with uniquely color-coded ear tags for primary identification. As a precaution, each bobcat also had a passive integrated transponder (PIT tag; Biomark, Boise, Idaho, USA) inserted for secondary identification in case one or both ear tags were lost. Age was determined based on tooth eruption, staining, and overall body size following Crowe (1975). Adults (age > 1 year) were fitted with a 250 g Tellus GPS-GSM collar (Followit Lindsberg AB, Sweden). The collars did not exceed 3% of each animal's body weight except in 1 case in which it did not exceed 3.6% of the individual's body weight. All collars were equipped with an internal antenna, mortality sensor, remote-drop switch and activity sensors. Capture locations were determined using a Garmin Etrex Legend GPS unit (Garmin International, Olathe, KS, USA). I then returned the bobcats to the trap until release after full recovery from the dissociative effects of the sedative. All animal housing and handling procedures were approved by the West Texas A&M University Animal Care and Use Committee (protocol 04-12-12).

Radiotelemetry

To determine habitat selection by bobcats, I programmed the GPS-GSM collars to record a GPS location using Universal Transverse Mercator (UTM) coordinates. During years 2009 through spring 2011, the collars were programmed to obtain a location every 2 hrs. This was found to reduce battery life ahead of schedule so all subsequent collars were programmed to obtain locations every 6 hrs. This was considered to be an acceptable compromise between extending battery life and obtaining an adequate portrayal of daily movements. Location data were downloaded from the Tellus website (http://tellus.televilt.se/) and from collars themselves by use of a 4-element RCD-04 handheld unit (Followit Lindsberg AB, Sweden). Frequencies were maintained at 148 MHz. All location points with a horizontal dilution of precision (HDOP) value greater than 5 were discarded because of their questionable accuracy. This was only done for the 8 collars (out of 22) that recorded HDOP values. I imported the relocations into a Geographic Information System (GIS) within ArcView version 3.3 (Environmental Systems Research Institute, Redlands, California, USA) for habitat mapping.

Habitat Mapping

Aerial photographs were incorporated into GIS coverage to develop habitat maps following Kazmaier et al. (2001). I used Digital Ortho Quarter Quadrangles (DOQQs) downloaded from Texas Natural Resources Information System (TNRIS 2014) for my background images. I used on-screen digitizing in ArcView to delineate habitat types on these habitat maps. My Minimal Mapping Unit (MMU) was set at 20 m x 20 m to account for error rates present in the GPS-GSM collars, the aerial photography I used, and errors inherent in GPS technology itself. Habitats equal to or greater than the MMU were classified into 1 of 6 types: grassland (GR), cropland (CR), anthropogenically-impacted areas (AI), roads and railroads (RR), prairie dog towns (PDT), and playas or wetlands (PW). Available habitats were defined as broad categories and were easily discernible from aerial photography. The grassland habitat type was comprised of natural shortgrass prairie or CRP lands. Croplands included all crop types as well as active and fallow fields. The term “anthropogenically-impacted area” was used to designate areas with human-constructed, 3-D structures such as houses, barns, government buildings, livestock corrals, debris piles, etc. These areas included active residential and commercial areas such as the town of Panhandle and Pantex Plant and also inactive areas such as abandoned houses and barns. An important notation is that although the term anthropogenically-impacted area is used to imply only one habitat type for the selection analyses; most of the other habitat types in the study area have some degree of anthropogenic-influence as well. Cropland is designated as a habitat type but cropland is obviously an anthropogenically-impacted feature on the landscape as are roads and railroads. Playas or wetlands included both natural and human-influenced structures such as retention ponds and stock tanks. In the case of playas, I endeavored to digitize the smallest polygon possible while still including all associated vegetative features as represented by the DOQQs I used.

My data collection spanned 2009-2013 and the aerial photography I used was taken in 2008, 2010 and 2012. I therefore accounted for yearly differences by comparing the DOQQs amongst themselves in addition to the digitized habitat map within the GIS for major habitat changes. Variations in land use were found to be minimal (<0.01% across study duration) so no habitat reclassification was necessary. I then calculated proportions of defined habitat types at several spatial scales to use for habitat selection analyses.

Habitat Selection

Presence vs. Absence Analysis.-- I determined selection for presence versus absence in defined habitat types by comparing habitat used to habitat available at 2 different spatial scales (second and third-order selection). My habitat types were defined in such a way that use would only be documented if the relocations actually fell within the digitized polygon for a given habitat type. Therefore, the animal is either present in that habitat type or it is absent. Habitats were ranked according to preference by comparing differences in log-ratios of use and availability between each habitat type following Aebischer et al. (1993). Compositional analysis utilizes log-ratios of use and availability in a multivariate approach to evaluate selection among available habitats (Aebischer et al. 1993, Kazmaier et al. 2001). For instances in which use and availability differed for a habitat type; preference was considered to occur when use > availability. Avoidance was considered to occur when use < availability. For this methodology, individuals were considered the experimental unit, not GPS locations. All selection analyses were performed within the Resource Selection Program for Windows (RSW, 1999). Statistical comparisons were evaluated at $\alpha = 0.05$.

Second-order selection.--I calculated home ranges at the 100% Minimum Convex Polygon (MCP) level following Mohr (1947) with the Animal Movement Analysis Extension (Hooge et al. 1999) within ArcView 3.3 for the purpose of habitat selection. The MCPs (habitat used) were overlain onto the digitized habitat map (habitat available) to compare proportional use of each defined habitat type

Third-order selection.-- Use was defined as the number of relocations within each habitat type. The habitat available was the amount of each habitat type within each 100% MCP. Relocations were compared against MCPs to evaluate proportional use of each habitat type.

Proximity Analysis.-- Most of the habitat polygons in my study area were very small. For example, an abandoned farmhouse on a plot of grassland surrounded by cropland would include 3 different polygons in a relatively small area. Additionally, the compounded GPS error rates encountered in my study caused uncertainty as to the accuracy of these relocations. Because of this, I also determined second and third-order selection for proximity to defined habitat types.

Second-order selection.-- I calculated buffer zones around each of the 6 habitat types. These zones were comprised of varying increments depending on habitat type, distribution and total proportion of the study area. Effort was made to obtain 6 different buffer increments for each habitat type to reduce problems associated with too many unusual habitats (Aebischer et al. 1993). Because some of the habitat types were such a small percentage of the total study area, they had quite a few buffer increments. For these, the sixth buffer zone included all subsequent zones in order to maintain consistency for analysis. Each buffered habitat type was portrayed on individual maps within ArcView. Bobcat 100% MCPs were overlain onto these maps to evaluate proportional use of each buffer increment. The area of the buffer increments within each

MCP represented the habitat used while the amount of each buffer increment within the study area represented the habitat available.

Third-order selection.--The same habitat buffer increments were used to compare use to availability in third-order selection. Use was defined as the number of relocations within each buffer increment. The habitat available was the amount of each buffer increment within the 100% MCP for each bobcat.

RESULTS

Habitat Availability

Habitat distribution across the study area was variable (Figure II.2). The majority of the study area was comprised of grassland (42.9%) followed by cropland (42.7%). Playas or wetlands (4.8%), anthropogenically-impacted areas (1.3%), prairie dog towns (1.6%), and roads and railroads (0.4%) accounted for the rest of the habitat available for second-order selection. The habitat available for proximity selection was also variable. Most habitat polygons were very small and so had a large number of buffer increments associated with them.

Radiotelemetry Effort

The GPS-GSM collars yielded over 17,400 relocations for 18 individuals (8F:10M). Five males were dropped from selection analyses because of insufficient relocations because of premature mortalities and collar malfunctions. Therefore habitat selection analyses were performed on 13 bobcats (8F:5M). Bobcats averaged 1,277 ± 1,024 relocations (mean ± 1 STD; range = 538-4,484, n = 13). Some of these individuals wore several successive collars while others were not recaptured so collar duration for habitat selection analyses was variable with a mean of 8 ± 4 months (range = 4-20 months, n = 13).

Habitat Selection

Presence vs. Absence Analysis.

Second-order selection.--Bobcat 100% MCPs ranged in size from 5,496 to 40,748 ha and encompassed varying percentages of defined habitat types. Bobcats exhibited selection for all 6 habitat types ($\lambda = 0.115$, $P<0.001$). The habitat rankings obtained by compositional analysis were: +PDT > +AI > +PW > +CR > -GR > -RR.

Third-order selection.-- Bobcats exhibited selection for all 6 habitat types ($\lambda = 0.077$, $P<0.001$). The habitat rankings obtained by compositional analysis were: +AI > +PW > -PDT > -RR > -GR > -CR.

Proximity Analysis.

Second-order selection.--Bobcats exhibited preference for habitats within or most closely associated with anthropogenically-impacted areas (up to 1 km away). They avoided habitats ≥ 1500 meters from anthropogenically-impacted areas ($\lambda = 0.084$, $P<0.001$).

Bobcats exhibited preference for areas adjacent to or near grasslands (up to 1 km away). They avoided being within grasslands or ≥ 1400 m away from grasslands (λ = 0.362, P = 0.021).

Bobcats exhibited highest preference for areas within or most closely associated with playas or wetlands in a linear progression (up to 1.5 km away). They avoided habitats ≥ 2 km from playas or wetlands ($\lambda = 0.093$, $P<0.001$).

Bobcats exhibited preference for areas within or most closely associated with cropland and avoided habitats ≥ 1200 m away from cropland (λ = 0.190, P<0.001).

Bobcats preferred areas furthest away from roads and railroads in a linear progression and exhibited avoidance for habitats within 1 km of roads and railroads (λ = 0.262, *P* = 0.038).

The selection for proximity to prairie dog towns was approaching statistical significance at (λ = 0.456, *P* = 0.070).

Third-order selection.--Bobcats preferred to be within or adjacent to anthropogenically-impacted areas and avoided habitats ≥ 1 km away in a linear progression (λ = 0.170, P<0.001).

They preferred to be within or closely associated with playas or wetlands (up to 1 km) and avoided habitats ≥ 1500 m away from playas and wetlands (λ = 0.327, P = 0.013).

Bobcats preferred to be within or in habitats most closely associated with grasslands and avoided any that were ≥ 1 km away (λ = 0.093, P<0.001).

Bobcats preferred to be adjacent to cropland (up to 600 m away) though they avoided being directly within it or ≥ 900 m away from cropland (λ = 0.095, P<0.001).

Bobcats preferred to be an intermediate distance from roads and railroads (up to 1 km away). They avoided areas within roads and railroads or areas furthest away (≥5 km) from roads and railroads (λ = 0.193, P<0.001).

The selection for proximity to prairie dog towns is approaching statistical significance at (λ = 0.441, *P* = 0.059).

DISCUSSION

The bobcats exhibited selection for all 6 habitat types across both spatial scales. They consistently preferred anthropogenically-impacted areas and playas or wetlands across all analyses while selection patterns for the other 4 habitat types were variable.

Presence vs. Absence Analysis

Second-order Selection.--Bobcats preferred prairie dog towns, anthropogenically-impacted areas, playas or wetlands and cropland at this selection level. There are a number of biological explanations for these habitat rankings. Prairie dog towns accounted for only 1.6% of the study area available to bobcats. While this figure seems almost inconsequential, the bobcats exhibited very high preference for this habitat type. Prairie dog towns are hotspots for both biological diversity and abundances (O'Melia et al. 1982, Agnew et al. 1986, Krueger 1986, Miller et al. 1990). They attract a variety of prey species including lagomorphs, small mammals and birds (Agnew et al. 1986, Kruger 1986, Shipley and Reading 2006). Additionally, the majority of prairie dog towns within the study area are closely associated with playas or wetlands (Pruett et al. 2009, Pruett et al. 2010). This is suggested to be because these playa lakes have not undergone substantive agricultural land use alterations for crop or livestock production (Pruett et al. 2009).

These playas serve as natural drainage systems and are known to provide natural habitat to a variety of prey species (Smith 2003). They also provide seasonally available surface water and lush vegetation for cover (Smith 2003). They generally fill only with precipitation or irrigation runoff and so are generally unsuitable for agricultural purposes and left uncultivated (Smith 2003). Thus, many of these playa basins and their associated slopes of grassland habitat have come to function as oases of natural habitat for a variety of species in an increasingly agriculturally-based landscape (Haukos and Smith 1992, Smith 2003). The demonstrated selection pattern for prairie dog towns could be fundamentally biased because all of my trapping effort was concentrated in the southwestern portion of the study area (i.e. on and around Pantex Plant) where the prairie dog towns were most concentrated. Because my trapping effort was focused on these areas it follows that I could have more points per area within prairie dog towns by my trapping design itself. It is also possible that I was generally trapping bobcats that frequented prairie dog towns. If my trapping effort had been more widespread across the study area, I may have captured bobcats in areas with less prairie dog towns and subsequently an alternate selection pattern. However, my study area was defined after the conclusion of the monitoring period and before I was aware of the concentration of prairie dog towns in the southwest portion of the study area. Also, the research objectives involved investigating the bobcats on Pantex Plant and nearby areas. A more widespread trapping effort was not considered, because of the increased proximity from the primary investigative area.

Bobcats also highly preferred anthropogenically-impacted areas at this spatial scale. This was expected and is further supported by a multitude of personal observations by researchers and Pantex records. These anthropogenically-impacted areas consist of houses, residential and industrial outbuildings, debris piles and livestock corrals; in other words, any human-built structure that provided vertical cover. The ability to exploit artificial shelter sites such as these is an important factor in the success of some species within urban associations (Lowry et al. 2013). Indeed, this ability indicates "phenotypic plasticity" or behavioral flexibility (Lowry et al. 2013). Their high preference for these areas could be speculated to be a strategy to cope with the relative lack of natural vertical structure in this area. Most resident bobcats with home ranges within the Pantex Plant site were moderately habituated to humans. They were commonly seen in most areas during both diurnal and nocturnal hours (J. D. Ray, Consolidated Nuclear Security, LLC, personal communication). Bobcats located off-site had a more persistent wariness of humans, possibly because of the persecution bobcats have faced across much of this area. This postulation is supported by anecdotal evidence in our study population. Approximately 3 of our study bobcats were prematurely lost to human hunter harvest. Urban bobcat populations are being increasingly studied (Tigas et al. 2002, Riley et al. 2003, Riley 2006). Some of these populations have been suggested to be moderately tolerant of human expansion and urbanization within their natural habitats (Tigas et al. 2002, Riley et al. 2003).

Bobcats exhibited preference for cropland in the presence vs. absence analysis for second-order selection. Medium-sized, generalist predators such as the bobcat often thrive in heterogeneous landscapes because croplands increase both foraging opportunities and efficiencies (Litvaitis and Villafuerte 1996, Oehler and Litvaitis 1996, Heske et al. 1999). Cropland may provide seasonal cover for bobcats in the instances of taller crops such as corn. Bobcats are an edge-adapted species (Prange et al. 2004). They frequently utilize disturbed areas and human-made travel corridors such as two-track roads (Tuviola 1999, Ruell et al. 2009) which are commonly found in cropland areas. Center-pivot irrigation is also a common agricultural practice in the Texas Panhandle (Kuykendall and Keller 2011). This method frequently results in excess water pooling along field perimeters. Although becoming less common, row-water irrigation systems result in excess water that accumulates in nearby retention ponds. These areas could be an alternative or even more reliable source for surface water than playas or natural wetlands which rely on precipitation (Smith 2003). This postulation is supported by my personal observation of resident bobcats hunting in cropland and drinking from pooled water within a newly-planted cornfield.

Bobcats demonstrated avoidance of both grasslands and roads and railroads in second-order selection presence vs. absence analysis. The avoidance of grasslands could be because of the lack of natural vertical cover on the Southern High Plains. Trees in this area are most often associated with other habitat types such as anthropogenically-impacted areas (Adams 1994). The vast majority of the grassland vegetative community is composed of grasses and forbs. Exposure because of lack of cover increases risks to the bobcats themselves from both predation by coyotes and as a target for human hunter harvest. Both of these threats have been documented to cause a total of 4 mortalities in my study population.

The selection patterns for second-order selection may have an analytical explanation as well as the biological one. The majority of the grasslands habitat available to bobcats is concentrated in the western portion of the study area in a relatively large and unfragmented polygon (see Figure II.2.). The rest of the grassland habitat within the study area is represented by much smaller polygons interspersed with the other habitat types. Only 2 bobcats ventured that far west. It could be that these individuals were outliers and their individual biases skewed the habitat available for the rest of the study population. If their datasets had not been included in selection analyses, the other available habitat type percentages would have been increased and a different selection pattern may have been obtained. Despite this, I chose to include their datasets primarily because I did not wish to reduce my sample size even further.

Bobcats avoided roads and railroads at this spatial level. This was likely because of several reasons. All roads can be said to be barriers or at least filters to animal movements (Forman and Alexander 1998). Road-avoidance is considered to be caused, in part, by traffic disturbance, visual disturbance, and pollutants (Forman and Alexander 1998). It has also been theorized that the presence of other predators moving along roadsides may be a deterrent (Forman and Alexander 1998). The effects of traffic noise on wildlife include hearing loss, increased stress, altered behavior, and deleterious effects on food supply and other habitat attributes (Forman and Alexander 1998). Minimal vegetation adjacent to roads and highways increases the amount of open space animals must traverse, which would potentially increase their reluctance to cross (Cain et al. 2003). Roadside lighting is also disruptive to wildlife species (Forman and Alexander 1998), including nocturnal predators such as the bobcat. Despite these risks, vehicle collisions were by far the most common cause of mortality in my study population. One male bobcat was killed by a train approximately 2 weeks after capture and subsequently excluded from all selection analyses. The literature suggests road mortalities are significant for bobcat populations throughout their geographic range (Tuovila 1999, Anderson and Lovallo 2003, Cain et al. 2003, Ruell et al. 2009). Bobcats are known to utilize roadway culverts for multiple purposes, including road crossing (Tuviola 1999, Cain et al. 2003). These culverts may attract bobcats and other mid-sized carnivores to the road vicinity, thereby increasing the likelihood of a collision (Cain et al. 2003).

Roads negatively impact bobcats in several ways. Aside from direct collisions they also increase the frequency of interactions with humans, contribute to direct and indirect habitat loss as well as habitat fragmentation (Forman and Alexander 1998, Ruediger 1996, Ruediger 1998). Bobcats, like other carnivores, are very susceptible to highway impacts (Tuovila 1999) because of their low reproductive rates, low population densities and large home ranges (Ruediger 1996). Additionally, the implementation of the North American Free Trade Agreement and significant human population growth in Texas have resulted in increased road traffic, expansions of existing roads as well as construction of new ones (Cain et al. 2003). Roadway construction projects are considered to have a permanent and severe impact on carnivore species (Ruediger 1996). These factors all contribute to increasing the likelihood of negative impacts on bobcat populations in Texas (Cain et al. 2003).

The second-order selection patterns were variable. Bobcats appeared to prefer a heterogeneous landscape within their home ranges and relied on a mixture of natural and artificial habitats to meet their resource requirements. Overall, they preferred areas with landscape “features” such as houses, buildings, agricultural crops, playa lakes, retention ponds, and prairie dog towns as opposed to the comparatively “featureless” habitats which were grasslands and roads and railroads. By selecting for so many habitat types at this spatial scale, it appears the bobcats are choosing to use areas with habitat edges and a measure of habitat fragmentation may be at least tolerable if not useful (Krausman 1999, Prange et al. 2004).

Third-order Selection.--Bobcats exhibited high preference for anthropogenically-impacted areas as well as playas or wetlands at this spatial scale. They avoided all other habitat types. Bobcats were observed directly in and around abandoned houses, beneath buildings and foundations, underneath truckbed campers and cattle-loading chutes. These structures often had associated weedy cover which provided shelter and additional habitat. Bobcats also rely upon abandoned buildings and features such as trees, utility poles and haystacks to avoid predators (J. D. Ray, Consolidated Nuclear Security, LLC, personal communication).

Anthropogenically-impacted habitats also attract a host of prey species such as small mammals, lagomorphs and birds (Falk 1976). These areas provide cover, shelter, nesting sites and hunting opportunities for a variety of species (Falk 1976). They are generally subsidized in scarce resources such as water or nutrients from fertilizers (Falk 1976) or decomposing building materials. Precipitation and dew collects upon rooflines and metal surfaces before falling to the vegetation below. Therefore the vegetative communities in these areas are often lush and taller than the surrounding habitat. These areas are often unaltered or uncultivated for a number of years which enables biotic succession to occur (McKinney 2002). Ornamental plants often provide fruits or seeds that are utilized by birds, bats (Adams 1994) or small mammals. This in turn attracts predators (McKinney 2002). Representatives of the entire food web, or at least evidence of their presence, can commonly be seen in these anthropogenic habitats (McKinney 2002).

Suburban areas, or areas with active human presence in relatively close proximity to a metropolitan complex, have reduced species diversity when compared to less altered, more rural habitats (McKinney 2002). Areas of active development tend to support low biodiversity, likely in part because of damaging developmental practices (McKinney 2002). However, biotic succession increases both floral and faunal species richness, to an extent, after a disturbance in natural ecosystems (Gibson et al. 2000). This pattern can also be seen in managed habitats that remain undisturbed long enough for this succession to occur (McKinney 2002). Succession increases species diversity, such as increased plant diversity in urban lots (Crowe 1979) and bird species richness in residential communities (Vale and Vale 1976). The result is that, over time, anthropogenic areas tend to exhibit higher species richness (Munyenyembe et al. 1989). This is speculated to be the case in my study area as many of the anthropogenically-impacted areas bobcats frequented were abandoned buildings and homes. They were overgrown with vegetation and animal sign, including bobcat, was readily apparent. Trap arrays placed in close proximity to these areas were among my most productive.

Bobcats exhibited very high preference for playas or wetlands in third-order presence vs. absence selection. As mentioned, playas or wetlands; which included retention ponds and large stock tanks, provide surface water. This water can be seasonally available or permanent depending upon the source. They are also associated with lush vegetation such as kochia (*Kochia scoparia*) as well as various grasses and forbs; all of which attract primary and secondary consumers. These vegetative communities could also provide bobcats with shade during the heat of the day and a reprieve from predation or harvest.

Bobcats avoided grasslands, croplands, roads and railroads, and prairie dog towns at this spatial scale. None of these habitat types are speculated to provide adequate or prolonged cover for a bobcat. In agricultural landscapes, both food and cover resources undergo annual fluctuations with the planting and harvesting of crops (Kuykendall and Keller 2011). As previously mentioned, roads present quite a few challenges to animal movements and facilitate habitat loss in a number of ways. Lastly, although prairie dog towns may meet some resource requirements for bobcats they could pose challenges as well. The vegetative community in prairie dog towns is comprised of grasses and forbs which are kept very short by the rodents (Birch 1977, Agnew et al. 1986). The rodents are known to alter vegetative structure by decreasing canopy cover and the height of plants (Archer et al. 1984). Bobcats in this area are suggested to depredate primarily upon rabbits (*Sylvilagus* spp.) and hares (*Lepus* spp.; Parker and Smith 1983), and hispid cotton rats (*Sigmodon hispidus*; Beasom and Moore 1977, Miller and Speake 1979). Anderson and Lovallo (2003) suggested that woodrats (*Neotoma* sp.) are also a very important prey item. It is important to note that the majority of the prey species mentioned above are not restricted to prairie dog towns (McCaffrey et al. 2009, Pruett et al. 2009, Pruett et al. 2010) and all are commonly encountered in other habitat types (Parker and Smith 1983, Anderson and Lovallo 2003).

Proximity Analysis

Second-order Selection.--Bobcats preferred areas within, adjacent to or near anthropogenically-impacted areas as well as playas or wetlands. For both of these habitat types, they avoided areas that were ≥1 km away. They preferred areas adjacent to or near grassland and cropland though they avoided areas within these habitat types or areas too far away (≥1400 m). Grassland was the most prevalent habitat type within the study area at 49.1%. Bobcats rely upon native prey species which are prevalent in grasslands (McCaffrey et al. 2009, Pruett et al. 2009, Pruett et al. 2010). Cropland was the second most common habitat type available in my study area at 42.7% and attracts a variety of prey species as well (Kuykendall and Keller 2011). Bobcats would likely find it challenging to avoid either of these habitats completely. They could be compromising by remaining within close proximity to these resources, which they are in some measure dependent upon, while avoiding the threats or disadvantages of being directly within them. Lastly, bobcats preferred habitats that were furthest away from roads and railroads and avoided areas that were within 1 km of them. The biological explanation for this outcome resembles those already mentioned.

Interestingly, selection for proximity to prairie dog towns at this spatial scale (second-order) was not statistically significant. There may be several explanations for this. As mentioned previously, prairie dog towns likely do not provide prolonged cover for a bobcat. However, Sims et al. (1978) suggests that the grazing of these rodents on the vegetative structure may not have as marked effect as in other areas because the canopy cover and height of the shortgrass prairie is already reduced. If this is the case in my study area and vegetative height in prairie dog towns is comparable to the surrounding grassland, it is interesting to note that bobcats avoided grasslands at this spatial scale. It could be speculated that the reduced vegetation in these two habitat types is a deterrent to some degree. Additionally, prairie dogs and other squirrels are generally not considered to be a major prey item in bobcat diets (Beasom and Moore 1977, Anderson and Lovallo 2003) although their being consumed by bobcats has been documented in my study area (J. D. Ray, Consolidated Nuclear Security, LLC, personal communication). These prairie dog towns attract a variety of prey species known to be important for bobcats; however, these same species are commonly found in other habitat types within the study area as well (McCaffrey et al. 2009, Pruett et al. 2009, Pruett et al. 2010).

Bobcats preferred areas within close proximity to a mixture of habitat types at this spatial scale. This suggests they are utilizing resources from both artificial and natural habitat types and that a heterogeneous landscape may be useful for this species (Krausman 1999, Prange et al. 2004).

Third-order Selection.--Bobcats preferred to be within or near anthropogenically-impacted areas and playas or wetlands at this selection level. Preferences for buffer increments decreased in a linear progression until approximately 1 km away at which point avoidance was exhibited. This suggests a measure of dependence upon these habitat features, possibly for water, dietary resources, protection from predation or a combination thereof (Prange et al. 2004). Bolen (1991) suggested that structural components of urban environments should be considered when assessing habitat viability for wildlife. These structures are suggested to be analogous to vertical structure in more natural environments (Bolen 1991). In urbanized areas, artificial resources are abundant and generally concentrated into patches (Prange et al. 2004).

Bobcats preferred to be within or closely associated to grasslands at this selection level. This could be explained by avoidance of grasslands when compared to other available habitat types as seen in the presence vs. absence analysis, while simultaneously requiring grasslands to meet some needs. They avoided distant buffer increments that were 1 km or more from any grassland habitat which suggests they are dependent upon this habitat type to some degree. Grasslands also provide hunting opportunities and travel corridors to other habitat types.

Bobcats preferred to be adjacent to and closely associated with cropland and avoided areas that exceeded 900 m in distance. Cropland was a large percentage of the habitat available within bobcat MCPs used for third-order selection analyses and likely served as a travel conduit to other habitat types. Additionally, cropland may provide abundant, if seasonally-limited, cover for bobcats in this area. Similar to grassland, the pattern for selection in cropland suggests bobcats are selecting for habitat edges. Being edge-adapted gives them an advantage over species that are more reliant on core areas and they are able meet their resource requirements from a more heterogeneous landscape (Krausman 1999, Prange et al. 2004).

Bobcat third-order selection for proximity to prairie dog towns approaches statistical significance ($P = 0.059$). Prairie dogs have faced intense persecution across their geographic range (Miller and Ceballos 1994) from eradication programs, sylvatic plague, unregulated shooting, and habitat loss (Van Putten and Miller 1999) which have significantly reduced colony sizes (Cheatam 1977). In my study site, they have become closely associated with playa slopes which serve as refuges for small colonies (Pruett et al. 2009). Therefore, to attain the resources provided by prairie dog towns, it is possible that bobcats must be within these areas and not merely close by. The prairie dog colonies in the study site are very small (Pruett et al. 2009, Pruett et al. 2010) which translated to small polygons while mapping my habitat types in the study area. It could be that the lack of demonstrable selection was an artifact of having small percentages of habitat types available for selection analyses which can affect habitat rankings in compositional analysis (Aebischer et al. 1993).

Bobcats preferred intermediate distances from roads and railroads and avoided being within them as well as too far (≥ 5 km) away. I expected a different outcome given the datasets for some of the individuals. As seen in the relocation data, point clusters are concentrated within and along several minor roadways as well as the Panhandle Northern Railroad. Not all bobcats exhibited this concentrated use of roads and railroads. Two bobcats were the main ones to do so. It is possible these individuals found somewhat suitable habitat along these structures. In addition to roadside culverts which are often utilized by bobcats as daytime resting places (Cain et al. 2003), bobcats could be attracted to food resources along roadsides such as basking prey and small mammals (Forman and Alexander 1998). Bobcats in general are known to commonly utilize human traffic corridors such as roadways (Tuovila 1999, Cain et al. 2003, Ruell et al. 2009). Non-invasive studies often employ road survey methods for scat samples (Anderson and Lovallo 2003, Ruell et al. 2009). This tendency to use roads as travel corridors could be considered a detriment to bobcats at both individual and population levels. Roads can pose quite a few challenges to wildlife such as traffic noise and nighttime lighting (Forman and Alexander 1998). These effects are not restricted to the road itself but extend beyond it and form road-effect zones which can then range up to several hundred meters away (Forman and Alexander 1998). These zones exhibit lower breeding densities and lower species richness when compared to control sites (Forman and Alexander 1998). The cumulative effects of highways combined with the total area of their avoidance zones supports the postulation that the ecological impact of road-avoidance is likely far greater than the impact of road mortalities or habitat loss in roadside corridors (Forman and Alexander 1998). Highways are a critical habitat issue and demand attention at all levels from land managers, wildlife management agencies and highway departments (Ruediger 1996).

The greatest challenges to this study were technology-based. The GPS collars I used did not account for quite a few factors known to affect GPS technology such as the multipath effect, ionispheric errors, positional dilution of precision (PDOP) or clock errors (Akim and Tuchin 2003). Positional dilution of precision errors alone can be extremely high in this area (R. T. Kazmaier, West Texas A&M University, personal communication). This led to some uncertainty as to the accuracy of the relocations, thus I decided to set my MMU at a higher number and focus on a broader selection scale. Also, the manufacturer estimated average collar duration at 1.5-2 years for our area, though in my study the maximum collar duration was 10 months and most only reached 6-8 months before they had to be dropped because of low battery signals.

Preferred habitats, across both spatial levels, were anthropogenically-impacted areas, playas or wetlands and, to some extent, prairie dog towns. Each of these habitat types had several features in common; prey availability and abundance, presence of other bobcats (i.e. mating opportunities), and associated cover (somewhat questionable in the case of prairie dog towns and generally only if they were associated with another habitat type). These are all known factors that influence habitat quality and subsequent habitat selection (Anderson 1987, Rucker et al. 1989, Conner et al. 1999, Lynch et al. 2008). As previously stated, cropland, grassland and roads and railroads are all consistently lacking in these attributes which may account for their avoidance or moderate preference in the instances of edge-selection.

Collectively, all available habitat types were not only used but selected by bobcats in my study area. This suggests that space use is not random in this species and that when presented with choices; bobcats prefer some habitat types over others. By preferring several types of habitat, both natural and artificial, bobcats exhibit a degree of behavioral flexibility that may be instrumental in their success and widespread distribution across their geographic range (Anderson 1987, Anderson and Lovallo 2003, Prange et al. 2004).

Therefore, I failed to reject my hypothesis as bobcats exhibited very high preference for anthropogenically-impacted areas in the second-order analyses and extremely high preference in the third-order selection analyses. I suggest more research is needed on other Texas Panhandle bobcat populations to determine whether these results can be extrapolated beyond my study area. A different experimental design and different technology would be necessary to assess bobcat selection for more fine-scaled habitat types. This is because of the inherent error rates involved in GPS technology as well as the multiplicative errors that can interfere with accurate GPS positioning (Akim and Tuchin 2003). For example, the roads and railroads habitat type comprised a very small percentage of my study area. This was not because of their absence but rather because most did not meet my MMU requirement and so could not be included in the habitat maps.

The growth of urban land use is accelerating faster than the rate of land preserved as parks or conservation areas (McKinney 2002). Much of this growth can be attributed to the spread of suburban housing (McKinney 2002). Bobcats are known to modify certain behaviors and activity patterns in response to habitat fragmentation and urbanization (Tigas et al. 2002, Riley et al. 2003, Riley 2006).

Likewise, the abundance and distribution of food resources is known to affect the movement and spatial distribution of solitary carnivores (Prange et al. 2004). Food availability and distribution is often altered in urban-associated habitats because of the occurrence of anthropogenically-impacted resources (Prange et al. 2004). Despite their suggested resilience to urban association, human-caused mortalities, both direct and indirect, cause the majority of mortalities in bobcat study populations (Anderson and Lovallo 2003, Cain et al. 2003, Riley et al. 2003). Additionally, direct and indirect mortalities have been suggested to be independent of urban association (Riley 2006). This indicates that even individuals with minimal urbanized areas within their home ranges are vulnerable to human-caused mortalities (Riley et al. 2003).

Bobcats in habitats similar to my study area may select for similar habitat types because of exposure to comparable habitat features. Further research should be done in comparable habitats to investigate whether this strategy facilitates long-term survival or is ultimately detrimental to the individual or at the population level. Likewise, further research should be done to assess whether urban association in this area is beneficial or detrimental to bobcat populations. Urban and semi-rural carnivore studies are increasing in frequency and feasibility (Riley et al. 2003, Prange et al. 2004, Riley 2006). Bobcats are considered to be adaptive generalists and may be becoming more adept at using humans to survive in a changing and challenging landscape (Prange et al. 2004). It is unclear, however, whether this relationship can continue if urban sprawl and the rate of habitat fragmentation continue unchecked.

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Figure II.1. The spatial relationship among my radiotelemetry study area (stippled polygon), the property boundaries of Pantex (black polygons), and the neighboring urban areas of Amarillo and Panhandle (gray polygons) within Carson and Potter counties, Texas.

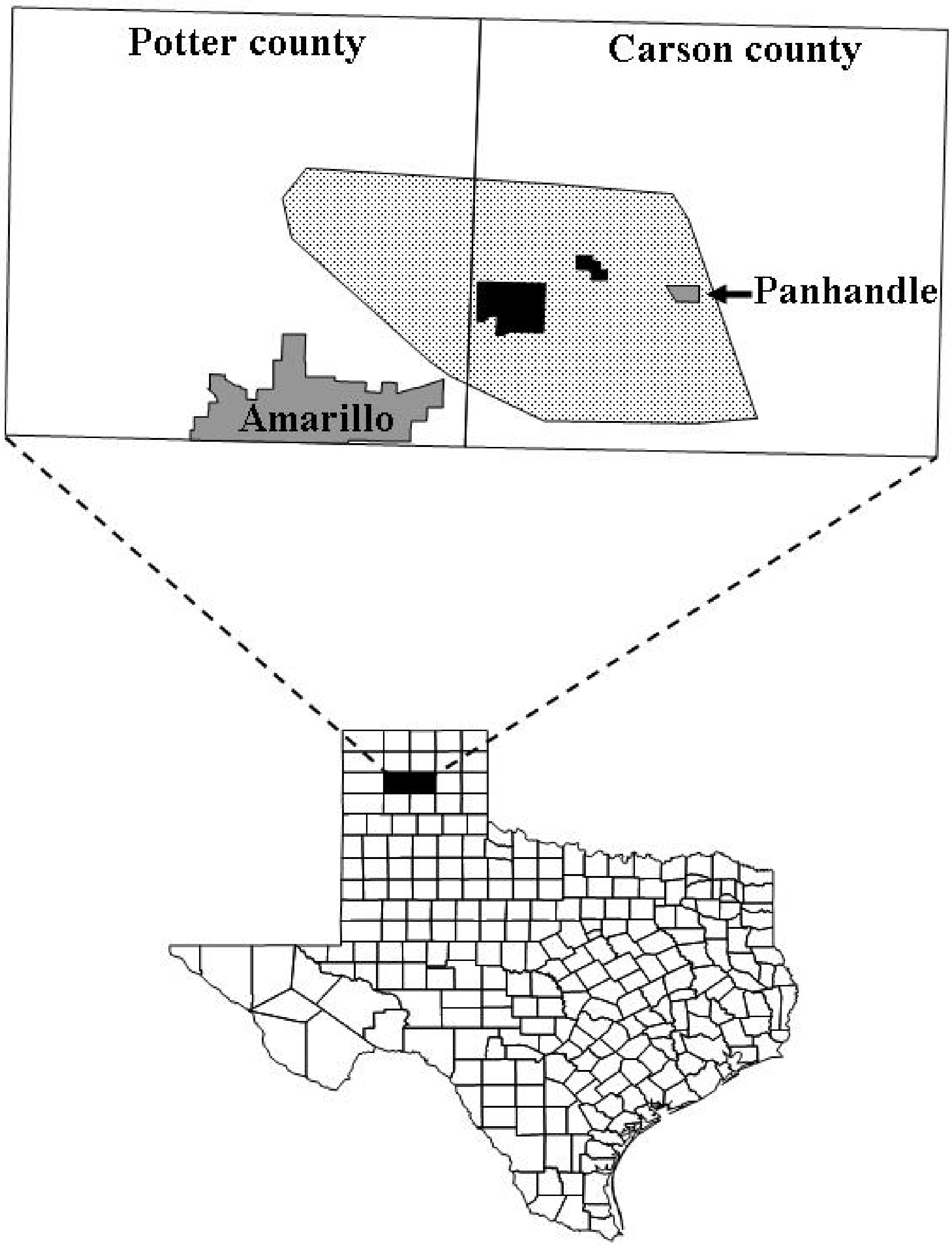
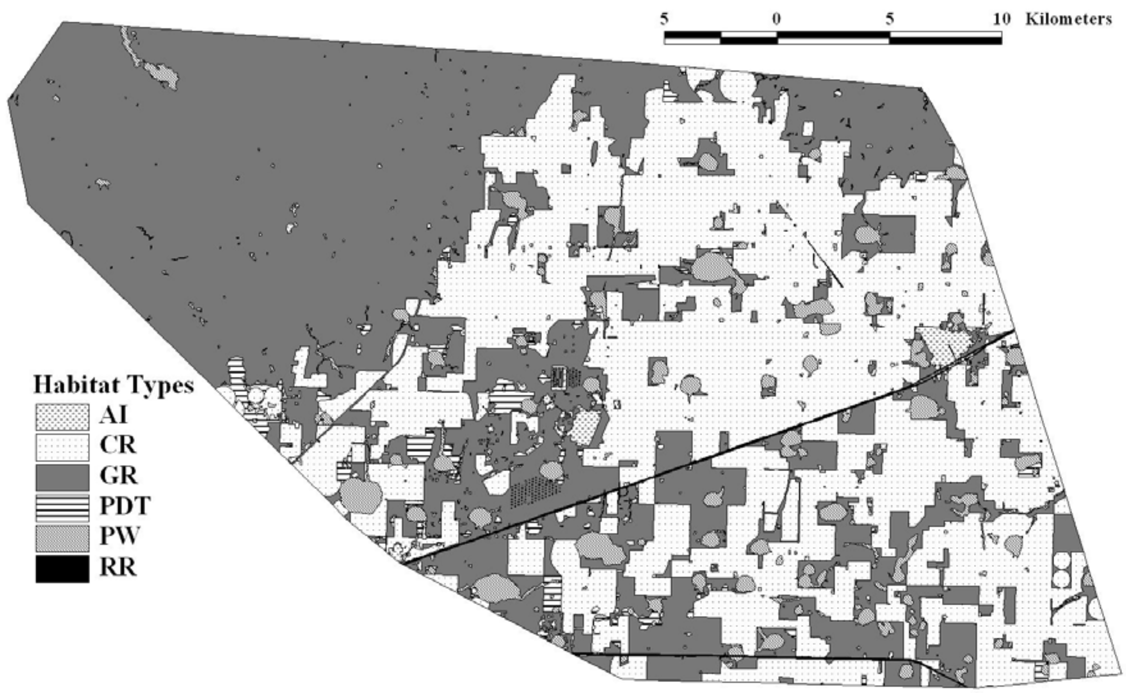


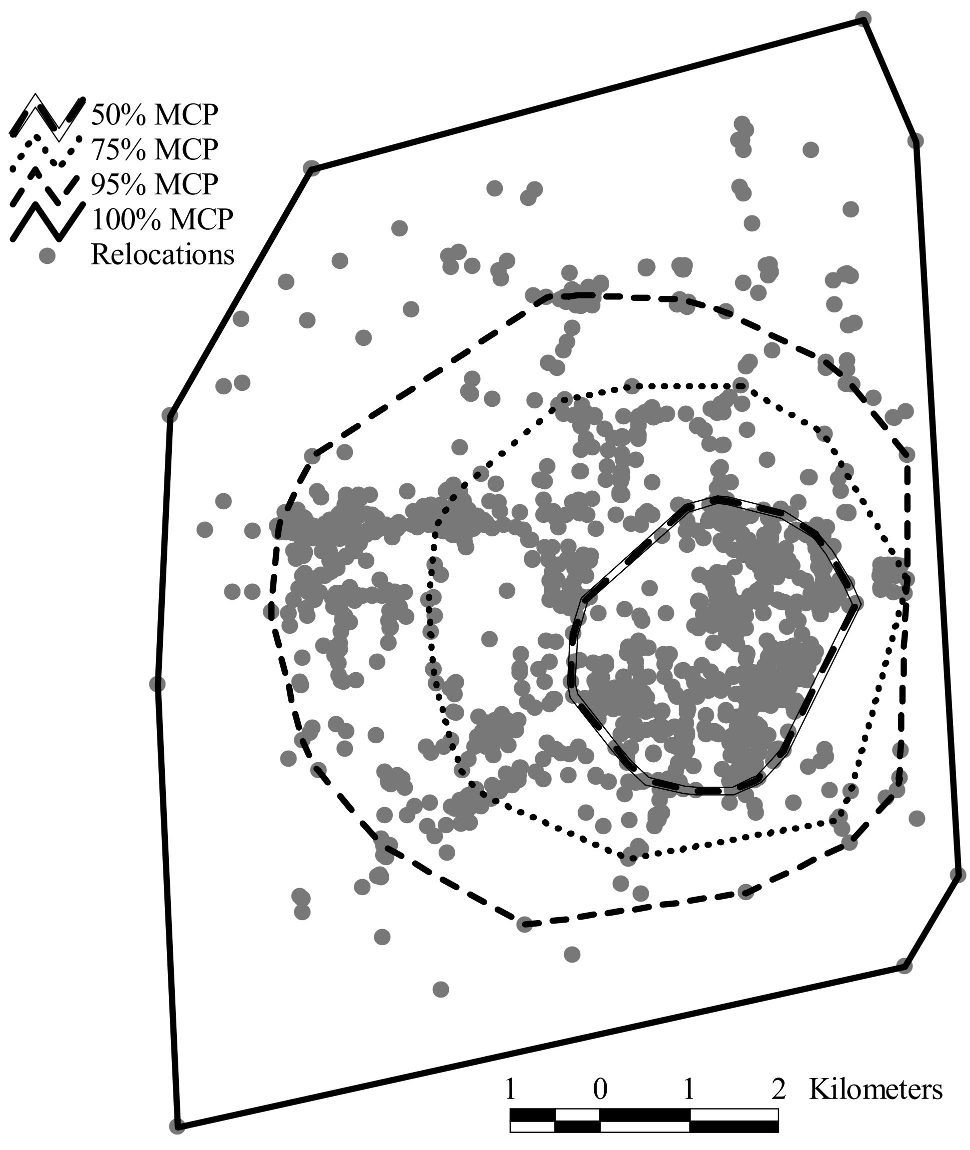
Figure II.2. Study area polygon with defined habitat types (AI= anthropogenically-impacted, CR= cropland, GR= grassland, PDT= prairie dog town, PW= playa or wetland, and RR= road or railroad) within Carson and Potter counties, Texas.



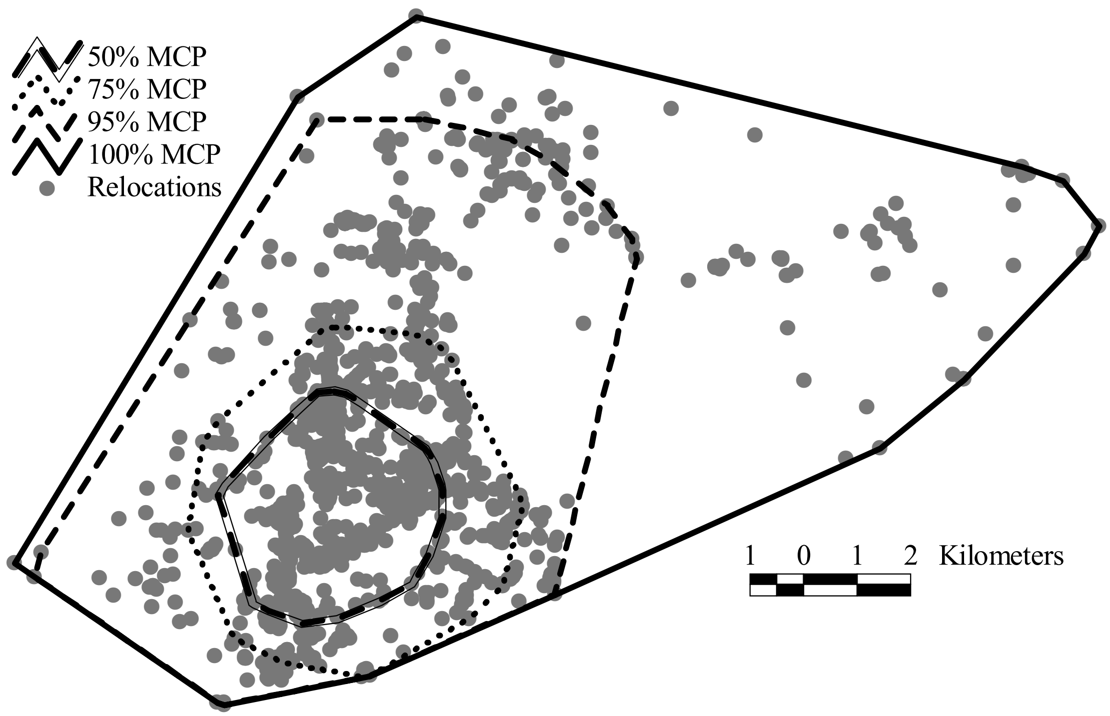
APPENDIX I

CUMULATIVE MCP HOME RANGES
OF BOBCATS MONITORED WITHIN
MARCH 2009-OCTOBER 2013
IN CARSON AND POTTER COUNTIES, TEXAS.

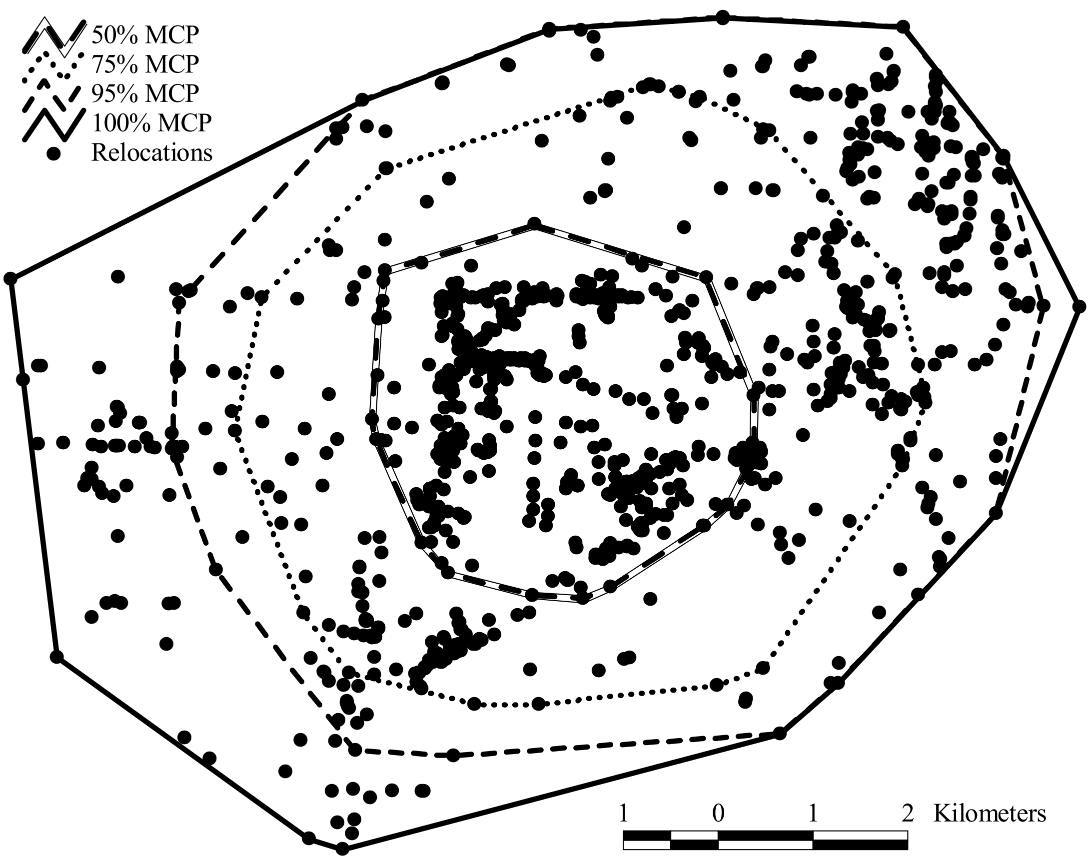
Appendix Figure I.1. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 1 and corresponding relocations (2,089 points) from 3 collars. Monitored 16 March 2009 through 8 October 2009; 7 April 2010 through 3 November 2011; and 17 October 2011 through 11 April 2012 in Carson and Potter counties, Texas.



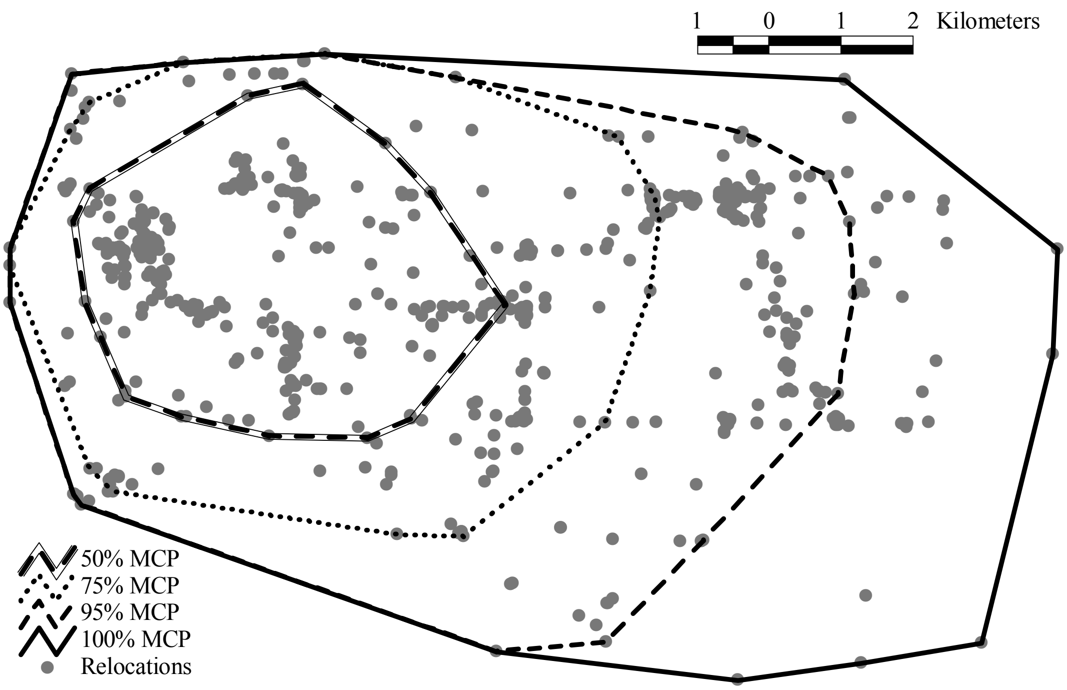
Appendix Figure I.2. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 2 and corresponding relocations (1,724 points). Monitored 19 March 2009 through 19 September 2009 in Carson and Potter counties, Texas.



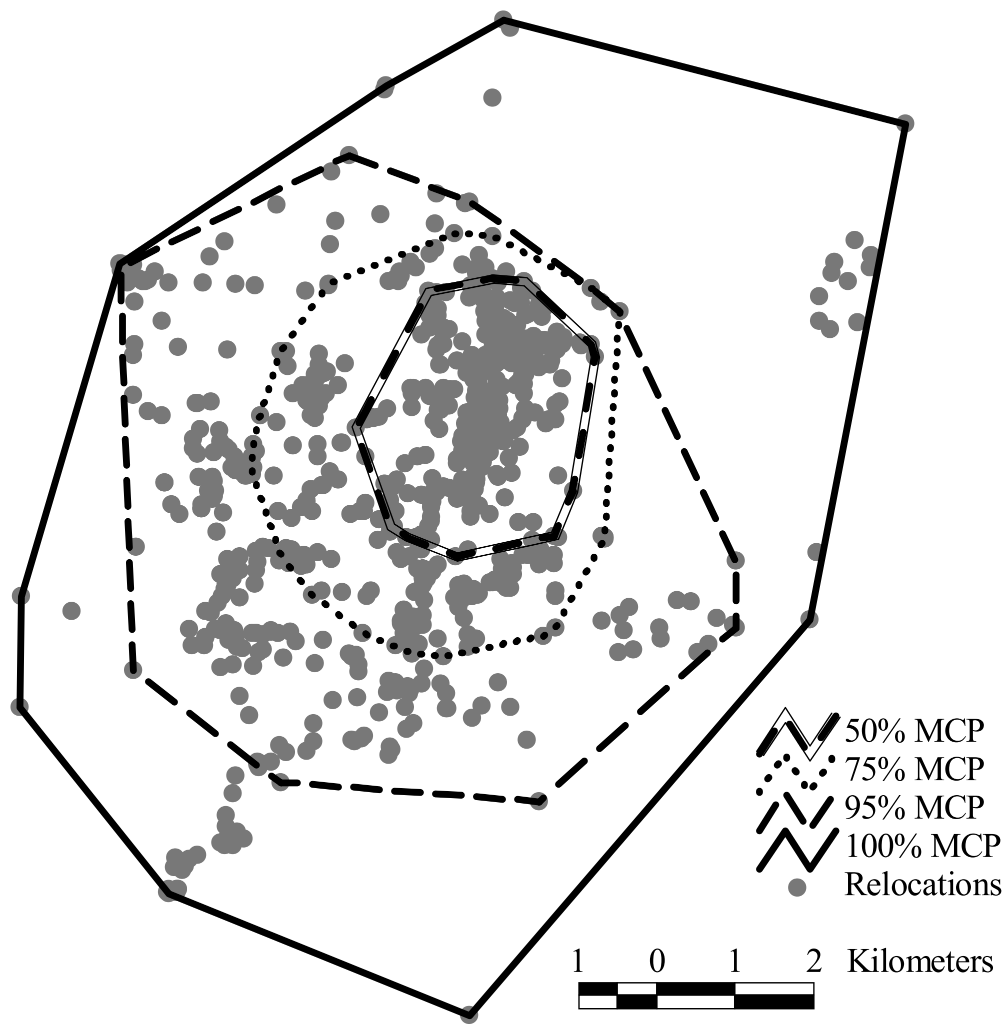
Appendix Figure I.3. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 4 and corresponding relocations (1,243 points) from 2 collars. Monitored 14 March 2010 through 30 August 2010 and 25 March 2011 through 4 April 2011 in Carson and Potter counties, Texas.



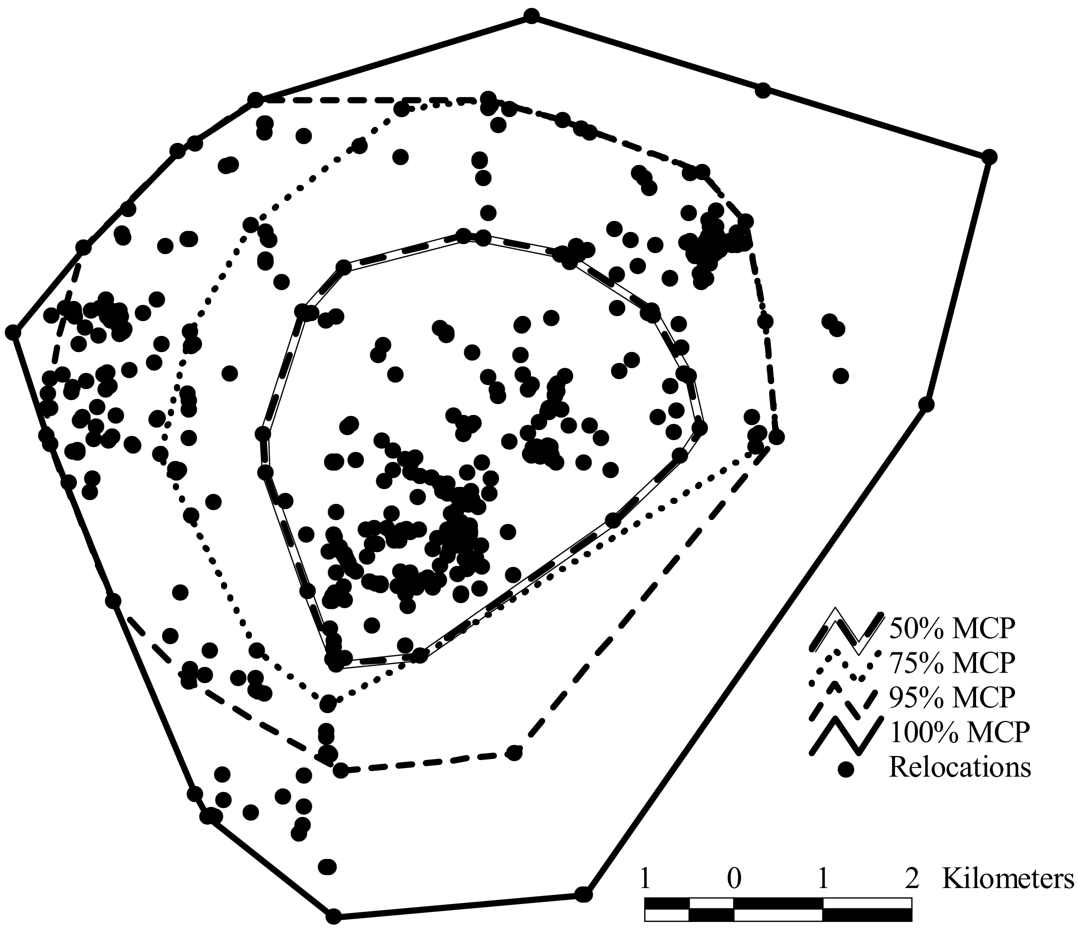
Appendix Figure I.4. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 5 and corresponding relocations (880 points). Monitored 29 June 2010 through 25 November 2010 in Carson and Potter counties, Texas.



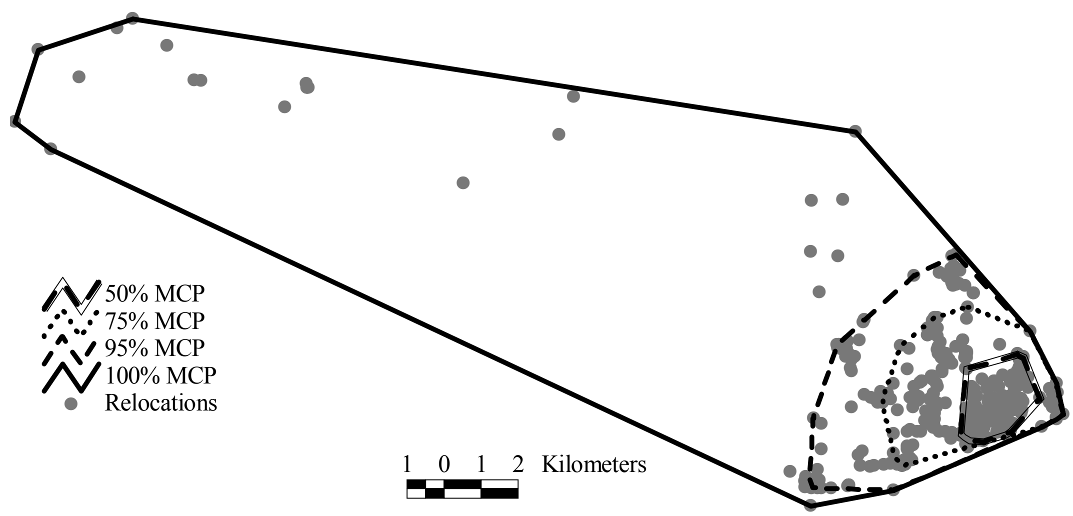
Appendix Figure I.5. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 6 and corresponding relocations (1,067 points). Monitored 27 March 2011 through 23 April 2012 in Carson and Potter counties, Texas.



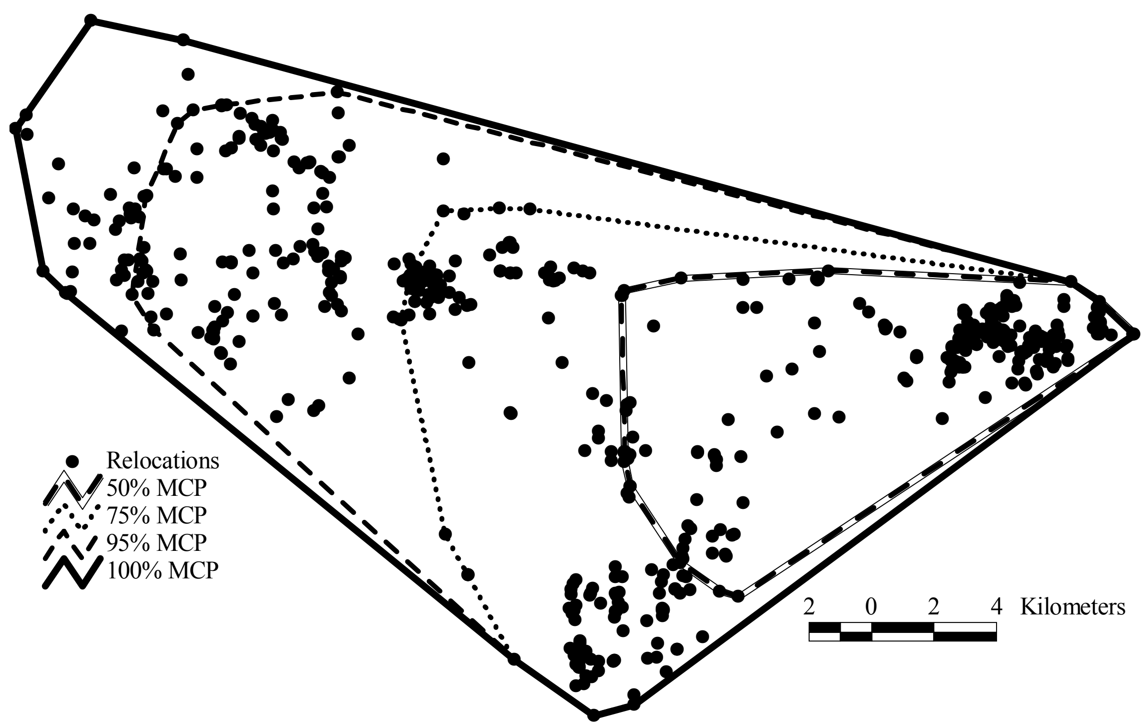
Appendix Figure I.6. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 7 and corresponding relocations (538 points). Monitored 30 March 2011 through 15 September 2011 in Carson and Potter counties, Texas.



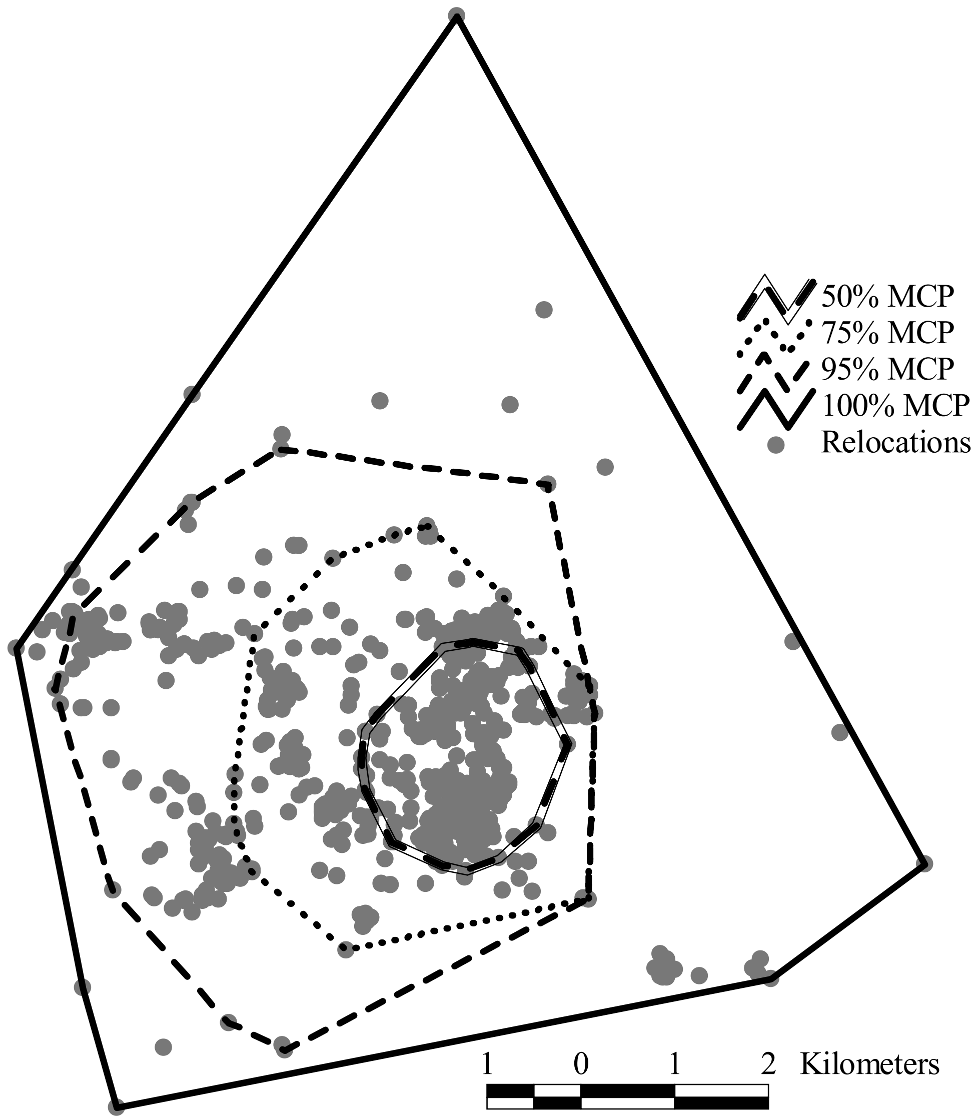
Appendix Figure I.7. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 8 and corresponding relocations (718 points). Monitored 13 October 2011 through 19 April 2012 in Carson and Potter counties, Texas.



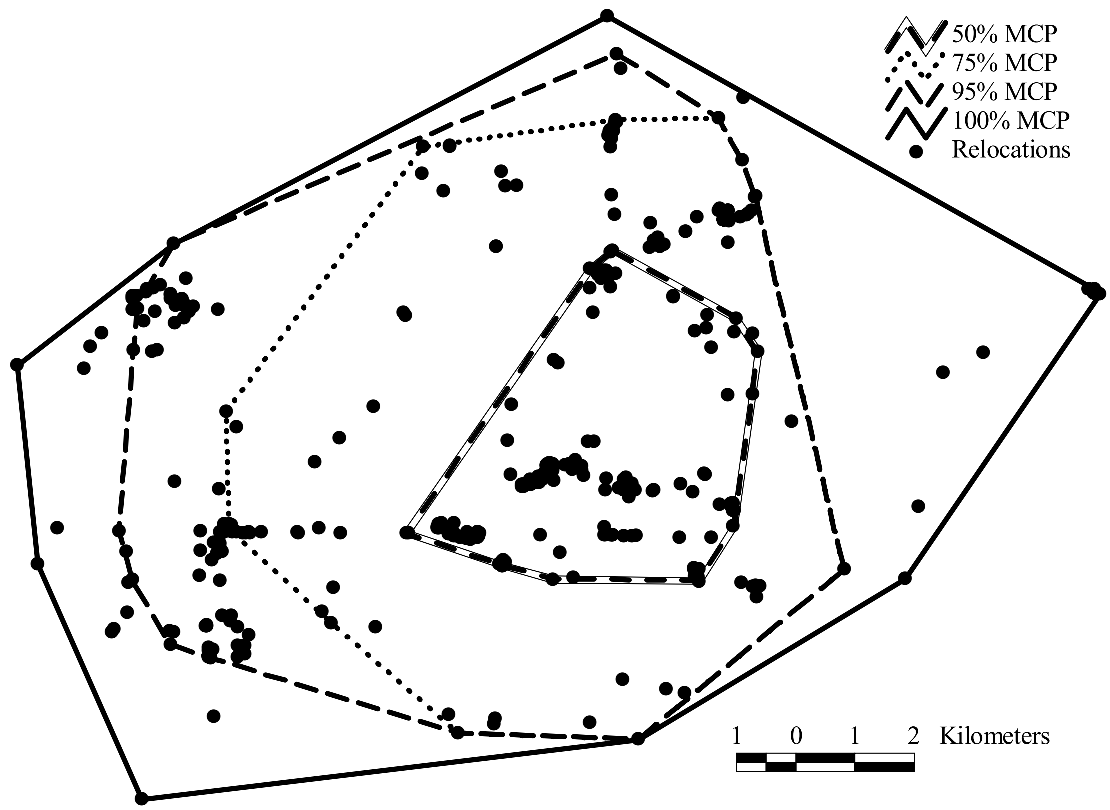
Appendix Figure I.8. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 11 and corresponding relocations (718 points). Monitored 26 April 2012 through 16 November 2012 in Carson and Potter counties, Texas.



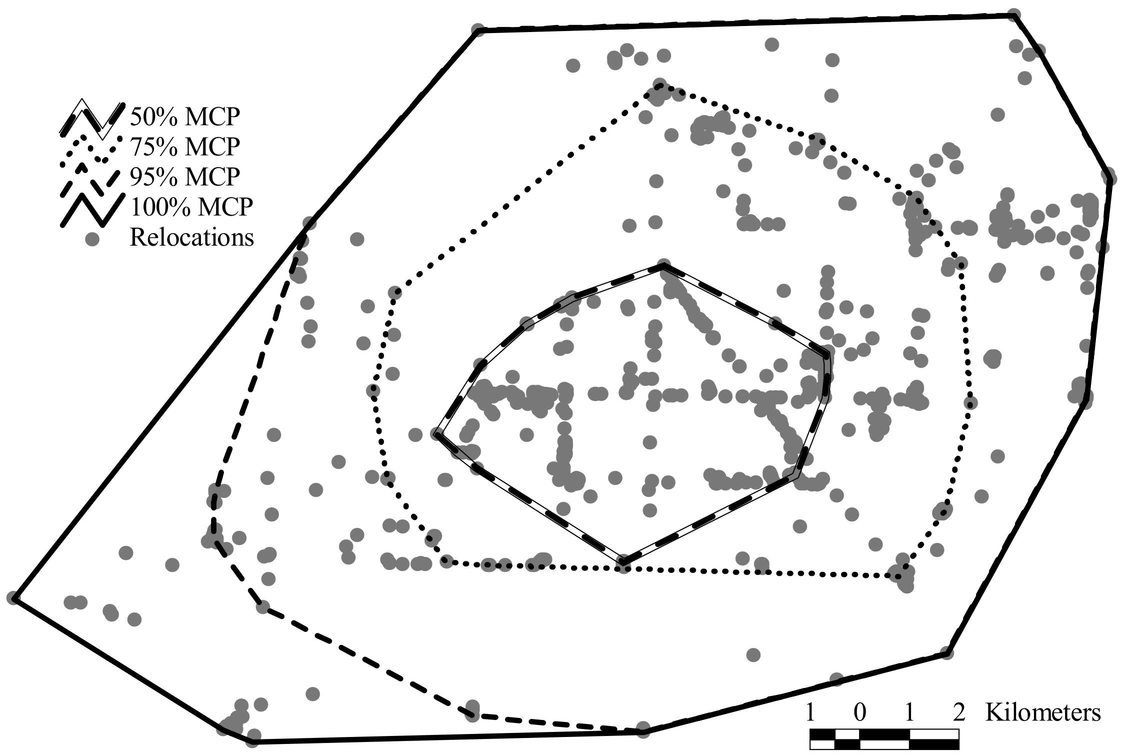
Appendix Figure I.9. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 12 and corresponding relocations (986 points). Monitored 12 August 2012 through 8 June 2013 in Carson and Potter counties, Texas.



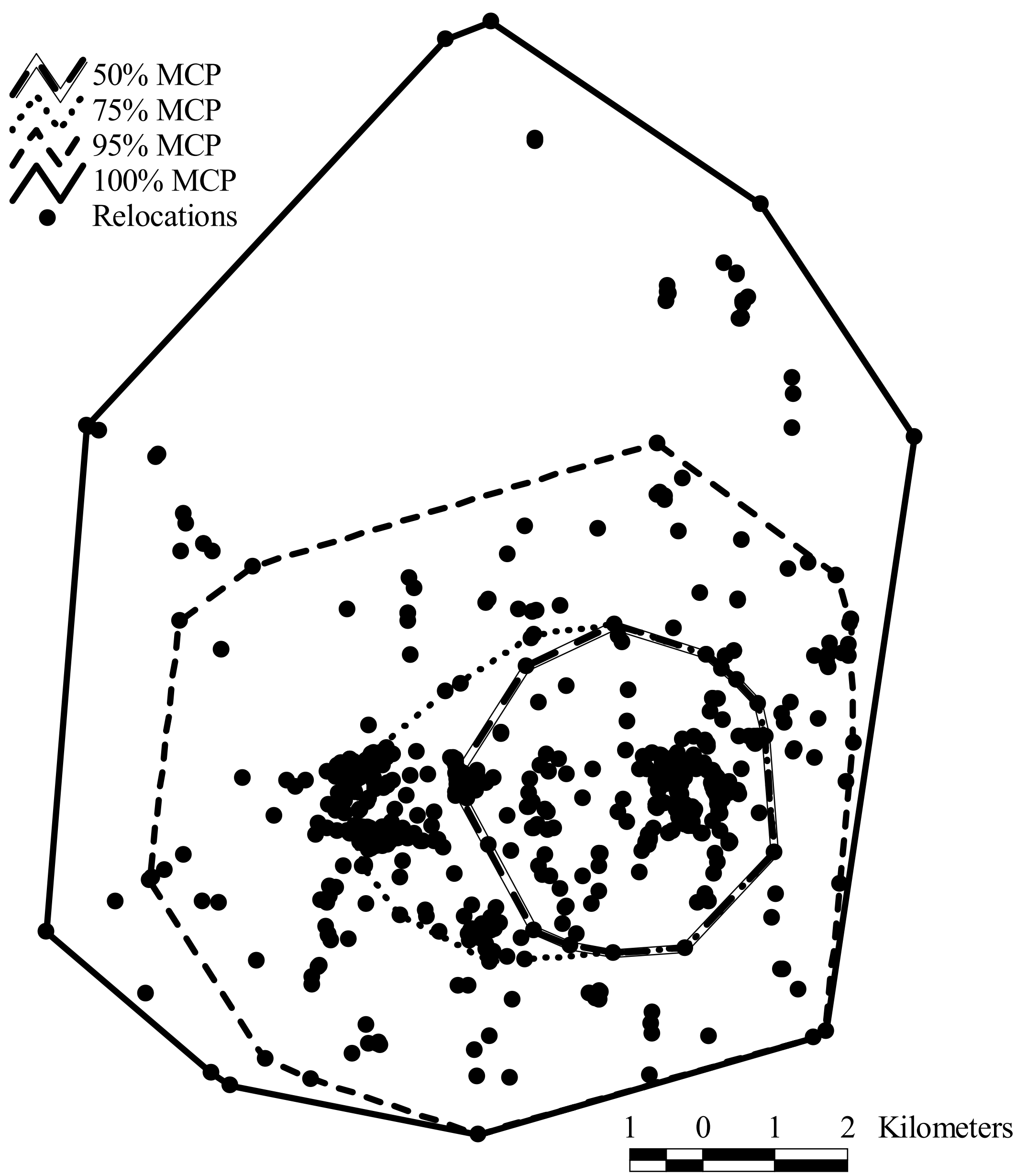
Appendix Figure I.10. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 14 and corresponding relocations (616 points). Monitored 4 September 2012 through 14 February 2013 in Carson and Potter counties, Texas.



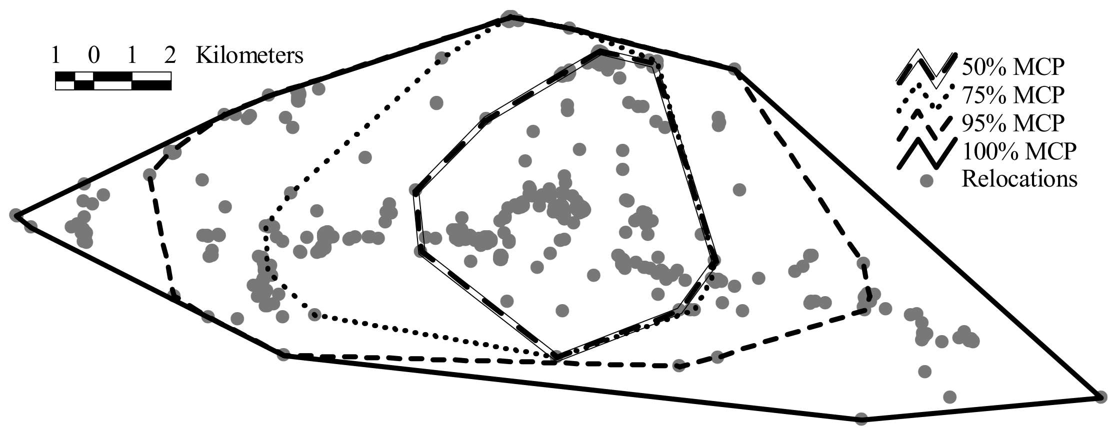
Appendix Figure I.11. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 16 and corresponding relocations (1,045 points). Monitored 26 October 2012 through 20 August 2013 in Carson and Potter counties, Texas.

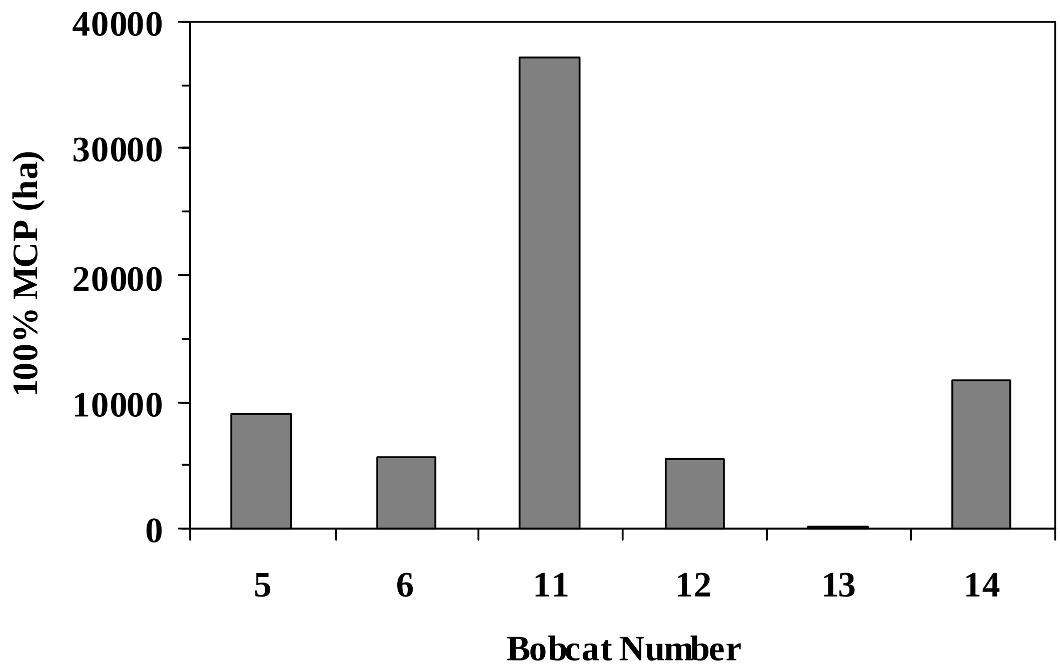


Appendix Figure I.12. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 17 and corresponding relocations (912 points). Monitored 20 December 2012 through 20 September 2013 in Carson and Potter counties, Texas.

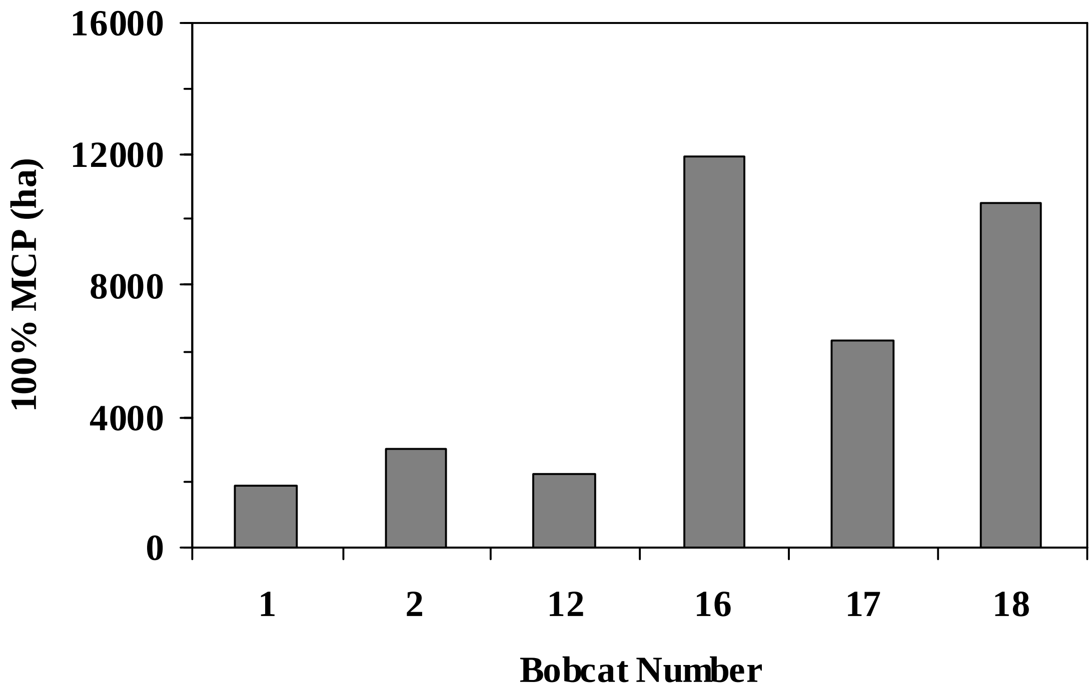


Appendix Figure I.13. Cumulative MCP home ranges (100, 95, 75, and 50%) of bobcat 18 and corresponding relocations (972 points). Monitored 1 February 2013 through 20 October 2013 in Carson and Potter counties, Texas.

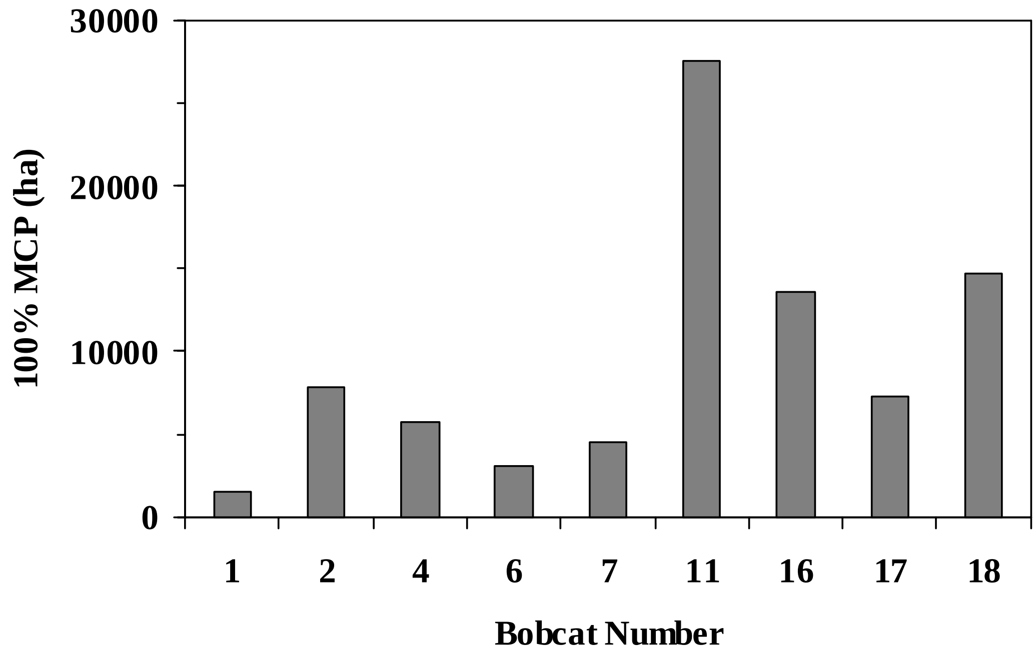




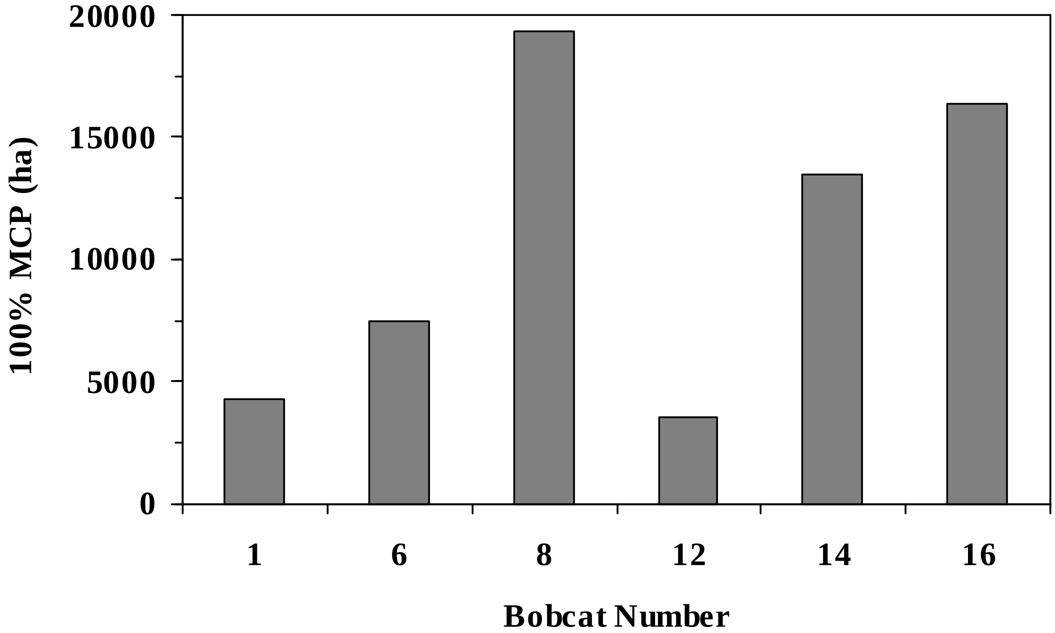
Appendix Figure I.14. Fall (September-November) seasonal home ranges (100% MCP) in hectares of bobcats monitored within March 2009- October 2013 in Carson and Potter counties, Texas.



Appendix Figure I.15. Spring (March-May) seasonal home ranges (100% MCP) in hectares of bobcats monitored within March 2009-October 2013 in Carson and Potter counties, Texas.



Appendix Figure I.16. Summer (June-August) seasonal home ranges (100% MCP) in hectares of bobcats monitored within March 2009-October 2013 in Carson and Potter counties, Texas.

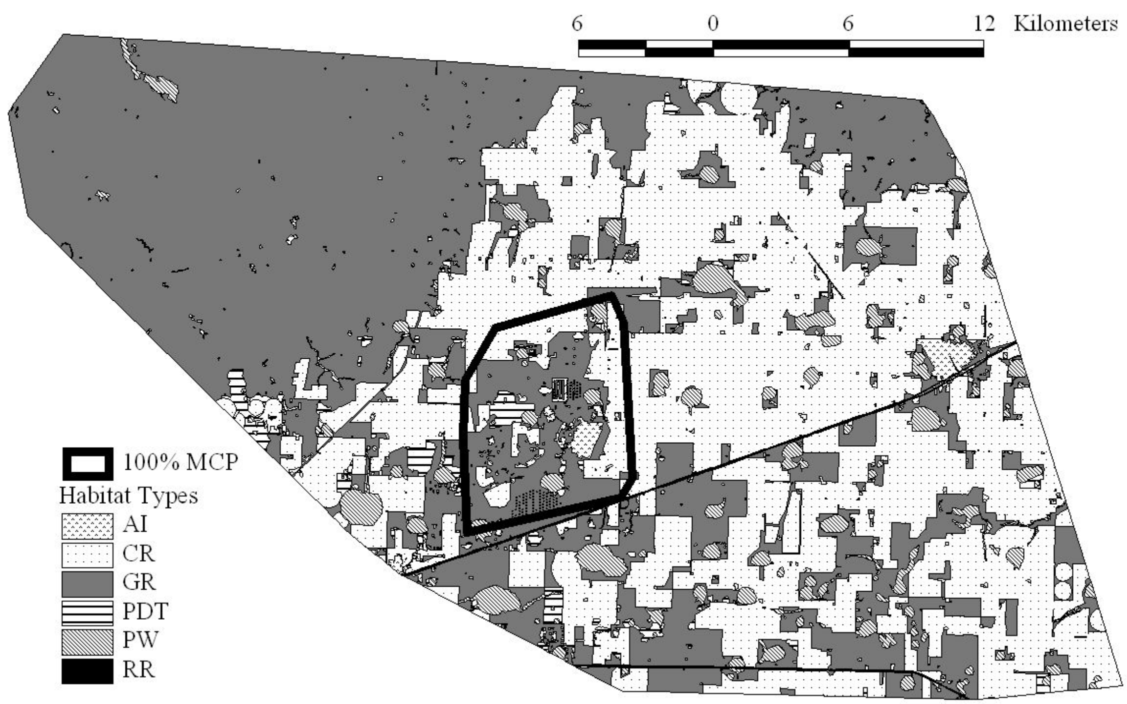


Appendix Figure I.17. Winter (December-February) seasonal home ranges (100% MCP) in hectares of bobcats monitored within March 2009-October 2013 in Carson and Potter counties, Texas.

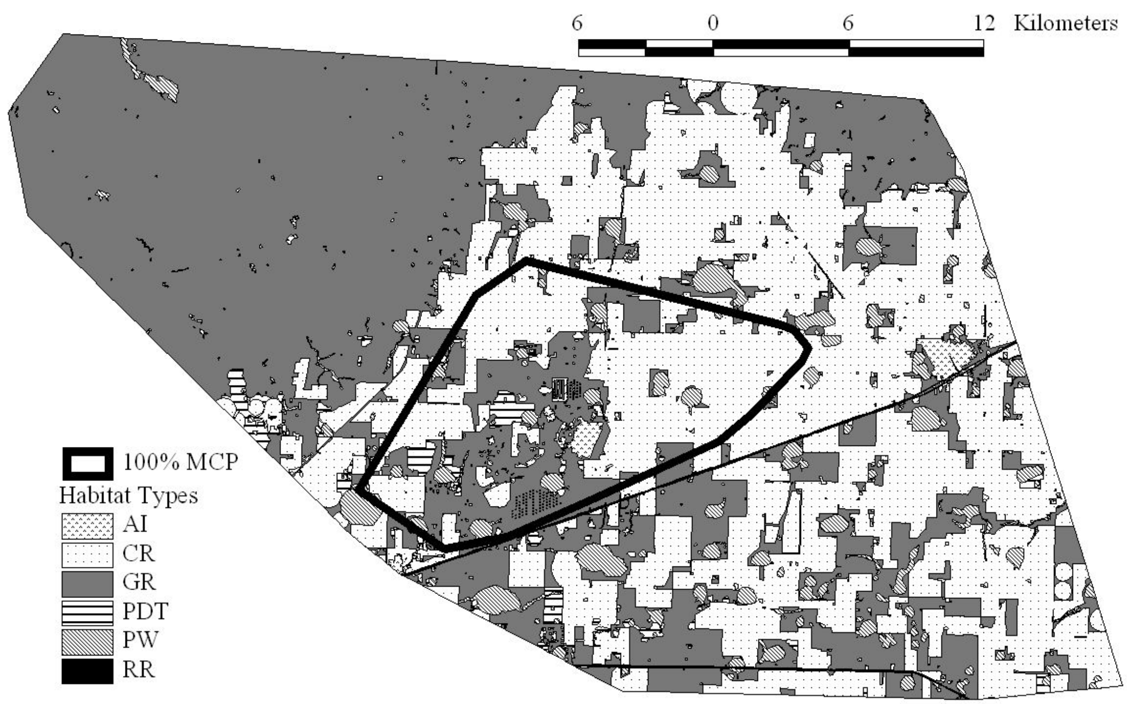
APPENDIX II

SECOND AND THIRD-ORDER
HABITAT SELECTION MAPS OF BOBCATS
MONITORED WITHIN MARCH 2009-OCTOBER 2013
IN CARSON AND POTTER COUNTIES, TEXAS.

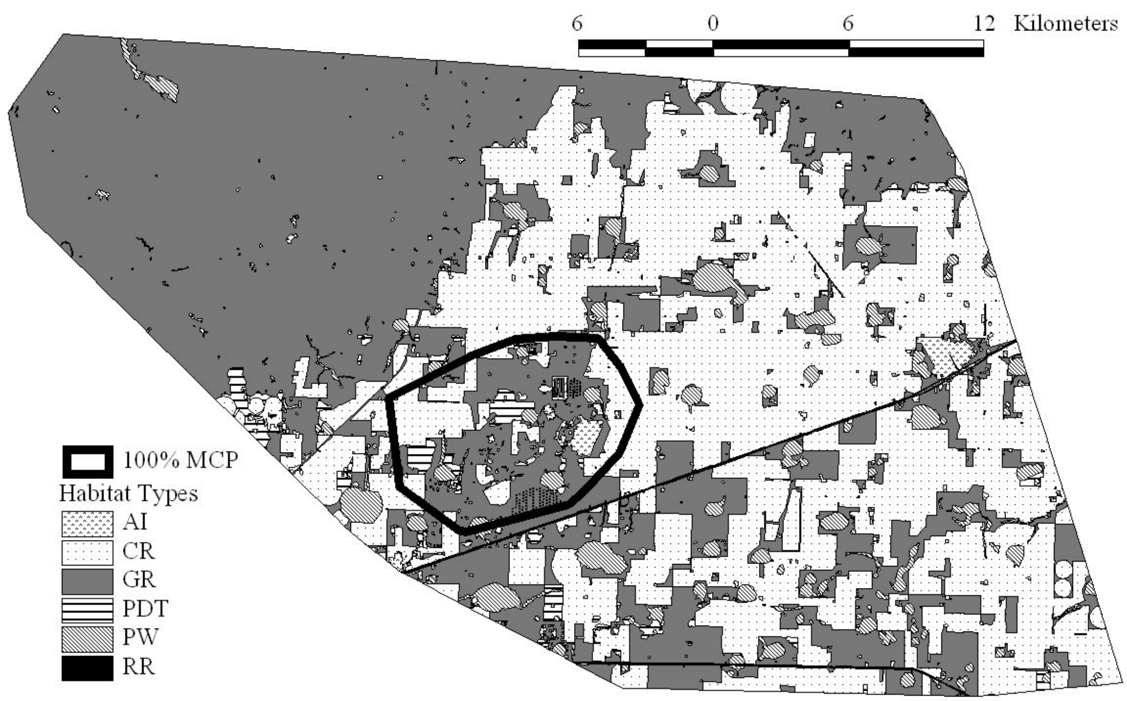
Appendix Figure II.1. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 1 for second-order habitat selection in Carson and Potter counties, Texas.



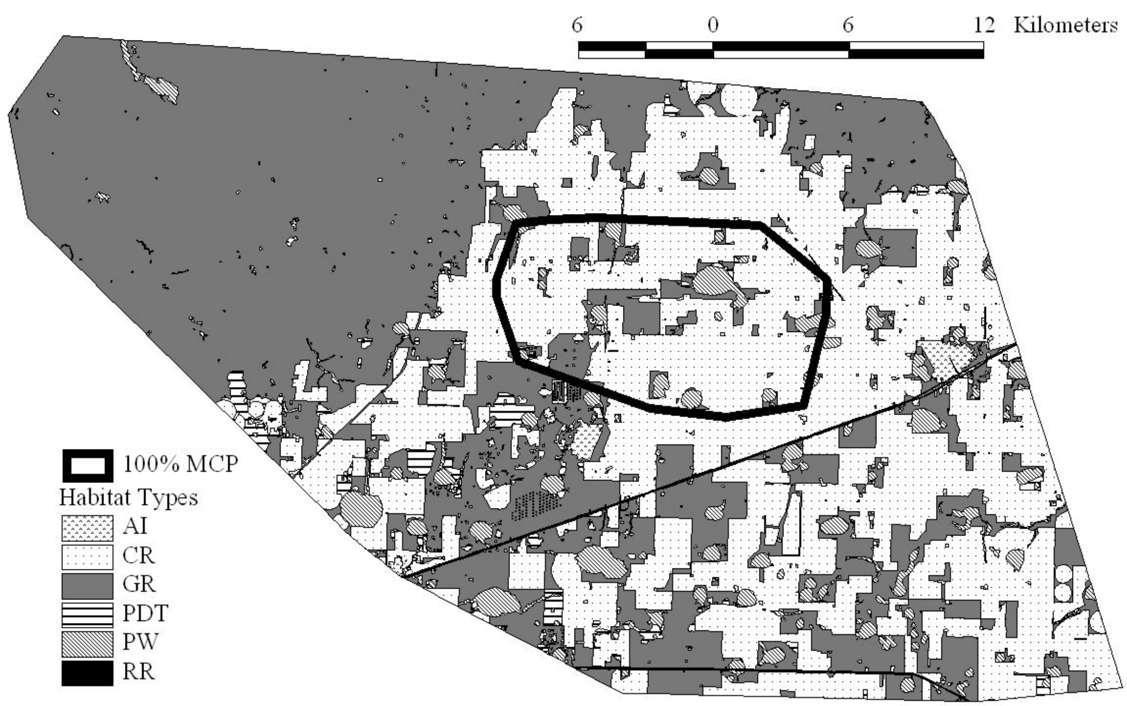
Appendix Figure II.2. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 2 for second-order habitat selection in Carson and Potter counties, Texas.



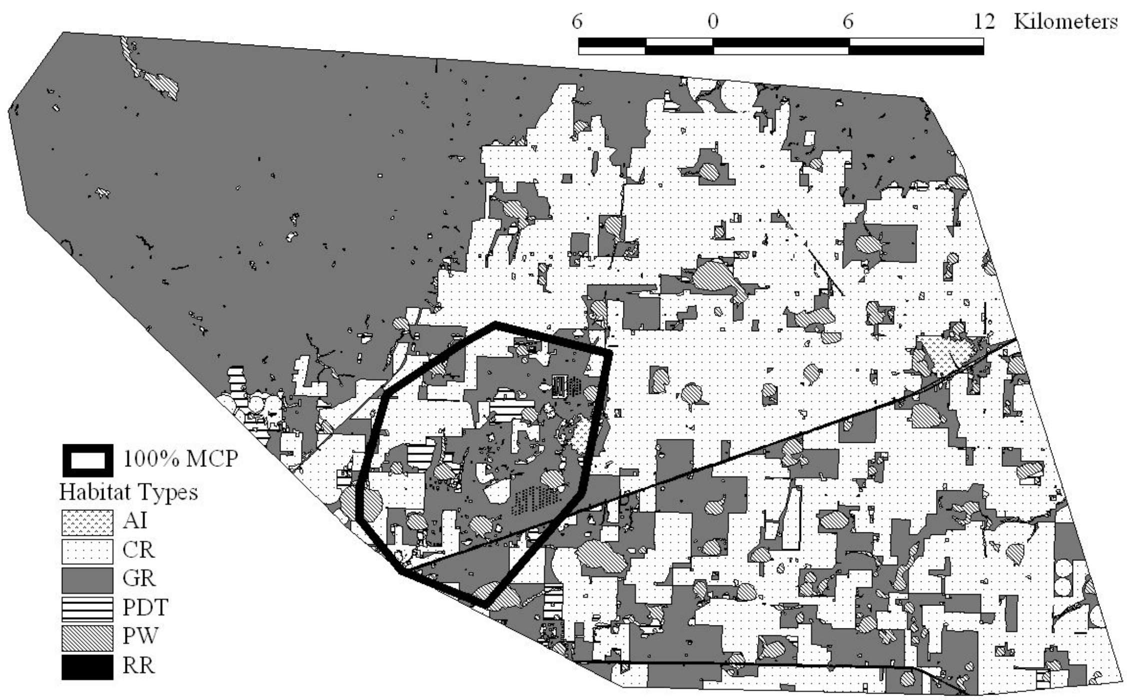
Appendix Figure II.3. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 4 for second-order habitat selection in Carson and Potter counties, Texas.



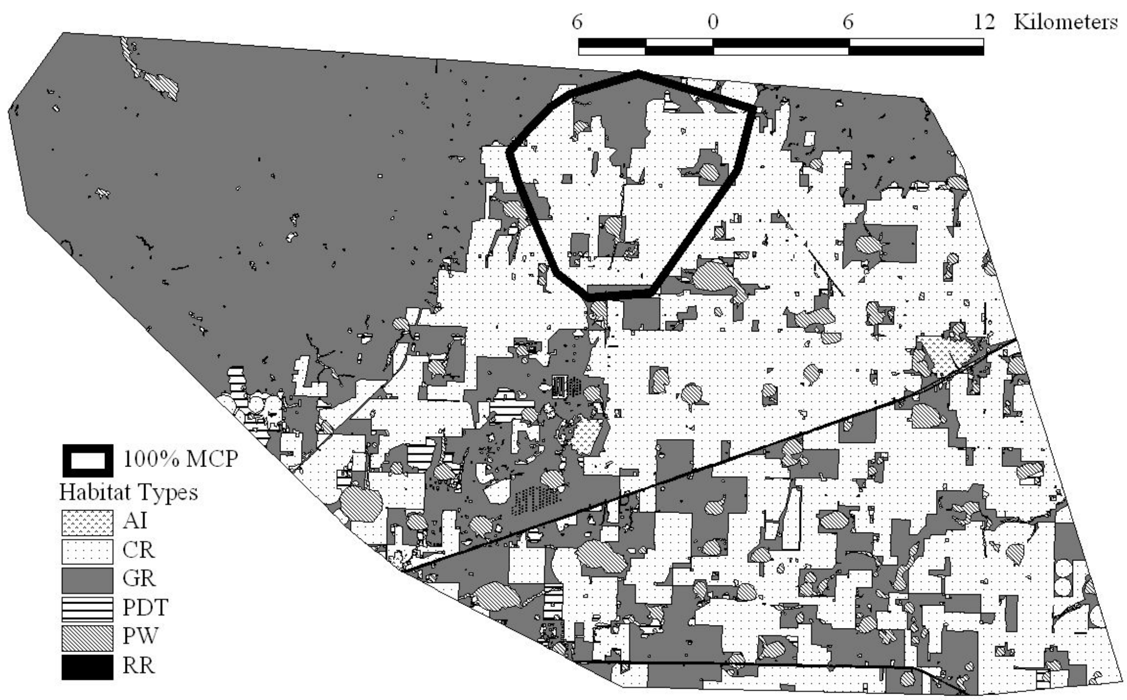
Appendix Figure II.4. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 5 for second-order habitat selection in Carson and Potter counties, Texas.



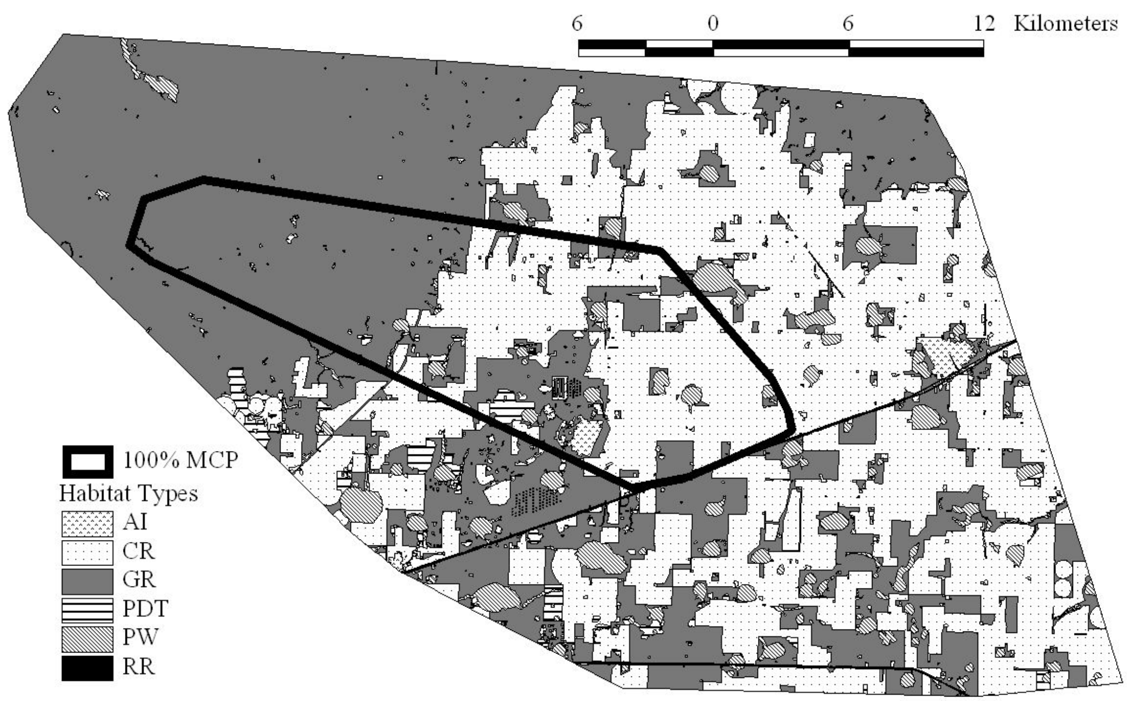
Appendix Figure II.5. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 6 for second-order habitat selection in Carson and Potter counties, Texas.



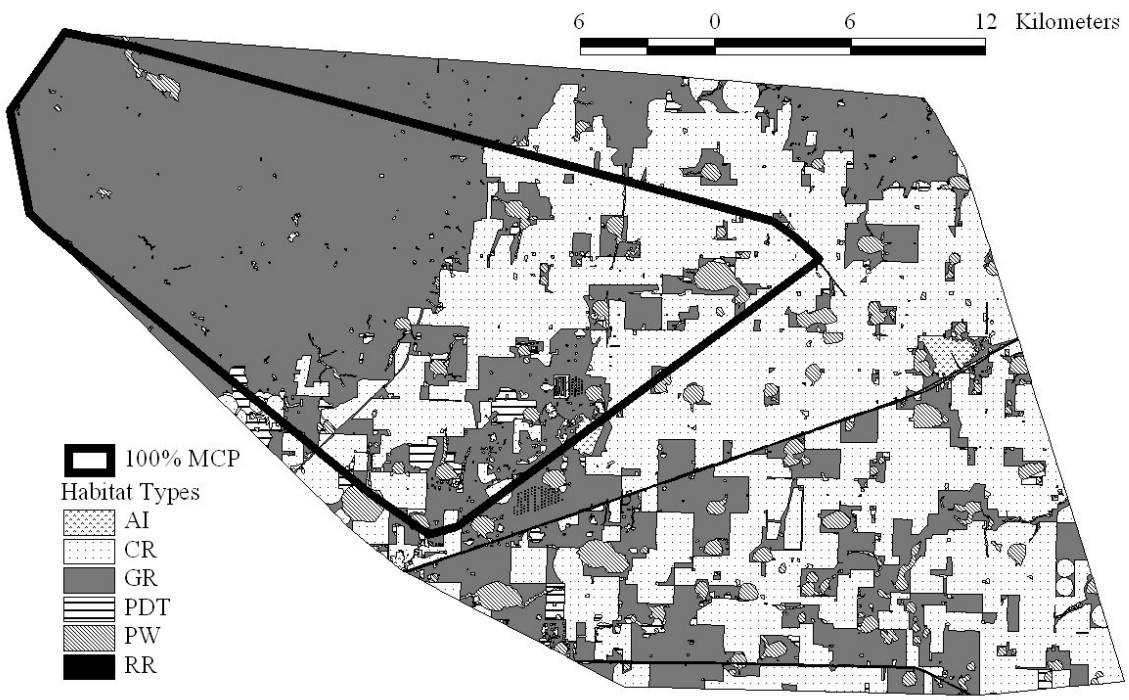
Appendix Figure II.6. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 7 for second-order habitat selection in Carson and Potter counties, Texas.



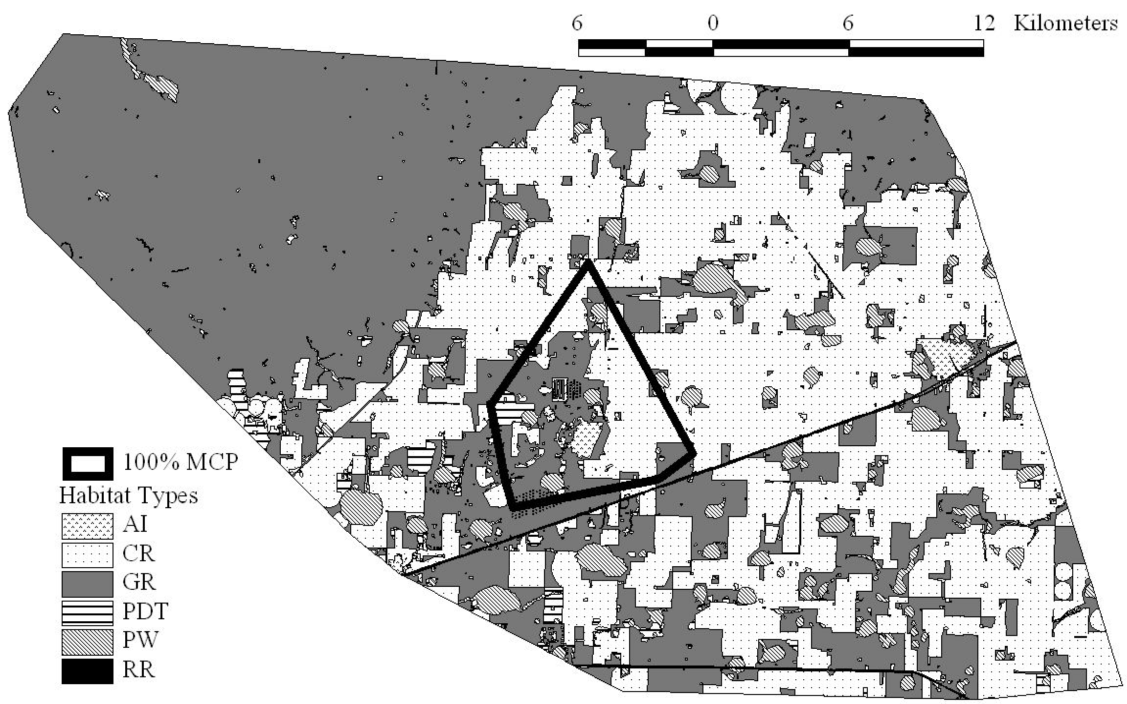
Appendix Figure II.7. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 8 for second-order habitat selection in Carson and Potter counties, Texas.



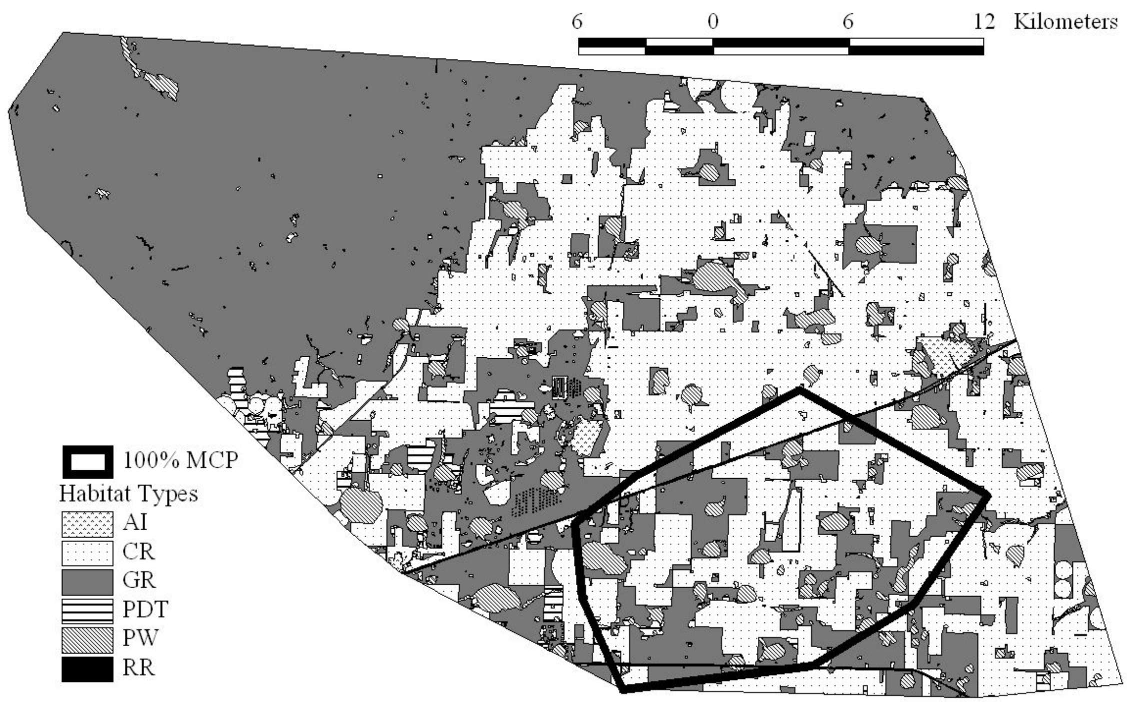
Appendix Figure II.8. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 11 for second-order habitat selection in Carson and Potter counties, Texas.



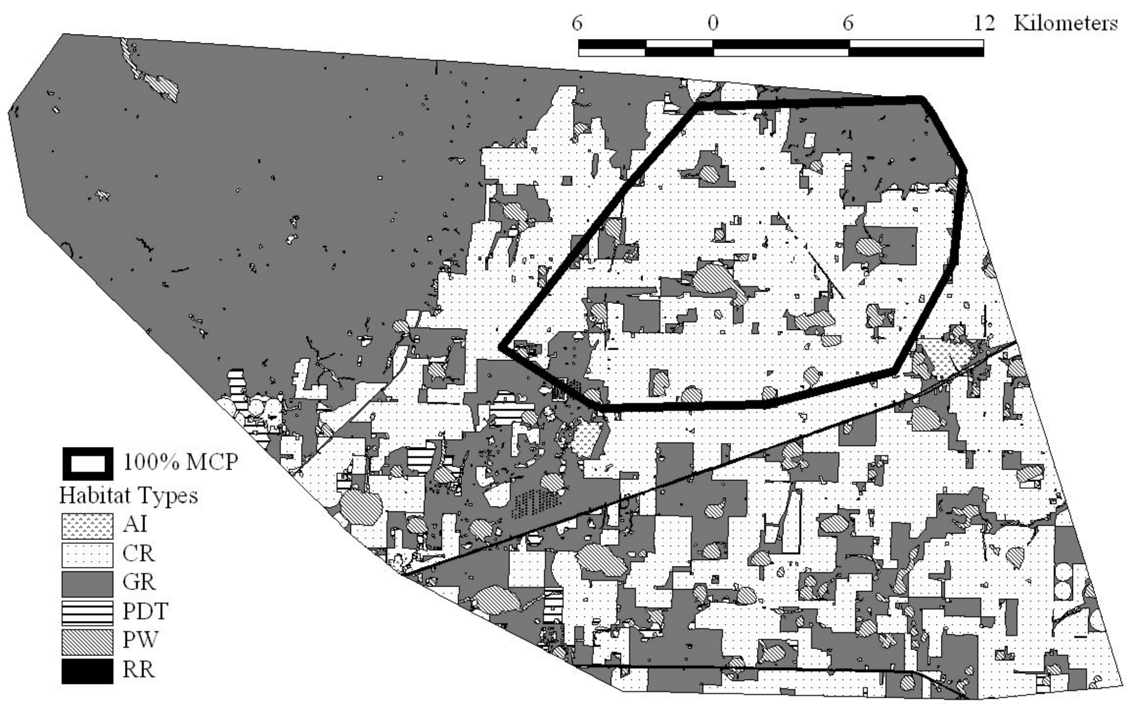
Appendix Figure II.9. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 12 for second-order habitat selection in Carson and Potter counties, Texas.



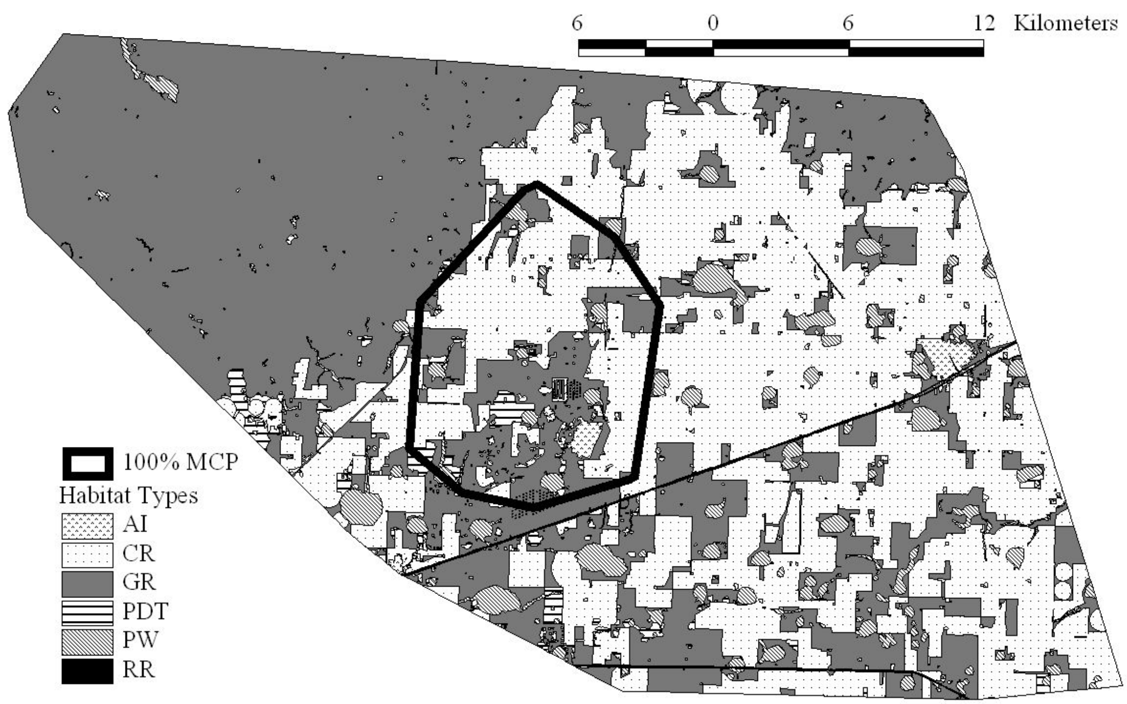
Appendix Figure II.10. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 14 for second-order habitat selection in Carson and Potter counties, Texas.



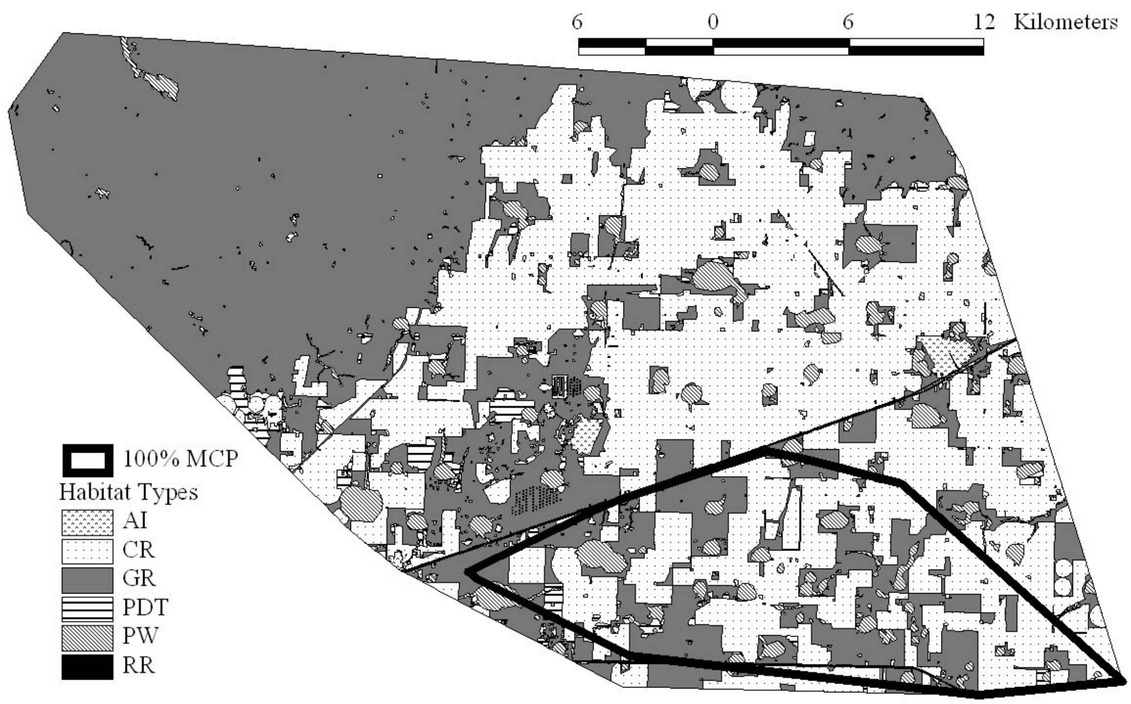
Appendix Figure II.11. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 16 for second-order habitat selection in Carson and Potter counties, Texas.



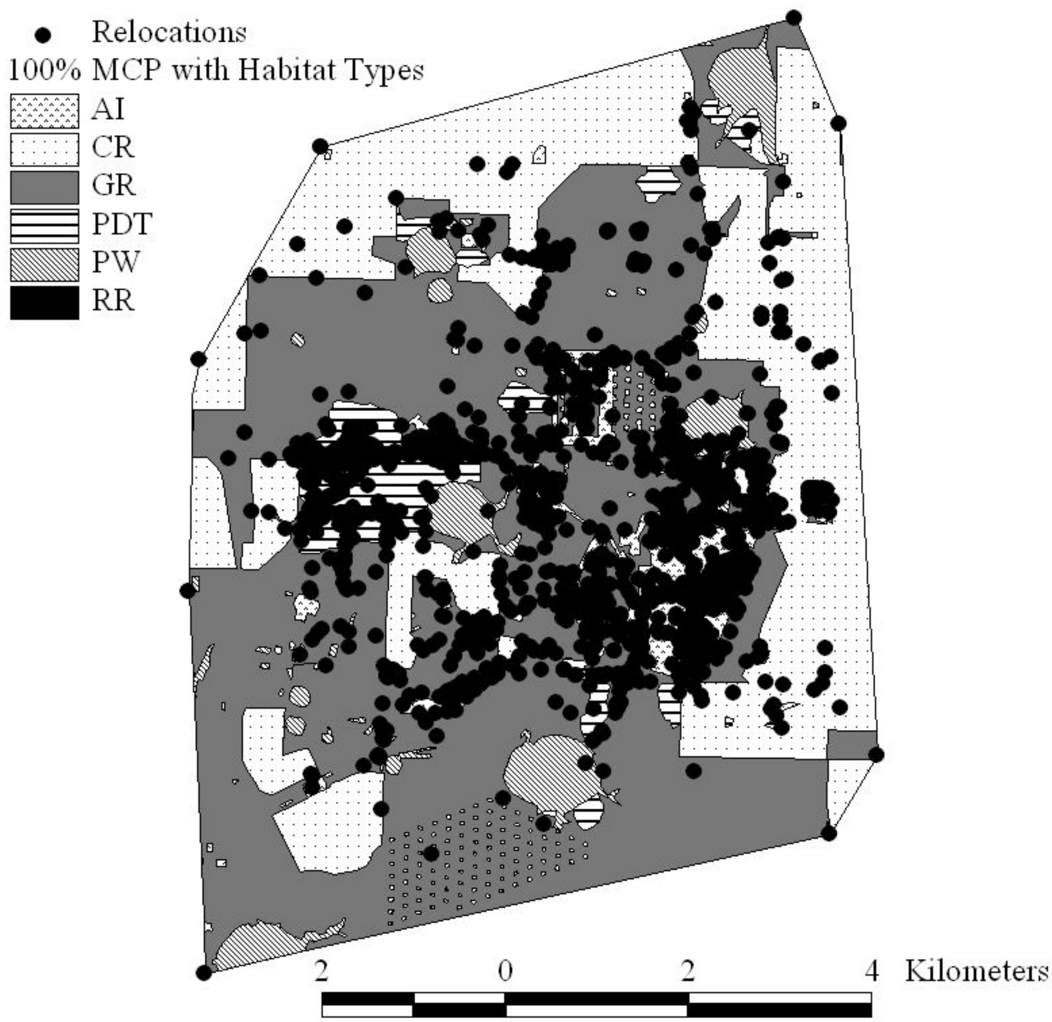
Appendix Figure II.12. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 17 for second-order habitat selection in Carson and Potter counties, Texas.



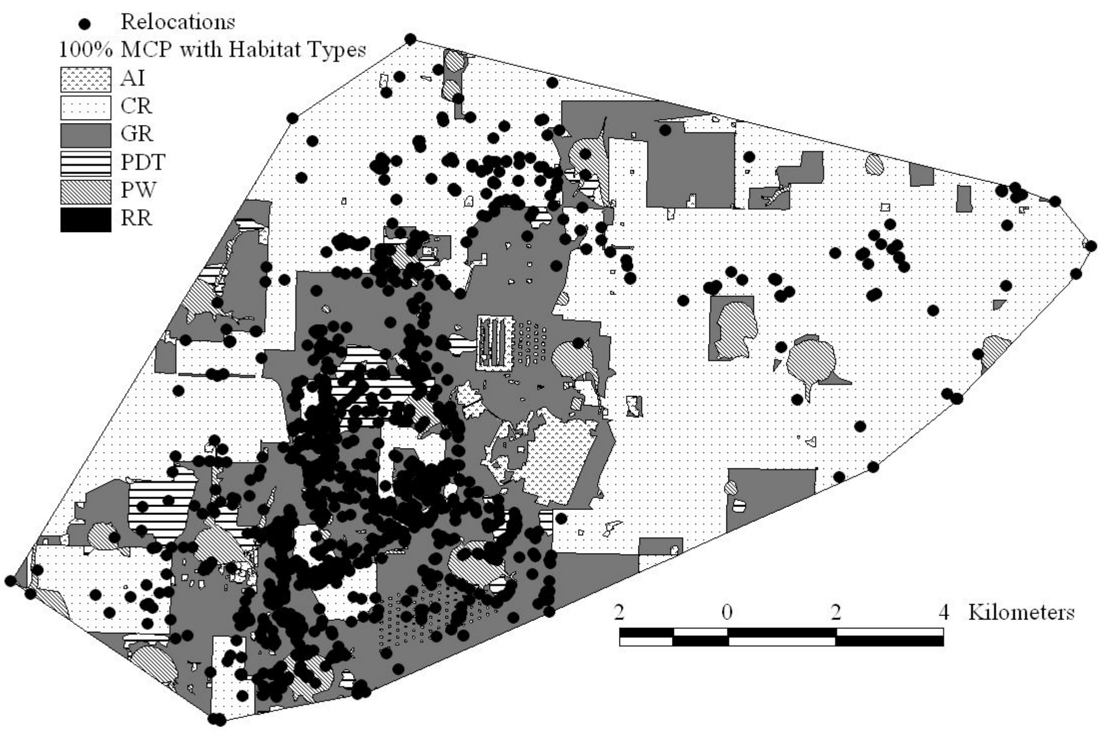
Appendix Figure II.13. Study area polygon with defined habitat types (AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playa or wetland, RR=road or railroad; depicting habitat available) and 100% MCP home range (black outline-depicting habitat used) of bobcat 18 for second-order habitat selection in Carson and Potter counties, Texas.



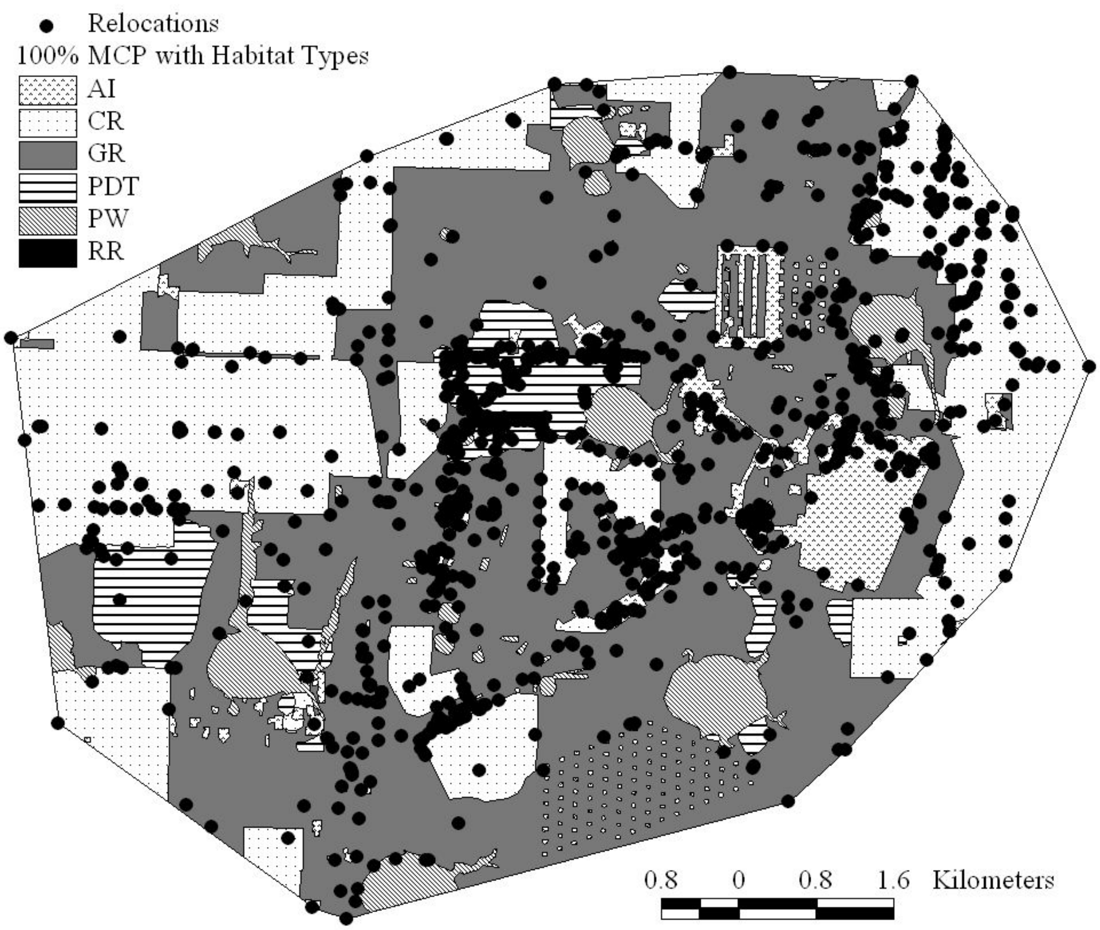
Appendix Figure II.14. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 1 in Carson and Potter counties, Texas.



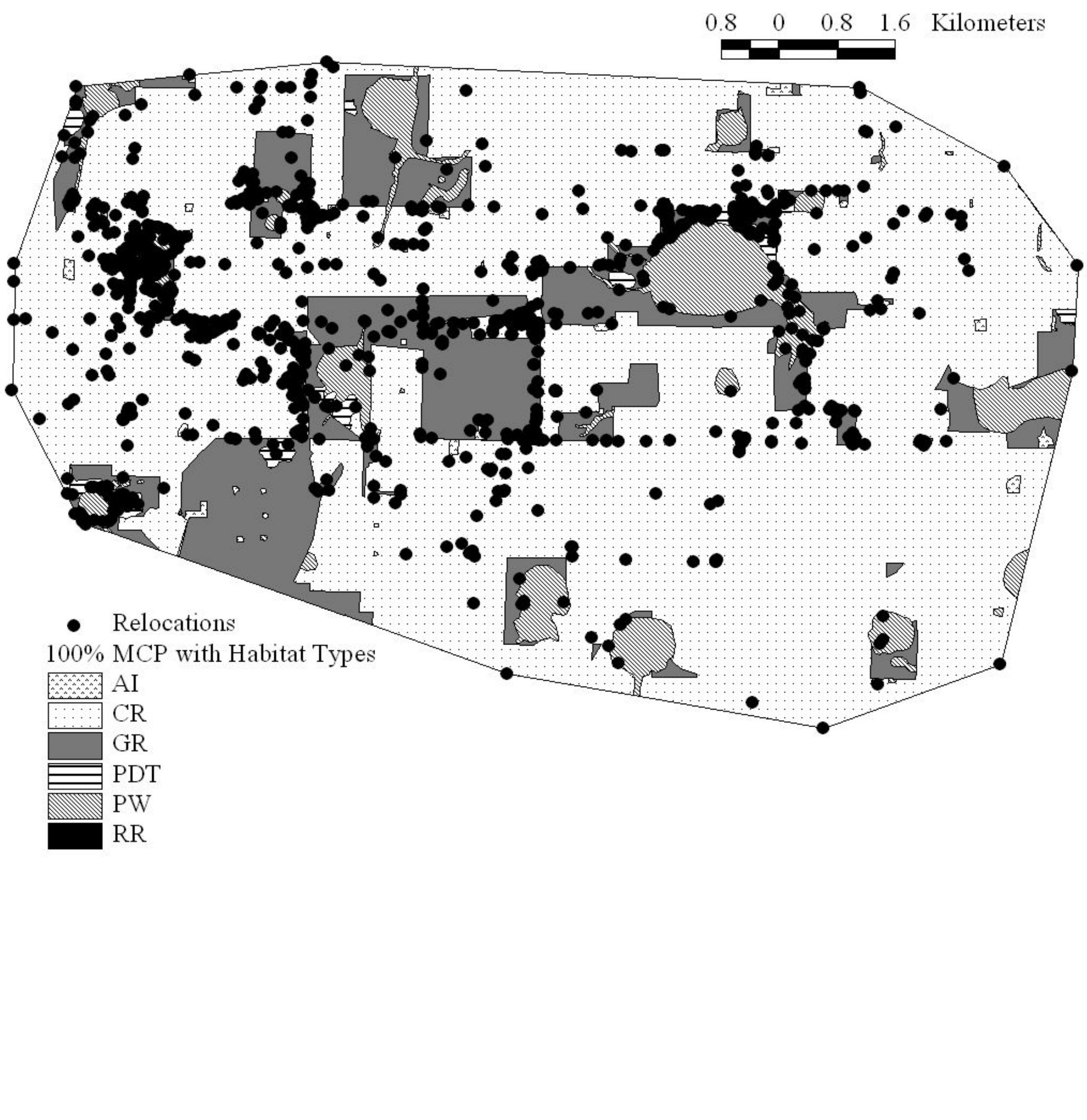
Appendix Figure II.15. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 2 in Carson and Potter counties, Texas.



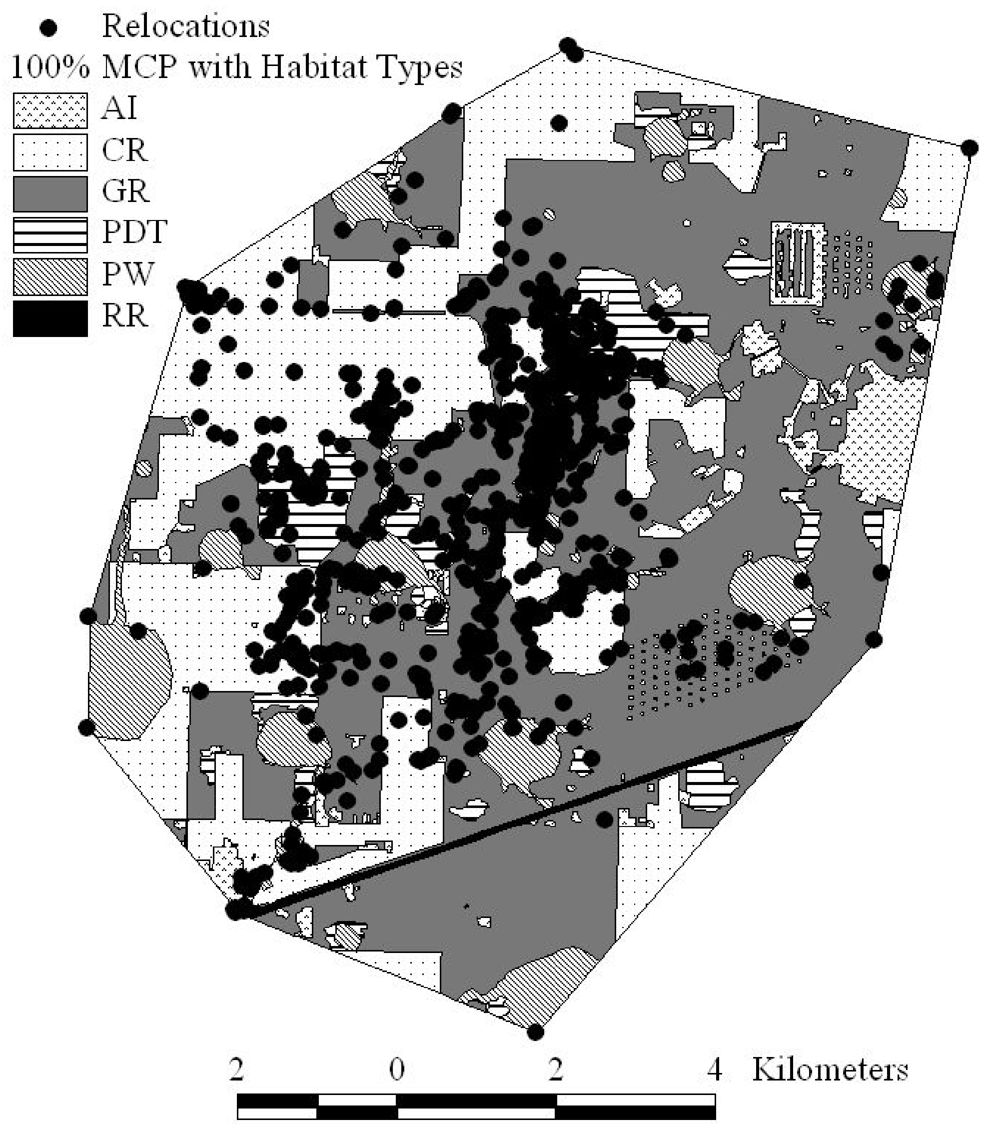
Appendix Figure II.16. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 4 in Carson and Potter counties, Texas.



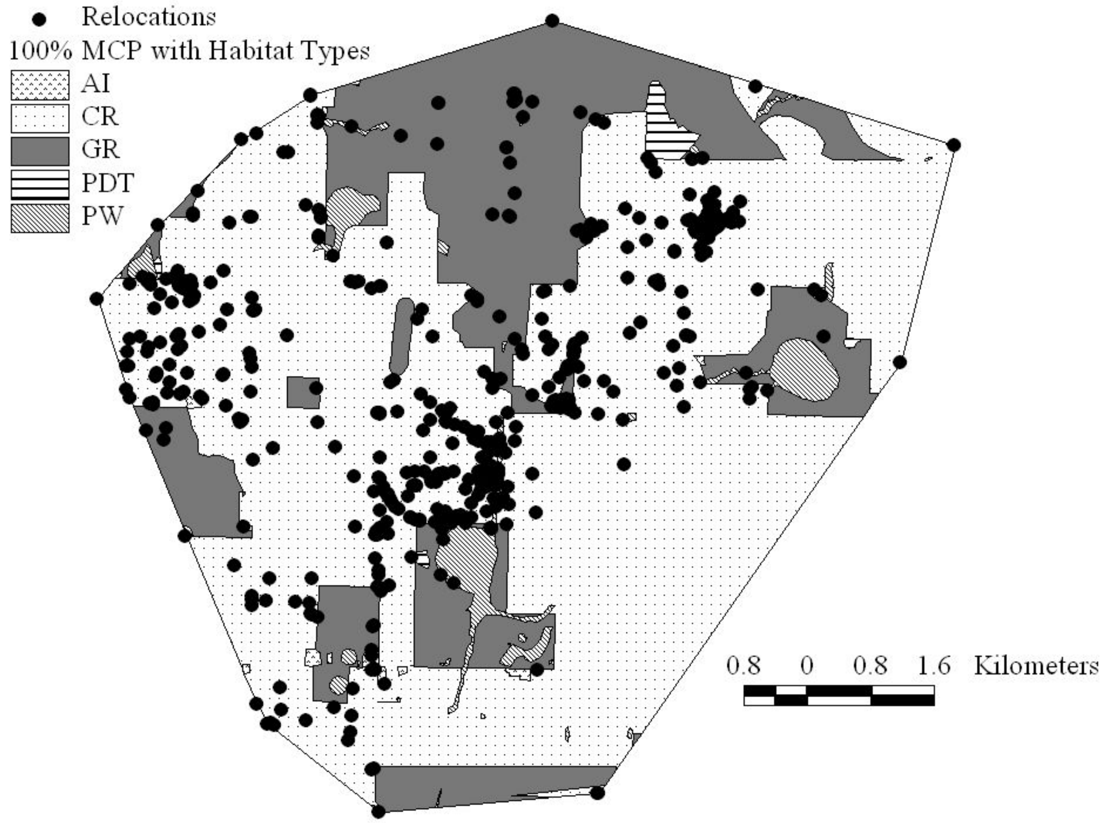
Appendix Figure II.17. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 5 in Carson and Potter counties, Texas.



Appendix Figure II.18. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 6 in Carson and Potter counties, Texas.

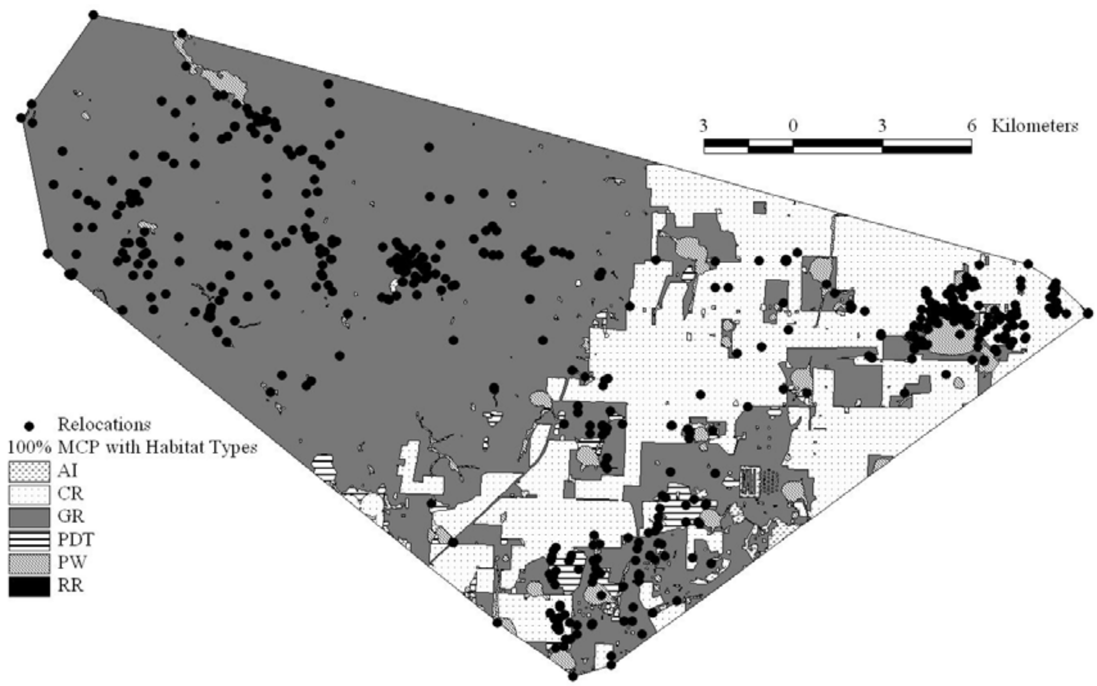


Appendix Figure II.19. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 7 in Carson and Potter counties, Texas.

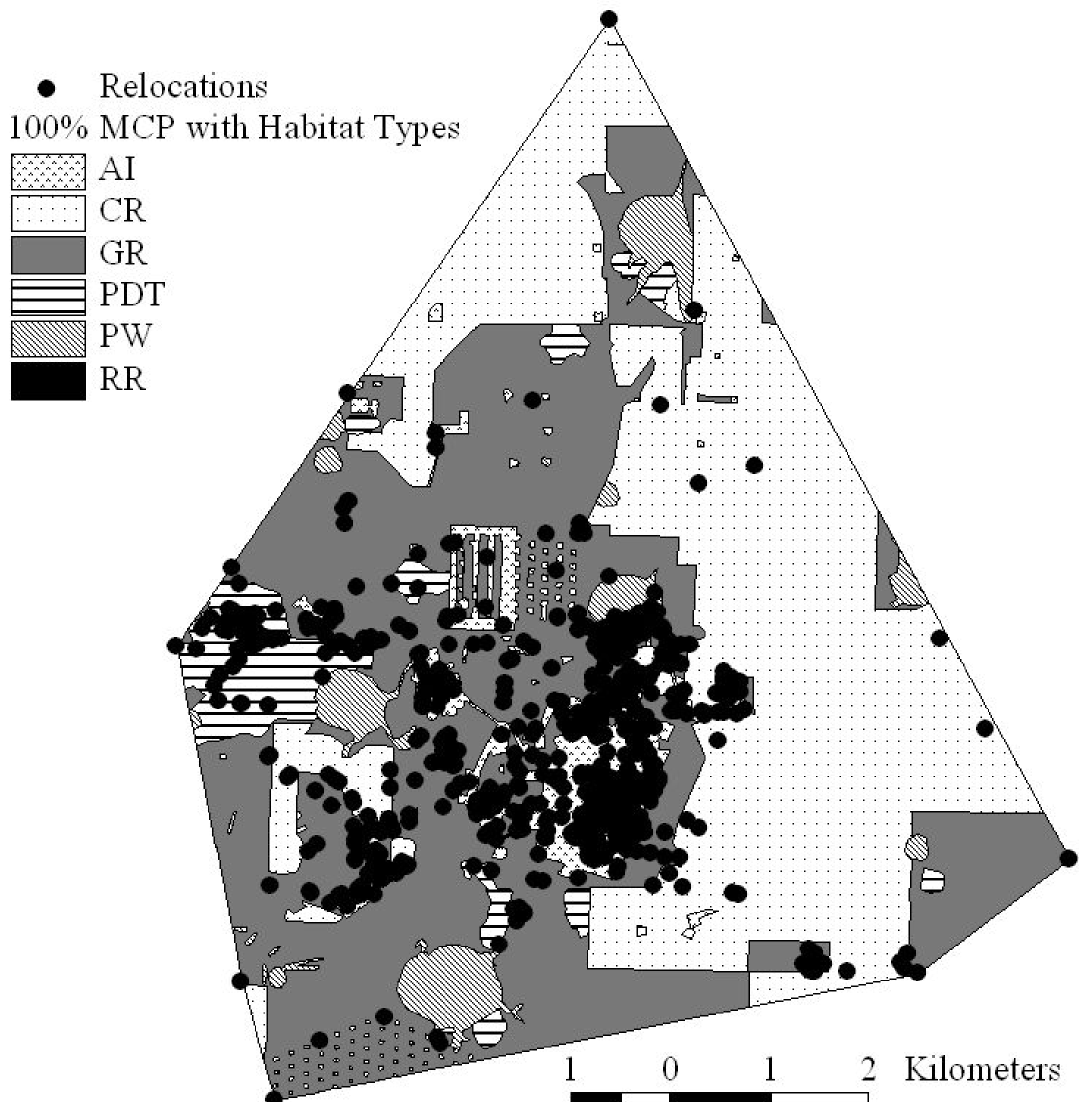


Appendix Figure II.20. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 8 in Carson and Potter counties, Texas.

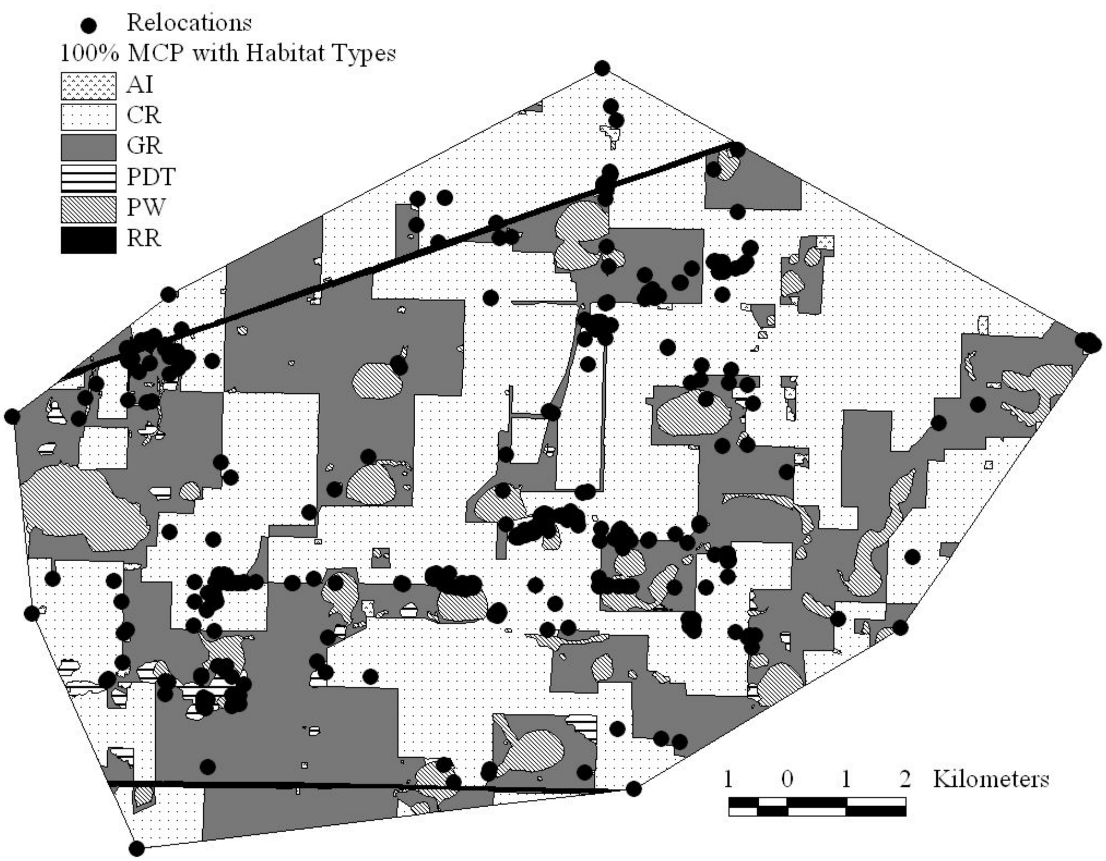
Appendix Figure II.21. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 11 in Carson and Potter counties, Texas.



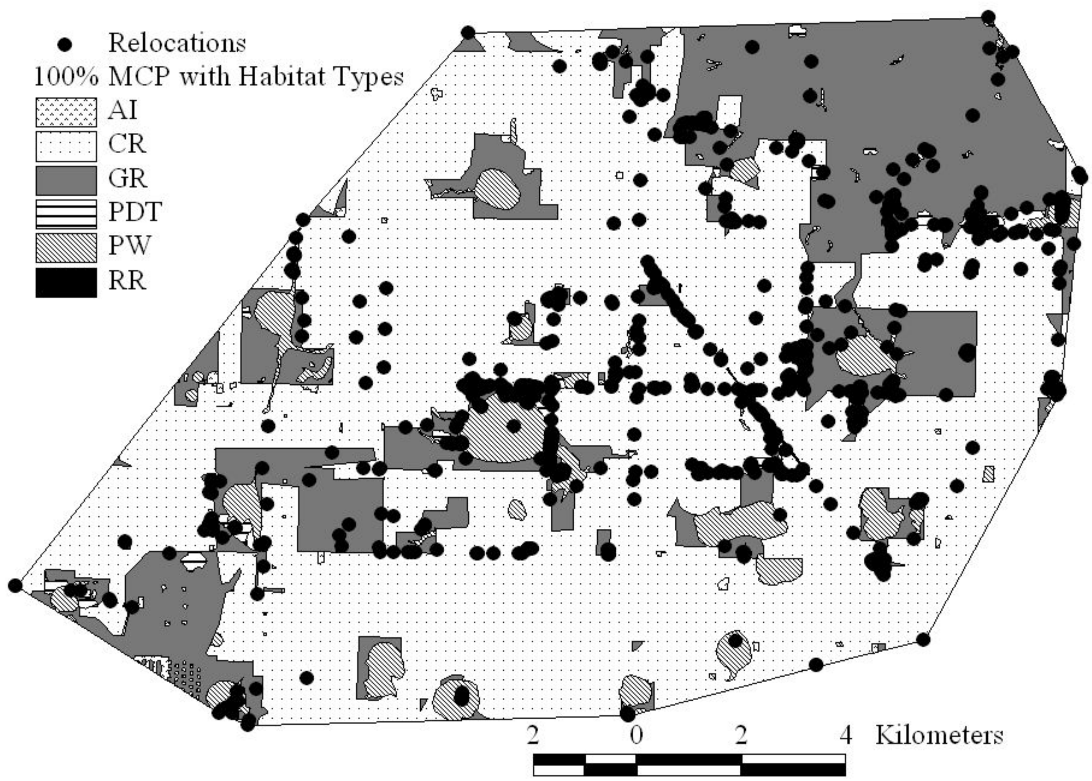
Appendix Figure II.22. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 12 in Carson and Potter counties, Texas.



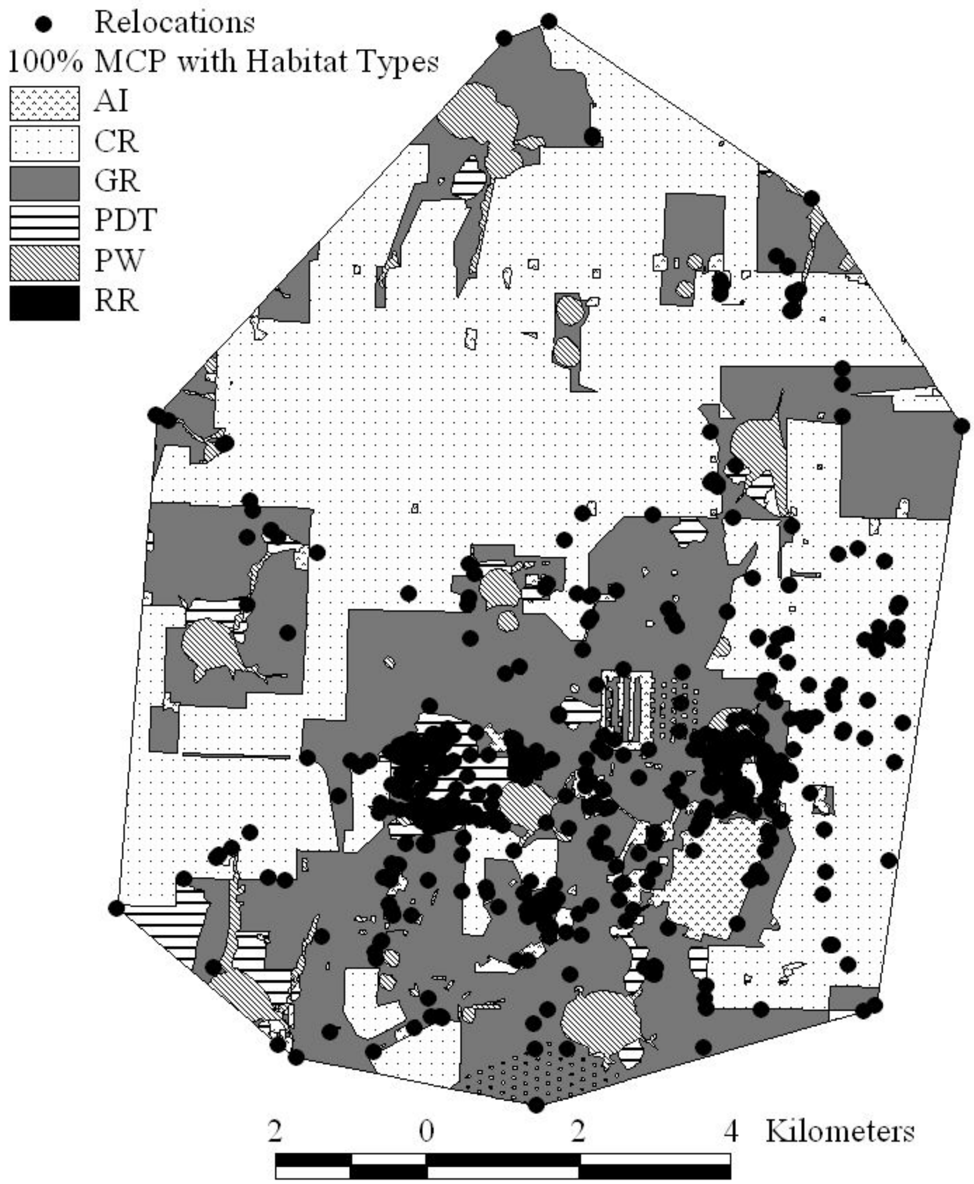
Appendix Figure II.23. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 14 in Carson and Potter counties, Texas.



Appendix Figure II.24. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 16 in Carson and Potter counties, Texas.



Appendix Figure II.25. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 17 in Carson and Potter counties, Texas.



Appendix Figure II.26. MCP home range (100%) with defined habitat types (polygons-AI=anthropogenically-impacted area, CR=cropland, GR=grassland, PDT=prairie dog town, PW=playas or wetlands, RR=roads or railroads) representing habitat available and corresponding relocations (black points) representing habitat used for third-order habitat selection of bobcat 18 in Carson and Potter counties, Texas.