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# Habitat Preference of Western Diamond-backed Rattlesnakes (Crotalus atrox) at Bosque del Apache National Wildlife Refuge, New Mexico: An Analysis at Multiple Scales

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**by**

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**TITLE PAGE**

Habitat Preference of Western Diamond-backed Rattlesnakes (*Crotalus atrox*) at Bosque del Apache National Wildlife Refuge, New Mexico: An Analysis at Multiple Scales

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## ABSTRACT

Bosque del Apache National Wildlife Refuge is located in central New Mexico in the Chihuahuan desert. Approximately 25% of the refuge spans the Rio Grande floodplain and consists of managed riparian and agriculture areas. The upland areas are dominated by creosote bush (*Larrea tridentata*), honey mesquite (*Prosopis sp.*), and four-wing saltbush (*Atriplex canescens*). Western diamond-backed rattlesnakes (*Crotalus atrox*) are habitat generalists of dry lowland areas and commonly use dry washes, *Larrea* and *Prosopis* desert, rocky slopes, scrub/grassland, man-made structures, and less commonly hydric habitats. A high diversity of vegetation types span the refuge and hydric and upland habitats are often in close proximity. To determine if *C. atrox* are found uniformly across the refuge and within their home ranges as well as what habitats are preferred and avoided, we investigate habitat preference at two spatial scales, landscape and home range. We used initial snake captures and search effort data for the landscape and radio-telemetry data for the home range analysis. We found that snakes use habitats

non-uniformly at both spatial scales. While snakes at the landscape scale were found more than expected in Riparian habitat, a variety of habitats were preferred and avoided at the home range level. Apparent selection and avoidance was found when grouping telemetered individuals, although, it was not significant. Individual variation within home ranges varied so dramatically that significant average preference or avoidance in certain habitats could not be determined for the telemetered group as a whole. Among individual home ranges, some habitats were preferred by some and avoided by others.

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# INTRODUCTION

The habitats used by organisms have been central to ecological research for decades and documentation of habitat reaches back to the natural history work of Aristotle and Charles Darwin (Morrison et al., 1992; Block and Brennan, 1993). Habitat is defined as a set of resources needed in an area for animals to survive and reproduce, including, abiotic and biotic conditions (Hall et al., 1997). Research into habitat requirements has provided important information for a variety of topics, including, natural history, game management, species decline, and animal distributions (Morrison et al., 1992). Studies of habitat selection and preference determine what components of habitat are being used disproportionally and those that might contribute to higher survivorship and reproductive success (Block and Brennan, 1993).

Habitat selection is the presumed result of "decision processes" of an animal regarding what habitats are used at different environmental scales (Hutto, 1985); whereas habitat preference or utilization (use) is the disproportional use of spatially distributed resources (Reinert, 1993; Hall et al., 1997). Animals are known to select various aspects of their habitat differently and selection often depends on spatial scale (Johnson, 1980; Wiens, 1989). Four different selection scales have been defined: 1) large scale geographic distributions, often called the "range" of a species (herein landscape level), 2) the location of home ranges within a species distribution, 3) within home range (herein home range level), and 4) food items at foraging sites (Johnson, 1980). Habitat selection and preference can be studied at these different spatial scales by measuring multiple components of animal habitat or by determining the usage and availability of vegetation types. The types of vegetation can be used to infer selection of other components of habitat, for example, vegetation structure, prey availability, and soil types.

Reptiles, particularly snakes may require specialized components of habitat to meet their morphological limitations and physiological needs (Moore and Gillingham, 2006). One of the reasons snakes move around in their environment is to regulate body temperature, which is influenced by many components of their environment (Lillywhite, 1987). Snake body temperature is influenced by substrate temperature (conduction), air temperature (convection), evaporation and long and shortwave radiation (Peterson et al., 1993). Being ectothermic and limbless animals, snakes may require certain vegetative structure to help them regulate body temperature. Variability in vegetative structure is an important character that influences habitat selection of reptiles (Reinert, 1993).

Research involving the movements and behavior of snakes, especially rattlesnakes has expanded with the advancement of radio telemetry. Rattlesnakes are heavy bodied, making them ideal for implanting radio transmitters. Radio telemetry has improved our ability to study the habitat selection and preference of snakes, which in the past, was biased by observational data (Reinert, 1992). Rattlesnakes are cryptic, ambush predators making them hard to detect without the help of telemetry. Learning which habitats are preferred by rattlesnakes is important in areas where human-snake interactions can occur in high frequency (Nowak, 2005). Habitat selection studies assist researchers in determining which habitat components snakes use most (Weatherhead and Prior, 1992; Reinert, 1993).

Within the geographic distribution of *Crotalinae,* (composed of the genera, *Crotalus* and *Sistrurus*), the highest diversity of rattlesnakes can be found in the southwestern United States. Within this region, the Western Diamond-backed Rattlesnake (*Crotalus atrox*) is the most widely distributed and is found in a variety of habitats (Stebbins, 2003, Degenhardt et al., 1996). *Crotalus atrox* is often described as an inhabitant of dry lowland regions of the Southwest (Klauber, 1956; Beck, 1995; Degenhardt et al., 1996; Stebbins, 2003). Although in some instances, this species has been documented to use more hydric vegetation types (Klauber, 1956; Nowak, 2005). Previous studies that involved habitat use for this species have been inconsistent in regard to the use of various habitats in proportion to their availability (Beck, 1995; Nowak, 2005). Herein we investigate habitat preference of *C. atrox* at Bosque del Apache National Wildlife Refuge (BANWR) in central New Mexico. Very little research involving this species has been conducted in this state making it an understudied area of its distribution (Stuart, 2005).

The refuge offers a unique opportunity to study *C. atrox* as it is located at the northern limits of the Chihuahuan Desert and has a high diversity of habitats on a relatively small spatial scale; including dry upland habitats, seasonally inundated wetlands, agriculture fields, and riparian woodlands that are all intersected with irrigation channels. This mosaic of habitats follows an elevation gradient from wet bottomland habitats with an interior riparian corridor to drier upland habitats. In some instances the transition is abrupt at cliff edges and separated by irrigation ditches. Refuge managers and biologists have noticed *C. atrox* to be numerous and widespread across BANWR, particularly within the managed floodplain. The types and juxtaposition of habitats and intensive management that BANWR employs, offered a unique opportunity to study *C. atrox* in a wetter, vegetatively complex environment.

Snakes are known to use habitats non-randomly, apparently selecting certain habitats in their environment (Reinert, 1984; Weatherhead and Charland, 1985; Burger and Zappalorti, 1988; Weatherhead and Prior, 1992). Habitat structure and resource availability are key components that influence snake movement and home range size and snakes have been shown to use different habitats for certain activities, such as foraging and hibernating (Reinert, 1993; Gregory et al., 1897). We approach potential habitat preference of *C. atrox* at the broad scale by using all initial captures and at a finer scale by using the daily locations of snakes carrying implanted radio transmitters. We predict *C. atrox* to use habitat non-randomly at BANWR. Due to the large amount of wetter vegetation types available at BANWR, the history of *C. atrox* sightings within the managed areas of the refuge, and the abundant rodent population, we predict *C. atrox* to be found using wetter habitat types more than proportionally available.

## MATERIALS AND METHODS

We investigate habitat preference of *C. atrox* at BANWR at two spatial scales- *landscape* and *home range*. Our landscape scale looks at how rattlesnakes are distributed among available habitats across 5,000 hectares (ha) of BANWR. Our home range scale looks at how individual rattlesnakes select among immediately available habitats in their daily movements.

*Objectives and Predictions-Landscape*

Objective 1: Determine if snakes occur non-uniformly across the variety of vegetation classes at BANWR.

Objective 2: If non-uniform use was found, determine what vegetation types are preferred at the landscape level.

Predictions: We predict that snakes would be found non-uniformly at the landscape level. We also predict wet habitats to be an important component for *C. atrox* at BANWR.

*Objectives and Predictions-Home Range*

Objective 1: Determine if snakes use vegetation types non-uniformly within their home range.

Objective 2: If non-uniform use was found, determine what vegetation types are preferred within home ranges.

Objective 3: Determine if there is variation among individuals in habitat preference.

Predictions: We predict that snakes would use vegetation types non-uniformly at the home range level and suspect that wet habitat types would be important habitat to *C. atrox* at BANWR. Based on preliminary observation we predict significant variation among individuals in habitat selection.

*Data Analysis*

To evaluate habitat preference of *C. atrox* at two spatial scales, we use initial captures of marked snakes for landscape analysis and daily locations of snakes carrying radios for home range analysis. We plot the initial captures of all snakes, calculate home range, and evaluate vegetation classifications using ArcGIS 9.3 (ESRI, Redlands, California) and Hawth's Analysis Tools (Beyer, 2004). For all statistical calculations, we use Microsoft Excel and the R statistical language, version 2.13.1 (R Development Core Team, 2008) with the selection ratio (wi) function within the AdehabitatHS package (Calenge, 2006).

*Landscape Analysis*

We analyze habitat preference of *C. atrox* at the landscape level by obtaining the frequencies of initial snake captures per habitat type across a large extent of BANWR (Figure 1). We assume that the initial capture of any snake would provide the best estimate of large scale habitat preference by eliminating the possible effects of handling, especially when snakes were recaptured after relatively short time periods. We quantify search effort in each habitat by recording GPS tracks on a daily basis. We programmed each GPS device to record a track point every 20 seconds. These data provide time and distance per track and can be converted to point data for use in ArcGIS (Figure 2). We remove sections of tracks that were recorded at high travel speeds (>32 kilometers per hour (kph)) and stationary (<.3 kph) points, i.e., the person carrying the GPS was not moving. This ensures we only include search effort when snakes would have been detected by researchers (Klauber, 1939; Rosen and Lowe, 1994; McDonald, 2012). We captured *C. atrox* and recorded GPS search effort from 29 August 2009 through 18 December 2011. We compare these observed counts to the expected values for equal distribution among habitats based on the distance searched in each habitat.

To determine habitat types at BANWR, we obtained vegetation maps for the refuge from the United States Geological Survey, Southwest Regional Gap Analysis Project (USGS, 2011). The USGS analyzed vegetation using 2000-2003, 30m resolution satellite imagery. The National Vegetation Classification System (NVCS) was used to classify each vegetation type. We characterize these classifications by dominant vegetation type to match the vegetation map of BANWR used for the home range analysis described later. Dominant vegetation types include: Four-wing Saltbush, Creosote, Mesquite, Riparian (including marsh and riparian wood habitats), and Disturbed (including agriculture, roads, and open areas). We use a Pearson's chi-square goodness of fit test to determine whether snakes use habitat uniformly at the landscape level. We can conclude non-uniform use if the chi-square statistic is significant.

*Home Range Analysis*

To assess habitat preference by individual snakes at the home range level, we compare the proportion of observations in unique habitat types to the proportion of each habitat within each potential home range. We estimate the potential home range using the minimum convex polygon (MCP) method to represent the area of habitat available to each snake. The MCP is one type of home range estimate and is calculated by drawing a convex polygon around the outermost activity locations, encompassing all locations the animal used (Mohr, 1947). This method is still commonly used for comparison (Laver and Kelly, 2008). We use 100% MCPs to determine which habitats were immediately available to each snake and assumed that snakes could access all of the area within the MCP (Johnson, 1980). We calculate the proportion of each habitat in all MCPs to determine what habitats are available to each snake (Figure 3 and 4).

To determine habitat type within each MCP, we digitized habitats using 1 meter (m) resolution, 2011 National Agriculture Imaging Program (NAIP) color infrared aerial photography in ArcGIS. We used a 2005 vegetation map of the refuge with 1 meter resolution to augment classification. For this analysis, we delineate habitats by dominant vegetation types and open areas, including 9 different groups: Four-wing Saltbush (SB), Creosote (CR), Disturbed/Vegetated (DV), Grassland (GL), Marsh (MA), Mesquite (ME), Open (OP), Riparian Wood (RW), and Upland Shrub (US). Disturbed/Vegetated are those areas which were mechanically disturbed and became densely vegetated, mostly by weedy plants. Agricultural areas are also grouped within the Disturbed/Vegetated classification. Agricultural areas changed seasonally from freshly tilled earth to dense alfalfa (*Medicago sativa*) or row crops of corn (*Zea mays*) and sorghum (*Sorghum sp.*). Open areas include BANWR headquarters, roads, and disturbed sites that mostly have exposed soil and few plants. We calculate the area of each vegetation type within each MCP, using ArcGIS 9.3 (ESRI, Redlands, California). Layering the daily movements of snakes over the vegetation map provide the observed number of positions in each habitat. We use the proportion of each habitat in the MCP to calculate the expected frequency of observations within each habitat.

We use Pearson's chi-square goodness of fit test to determine if snakes were using habitats within their home ranges uniformly ($\chi^2 = \Sigma[(o-e)^2/e]$, o = the observed number of observations per habitat and e = the expected number of observations per habitat, i.e. the proportion of habitat multiplied by the total number of observations). We test the null hypothesis that snakes uniformly use habitats throughout their home ranges, i.e. snakes use habitats in proportion to habitat availability. We test this null hypothesis for all telemetered snakes, by pooling observations and habitats across all individuals. We also conduct chi-square tests for each individual to determine if individuals were using habitats within each home range non-uniformly. We can conclude that snakes use vegetation types within their home ranges non-uniformly, if chi-square statistics were significant.

At the individual level, many of the expected values were smaller than recommended for statistical testing (Zar, 2010). Low expected values can bias results by inflating the chi-square statistic, leading to Type 1 error, rejecting a true null hypothesis (Zar, 2010). Thus, we used a corrected chi-square statistic to determine significance with alpha of 0.05 ($\chi_c^2$). Common solutions to this problem include removing the data with low expected values or grouping into more general categories. This is not ideal as potentially relevant information could be removed from the analysis, especially in case of habitat preference or avoidance. We chose to assess each expected value and the contribution these values made to the overall summed chi-square statistic. To determine significance, for each individual with low expected values we removed the chi-square component from each inflated chi-square contribution resulting from small proportions of habitat (Appendix 1 and 2).

We determine what habitats were selected and avoided by individuals, when non-uniform habitat use was indicated by selection ratios (used/availability) to determine which habitats were used disproportionately more or less than their availability (Manly et al., 2002). Selection ratios from zero to one represent habitat types that are used less than available or "avoided", while selection ratios above one designate habitat used more than available or "preferred" (Calenge and Dufour, 2006). We use population selection ratios to determine overall habitat preference (Manly et al., 2002). This selection ratio is, $w_i = u_{i+/}\boldsymbol{\Sigma}\ \boldsymbol{\pi}_{ij} * u_{+j}$, the total number of observations per habitat divided by the expected number of observations per habitat based on the proportion of available habitat in each home range. We determine the overall habitat preference for all individuals by calculating the standard error and corrected 95% confidence intervals for each habitat category (Manly et al., 2002). We determine significant habitat preference as preferred if the lower limit confidence interval was above one and avoided if the upper limit confidence level was below one. We calculate individual selection ratios to evaluate the individual variability within the overall population analysis. Individual selection ratio is, $w_{ij} = (u_{ij}/u_{+j})/\boldsymbol{\pi}_{ij}$, the proportion of observations per habitat j (number of observation per habitat j divided by the total number of observations) divided by the proportion of available habitat j. We conduct a chi-square goodness of fit test between the extreme selection ratios (between largest and smallest) to determine which habitats were significantly preferred or avoided by individuals. We continue to calculate chi-square tests from increasing to decreasing extreme values until no significance difference was found.

*Study Area*

We study habitat preference of *C. atrox* at Bosque del Apache National Wildlife Refuge, located 30 kilometers (km) south of Socorro, Socorro County, central New Mexico (33.801, -106.876, Figure 5). The refuge is approximately 23,000 ha and is situated within Chihuahuan Desert Scrub and Plains-Mesa Sand Scrub vegetation types (Dick-Peddie, 1993). Common upland plants include, four-wing saltbush (*Atriplex canescens*), creosote bush (*Larrea tridentata*), and mesquite (*Prosopis* spp.). Approximately 25% of BANWR spans the Rio Grande floodplain and consists of managed riparian (inundated marsh and riparian woodland) and cultivated areas. Dominant riparian vegetation in these areas include, cottonwood (*Populus deltoides*), coyote willow (*Salix exigua*), and saltcedar (*Tamarix spp.*). Elevation ranges from the Rio Grande at 1370 m to the Chupadera Peak at 1888 m. While an initial analysis includes data from the whole refuge, most of the work in this thesis focuses on a smaller portion of BANWR, west of the Rio Grande including riparian and upland habitats, approximately 5000 ha (Figure 1).

*Data Collection*

We captured *C. atrox* opportunistically while driving and walking in natural and managed areas from 2009 to 2011. In an attempt to capture *C. atrox* from a variety of vegetation types, we searched in both the upland and floodplain areas. Researchers and volunteers searched in previously known snake locations and across wide extents of previously unsearched areas. We used the intricate network of roads on the refuge to access the managed areas. We used the main highway, railroad tracks, powerline road, and two refuge trails to access and search the upland habitats. We captured, individually marked, and processed *C. atrox* encountered in the study area and recorded: snout-vent length, tail length, (measurements to the nearest millimeter) mass, gender (by probing; Laszlo, 1975), and photographed color pattern of the tail. Any reproductive notes and food items were also documented. Snakes were marked using PIT-tags (passive integrated transponders), that are small implantable microchips commonly used to identify individual snakes (BIOMARK HPT12, Biomark, Inc., Boise, ID). PIT-tags have been used by wildlife researchers since the early 1980's and are commonly used in fish, mammal, reptile and amphibian mark-recapture studies and for zoo, veterinary and livestock purposes (Gibbons and Andrews, 2004). We used the recommended methods for handling and transporting venomous snakes designated by the Herpetological Animal Care and Use Committee (HAUC, 2004). We used snake tongs and hooks for capturing, snake bags and buckets with threaded lids for transporting, and worked in pairs for all processing.

Some PIT-tagged snakes were used for radio-telemetry. The selection process for radio implantation depended on when snakes were found and their size. We used isoflurane to anesthetize the snakes for the surgical implantation of radio transmitters and iButtons® (Maxim Integrated Products, Inc., Sunnyvale, CA; Reinert and Cundall, 1982). Our transmitters were VHF (very high frequency) radios with frequencies ranging from 164.000 to 164.900 and had a life span of 24 months. Transmitters weighed <5% of snake body mass. In 2009, we implanted 7 of 8 snakes with CHP/5P 8 gram (g) radios (Telonics, Inc., Mesa, AZ), but due to failure of all radios over a three month period and the subsequent loss of these snakes, we switched to SI-2, 13g radios (Holohil Systems Ltd., Carp, Ontario, Canada) the following year. In addition to radios, we also implanted iButtons®, small temperature data loggers, to record body temperatures. The University of New Mexico, Institutional Animal Care and Use Committee approved all processing and surgical procedures (Protocol #09-100291-MCC).

Radio-tracking commenced the day after the release of each snake and continued on a daily basis during the active season, transitioning to once a week during winter months in 2010 and once a month in 2011. Due to the increasing number of snakes to track and time involved in recording multiple locations per day, it became necessary to reduce our efforts to tracking snakes once daily. We only included the first location taken per day for analysis. For example, if a snake was radio-tracked three times in one day, only the first location of the day was kept in the data set. We also excluded the hibernation period from analyses. We defined the hibernation period as the day after the last day the snakes entered their hibernacula in the fall to one day prior to their first movement in the spring. We recorded snake locations using a Garmin GPSmap76CSx hand-held global positioning system unit (average accuracy, 9m and 4m in 2010 and 2011), using World Geographic System 1984 datum.

## RESULTS

*Landscape Level*

We made 235 initial captures of *C. atrox* and recorded 350,728 GPS track points from 29 August 2009 to 18 December 2011. Tracks totaled 8,871 km of effort, either walking or driving slowly (Figure 2).

Approximately 8000 km of searching occurred in five types of habitat. We searched in Four-wing Saltbush in the greatest proportion of all habitats (46.8%) and in Disturbed the least (2.3%, Table 1). The number of captured *C. atrox* per habitat ranged from 1 in Disturbed to 172 in Riparian (Table 1). *Crotalus atrox* did not use habitats uniformly ($\chi^2$ = 109.68, df = 4, P = <0.0001, Table 1). *Crotalus atrox* were found more often than expected in Riparian and less often than expected in all other habitats. Excluding captures made in Riparian shows that, of the four remaining habitats, *C. atrox* used them uniformly ($\chi^2$ = 4.1, df = 3, P = .251, Table 2). Although habitat preference was not significant among these four habitats, there was a general trend for *C. atrox* to use Four-wing Saltbush more than expected and Creosote, Mesquite, and Disturbed less than expected (Table 2).

*Home Range Level*

In late summer 2009, eight *C. atrox* were fitted with radio-transmitters; however, seven radios failed and those snakes were lost. We continued telemetry efforts in 2010 with an additional 17 snakes (*N* = 18, 7 females and 11 males). One male died less than two months post-surgery. The cause of death is unknown, although just prior to death; this individual crossed a highway and may have been struck by a vehicle. It is also possible that it died as a consequence of the surgery. We did not include data for this snake in the analyses. Another individual was excluded from the 2010 analyses because it was captured late in the active season, limiting observations for that year. Due to the exclusion of these two individuals, sample size was reduced to 16 individuals (N = 16, 7 females and 9 males) for 2010.

In 2010, a total of 2024 localities were recorded (Appendix 3). The number of localities per snake ranged from 53 to 197 (mean = 126.5, SD = 32.6, Appendix 4). Predation events on telemetered snakes reduced the sample size in 2011 ($N$ = 10, 3 females and 7 males). In 2011, telemetered snakes died during the hibernation period, spring emergence from hibernacula, and various times early in the active season (Appendix 3). Observations from one of these individuals were included in the analysis, as substantial data were recorded prior to death (one female of eight total mortalities). By fall 2011, only 9 snakes returned to their hibernacula (two females and seven males) (Appendix 3). In 2011, a total of 1715 localities were recorded and the total number of locations per individual ranged from 125-202 (mean = 171.5, SD = 23.0, Appendix 4).

Overall results for 2010, indicate that telemetered snakes did not use habitats within their home ranges uniformly ($\chi^2$ = 292.1, df = 8, P = <0.0001, Table 3). In general, snakes prefer Creosote, Disturbed/Vegetated, Mesquite, and Riparian Wood habitats, whereas, Four-wing Saltbush, Grassland, Marsh, Open, and Upland Shrub habitats were avoided (Table 3). We recorded the highest number of daily telemetry locations in Riparian Wood habitat (19.1%) and the least in Grassland areas (<.1%). Pooled selection ratios demonstrate that 5 of 9 habitats were used more than predicted by their availability (Table 4). Habitats used disproportionately more than their availability, ranked in decreasing selection ratios greater than one, include: Disturbed/Vegetated, Marsh, Riparian Wood, Creosote, and Mesquite (Table 4). Habitats that were used less than available, ranked by decreasing selection ratios less than one, include: Four-wing Saltbush, Open, Upland Shrub, and Grassland (Table 4). Although pooled selection ratios indicate overall selection and avoidance of habitats, the confidence intervals show that there was no significant habitat selection shared by all snakes for any habitat. The large confidence intervals indicate individual variation in preference among telemetered individuals (Figure 6). This suggests that no habitats were consistently selected or avoided in a similar manner by all snakes.

Chi-square tests of individuals indicate that 15 of 16 telemetered snakes did not use habitats within their home ranges uniformly (Appendix 1). Selection ratios for individual snakes indicate that habitat preference varied across individuals (Table 5). The variation among individuals leads to insignificant habitat preference when pooling all telemetered snakes. Individual variability occurred due to four reasons: 1) habitats were selected by some individuals, but not others; 2) available habitats were not always used; and 3) not all habitats were available to all snakes. The habitats most preferred by individual snakes varied within 8 of 9 habitat types. No habitat type was preferred by more than three individuals and Disturbed/Vegetated, Open, and Riparian Wood were each preferred by three individuals. A summation of the most preferred habitats across all individuals show that two snakes preferred Creosote, three Disturbed/Vegetated, one Grassland, one Mesquite, three Open, three Riparian Wood, two Four-wing Saltbush, and one individual preferred Upland Shrub the most. Habitats that were selected by some snakes were also avoided by others. The most avoided habitats include: Creosote, Grassland, Marsh, Open, Riparian Wood, Upland Shrub, and Four-wing Saltbush. Significant preference and avoidance of habitats differed among individuals (Table 5).

Results from 2011 were similar to 2010: the overall population of telemetered snakes did not uniformly use habitats within their home ranges ($\chi^2$ = 343.1, df = 8, P = <0.0001, Table 6). Chi-square analysis indicates preference of these habitats: Creosote, Disturbed/Vegetated, Mesquite, and Riparian Wood, whereas; avoided habitats include: Four-wing Saltbush, Grassland, Marsh, Open, and Upland Shrub (Table 6). We documented telemetered snakes most often in Riparian Wood habitat (23.3%) and least in Grassland (~1%). 2011 overall selection ratios indicate that only 4 of 9 habitats were used more than availability, compared to 5 of 9 in 2010 (Table 7). Habitats that were used more than expected, in decreasing order, are: Riparian Wood, Disturbed/Vegetated, Mesquite, and Creosote (Table 7). With the exception of Marsh, these habitats are similar to those selected in 2010; however, they occur in a different order of use. This variation may be due to the smaller sample size in 2011. Habitats that were used disproportionately less than available, in decreasing order of selection ratio, include: Four-wing Saltbush, Open, Upland Shrub, Grassland, and Marsh. As in 2010, the large confidence intervals indicate variability between individuals (Figure 7). The confidence intervals revealed no habitats were significantly selected or avoided.

In 2011, no individuals used habitats within their home ranges uniformly (N = 10, Appendix 2). As in 2010, 2011 results from individual selection ratios show variation among individuals in the most preferred and avoided habitats (Table 8). The habitats most preferred among snakes included 5 of 9 types, Creosote, Disturbed/Vegetated, Grassland, Riparian Wood, and Four-wing Saltbush. The number of snakes that preferred each habitat varied from 1 to 3 individuals, with Creosote preferred by more snakes than any other habitat. As in 2010, some individuals avoided habitats that were preferred by others. The most avoided habitats include Creosote, Grassland, Marsh, Open, and Upland Shrub. Creosote and Marsh habitats were each avoided by three individuals. Significantly preferred and avoided habitats varied among individuals (Table 8).

## DISCUSSION

We observed *C. atrox* using habitats at both the landscape and home range levels non-uniformly. Similar to other taxa, snakes are known to use habitats non-uniformly at various spatial levels and often habitat preference changes depending on scale (Johnson, 1980; Powell, 1994; Moore and Gillingham, 2006; Hoss et al., 2010). At the landscape level snakes were found most often in the Riparian habitat, while at home range level, using a finer resolution vegetation map, results determined that snakes selected Disturbed/Vegetated in 2010 and Riparian Wood in 2011. In both years, we observed snakes using Disturbed/Vegetated, Riparian Wood, Open, and Creosote disproportionately more than the availability of those habitats predicted. However, individual preference varied dramatically in both years, indicating that pooling selection ratios can provide a misleading summary of overall habitat preferences (Calenge and Dufour, 2006).

Our analyses of habitat preference at the landscape and home range scales, demonstrate the importance of telemetry to record the daily movements of snakes. For instance, our fine-scale telemetry data can help explain the results found at the landscape level. Despite the intensive search effort made in Four-wing Saltbush habitat we did not detect as many snakes as we expected in this habitat. It could be that while searching this habitat type, snakes were more often in refugia, thus were not observable. In general, we observed that telemetered snakes at BANWR were often located in refugia while in upland habitats, such as Four-wing Saltbush and Mesquite. A variety of refugia were used, for example burrows and pack rat (*Neotoma spp*.) middens. Although habitat preference at the home range level varied among individuals, we did observe snakes using Riparian Woodland and Marsh habitats for foraging. In general, snakes might have been more active in the Riparian area, due to prey availability, mate searching, mating, and reproducing.

Hydric vegetation types could be an important habitat for *C. atrox*. We found that some *C. atrox* at BANWR use wet habitats more than expected when available. This species has been known to use wet habitat in various parts of its distribution, including irrigated areas, vegetation along flowing rivers, and inundated cattail (*Typha spp.*) marshes (Klauber, 1956; Nowak, 2005). Research that has determined habitat use of this species shows inconsistencies (Beck, 1995; Nowak, 2005). In the Tucson Mountains east of Tucson, AZ, snakes use habitats non-uniformly and show a preference for creosote bush (Beck, 1995). In north-central Arizona, *C. atrox*; appear to use the habitat uniformly; however, small sample sizes and correspondingly low statistical power might have influenced this result (Nowak, 2005). At this second site, wet habitats were available and used by snakes; however, snakes did not use them more than what was expected, based on availability of habitat. From these two studies it is unclear what habitats *C. atrox* typically use as somewhat different habitats were available and non-random use of available habitats was inconsistent.

Wet habitats may be important areas for snake foraging activity. Prey availability has been shown to be highest in riparian habitats in the desert Southwest, when comparing a transition from riparian areas to uplands (Soykan and Sabo, 2009). A brief exploratory project at BANWR that involved studying mammal populations along an elevation gradient, from riparian to upland habitats showed similar trends (Stephens and Anderson, unpubl.). Various studies of mammal populations at BANWR have found high abundance of rodents in wet habitats in the managed portions of the refuge (Ellis et al., 1997; Wright, 2012). Due to the stable source of water at BANWR required for the management of waterfowl, mammal populations may be inflated in these areas. Ellis et al. (1997) found that at BANWR, mammalian species richness was higher in non-native riparian than native riparian habitat (Ellis et al., 1997). Ellis and colleagues (1997) found that upland mammal species were using non-native riparian habitats and attributed this increase to proximity to upland habitats.

Thus, as a predator, abundance and species richness of prey items might directly influence *C. atrox* selection of these wet areas. *Crotalus atrox* were often seen in ambush positions, coiled either at surface level or up in dead cattail masses, as well as hanging in live cattails of inundated marshes. *Crotalus atrox* were also found in dense riparian woodlands consisting of nearly impenetrable willow species with an over-story of cottonwood trees. We also found individuals in smaller patches of extremely dense coyote willow. These woodlands are adjacent or completely surrounded by areas that experience periodic flooding.

Greater availability and the presumed increase in consumption of prey have direct physiological benefits. Increased food availability has been shown to have dramatic effects on female *C. atrox* (Taylor et al., 2005). Food supplementation to free-ranging female *C. atrox* resulted in increased growth, more frequent reproduction, and better body condition post-reproduction (Taylor et al., 2005). These advantages of higher prey availability and potentially higher prey consumption in wet habitats could be an obvious reason why *C. atrox* at BANWR select the hydric vegetation types more frequently than upland areas during the summer activity period.

Use of Disturbed/Vegetated areas might have the same advantages as using wet vegetation types, such as increased prey availability. Disturbed/Vegetated habitat at BDA is often overgrown with an invasive, weedy, non-native plant, Kochia (*Kochia scoparia*). *Kochia scoparia* is a nutritional forage plant and is eaten by domestic livestock and wildlife (Everitt et al., 1983; Stubbendieck et al., 2003; Friesen et al., 2009). We observed *C. atrox* in dense stands of *K. scoparia* and on the edge where these stands meet other native habitats, for example Marsh or Riparian Wood. Foraging opportunities for *C. atrox* may be increased in Disturbed/Vegetated areas with *K. scoparia* due to the potential of increased prey attracted to abundant food sources.

Some telemetered snakes made long distance migrations from their hibernacula, transitioning from upland habitats to riparian areas. Many rattlesnake species are known to have similar migrations from hibernacula to summer activity ranges, areas where they forage, mate, and give birth (Duvall et al., 1985; Wastell and Mackessy, 2010). At BANWR, while some individuals migrated, others did not and were located within the managed floodplain areas of the refuge - the same habitats as their hibernacula. We documented only one individual that did not migrate from its home range in the upland areas to the floodplain. Although this individual did move from slightly higher to lower elevation vegetation, it did not extend into the wetter floodplain vegetation. This migration of upland hibernating snakes could indicate that the lower floodplain is more suitable for foraging. This could also be why *C. atrox* are seen in such abundance during the spring, summer, and fall months throughout the managed areas.

In summary, *C. atrox* at BANWR use habitats non-uniformly at the landscape and home range levels. Pooling results from telemetered snakes did not indicate significant habitat selection of any habitat. Individual variation among telemetered snakes was such that some individuals preferred a habitat while others avoided it. This variation leads to insignificant results when pooling data across all telemetered snakes. Although preference at the home range level ranged across a variety of vegetation types, it is clear that habitat within the managed floodplain is important for *C. atrox*. This study and others like it, provides a better understanding of what vegetation types this species selects across its wide distribution.

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## TABLES

Table 1. Chi-square goodness of fit test for the landscape level, including proportion of habitats searched, the observed number of captures, and the expected number of Western Diamond-backed Rattlesnake (*Crotalus atrox*) captures per habitat ($\chi^2$ = 109.68, df = 4, P = <0.0001) from 2009 to 2011.

| **Habitat Type** | **% Search Effort** | **Observed** | **Expected** | **O-E** |
|---|---|---|---|---|
| Creosote | 17.1 | 19 | 40 | -21.1 |
| Disturbed | 2.3 | 1 | 5 | -4.5 |
| Four-wing Saltbush | 46.8 | 74 | 110 | -35.9 |
| Mesquite | 7.1 | 8 | 17 | -8.7 |
| Riparian | 26.7 | 133 | 63 | 70.2 |
| Total | 100 | 235 | 235 | 0 |

O=observed number of captures
E=expected number of captures

Table 2. Chi-square goodness of fit test for the landscape level, with the Riparian vegetation type removed ($\chi^2$ = 4.1, df = 3, P = .251) 2009 to 2011.

| **Habitat Type** | **% Search Effort** | **Observed** | **Expected** | **O-E** |
|---|---|---|---|---|
| Creosote | 23.3 | 19 | 24 | -4.8 |
| Disturbed | 3.2 | 1 | 3 | -2.3 |
| Four-wing Saltbush | 63.8 | 74 | 65 | 8.9 |
| Mesquite | 9.7 | 8 | 10 | -1.9 |
| Total | 100 | 102 | 102 | 0 |

O=observed number of captures
E=expected number of captures

Table 3. Chi-square goodness of fit results for the home range level of pooled individuals ($\chi^2$ = 292.1, df = 8, P = <0.0001) in 2010.

| **Habitat** | | | | **Locations** | | **$\chi^2$** | | |
|---|---|---|---|---|---|---|---|---|
| **Habitat Type** | **Abbr.** | **Hectares** | **Prop** | **Used** | **Expected** | **o-e** | **$(o-e)^2$** | **$(o-e)^2/e$** |
| Four-wing Saltbush | SB | 104.1 | 0.20 | 322 | 396 | -74 | 5435 | 13.7 |
| Creosote | CR | 73.6 | 0.14 | 292 | 280 | 12 | 151 | 0.5 |
| Disturbed/Vegetated | DV | 65.3 | 0.12 | 267 | 248 | 19 | 358 | 1.4 |
| Grassland | GR | 9.8 | 0.02 | 16 | 37 | -21 | 453 | 12.2 |
| Marsh | MA | 65.0 | 0.12 | 189 | 247 | -58 | 3350 | 13.6 |
| Mesquite | ME | 56.0 | 0.11 | 241 | 213 | 28 | 794 | 3.7 |
| Open | OP | 59.1 | 0.11 | 197 | 225 | -28 | 760 | 3.4 |
| Riparian Wood | RW | 49.4 | 0.09 | 387 | 188 | 199 | 39713 | 211.6 |
| Upland Shrub | US | 50.3 | 0.09 | 113 | 191 | -78 | 6116 | 32.0 |
| Total | | 532.5 | 1.00 | 2024 | 2024 | 0 | 0 | 292.1 |

Table 4. Pooled individual selection ratios (Wi), standard error (SE), and upper and lower confidence intervals (CI) for each habitat type in 2010.

| **Habitat Type** | **Abbr.** | **Wi** | **SE** | **CI Lower** | **CI Upper** |
|---|---|---|---|---|---|
| Four-wing Saltbush | SB | 0.923 | 0.206 | 0.351 | 1.496 |
| Creosote | CR | 1.037 | 0.491 | -0.324 | 2.399 |
| Disturbed/Vegetated | DV | 1.598 | 0.738 | -0.450 | 3.646 |
| Grassland | GL | 0.513 | 0.188 | -0.008 | 1.034 |
| Marsh | MA | 1.270 | 0.282 | 0.487 | 2.052 |
| Mesquite | ME | 1.013 | 0.180 | 0.513 | 1.513 |
| Open | OP | 0.731 | 0.216 | 0.133 | 1.330 |
| Riparian Wood | RW | 1.070 | 0.235 | 0.417 | 1.723 |
| Upland Shrub | US | 0.636 | 0.171 | 0.161 | 1.110 |

Table 5. Selection ratios for each habitat type within each snake home range in 2010.

| Snake # | SB | CR | DV | GL | MA | ME | OP | RW | US |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 2.490 | 0.493 | 58.472 | | 0.937 | 0.0 | 0.0 | 8.295 | 0.267 |
| 3 | 0.786 | 1.122 | 0.775 | 0.526 | 0.850 | 4.090 | 0.215 | 1.998 | 1.931 |
| 4 | 0.872 | 3.442 | | 0.535 | | 0.811 | 2.546 | 0.284 | 2.591 |
| 5 | 2.007 | 0.180 | | 47.667 | | 2.676 | 0.354 | 0.678 | 0.491 |
| 6 | 0.853 | 0.391 | | | 2.066 | 0.354 | 0.0 | 4.230 | 2.237 |
| 7 | 0.100 | 6.731 | 0.206 | 0.102 | 0.469 | 0.264 | 0.0 | 1.908 | 0.240 |
| 8 | 1.911 | 0.742 | 10.404 | | 0.0 | 1.093 | 0.779 | 2.482 | 0.642 |
| 9 | 1.000 | | 0.855 | | | | 2.802 | 0.835 | |
| 10 | 1.094 | | | | | | 6.243 | 0.364 | |
| 11 | 0.766 | 9.294 | 0.731 | | 1.525 | 1.510 | 0.130 | 2.428 | 14.321 |
| 12 | 126.935 | 0.403 | 2.343 | | 4.312 | 1.018 | 1.283 | 2.858 | 0.647 |
| 14 | 0.0 | 0.0 | 4.259 | | | 0.680 | 19.836 | 0.472 | 0.0 |
| 15 | 2.067 | 2.021 | | | | 1.359 | 0.429 | 0.0 | 0.0 |
| 16 | 0.305 | 0.278 | 0.669 | 0.0 | 5.281 | 0.292 | 3.219 | 7.490 | 0.256 |
| 17 | 1.075 | 0.271 | 0.641 | 0.0 | 0.441 | 2.055 | 0.120 | 4.962 | 0.520 |
| 18 | 0.0 | | 24.379 | | 11.445 | | 0.281 | 0.786 | |

Blank Cells=habitats that were not available to an individual
Red Cells=habitats significantly preferred
Green Cells=habitats significantly avoided
1=no preference, <1=avoidance, >1=preference, 0=absolute avoidance

Table 6. Chi-square goodness of fit results for the home range level of pooled individuals ($\chi^2$ = 343.1, df = 8, P = <0.0001) in 2011.

| **Habitat** | | | | **Locations** | | **$\chi^2$** | | |
|---|---|---|---|---|---|---|---|---|
| **Habitat Type** | **Abbr.** | **Hectares** | **Prop** | **Used** | **Expected** | **o-e** | **$(o\text{-}e)^2$** | **$(o\text{-}e)^2/e$** |
| Four-wing Saltbush | SB | 77.1 | 0.248 | 300 | 426 | -126.2 | 15919.0 | 37.4 |
| Creosote | CR | 35.0 | 0.113 | 208 | 193 | 14.8 | 218.0 | 1.1 |
| Disturbed/Vegetated | DV | 15.9 | 0.051 | 165 | 88 | 77.3 | 5968.0 | 68.0 |
| Grassland | GR | 9.3 | 0.030 | 25 | 51 | -26.2 | 686.8 | 13.4 |
| Marsh | MA | 30.3 | 0.098 | 88 | 167 | -79.5 | 6320.0 | 37.7 |
| Mesquite | ME | 41.6 | 0.134 | 264 | 230 | 34.1 | 1164.8 | 5.1 |
| Open | OP | 23.8 | 0.077 | 117 | 131 | -14.4 | 207.0 | 1.6 |
| Riparian Wood | RW | 44.2 | 0.142 | 436 | 244 | 191.9 | 36809.8 | 150.8 |
| Upland Shrub | UP | 33.2 | 0.107 | 112 | 184 | -71.7 | 5147.0 | 28.0 |
| Total | | 310.3 | 1.000 | 1715 | 1715 | 0.0 | 0.0 | 343.1 |

Table 7. Pooled individual selection ratios (Wi), standard error (SE), and upper and lower confidence intervals (CI) for each habitat type in 2011.

| Habitat Type | Abbr. | Wi | SE | Lower CI | Upper CI |
|---|---|---|---|---|---|
| Four-winged Saltbush | SB | 0.968 | 0.294 | 0.153 | 1.783 |
| Creosote | CR | 1.039 | 0.478 | -0.286 | 2.365 |
| Disturbed/Vegetated | DV | 1.176 | 0.510 | -0.238 | 2.591 |
| Grassland | GL | 0.718 | 0.745 | -1.348 | 2.784 |
| Marsh | MA | 0.466 | 0.230 | -0.170 | 1.103 |
| Mesquite | ME | 1.103 | 0.168 | 0.636 | 1.569 |
| Open | OP | 0.951 | 0.341 | 0.004 | 1.897 |
| Riparian Wood | RW | 1.324 | 0.335 | 0.395 | 2.254 |
| Upland Shrub | US | 0.750 | 0.355 | -0.234 | 1.735 |

Table 8. Selection ratios for each habitat type within each snake home range in 2011.

| Snake # | SB | CR | DV | GL | MA | ME | OP | RW | US |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 6.960 | 0.878 | 24.291 | | 0.213 | 2.362 | 0.510 | 2.353 | |
| 7 | 0.283 | 1.756 | 0.414 | 0.066 | 1.573 | 0.059 | 0.089 | 5.482 | 0.0 |
| 8 | 2.690 | 0.0 | 0.0 | | 1.169 | 1.081 | 0.694 | 2.076 | 0.047 |
| 10 | 3.275 | | 0.0 | 0.0 | 1.437 | | 0.379 | 0.904 | |
| 11 | 0.369 | 64.103 | 0.666 | | 0.0 | 1.796 | 0.059 | 0.464 | 2.359 |
| 12 | 75.014 | 0.390 | 1.994 | | 1.949 | 0.965 | 1.685 | 5.681 | 0.784 |
| 13 | 0.381 | 1.322 | | 6.055 | | 2.232 | 0.0 | | 0.253 |
| 14 | 2.069 | 0.0 | 2.194 | | | 1.679 | 0.988 | 0.761 | 0.0 |
| 16 | 0.548 | 11.891 | 0.282 | 0.0 | 0.322 | 0.787 | 2.765 | 3.382 | 1.171 |
| 17 | 0.817 | 0.181 | 0.978 | 0.660 | 0.0 | 0.463 | 0.905 | 7.150 | 1.659 |

Blank Cells=habitats that were not available to an individual
Red Cells=habitats significantly preferred
Green Cells=habitats significantly avoided
1=no preference, <1=avoidance, >1=preference, 0=absolute avoidance

## FIGURES

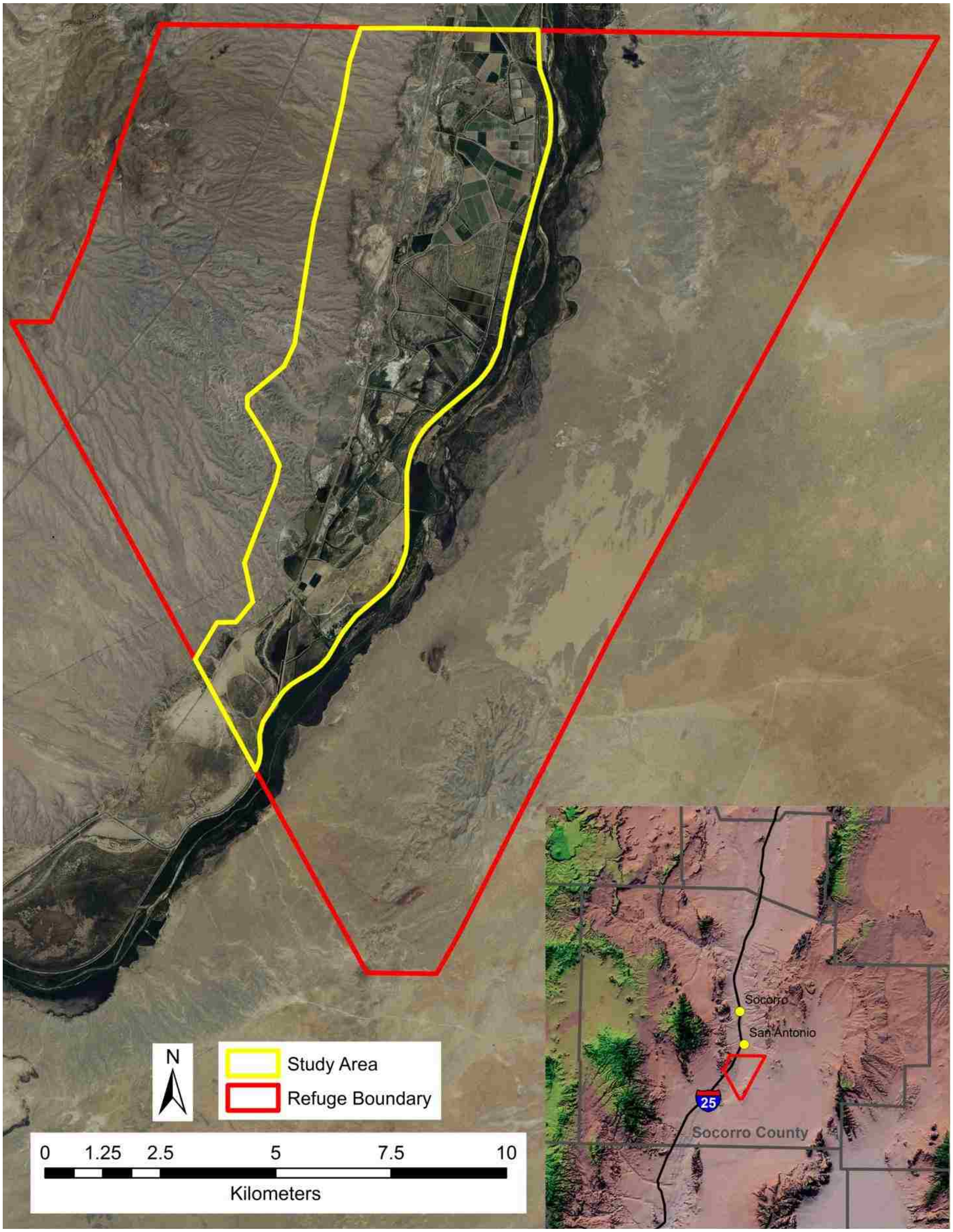

Figure 1. Study area at Bosque del Apache National Wildlife Refuge, New Mexico.

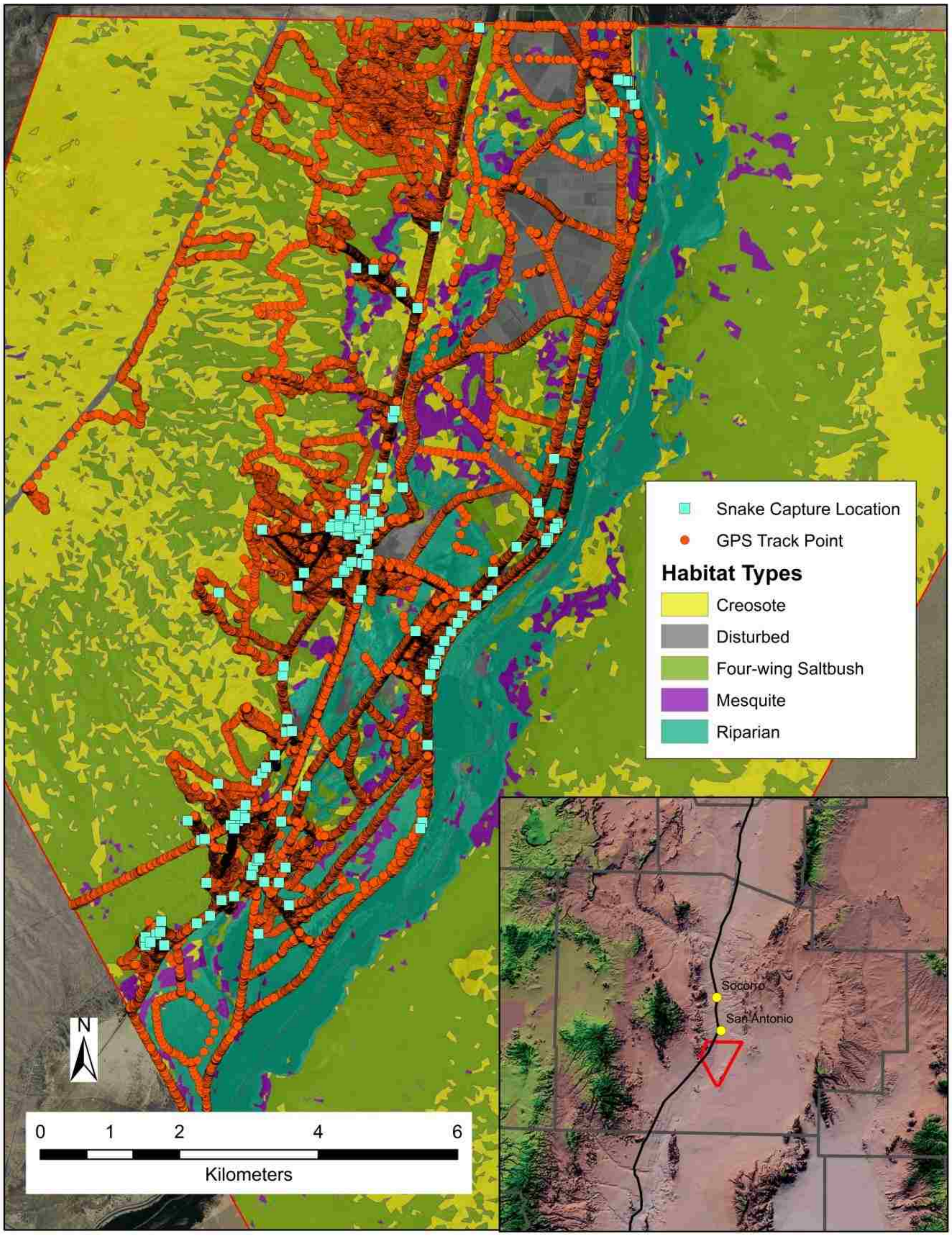


Figure 2. Landscape level habitat types, 350,728 GPS track points, and 235 first time *Crotalus atrox* captures at Bosque del Apache National Wildlife Refuge, New Mexico in 2010 and 2011.

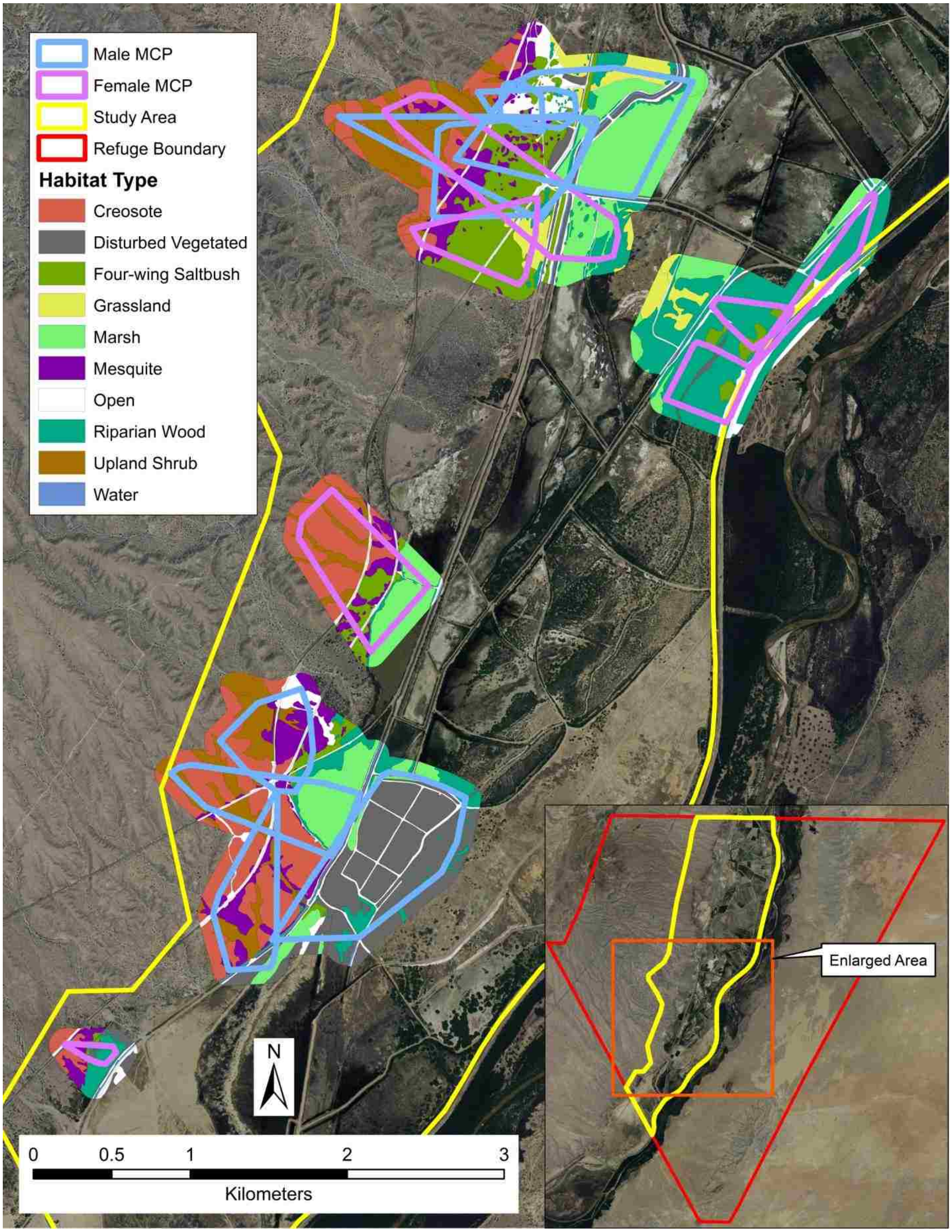


Figure 3. Home range level habitat types and individual *Crotalus atrox* Minimum Convex Polygons at Bosque del Apache National Wildlife Refuge, New Mexico in 2010.

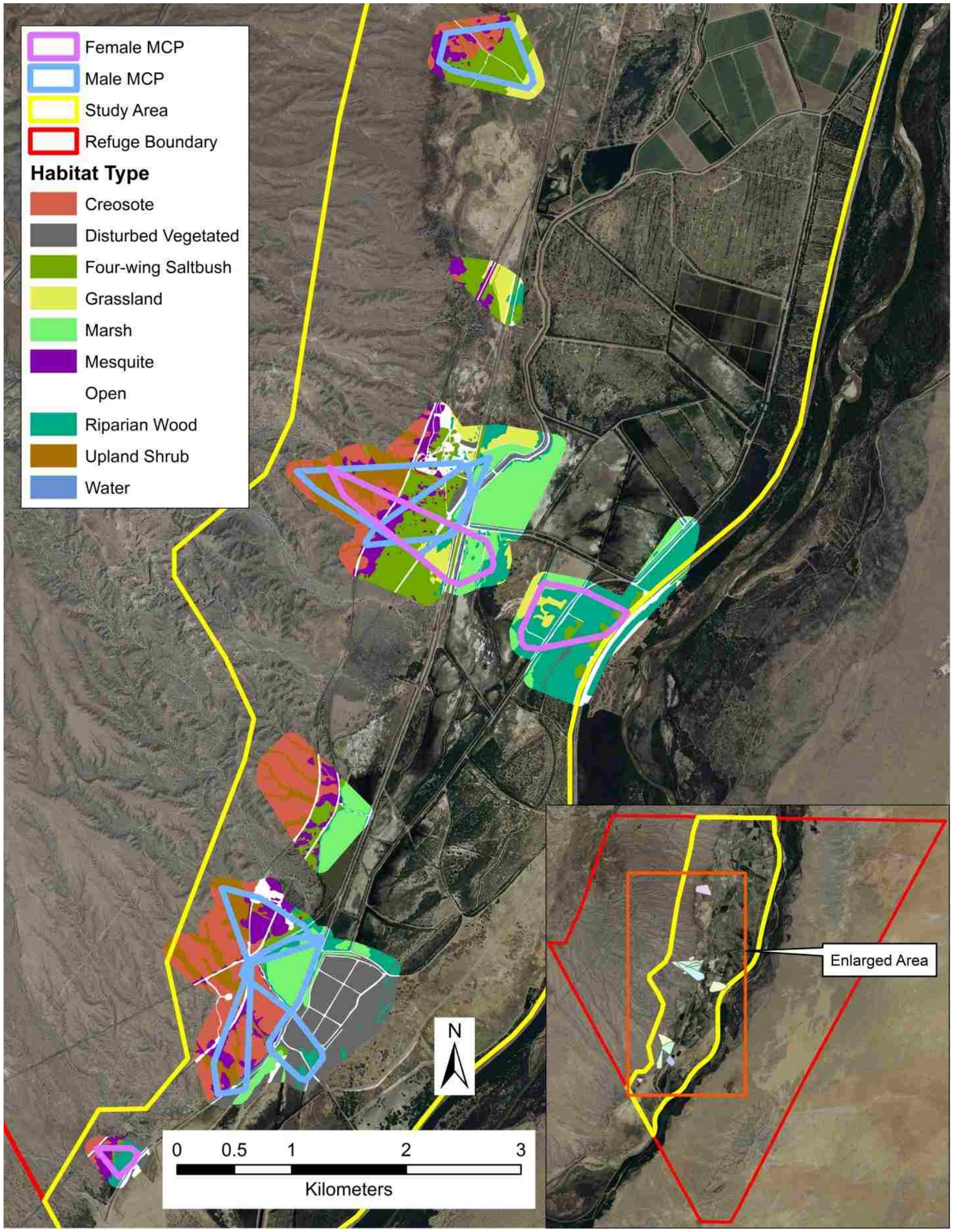


Figure 4. Home range level habitat types and individual *Crotalus atrox* Minimum Convex Polygons at Bosque del Apache National Wildlife Refuge, New Mexico in 2011.

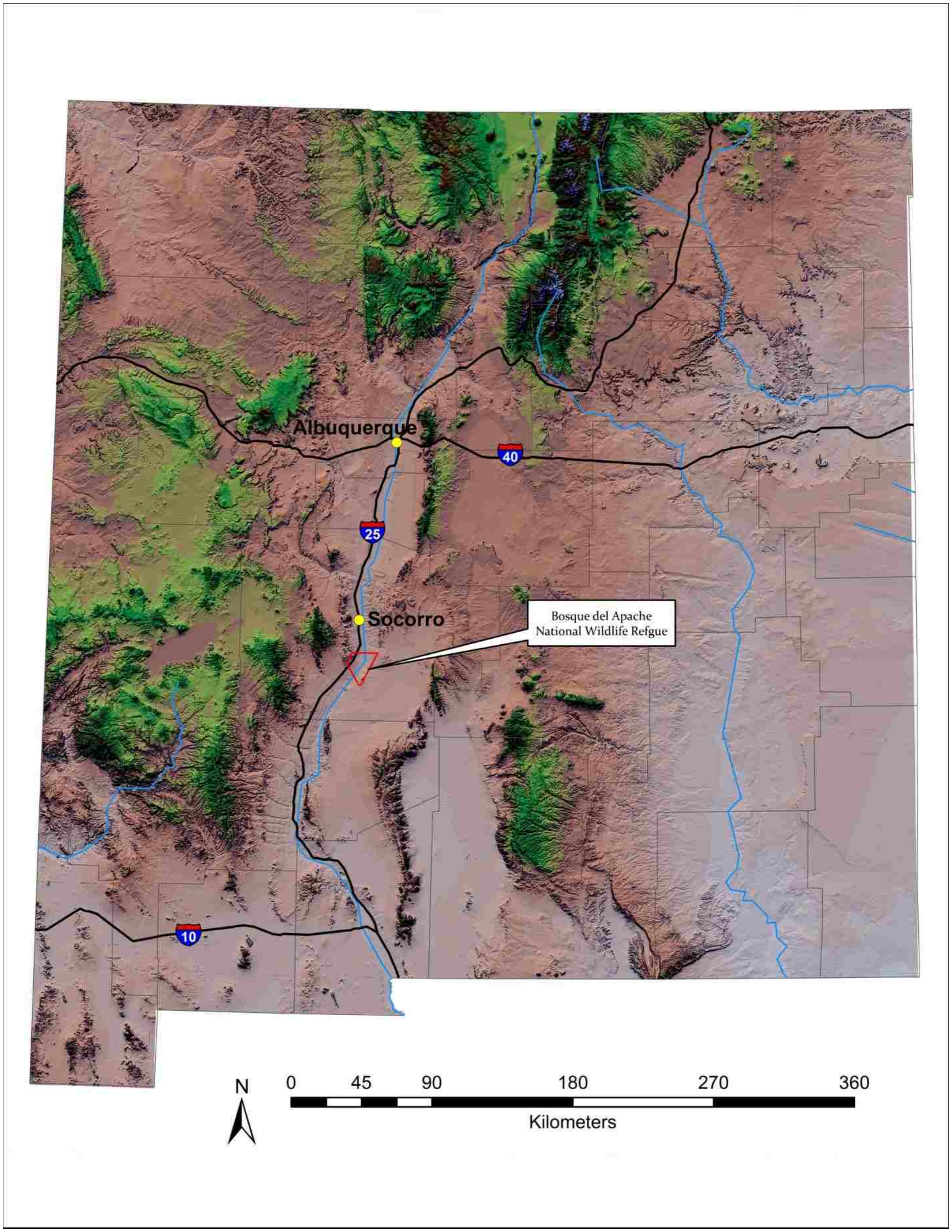

Figure 5. Bosque Del Apache National Wildlife Refuge, located 30 km south of Socorro, New Mexico.

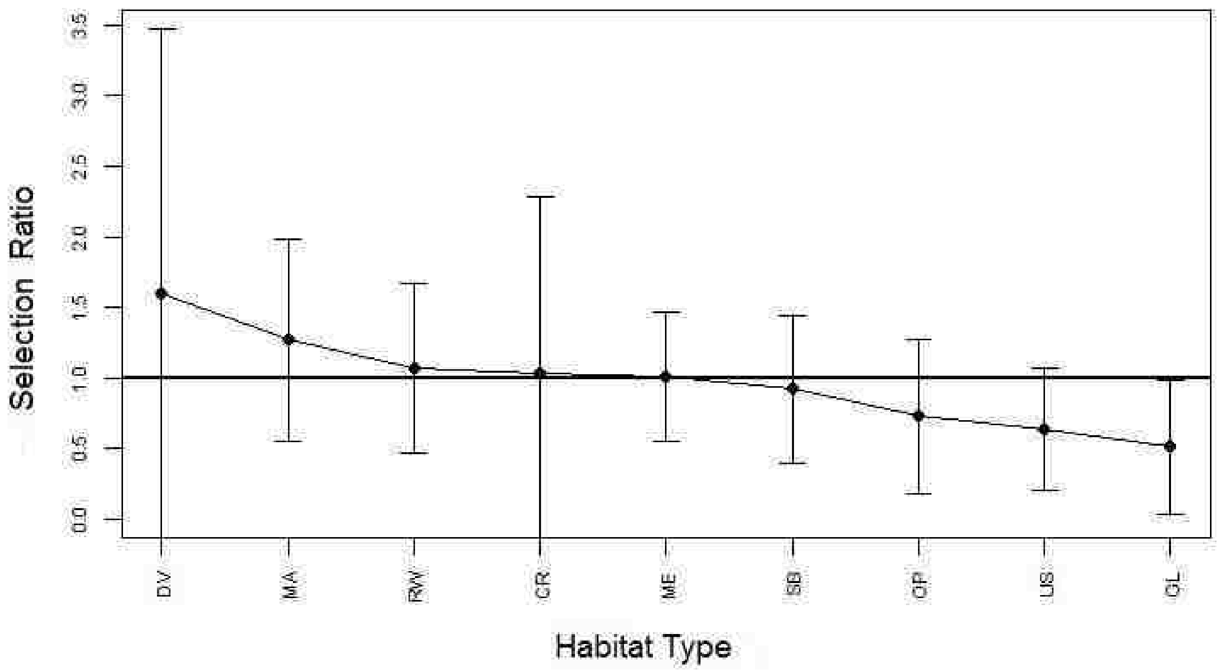

Figure 6. Selection ratios and 95% confidence intervals for each habitat at the home range level, in decreasing order from highest to lowest, at Bosque del Apache National Wildlife Refuge, New Mexico in 2010.

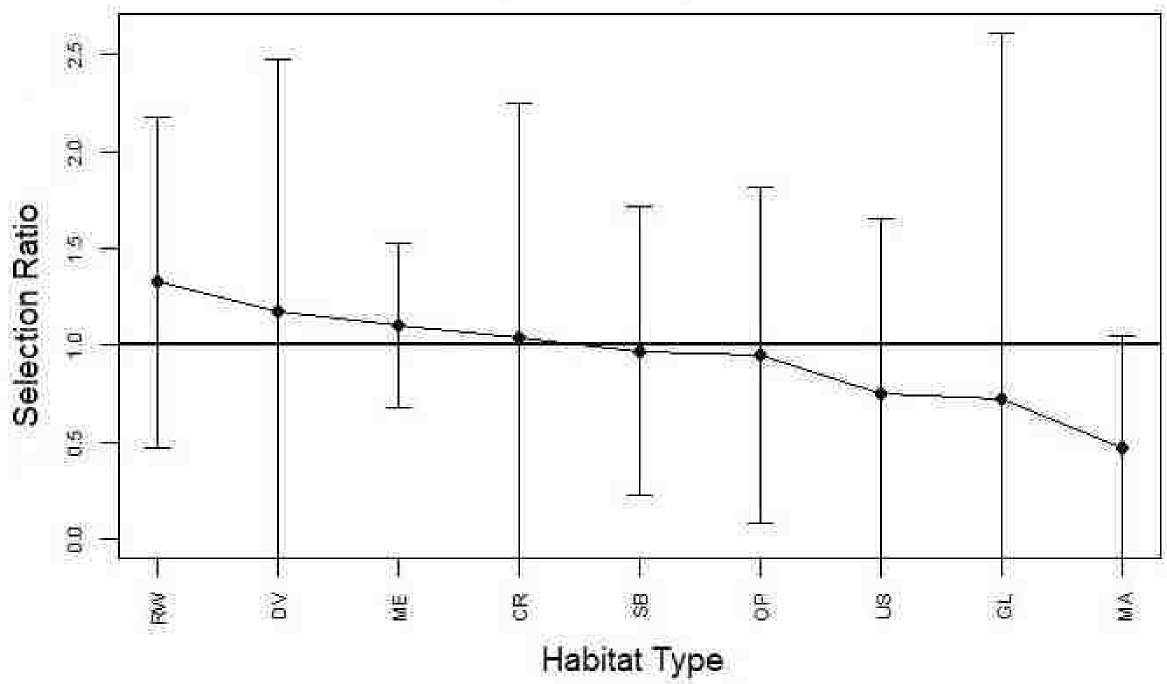


Figure 7.  Selection ratios and 95% confidence interval for each habitat at the home range level, in decreasing ordered from highest to lowest, at Bosque del Apache National Wildlife Refuge, New Mexico in 2011.

**APPENDICES**

Appendix 1. Individual Chi-Square Goodness of fit test at Bosque del Apache National Wildlife Refuge, New Mexico in 2010. Expected values less than five, highlighted in yellow, and the large contribution of those values to the chi-square statistic highlighted in light brown.

| **Habitat/Snakes** | **Area (ha)** | **Area Prop** | **Obs** | **Expected** | **o-e** | **$(o-e)^2$** | **$(o-e)^2/e$** | **$\chi_c^2$** |
|---|---|---|---|---|---|---|---|---|
| Four-wing Saltbush | 0.4 | 0.01 | 4 | 2 | 2 | 5.7 | 3.6 | |
| Creosote | 14.3 | 0.39 | 28 | 57 | -29 | 830.3 | 14.6 | |
| Disturbed/Vegetated | 0.1 | 0.00 | 25 | 0 | 25 | 603.8 | 1412.2 | |
| Marsh | 11.0 | 0.30 | 41 | 44 | -3 | 7.6 | 0.2 | |
| Mesquite | 1.5 | 0.04 | 0 | 6 | -6 | 36.2 | 6.0 | |
| Open | 2.3 | 0.06 | 0 | 9 | -9 | 80.0 | 8.9 | |
| Riparian Wood | 1.2 | 0.03 | 41 | 5 | 36 | 1300.1 | 263.0 | |
| Upland Shrub | 5.7 | 0.16 | 6 | 22 | -16 | 271.6 | 12.1 | |
| **Snake 2** | **36.5** | **1.00** | **145** | **145** | **0** | **0.0** | **1720.6** | **308.4** |
| Four-wing Saltbush | 15.4 | 0.19 | 13 | 17 | -4 | 12.5 | 0.8 | |
| Creosote | 0.8 | 0.01 | 1 | 1 | 0 | 0.0 | 0.0 | |
| Disturbed/Vegetated | 6.0 | 0.08 | 5 | 6 | -1 | 2.1 | 0.3 | |
| Grassland | 3.5 | 0.04 | 2 | 4 | -2 | 3.2 | 0.9 | |
| Marsh | 30.7 | 0.38 | 28 | 33 | -5 | 24.5 | 0.7 | |
| Mesquite | 5.0 | 0.06 | 22 | 5 | 17 | 276.3 | 51.4 | |
| Open | 13.0 | 0.16 | 3 | 14 | -11 | 119.7 | 8.6 | |
| Riparian Wood | 4.2 | 0.05 | 9 | 5 | 4 | 20.2 | 4.5 | |
| Upland Shrub | 1.4 | 0.02 | 3 | 2 | 1 | 2.1 | 1.3 | |
| **Snake 3** | **80.2** | **1.00** | **86** | **86** | **0** | **0.0** | **68.5** | |
| Four-wing Saltbush | 16.2 | 0.66 | 78 | 89 | -11 | 130.4 | 1.5 | |
| Creosote | 0.9 | 0.04 | 18 | 5 | 13 | 163.1 | 31.2 | |
| Grassland | 3.0 | 0.12 | 9 | 17 | -8 | 61.0 | 3.6 | |
| Mesquite | 2.5 | 0.10 | 11 | 14 | -3 | 6.6 | 0.5 | |
| Open | 1.2 | 0.05 | 17 | 7 | 10 | 106.6 | 16.0 | |
| Riparian Wood | 0.6 | 0.03 | 1 | 4 | -3 | 6.4 | 1.8 | |
| Upland Shrub | 0.1 | 0.01 | 2 | 1 | 1 | 1.5 | 2.0 | |
| **Snake 4** | **24.7** | **1.00** | **136** | **136** | **0** | **0.0** | **56.5** | |

Appendix 1. Continued

| Habitat/Snakes | Area (ha) | Area Prop | Obs | Expected | o-e | $(o-e)^2$ | $(o-e)^2/e$ | $\chi_c^2$ |
|---|---|---|---|---|---|---|---|---|
| Four-wing Saltbush | 2.4 | 0.21 | 42 | 21 | 21 | 444.1 | 21.2 | |
| Creosote | 0.6 | 0.05 | 1 | 6 | -5 | 20.7 | 3.7 | |
| Grassland | 0.0 | 0.00 | 4 | 0 | 4 | 15.3 | 182.8 | |
| Mesquite | 1.3 | 0.11 | 30 | 11 | 19 | 353.0 | 31.5 | |
| Open | 6.2 | 0.53 | 19 | 54 | -35 | 1204.0 | 22.4 | |
| Riparian Wood | 0.5 | 0.04 | 3 | 4 | -1 | 2.0 | 0.5 | |
| Upland Shrub | 0.7 | 0.06 | 3 | 6 | -3 | 9.7 | 1.6 | |
| **Snake 5** | **11.7** | **1.00** | **102** | **102** | **0** | **0.0** | **263.6** | **80.9** |
| Four-wing Saltbush | 4.4 | 0.11 | 14 | 16 | -2 | 5.8 | 0.4 | |
| Creosote | 17.3 | 0.44 | 25 | 64 | -39 | 1522.3 | 23.8 | |
| Marsh | 7.2 | 0.18 | 55 | 27 | 28 | 805.7 | 30.3 | |
| Mesquite | 3.8 | 0.10 | 5 | 14 | -9 | 83.0 | 5.9 | |
| Open | 2.0 | 0.05 | 0 | 7 | -7 | 53.9 | 7.3 | |
| Riparian Wood | 0.9 | 0.02 | 14 | 3 | 11 | 114.3 | 34.5 | |
| Upland Shrub | 4.1 | 0.10 | 34 | 15 | 19 | 353.5 | 23.3 | |
| **Snake 6** | **39.8** | **1.00** | **147** | **147** | **0** | **0.0** | **125.4** | **90.9** |
| Four-wing Saltbush | 14.8 | 0.25 | 5 | 50 | -45 | 2034.6 | 40.6 | |
| Creosote | 5.8 | 0.10 | 132 | 20 | 112 | 12631.4 | 644.1 | |
| Disturbed/Vegetated | 1.4 | 0.02 | 1 | 5 | -4 | 14.8 | 3.1 | |
| Grassland | 2.9 | 0.05 | 1 | 10 | -9 | 78.1 | 7.9 | |
| Marsh | 7.5 | 0.13 | 12 | 26 | -14 | 185.2 | 7.2 | |
| Mesquite | 6.7 | 0.12 | 6 | 23 | -17 | 279.7 | 12.3 | |
| Open | 4.2 | 0.07 | 0 | 14 | -14 | 198.7 | 14.1 | |
| Riparian Wood | 4.9 | 0.09 | 32 | 17 | 15 | 232.0 | 13.8 | |
| Upland Shrub | 9.8 | 0.17 | 8 | 33 | -25 | 645.0 | 19.3 | |
| **Snake 7** | **58.0** | **1.00** | **197** | **197** | **0** | **0.0** | **743.2** | |
| Four-wing Saltbush | 1.4 | 0.05 | 14 | 7 | 7 | 44.6 | 6.1 | |
| Creosote | 5.3 | 0.21 | 21 | 28 | -7 | 53.4 | 1.9 | |
| Disturbed/Vegetated | 0.1 | 0.01 | 8 | 1 | 7 | 52.3 | 68.0 | |
| Marsh | 0.0 | 0.00 | 0 | 0 | 0 | 0.0 | 0.1 | |
| Mesquite | 7.8 | 0.31 | 45 | 41 | 4 | 14.6 | 0.4 | |
| Open | 3.4 | 0.13 | 14 | 18 | -4 | 15.7 | 0.9 | |
| Riparian Wood | 0.8 | 0.03 | 10 | 4 | 6 | 35.6 | 8.8 | |
| Upland Shrub | 6.5 | 0.26 | 22 | 34 | -12 | 151.0 | 4.4 | |
| **Snake 8** | **25.2** | **1.00** | **134** | **134** | **0** | **0.0** | **90.6** | **13.7** |

Appendix 1.  Continued

| **Habitat/Snakes** | **Area (ha)** | **Area Prop** | **Obs** | **Expected** | **o-e** | **$(o\text{-}e)^2$** | **$(o\text{-}e)^2/e$** | **$\chi_c^2$** |
|---|---|---|---|---|---|---|---|---|
| Four-wing Saltbush | 1.0 | 0.06 | 9 | 9 | 0 | 0.0 | 0.0 | |
| Disturbed/Vegetated | 0.8 | 0.05 | 6 | 7 | -1 | 1.0 | 0.1 | |
| Open | 1.3 | 0.08 | 31 | 11 | 20 | 397.4 | 35.9 | |
| Riparian Wood | 13.1 | 0.81 | 96 | 115 | -19 | 358.0 | 3.1 | |
| **Snake 9** | **16.2** | **1.00** | **142** | **142** | **0** | **0.0** | **39.2** | |
| Four-wing Saltbush | 1.7 | 0.19 | 11 | 10 | 1 | 0.9 | 0.1 | |
| Open | 0.8 | 0.08 | 28 | 4 | 24 | 552.9 | 123.3 | |
| Riparian Wood | 6.5 | 0.73 | 14 | 38 | -24 | 598.4 | 15.6 | |
| **Snake 10** | **9.0** | **1.00** | **53** | **53** | **0** | **0.0** | **138.9** | **15.6** |
| Four-wing Saltbush | 0.6 | 0.01 | 1 | 1 | 0 | 0.1 | 0.1 | |
| Creosote | 1.4 | 0.02 | 28 | 3 | 25 | 624.4 | 207.2 | |
| Disturbed/Vegetated | 50.9 | 0.74 | 82 | 112 | -30 | 909.7 | 8.1 | |
| Marsh | 3.9 | 0.06 | 13 | 9 | 4 | 20.0 | 2.4 | |
| Mesquite | 1.2 | 0.02 | 4 | 3 | 1 | 1.8 | 0.7 | |
| Open | 7.0 | 0.10 | 2 | 15 | -13 | 179.1 | 11.6 | |
| Riparian Wood | 3.6 | 0.05 | 19 | 8 | 11 | 124.9 | 16.0 | |
| Upland Shrub | 0.1 | 0.00 | 2 | 0 | 2 | 3.5 | 24.8 | |
| **Snake 11** | **68.5** | **1.00** | **151** | **151** | **0** | **0.0** | **270.8** | **38.8** |
| Four-wing Saltbush | 0.0 | 0.00 | 29 | 0 | 29 | 827.8 | 3623.3 | |
| Creosote | 13.0 | 0.45 | 26 | 64 | -38 | 1479.4 | 22.9 | |
| Disturbed/Vegetated | 1.0 | 0.04 | 12 | 5 | 7 | 47.3 | 9.2 | |
| Marsh | 0.4 | 0.01 | 8 | 2 | 6 | 37.8 | 20.4 | |
| Mesquite | 6.3 | 0.22 | 32 | 31 | 1 | 0.3 | 0.0 | |
| Open | 2.4 | 0.08 | 15 | 12 | 3 | 10.9 | 0.9 | |
| Riparian Wood | 0.3 | 0.01 | 4 | 1 | 3 | 6.8 | 4.8 | |
| Upland Shrub | 5.6 | 0.19 | 18 | 28 | -10 | 96.3 | 3.5 | |
| **Snake 12** | **29.1** | **1.00** | **144** | **144** | **0** | **0.0** | **3685.1** | **41.4** |
| Four-wing Saltbush | 0.2 | 0.07 | 0 | 10 | -10 | 91.0 | 9.5 | |
| Creosote | 0.1 | 0.04 | 0 | 6 | -6 | 31.0 | 5.6 | |
| Disturbed/Vegetated | 0.3 | 0.14 | 83 | 19 | 64 | 4033.9 | 207.0 | |
| Mesquite | 0.5 | 0.21 | 20 | 29 | -9 | 88.3 | 3.0 | |
| Open | 0.0 | 0.00 | 3 | 0 | 3 | 8.1 | 53.7 | |
| Riparian Wood | 1.3 | 0.55 | 37 | 78 | -41 | 1715.7 | 21.9 | |
| Upland Shrub | 0.0 | 0.00 | 0 | 0 | 0 | 0.2 | 0.4 | |
| **Snake 14** | **2.4** | **1.00** | **143** | **143** | **0** | **0.0** | **301.1** | **247.4** |

Appendix 1. Continued

| Habitat/Snakes | Area (ha) | Area Prop | Obs | Expected | o-e | $(o-e)^2$ | $(o-e)^2/e$ | $\chi_c^2$ |
|---|---|---|---|---|---|---|---|---|
| Four-wing Saltbush | 1.4 | 0.21 | 46 | 22 | 24 | 563.9 | 25.3 | |
| Creosote | 0.2 | 0.02 | 5 | 2 | 3 | 6.4 | 2.6 | |
| Mesquite | 1.4 | 0.21 | 30 | 22 | 8 | 62.7 | 2.8 | |
| Open | 3.4 | 0.52 | 23 | 54 | -31 | 937.0 | 17.5 | |
| Riparian Wood | 0.1 | 0.01 | 0 | 1 | -1 | 0.7 | 0.8 | |
| Upland Shrub | 0.2 | 0.03 | 0 | 3 | -3 | 7.6 | 2.8 | |
| **Snake 15** | **6.6** | **1.00** | **104** | **104** | **0** | **0.0** | **51.8** | |
| Four-wing Saltbush | 22.5 | 0.43 | 15 | 49 | -34 | 1168.2 | 23.8 | |
| Creosote | 5.0 | 0.09 | 3 | 11 | -8 | 60.9 | 5.6 | |
| Disturbed/Vegetated | 2.1 | 0.04 | 3 | 4 | -1 | 2.2 | 0.5 | |
| Grassland | 0.2 | 0.00 | 0 | 0 | 0 | 0.2 | 0.5 | |
| Marsh | 1.9 | 0.04 | 22 | 4 | 18 | 318.0 | 76.3 | |
| Mesquite | 11.0 | 0.21 | 7 | 24 | -17 | 288.5 | 12.0 | |
| Open | 4.6 | 0.09 | 32 | 10 | 22 | 486.5 | 48.9 | |
| Riparian Wood | 1.9 | 0.04 | 31 | 4 | 27 | 721.5 | 174.3 | |
| Upland Shrub | 3.6 | 0.07 | 2 | 8 | -6 | 33.7 | 4.3 | |
| **Snake 16** | **52.7** | **1.00** | **115** | **115** | **0** | **0.0** | **346.3** | **95.7** |
| Four-wing Saltbush | 18.6 | 0.33 | 41 | 38 | 3 | 8.1 | 0.2 | |
| Creosote | 7.2 | 0.13 | 4 | 15 | -11 | 116.0 | 7.9 | |
| Disturbed/Vegetated | 2.3 | 0.04 | 3 | 5 | -2 | 2.8 | 0.6 | |
| Grassland | 0.1 | 0.00 | 0 | 0 | 0 | 0.0 | 0.2 | |
| Marsh | 2.2 | 0.04 | 2 | 5 | -3 | 6.4 | 1.4 | |
| Mesquite | 6.9 | 0.12 | 29 | 14 | 15 | 221.7 | 15.7 | |
| Open | 4.1 | 0.07 | 1 | 8 | -7 | 54.0 | 6.5 | |
| Riparian Wood | 2.1 | 0.04 | 21 | 4 | 17 | 281.2 | 66.4 | |
| Upland Shrub | 12.2 | 0.22 | 13 | 25 | -12 | 144.0 | 5.8 | |
| **Snake 17** | **55.7** | **1.00** | **114** | **114** | **0** | **0.0** | **104.6** | **38.2** |
| Four-wing Saltbush | 0.7 | 0.06 | 0 | 7 | -7 | 44.4 | 6.7 | |
| Disturbed/Vegetated | 0.2 | 0.01 | 39 | 2 | 37 | 1398.8 | 874.4 | |
| Marsh | 0.1 | 0.01 | 8 | 1 | 7 | 53.3 | 76.3 | |
| Open | 3.4 | 0.29 | 9 | 32 | -23 | 532.7 | 16.6 | |
| Riparian Wood | 7.4 | 0.63 | 55 | 70 | -15 | 223.8 | 3.2 | |
| **Snake 18** | **11.8** | **1.00** | **111** | **111** | **0** | **0.0** | **977.1** | **26.5** |

Appendix 2. Individual Chi-Square Goodness of Fit test at Bosque del Apache National Wildlife Refuge, New Mexico in 2011. Expected values less than five, highlighted in yellow, and the large contribution of those values to the chi-square statistic highlighted in light brown.

| **Habitat/Snakes** | **Area (ha)** | **Area Prop** | **Obs** | **Expected** | **o-e** | **$(o-e)^2$** | **$(o-e)^2/e$** | **$\chi_c^2$** |
|---|---|---|---|---|---|---|---|---|
| Four-wing Saltbush | 0.4 | 0.02 | 23 | 3 | 20 | 387.9 | 117.4 | |
| Creosote | 3.1 | 0.12 | 21 | 24 | -3 | 8.6 | 0.4 | |
| Disturbed/Vegetated | 0.2 | 0.01 | 46 | 2 | 44 | 1945.4 | 1027.3 | |
| Marsh | 16.4 | 0.64 | 27 | 127 | -100 | 9960.7 | 78.6 | |
| Mesquite | 1.0 | 0.04 | 19 | 8 | 11 | 120.0 | 14.9 | |
| Open | 1.3 | 0.05 | 5 | 10 | -5 | 23.0 | 2.4 | |
| Riparian Wood | 3.1 | 0.12 | 57 | 24 | 33 | 1074.1 | 44.3 | |
| **Snake 2** | **25.6** | **1.00** | **198** | **198** | **0** | **0.0** | **1285.2** | **257.9** |
| Four-wing Saltbush | 12.2 | 0.26 | 11 | 39 | -28 | 778.1 | 20.0 | |
| Creosote | 6.3 | 0.13 | 35 | 20 | 15 | 227.1 | 11.4 | |
| Disturbed/Vegetated | 1.5 | 0.03 | 2 | 5 | -3 | 8.0 | 1.7 | |
| Grassland | 4.7 | 0.10 | 1 | 15 | -14 | 198.7 | 13.2 | |
| Marsh | 6.6 | 0.14 | 33 | 21 | 12 | 144.4 | 6.9 | |
| Mesquite | 5.3 | 0.11 | 1 | 17 | -16 | 255.7 | 15.0 | |
| Open | 3.5 | 0.07 | 1 | 11 | -10 | 104.5 | 9.3 | |
| Riparian Wood | 3.8 | 0.08 | 66 | 12 | 54 | 2911.9 | 241.9 | |
| Upland Shrub | 3.1 | 0.07 | 0 | 10 | -10 | 100.2 | 10.0 | |
| **Snake 7** | **47.1** | **1.00** | **150** | **150** | **0** | **0.0** | **329.4** | |
| Four-wing Saltbush | 2.4 | 0.09 | 43 | 16 | 27 | 729.7 | 45.6 | |
| Creosote | 1.3 | 0.05 | 0 | 9 | -9 | 73.5 | 8.6 | |
| Disturbed/Vegetated | 0.1 | 0.01 | 0 | 1 | -1 | 0.9 | 0.9 | |
| Marsh | 2.1 | 0.07 | 16 | 14 | 2 | 5.3 | 0.4 | |
| Mesquite | 8.9 | 0.32 | 63 | 58 | 5 | 22.4 | 0.4 | |
| Open | 3.3 | 0.12 | 15 | 22 | -7 | 43.9 | 2.0 | |
| Riparian Wood | 3.2 | 0.12 | 44 | 21 | 23 | 520.1 | 24.5 | |
| Upland Shrub | 6.5 | 0.23 | 2 | 43 | -41 | 1657.9 | 38.8 | |
| **Snake 8** | **28.0** | **1.00** | **183** | **183** | **0** | **0.0** | **121.3** | |
| Four-wing Saltbush | 2.8 | 0.08 | 45 | 14 | 31 | 977.1 | 71.1 | |
| Disturbed/Vegetated | 0.2 | 0.01 | 0 | 1 | -1 | 1.4 | 1.2 | |
| Grassland | 2.8 | 0.08 | 0 | 14 | -14 | 189.9 | 13.8 | |
| Marsh | 0.9 | 0.03 | 6 | 4 | 2 | 3.3 | 0.8 | |
| Open | 2.2 | 0.06 | 4 | 11 | -7 | 42.9 | 4.1 | |
| Riparian Wood | 24.9 | 0.74 | 109 | 121 | -12 | 133.7 | 1.1 | |
| **Snake 10** | **33.9** | **1.00** | **164** | **164** | **0** | **0.0** | **92.1** | |

Appendix 2. Continued

| Habitat/Snakes | Area (ha) | Area Prop | Obs | Expected | o-e | o-e$^2$ | o-e$^2$/e | $\chi_c^2$ |
|---|---|---|---|---|---|---|---|---|
| Four-wing Saltbush | 0.5 | 0.03 | 2 | 5 | -3 | 11.7 | 2.2 | |
| Creosote | 0.1 | 0.01 | 66 | 1 | 65 | 4221.2 | 4099.8 | |
| Disturbed/Vegetated | 8.9 | 0.59 | 63 | 95 | -32 | 996.5 | 10.5 | |
| Marsh | 0.4 | 0.03 | 0 | 5 | -5 | 21.1 | 4.6 | |
| Mesquite | 0.7 | 0.05 | 14 | 8 | 6 | 38.5 | 4.9 | |
| Open | 1.6 | 0.11 | 1 | 17 | -16 | 256.0 | 15.1 | |
| Riparian Wood | 2.8 | 0.19 | 14 | 30 | -16 | 261.3 | 8.7 | |
| Upland Shrub | 0.0 | 0.00 | 1 | 0 | 1 | 0.3 | 0.8 | |
| **Snake 11** | **15.2** | **1.00** | **161** | **161** | **0** | **0.0** | **4146.6** | **46.7** |
| Four-wing Saltbush | 0.0 | 0.00 | 33 | 0 | 0 | 1060.2 | 2409.9 | |
| Creosote | 8.0 | 0.41 | 32 | 82 | -50 | 2505.4 | 30.5 | |
| Disturbed/Vegetated | 0.7 | 0.04 | 15 | 8 | 7 | 55.9 | 7.4 | |
| Marsh | 0.1 | 0.00 | 1 | 1 | 0 | 0.2 | 0.5 | |
| Mesquite | 4.8 | 0.24 | 47 | 49 | -2 | 2.9 | 0.1 | |
| Open | 1.6 | 0.08 | 27 | 16 | 11 | 120.5 | 7.5 | |
| Riparian Wood | 0.2 | 0.01 | 12 | 2 | 10 | 97.8 | 46.3 | |
| Upland Shrub | 4.4 | 0.22 | 35 | 45 | -10 | 93.0 | 2.1 | |
| **Snake 12** | **19.8** | **1.00** | **202** | **202** | **0** | **0.0** | **205.9** | **92.3** |
| Four-wing Saltbush | 17.4 | 0.57 | 27 | 71 | -44 | 1928.9 | 27.2 | |
| Creosote | 6.3 | 0.21 | 34 | 26 | 8 | 68.4 | 2.7 | |
| Grassland | 0.9 | 0.03 | 23 | 4 | 19 | 368.7 | 97.1 | |
| Mesquite | 4.4 | 0.14 | 40 | 18 | 22 | 487.5 | 27.2 | |
| Open | 0.7 | 0.02 | 0 | 3 | -3 | 7.1 | 2.7 | |
| Upland Shrub | 1.0 | 0.03 | 1 | 4 | -3 | 8.8 | 2.2 | |
| **Snake 13** | **30.6** | **1.00** | **125** | **125** | **0** | **0.0** | **159.0** | **61.9** |
| Four-wing Saltbush | 0.2 | 0.05 | 17 | 8 | 9 | 77.2 | 9.4 | |
| Creosote | 0.5 | 0.09 | 0 | 15 | -15 | 236.2 | 15.4 | |
| Disturbed/Vegetated | 0.4 | 0.08 | 32 | 15 | 17 | 303.3 | 20.8 | |
| Mesquite | 0.8 | 0.15 | 44 | 26 | 18 | 316.8 | 12.1 | |
| Open | 0.0 | 0.01 | 1 | 1 | 0 | 0.0 | 0.0 | |
| Riparian Wood | 3.1 | 0.61 | 81 | 106 | -25 | 644.9 | 6.1 | |
| Upland Shrub | 0.1 | 0.02 | 0 | 3 | -3 | 10.4 | 3.2 | |
| **Snake 14** | **5.1** | **1.00** | **175** | **175** | **0** | **0.0** | **66.9** | |

Appendix 2. Continued

| Habitat/Snake | Area (ha) | Area Prop | Obs | Expected | o-e | o-e$^2$ | o-e$^2$/e | $\chi_c^2$ |
|---|---|---|---|---|---|---|---|---|
| Four-wing Saltbush | 17.7 | 0.52 | 53 | 97 | -44 | 1913.9 | 19.8 | |
| Creosote | 0.2 | 0.01 | 16 | 1 | 15 | 214.8 | 159.6 | |
| Disturbed/Vegetated | 1.9 | 0.06 | 3 | 11 | -8 | 58.2 | 5.5 | |
| Grassland | 0.1 | 0.00 | 0 | 1 | -1 | 0.4 | 0.6 | |
| Marsh | 2.8 | 0.08 | 5 | 16 | -11 | 111.3 | 7.2 | |
| Mesquite | 5.8 | 0.17 | 25 | 32 | -7 | 45.6 | 1.4 | |
| Open | 3.2 | 0.10 | 49 | 18 | 31 | 978.2 | 55.2 | |
| Riparian Wood | 1.8 | 0.05 | 33 | 10 | 23 | 540.3 | 55.4 | |
| Upland Shrub | 0.2 | 0.00 | 1 | 1 | 0 | 0.0 | 0.0 | |
| **Snake 16** | **33.9** | **1.00** | **185** | **185** | **0** | **0.0** | **304.7** | **145.1** |
| Four-wing Saltbush | 23.3 | 0.33 | 46 | 56 | -10 | 106.5 | 1.9 | |
| Creosote | 9.2 | 0.13 | 4 | 22 | -18 | 329.5 | 14.9 | |
| Disturbed/Vegetated | 1.7 | 0.02 | 4 | 4 | 0 | 0.0 | 0.0 | |
| Grassland | 0.6 | 0.01 | 1 | 2 | -1 | 0.3 | 0.2 | |
| Marsh | 1.0 | 0.01 | 0 | 2 | -2 | 6.2 | 2.5 | |
| Mesquite | 9.8 | 0.14 | 11 | 24 | -13 | 163.3 | 6.9 | |
| Open | 6.4 | 0.09 | 14 | 15 | -1 | 2.1 | 0.1 | |
| Riparian Wood | 1.2 | 0.02 | 20 | 3 | 17 | 295.9 | 105.8 | |
| Upland Shrub | 17.9 | 0.25 | 72 | 43 | 29 | 817.8 | 18.8 | |
| **Snake 17** | **71.1** | **1.00** | **172** | **172** | **0** | **0.0** | **151.1** | **45.3** |

Appendix 3. Individual snake data-release, ingress, egress, and mortality dates from Bosque del Apache National Wildlife Refuge, New Mexico in 2009, 2010, and 2011.

| **Snake #** | **Gender** | **Release Date** | **Ingress 2010** | **Egress 2011** | **Ingress 2011** | **Mortality Date** |
|---|---|---|---|---|---|---|
| 1 | Male | 28 Jul 10 | N/A | N/A | N/A | 21 Aug 10 |
| 2 | Male | 30 May 10 | 24 Oct | 20 Mar | 23 Oct | Aug 12 |
| 3 | Male | 26 Jul 10 | 19 Oct | 16 Apr | N/A | 26 Jun 11 |
| 4 | Female | 18 Jun 10 | 1 Nov | 20 Mar | N/A | 26 Mar 11 |
| 5 | Male | 20 Jul 10 | 7 Nov | 9 Apr | N/A | 19 Jun 11 |
| 6 | Female | 30 May 10 | 26 Oct | 16 Mar | N/A | 7 May 11 |
| 7 | Female | 14 Sep 09 | 1 Nov | 23 Apr | N/A | 7 Oct 11 |
| 8 | Male | 1 Jun 10 | 14 Oct | 8 Apr | 30 Oct | UNK-12 |
| 9 | Female | 1 Jun 10 | 25 Oct | N/A | N/A | Feb 11 |
| 10 | Female | 29 Aug 10 | 20 Oct | 23Apr | 4 Oct | N/A |
| 11 | Male | 1 Jun 10 | 9 Nov | 22 May | 31 Oct | N/A |
| 12 | Male | 30 May 10 | 26 Oct | 8 Apr | 19 Nov | N/A |
| 13 | Male | 30 Aug 10 | 1 Oct | 29 May | 30 Sep | N/A |
| 14 | Female | 30 May 10 | 26 Oct | 19 Mar | 14 Oct | N/A |
| 15 | Male | 20 Jul 10 | 10 Nov | N/A | N/A | 10 Mar 11 |
| 16 | Male | 15 Jul 10 | 21 Nov | 19 Mar | 12 Oct | N/A |
| 17 | Male | 4 Jul 10 | 25 Oct | 7 May | 25 Oct | UNK-12 |
| 18 | Female | 28 Jul 10 | 19 Oct | N/A | N/A | Feb 11 |

Appendix 4. Individual snake data-number of observations, size of Minimum Convex Polygon (MCP), and number of habitats available and used in Bosque del Apache National Wildlife Refuge, New Mexico in 2010, and 2011.

| **Snake #** | **# Locations** | **MCP (ha)** | **# Hab Avail** | **# Hab Used** | **# Locations** | **MCP (ha)** | **# Hab Avail** | **# Hab Used** |
|---|---|---|---|---|---|---|---|---|
| | 2010 | | | | 2011 | | | |
| 2 | 145 | 36.5 | 8 | 6 | 198 | 25.6 | 7 | 7 |
| 3 | 86 | 81.3 | 9 | 9 | N/A | N/A | N/A | N/A |
| 4 | 136 | 24.7 | 7 | 7 | N/A | N/A | N/A | N/A |
| 5 | 109 | 11.7 | 7 | 7 | N/A | N/A | N/A | N/A |
| 6 | 147 | 39.8 | 7 | 6 | N/A | N/A | N/A | N/A |
| 7 | 197 | 58.5 | 9 | 8 | 150 | 47.6 | 9 | 8 |
| 8 | 134 | 25.2 | 8 | 7 | 183 | 28.0 | 8 | 6 |
| 9 | 142 | 16.5 | 4 | 4 | N/A | N/A | N/A | N/A |
| 10 | 53 | 9.0 | 3 | 3 | 164 | 34.2 | 6 | 4 |
| 11 | 151 | 69.3 | 8 | 8 | 161 | 15.6 | 8 | 7 |
| 12 | 144 | 29.3 | 8 | 8 | 202 | 20.0 | 8 | 7 |
| 13 | 33 | 4.5 | N/A | N/A | 125 | 30.6 | 6 | 5 |
| 14 | 143 | 2.4 | 7 | 4 | 175 | 5.1 | 7 | 5 |
| 15 | 104 | 6.6 | 6 | 4 | N/A | N/A | N/A | N/A |
| 16 | 115 | 52.9 | 9 | 8 | 185 | 34.0 | 9 | 8 |
| 17 | 114 | 55.9 | 9 | 8 | 172 | 71.0 | 9 | 8 |
| 18 | 111 | 12.5 | 5 | 4 | N/A | N/A | N/A | N/A |