Bobcats in Tucson

A Study of Bobcats Living Along the Urban/ Wildlands Interface

Final Report

November of 2024

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With Margaret Mercer, Jesse Allston, and Alexandra Diane Burnette

PREFACE AND ACKNOWLEDGEMENTS

The initial team for the Bobcats in Tucson Project (BIT) consisted of 5 Arizona Game and Fish retirees: Cheryl Mollohan Al LeCount, Kerry Baldwin, Ron Day, and Dave Brown, who brought to the project over 130 years of combined service with the Arizona Game and Fish Department and almost 200 years of professional wildlife experience in research, animal capture, management, and education. The Southwest Wildlife Conservation Center with then Director Linda Searles agreed to sponsor the project under their 501-C Non-Profit Status. Robert Davis, of Arizona GIS, agreed to provide the Geographic Information Systems and mapping and analysis expertise. Robert's efforts allowed us to provide "personalized" maps to Tucsonans who contacted us with bobcat locations and other information. This contributed greatly to solidifying interest in bobcats in Tucson and support for the project. The Arizona Exotic Animal Hospital, with co-owners Dr. Ericka Johnson and Dr. Jay Johnson agreed to provide veterinary services at captures which included administering and storing the drugs used to immobilize the bobcats during handling and radio collaring. Veterinarians who assisted with handling of captured bobcats included Dr. Ericka Johnson, Dr. Erica Giles, Dr. Lacey Klein, and Dr. Greg Walth. Their expertise was invaluable.

Everyone involved with the BIT project volunteered their time and expertise. It was a remarkable team coming together to work for bobcats, science, and the residents of Tucson.

We submitted our proposal to the Arizona Game and Fish Heritage Urban Wildlife Grant Program for just under $34,000 in the fall of 2019. It was approved in the spring of 2020 and in November we captured, and radio collared our first Tucson urban bobcats. The original $34,000 paid for nine satellite radio collars and ten bobcat capture cages custom designed for bobcat research by Ron Day. Over the course of the next three years, we captured a total of 56 different bobcats on 68 occasions, and radio collared 38.

Individuals and organizations donated funds and supported the project in many ways. Almost $82,000 in funds combined were donated from Tucson Vice Mayor Kevin Dahl's office, Safari Club International of Arizona, the Southwest Wildlife Conservation Center, Marleigh Fletcher, Gale Sherman, Kerry Baldwin, and others. The BIT team donated over 19,000 vehicle miles and almost 4000 person hours. Along the way, we also added additional BIT team members: Gale Sherman became our photographer, website manager, and a great advocate for bobcats in Tucson, Charlie and Jennifer Turner joined the group and contributed in many ways and Karen Dotson became BIT's voice and advocate on the "Nextdoor", an app for neighborhood communication that included residents living in the study area.

We successfully collaborated with three graduate students and their major advisors, all of which strengthened and broadened our base of understandings about Tucson bobcats: then doctoral degree student Natalie Payne (now Dr. Payne) and Dr. Melanie Culver used DNA and other samples we collected during bobcat capture and handling to complete the genetic kinship analysis and virus analysis of the Tucson bobcat population, doctoral degree student Alexandra Diane Burnette (now Dr. Burnette) with advisor Dr. Michael Bogan completed the food habits analysis, and Master's degree student Margaret Mercer with Dr. Jesse Allston completed a Bobcats and Roads analysis. These collaborations all strengthened the Project overall and broadened our base of understanding about Tucson bobcats.

Rick Wheeler, artist and then Tucson resident graciously donated the beautiful bobcat artwork for the BIT logo.

Many Tucsonans (in no particular order) made the BIT Project stronger through their support and participation: John R. Gentile and Katie Iverson, Dan Weisz, Jerry Rowlette, Pete Pfeiffe, Doris Evans, Mary Nichols, Chris Wesselman, Alice Roe, Henry Brean, Tony Paniagua, Hans and Anne Huth, Charlotte Ackerman, Sherri Ferguson, Carol Sullivan, Valerie Greenhill, Colleen Lienhard, Larry Venable, Gregg Townsend, Terry Lutrick, Michael Virnig, Charles Schultz, Lizzy Weeks, Shaye Ericksen, Diane Shifflett, Natalie Georgalas, Kom Loh, John O'Hanlon, Lucy Sampogna, Eric Aldrich, Lynn and Marty Badegian, Kristin Terpening and Shannon Breslin, Michael and Priscilla Baldwin, Elizabeth Taylor, Tracy Carstensen, David Chipman, Diane Huntsinger, Gay

Gilbert, Doug Engelbert and Dahlia Lee, Romy Fouad, Cathy and Lance Wilson, Terry Hyer, Ade and Butch Hughes, Jan and Kevin Hyneman, Jamie Haas, Sarah Davis, Ian Milliken, Joan Watson and Katie Ray, Judy Constantine, Roni Bader-Tables, Doris Northrop, Nancy and Fe Tom, Alex Brinker and Sue Engle, Kathy and Terry McLean, and Pam Parrish, Arron Arzoumanian and Agnes Maina. And the hundreds of others not mentioned by name here who contributed bobcat sightings, social media posts, and other types of support to the Project.

Many citizen scientists and other Tucsonans provided support, including providing bobcat activity reports (over 1300), permission to capture bobcats on their property, and social media posts, and letters.

This report is dedicated to the residents (2 and 4-legged) of Tucson…and to the two invaluable team members and friends we lost during the study…Dave Brown and Kerry Baldwin.

A Bobcat Mother Nurses Her Kitten in a Tucson Backyard

As a group, wild cats are the most highly evolved of carnivores with numerous specialized adaptations to help them capture prey (Sunquist and Sunquist 2002). Of the 38 species of wild cats in the world, only 11, which includes the bobcat *(Lynx rufus)*, are considered by the IUCN Cat Group as a species of "least concern" relative to its potential for endangerment. Arizona bobcats are numerous and widespread across the state and thrive in a variety of habitats, including residential backyards. The experience of watching a bobcat hunting or quietly napping in the shade, or a female raising kittens provides a remarkably high quality and unique watchable wildlife opportunity in Arizona.

Bobcats are solitary obligate carnivores with a strong reliance on natural prey, especially rabbits. They are much less likely to be involved in direct conflicts with humans as more omnivorous carnivores such as coyotes *(Canis latrans)* or raccoons *(Procyon lotor)* (Gehrt et al. 2010), since bobcats rarely scavenge prey killed by other animals or eat human leftovers or garbage. However, individuals or homeowners encountering bobcats in an urban situation may still react in a fearful or negative way, especially if they have little information or knowledge about bobcats.

Increasingly bobcats are utilizing urban habitats (Gehrt et al. 2010). Between 2015 and October 2, 2019, the Arizona Game and Fish Department recorded 11,234 calls in Maricopa and Pima counties in the Wildlife Conflicts Database, with 1,375 calls focusing on bobcats (A. Howard, AZGFD, Personal Communication) and showing an increasing trend. Crooks (2002) considered bobcats to be intermediate in their sensitivity to fragmentation of natural habitats, between coyotes that routinely utilize highly fragmented habitats with patch sizes less than 1 km. sq. and mountain lions *(Puma concolor)* which he classified as extremely sensitive to the loss and fragmentation of habitat and requiring patch sizes >100 km. sq.

Reports of bobcat females raising kittens in highly urbanized environments are becoming more common (Craddock et al. 2010, Riley et. al. 2010). Kellert (1996) reported that mammalian carnivores, while often controversial, generate public interest and are often the focus of conservation efforts.

Utilizing data collected from radio collared bobcats that utilize urban habitats to identify and address potential conflicts and concerns can help to mitigate such conflicts and concerns, and increase appreciation for this remarkable wild cat.

Fifty-six different bobcats were captured along the urban/wildlands interface on the west side of Tucson, Arizona, between November 2020 and December of 2023. Thirty-eight were fitted with satellite-enabled GPS radio collars that provided over 53,000 locations. We utilized the locations generated to evaluate habitat use and selection of urban versus wildlands habitats, use of travel ways and corridors, selection for denning and kitten rearing habitat and mortality. Twelve radio collared bobcats died during the study, all from human related activities except one unknown. Over 1,250 bobcat activity reports were collected from citizen scientists, most reported on bobcat activity at their home or property. In addition, 1,500 Tucsonans completed the “Living with Bobcats” Attitude and Values Survey on the Bobcats in Tucson study website, providing insight into the public’s perceptions and perspectives on living closely with bobcats.

STUDY OBJECTIVE:

Develop strategies, educational programs, and materials to reduce the risk of conflict, and increase homeowner, neighborhood, city and statewide appreciation of bobcats as watchable wildlife, and add to the knowledge of urban bobcats

STUDY GOALS:

Use habitat selection and use data from radio collared bobcats utilizing urban and adjacent wildland habitats to:

Determine annual survival, mortality causes, and home range size of bobcats using the urban/wildlands interface.

Evaluate bobcat habitat use and selection at the urban/wildlands interface.

Identify bobcat natal dens and kitten rearing habitat.

Increase homeowner, neighborhood, city, and statewide level appreciation of bobcats as watchable wildlife

STUDY AREA

Tucson is the second largest city in Arizona, encompassing 227 mi^2 (587 km^2). The city sits in a Sonoran Desert basin surrounded by five mountain ranges, the Santa Catalinas, the Tortolitas, Santa Ritas, Rincons, and Tucson mountains. Several major and numerous small washes extend out from these mountains ending at the Santa Cruz River. Vegetation consists of a variety of cactus species, diverse annual and perennial forbs, and shrubby species overlaid by Mesquites (*Prosopis sp.)* and Palo Verde (*Parkinsonia florida*). The topography consists of numerous washes separated by low ridgetops. These ridgetops and hillsides are where the over 900,000 people that inhabit greater Tucson have built a variety of human structures such as houses, businesses, recreation areas and roads.

The portion of Tucson selected for the original capture study area was an approximately 81 sq. km area on the east side of the Tucson Mountains and Saguaro National Park. The area was bounded on the south by 36th street, on the north by El Camino del Cerro, Tucson Mountain Park and Saguaro National Park to the west, and Silverbell Road to the east. In 2023, the capture study area was expanded to the north to Sunset Road and to the east to include the east side of the Santa Cruz River drainage (Fig. 1).

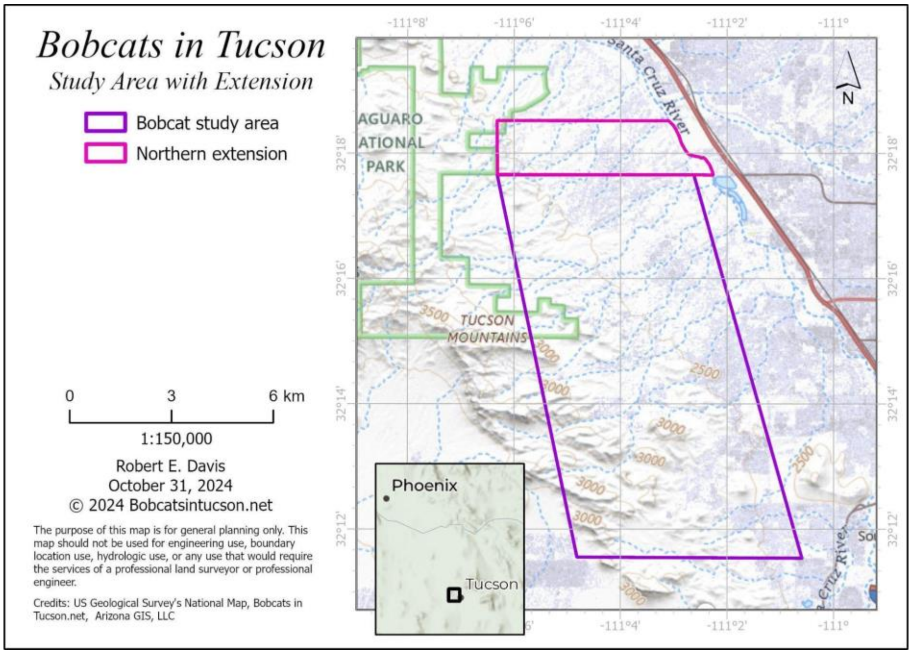


Figure 1. The Bobcats in Tucson Capture Study Area with 2023 Extension

Ultimately the area used for analysis was determined by radio-collared bobcat use. The study area encompassed the urban wildlands interface where pristine Sonoran Desert habitat in Tucson Mountain Park and Saguaro National Park met scattered low-density housing, (0-10 houses per sq. km.) dispersed medium density housing (>10 and <100), and (>100 and <500 houses per sq. km.) high density housing (>500 and <1000 houses per sq. km.), and the Santa Cruz River Bottom. The highest density housing classification (1000-1500 houses per sq. km.) is underrepresented on the study area, occurring primarily in the densest parts of central Tucson. Houses and other structures were separated by patches of typically native vegetation on the hillsides and along washes.

METHODS

Bobcat Capture

Capture efforts were conducted during the cooler desert months (November – April) in 2020, 2021, 2022 and 2023. Bobcats were captured using cage traps baited with rabbit parts (*Sylvilagus sp., Lepus sp.*) sight attractants, and commercial lures.

Figure 2. A Baited Bobcat Cage Trap

Traps were placed at locations frequented by bobcats, e.g. wash bottoms, culverts, travel ways, and a golf course. Traps were also placed, with the homeowner's permission, on private property.

Figure 3. Bobcat #14, Bunny, in the Cage Trap from Figure 2

Initial capture efforts focused on the western edge of the study area where high quality Tucson Mountain Park or Saguaro National Park wildlands Sonoran Desert habitat adjoined private property with relatively low densities of houses and other human structures (< 10 to <100 buildings per sq. km.) In successive years, capture efforts moved further east to encompass higher urbanization (building densities of up >100 and <1000 buildings/sq. km.) and less topography (Fig. 4). In the final capture year (2023) capture efforts included the Santa Cruz River Drainage.

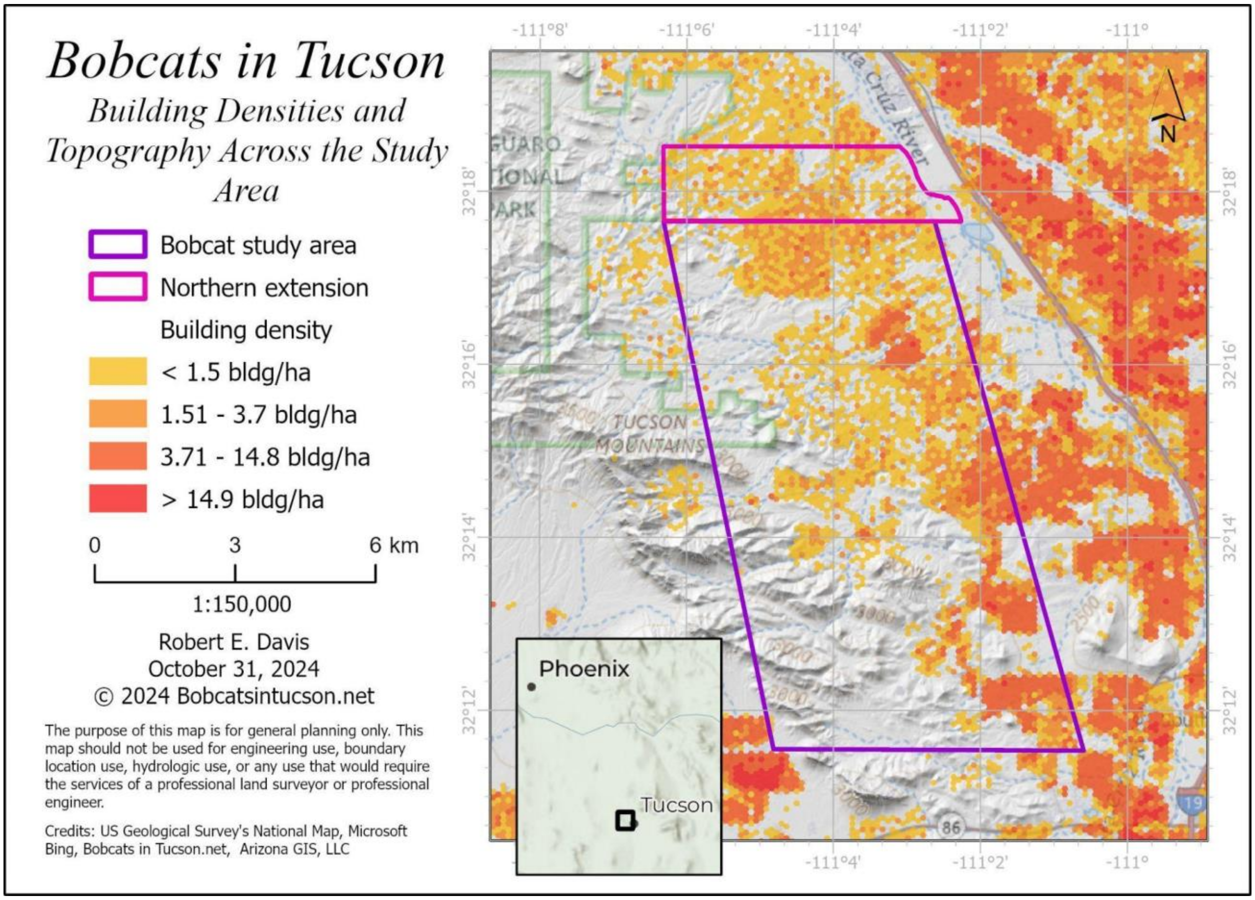


Figure 4. Building Densities Increase and Topography Decreases from West to East on the Study Area

Bobcats were immobilized with a mixture of Ketamine (4 mg/kg body weight), Dexdomitor (.04mg/kg body weight, and Butorphanol (.4 mg/kg body weight) (Kreeger and Arnemo 2018) based on estimated body weight. Bobcats were hand injected by a veterinarian from the Arizona Exotic Animal Hospital in Tucson.

Figure 5. Veterinarian Dr. Ericka Johnson hand injects a captured bobcat

Each captured bobcat was assigned a unique number, and radio collared bobcats were assigned a “nickname” to facilitate identification. Names were chosen by project staff, project contributors, and property owners if the bobcat was captured at a residence.

Immobilized bobcats were removed from the cage trap and protective optical lubricant and a blindfold were applied for eye protection. Weight and sex were determined. Age was estimated by tooth replacement and wear. Blood, fecal, cheek swabs, and hair samples were collected, and a series of photographs showing pelage patterns (Heilbrun et al. (2003) were taken.

Bobcats weighing at least 12 pounds were custom-fitted with a programmable Telonics TGW-4277 Iridium satellite radio collar with GPS and VHF capability and a Telonics programmable CR-7B breakaway mechanism programmed prior to deployment with a breakaway date based on a conservative estimate of battery use. Three bobcats weighing less than 12 pounds were fitted with the TGW-4177 collar (Figure 7).

Figure 7. Telonics TGW-4277 (top) and TGW-4177 (bottom) radio collars

Radio collars weighed either 280 or 140 grams respectively. Programming of both collar models included programs for two, six and 13-hour GPS location frequency. Collar programs could be changed by study personnel through direct communication with the collar. VHF availability was also pre-programmed for 1- 2 hours daily. The VHF signal was used to investigate possible mortalities, locate den sites, and retrieve collars in which the CR-7B or CR-5B breakaway unit had deployed successfully and the collar had fallen off as planned.

Bobcats were placed back into a cage trap after handling. Atipamazole (.2 -.4 mg/kg body weight) was hand injected to reverse the effects of Dexdomitor (Kreeger and Arnemo 2018). The recovery cage was placed in a safe location for release near the capture location and completely covered with shade cloth and vegetation.

Figure 8. BIT team member Al LeCount prepares to release a recovered bobcat from a cage

The bobcat was closely monitored from a distance until it was completely recovered (usually 1.5-2 hours) then released.

Location Analysis

Each location was evaluated for GPS precision and logical consistency with those exhibiting a dilution of precision greater than six being excluded (Van Sickle 2015). Additionally, locations deemed implausible based on travel distance within given time frames were filtered out. The result was a robust dataset with 53,683 reported bobcat locations or data points.

A convex hull, the smallest convex polygon that contained the 53,683 bobcat locations was created with an area of 21,304.8 hectares (Fig. 9) and served as a boundary for spatial analysis.

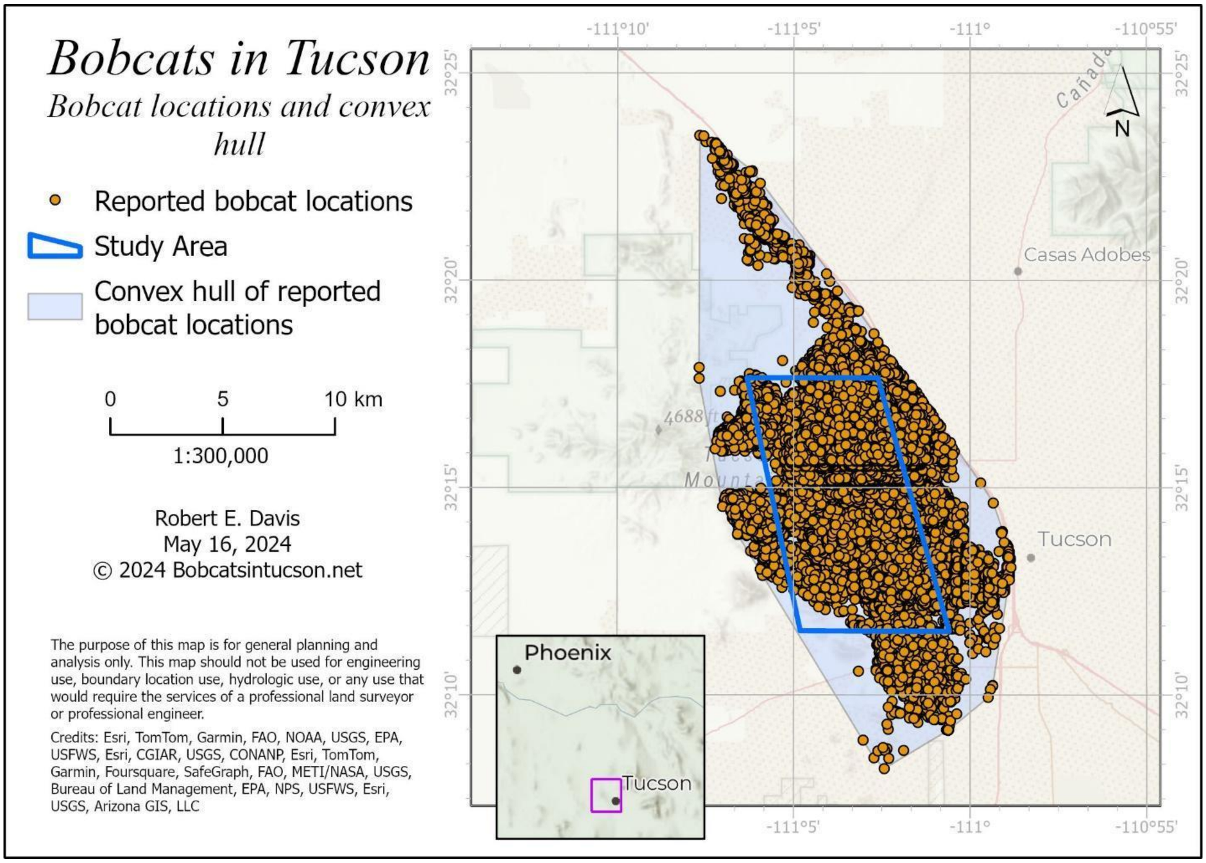


Figure 9. Bobcat locations and convex hull

The most current dataset of spatial building footprints was downloaded from Microsoft which uses computer vision algorithms on satellite imagery to create spatial representations of building footprints (*Microsoft/USBuildingFootprints*). The number of building footprints within the convex hull is 31,625 (Fig. 10).

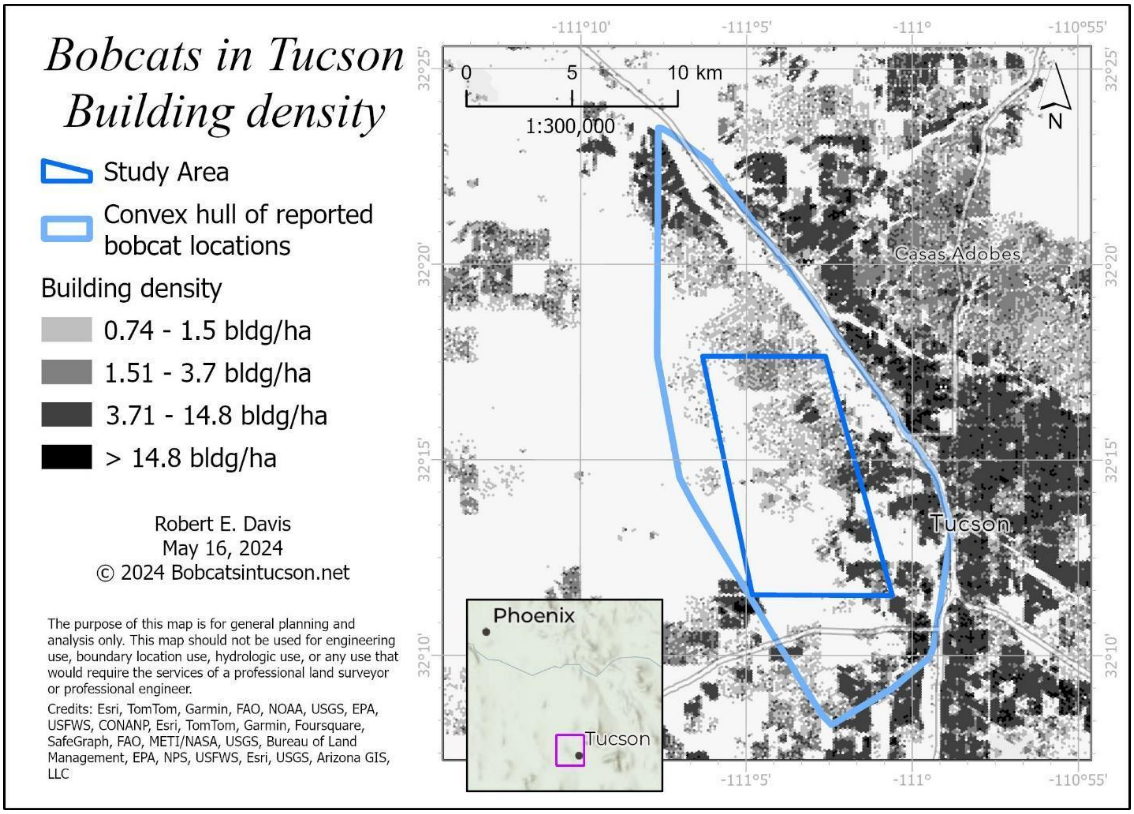


Figure 10. Building Densities within the Study Area

A building density analysis was determined by overlaying an area of equal size atop the building footprints throughout the convex hull and then counting the buildings in each of those equal sized areas. The area of equal size, or "unit area," was calculated where twice the area of the convex hull is divided by the number of building footprints (Mitchell 82). The total number of unique buildings within that hull was 31,625. Twice 21,304.8 divided by 31,625 results in a unit area of 1.35 hectares.

A "tessellation" of hexagons throughout the convex hull, each sized with the unit area of 1.35 hectares (Generate Tessellation (Data Management)—ArcGIS Pro | Documentation) was then overlaid.

To ensure a building was only counted once, a centroid point was determined for each polygon and used to determine building density. The number of building centroid points within each hexagon was counted and divided by the area of the hexagon (1.35 hectares) resulting in a density of buildings per hectare.

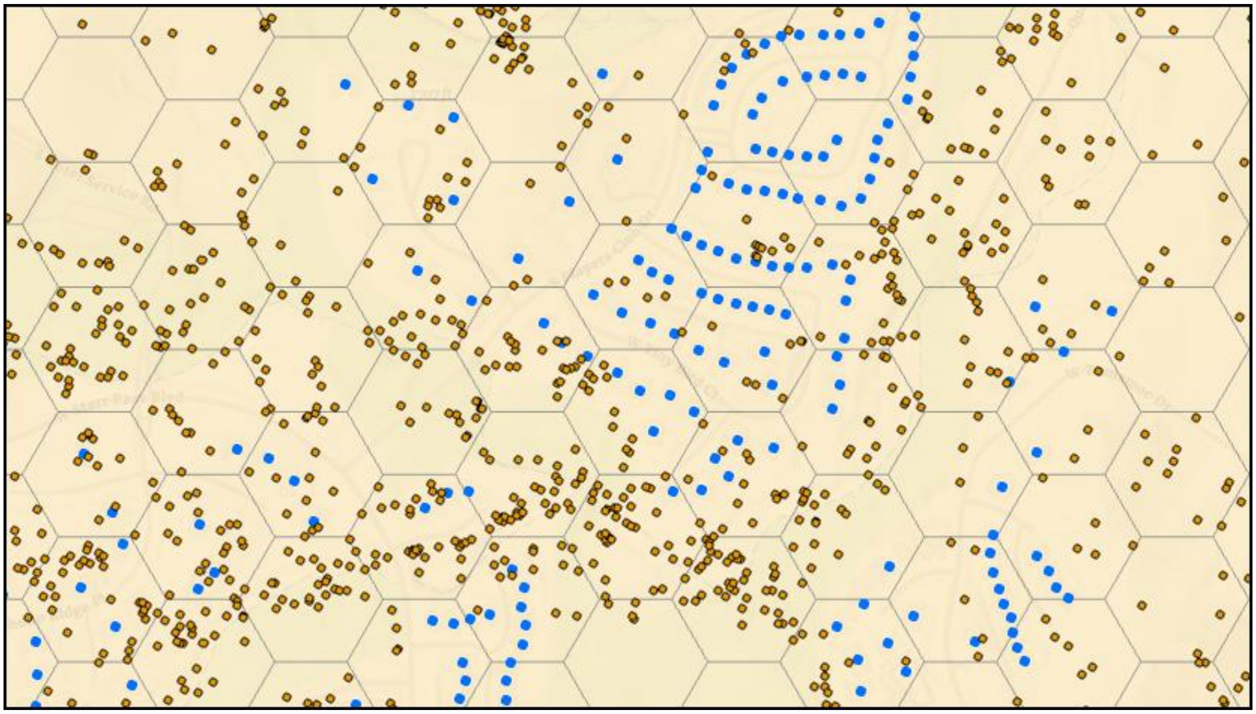


Figure 11. Bobcat locations, building centroids, and units of analysis. *The brown points are the reported bobcat locations. The blue points are building locations. The tan hexagons are the 1.35-hectare units of analysis. The building density was computed by dividing the number of buildings in each hexagon by 1.35 resulting in buildings per hectare. For each reported bobcat location, the building density of the underlying hexagon was added as an attribute.*

Annual Survival and Mortality

If the GPS signal indicated the collar had not moved in four hours, the collar was located as soon as possible using a VHF receiver and investigated as a mortality. Photographs were taken and initial analysis of the carcass and site for cause of death was completed before the carcass was moved for a more extensive necropsy.

We estimated annual survival rates of radio-marked bobcats using the staggered-entry design modification to the Kaplan-Meier survival estimator (Pollock et al. 1989).

Home Range and Core Area Analysis

We produced bobcat home range (95% contour) and core area (50% contour) size estimates for bobcats with >50 locations (Seaman et al. 1999) and more than 1 month of tracking data. We used the non-parametric Kruskal–Wallis test to determine differences in home range and core area sizes between sexes. We estimated bobcat home range and core area sizes using the fixed kernel method (Worton 1989) and calculated them using the '*adehabitatHR'* package (Calenge 2006) in R version 4.4.1 (R Core Team 2021), with *href* as the smoothing factor. Although *href* can over smooth home-range estimates under some conditions, least squares cross-validation home ranges often fail (>60%; Hemson et al. 2005) with large sample sizes generated by GPS radio collars.

Shared mother-daughter home ranges

Genetic analyses were conducted, and mother-daughter pairs were defined. Mother-daughter pairs with substantial overlap were identified, and four pairs were defined with >47.0% home range overlaps (Payne et al. 2024). We hypothesized that the pairs with substantial overlap would have home ranges with enough resources to support a mother and her adult daughter. Given that home range size is often inversely proportional with resource abundance, we predicted that shared home ranges would be smaller. We tested the home range size of overlapping pairs vs. non-overlapping and non-related pairs using the Kruskal-Wallis test.

Habitat Use and Availability

53,683 bobcat locations were used to create a convex hull that served as a boundary for spatial analysis. This convex hull had an area of 21,304.8 ha. Within this area, an equal number of randomly distributed points were generated. An analysis of variance (ANOVA) to test for a difference between the distance from bobcat locations and random points to habitat features, including building density, the nearest building, road, major road, wash, park or recreational area, night brightness, and land classification.

Bobcats and Roads Analysis - Margaret Mercer and Jesse Alston

The 53,683 total GPS points collected from 38 individual bobcats in west Tucson between November 18, 2020, and May 4, 2024, were used for this analysis. The length of time the collar was deployed ranged from one day to 2.5 years, with mean and median values of one year. The sampling interval (i.e. length between GPS fixes) ranged from two to 13 hours with an average of 5.4 hours and a median of four hours.

The roads data utilized was acquired from the Pima County Geospatial Data Portal, from which a shape file of all streets in Pima County (Pima County Open Data, n.d.) was downloaded. This file was reduced to only include roads within a ten km. buffer around the combined ranges of all bobcats. Major roads (interstate, state, frontage, and major local roads) and minor roads (minor local roads) were included in the analysis. Preliminary analysis showed that results did not change dramatically when only major roads were used, however, major roads accounted for most of the variation observed. Unless specified, all analyses were based on data derived from all roads (major and minor).

Road crossing structure data was acquired from the ADOT bridges dataset (ADOT NBI bridge and culvert conditions). This dataset includes bridges and culverts. The data was reduced to only include crossing structures within a 100m buffer around the combined ranges of all bobcats. Each crossing structure was visually assessed using Google maps to ensure that the location was correct and to identify the type of crossing structure. Within the study area (Fig. 1), there were 83 crossing structures: 38 bridges over riverbeds, 34 culverts, 10 bridges over roads, and one bridge over a railroad.

The ctmm package (Noonan 2019) was used and the analysis was based off Noonan 2022. The measurement error of the collars was calibrated, and outliers were removed. The home range for each bobcat was estimated using Autocorrelated Kernel Density Estimation to identify a polygon that contained 95% of the individual's movements. The total length of all roads within everyone’s home range was estimated and divided by the area of the home range to get the road density.

Broad patterns in bobcat movement were identified before asking specific questions. Using a linear regression, the correlation between road density within a bobcat's range and the number of times that bobcat crossed roads per day was assessed. Using t-tests, the sex of the bobcat, number of road crossings per day, road density within the bobcat's home range, and frequency of crossing structure use, were analyzed for impact on home range size.

Using the movement data and a map of roads in the Tucson area the total number of times each animal's path crossed a road was calculated. Movement data was simulated to see what a "random" movement pattern would look like, e.g. if a bobcat was unconcerned by roads, Next, the number of times the simulated path crossed a road was calculated. Simulations accounted for both home range size and the length of time collars were deployed. For each bobcat, simulations were run 1000 times and the results were averaged. This number was then compared to the actual number of road crossings in the movement data using a paired t-test to determine whether the observed bobcats crossed roads more or less frequently than would be expected under a null model.

A crossing structure was defined as any of the structures found within the combined bobcat ranges that were recorded in the ADOT bridges dataset (ADOT NBI bridge and culvert conditions). After reducing the dataset to only those bridges within the study area, the points were visually assessed in Google maps to determine whether they were associated with a crossing structure and, if so, the type of crossing structure (bridge over road, bridge over riverbed, or culvert). Crossing structures incidentally discovered during visually assessing the study area were added. The coordinates of both ends of the crossing structure for use in the analysis were added. The sf package in R was used to connect the end coordinates to create a line representing each bridge. Every crossing event on the road within the median measurement error (7 meters) of a crossing structure was identified.

Reproductive Timing, Denning, and Kitten Rearing

Radio collars were programmed to take a location every two hours beginning in late March and continued for approximately eight weeks after denning behavior was verified. In some cases, dependent upon available battery life, the two-hour location schedule was maintained for an additional four to 12 weeks. In some cases, once the female began moving the kittens more often, the telemetry schedule was changed to a location every six hours. Moen et al. (2008) found that repeated location of a female in the same location on successive days typically indicates denning in Canada lynx. We monitored daily movements of reproductive females beginning in late March using GPS locations. A female returning to the same location for successive days is a valid indication of denning since bobcats rarely return to the same location repeatedly, especially in consecutive days. If denning was suspected, attempts were made to visit accessible dens during the scheduled daily time the VHF signal on the collar was active. Moen et al. (2008) reported walking completely around a den site at about 300 meters while taking multiple triangulations to locate the den. Fernandez and Delibes (2002) successfully used this technique to locate denning Iberian lynx females. Other researchers (Apps 2000 and Organ et al. 2008) have utilized this methodology while reporting no negative consequences to females and kittens. C. Mollohan (Pers. Comm. 2024) successfully located 11 bobcat natal dens in Ohio by closely monitoring daily female movements until she remained in the same location for successive days.

If a female left a verified den site and did not return it was assumed the litter was lost. These females were monitored closely beginning 63 days (average gestation period) after the loss of the litter for denning and kitten rearing behavior. Bobcat females losing complete litters typically re-breed very quickly and produce a second litter. Based on backdating from when kittens were born, the annual breeding season when most breeding activity took place was identified.

Genomic Analysis of Relationships - Natalie Payne

DNA from blood (n = 28) and buccal swabs (n = 10) was extracted using Qiagen's DNeasy Blood and Tissue Kit. Genomic libraries were prepared following the double digest restriction site associated DNA (ddRAD) protocol by Peterson et al. (2012) with modifications using the restriction enzyme pair *Nla*III and *Eco*RI-HF and a target fragment size range of 300 – 380 base pairs (chosen for comparability with a previous bobcat study by Kozakiewicz et al., 2019). The final library was sequenced on a HiSeq X Ten (150 bp paired-end) at Novogene. Sequence data was bioinformatically processed using the Stacks v. 2.60 pipeline (Catchen et al., 2011, 2013; Rochette et al., 2019), resulting in assembled loci containing single nucleotide polymorphisms (SNPs). We sequentially filtered our results using PLINK v. 1.9 (Purcell et al., 2007), first removing loci genotyped in less than 75% of individuals (--geno 0.25), followed by individuals with more than 50% missing data (--mind 0.5), and then loci with a minor allele frequency (MAF) less than 5% (--maf 0.05). We used the list of filtered SNPs to rerun the Stacks *populations* module to generate the final SNP dataset.

Prior to analyses of relatedness, we performed population structure analyses to confirm the samples represent a single population, using ADMIXTURE v. 1.3.0 (Alexander et al., 2009) and the R package *adegenet* (for performing a principal components analysis, PCA; Jombart, 2008). To investigate the possibility that genomic variation is shaped by isolation by distance (IBD) within the study area, we performed Mantel tests with *adegenet*, using geographic Euclidean distance and genetic distance (the inverse proportion of shared alleles, D_{PS}) for each sample pair as input. In addition to using the full set of samples represented in the SNP dataset, independent Mantel tests for males (n = 16) and females (n = 16) were conducted to assess differences in dispersal between sexes.

To investigate relationships present among sampled individuals, relatedness coefficients were estimated between individuals using the R package *related* (Pew et al., 2015). Relatedness among pairs of females, pairs of males, and male-female pairs were compared using a Kruskal-Wallis test, followed by a Dunn post-hoc test. The R package *sequoia* (Huisman, 2017) was used for pedigree reconstruction, using known birth year or estimated minimum/maximum birth year for each sample and a filtered subset of SNPs (optimized using expected first-degree relatives from *related* results). The pedigree analysis was later updated to include five additional samples (sequenced in a supplemental ddRAD library) from late 2023.

The relationships identified with *sequoia* (prior to the supplemental sequencing) were used to observe patterns of home range overlap among mother-daughter pairs and other female pairs. 95% kernel density estimate (KDE) home ranges were calculated in ArcGIS Pro to estimate the home range of each female bobcat overlapping with another female for approximately four months or more (based on the time periods the individuals were collared); BC #42 Beverly and BC #24 Sadie were an exception to this, as #24 Sadie was shot before her mother, #42 Beverly, was collared. The percentage of overlap between females with adjoining home ranges, excluding overlaps with one individual (BC #34 Danielle) due to a shift in her home range during the study, was then calculated. The significance was assessed using a Wilcoxon rank sum test, comparing our mother-daughter home range sharing (MDHS) pairs with all other overlapping females.

To investigate fine-scale spatiotemporal overlap of MDHS pairs, 50% KDE home ranges were further calculated, along with the percentage overlap in ArcGIS Pro. For the three pairs with known temporal overlap (excluding BC #24 Sadie and BC #42 Beverly), 95% KDE home ranges were additionally calculated in week-long windows to examine the proportion of mother-daughter overlap each week. The distance for each daily mother-daughter pair of coordinates was also calculated to assess trends in distance over time, using the R package *geosphere* (Hijmans 2022).

A more detailed discussion of the genomic methods and results of this study is available in the manuscript currently undergoing peer review at the Journal of Heredity (Payne et al. 2024).

Food Habits

Hair samples were collected from bobcats during collaring as well as hair and feather samples collected from common prey items (e.g., cottontails, rodents, doves, etc.). Samples from prey items were collected from hunting check stations, during rodent trapping for other projects, as well as opportunistically from road kills. All hair and feather samples were weighed, rinsed with a 2:1 chloroform-methanol solution and deionized water, and processed in the Environmental Stable Isotope Facility on the University of Arizona's campus.

The R (v.4.4.1) and RStudio were used to visualize and compare isotopic signatures and conduct a Bayesian mixing model to determine the dietary proportions for suburban bobcats. *MixSIAR* (Stock et al., 2018) was used to create isospace plots and run Bayesian models to estimate the proportion of each source consumed by suburban bobcats. Discrimination factors derived by Parng et al. (2014) for bobcats were used. The sources used included lagomorphs (cottontails (*Sylvilagus audobonii)* and black-tailed jackrabbits (*Lepus californicus*)), non-domesticated birds (doves (*Zenaida sp.*) and Gambel's quail *(Callipepla gambelii*)), domestic chickens (*Gallus domesticus*), domestic cats (*Felis catus*), and domestic dogs (*Canis familiaris*). We chose these sources based on literature stating that lagomorphs were the primary prey item of bobcats in the Southwest (Leopold and Krausman 1986, Delibes and Hiraldo 1987) as well as eyewitness accounts in which bobcats were observed feeding on doves. Additionally included were domestic chickens, dogs, and cats due to resident concerns. Two separate models, one with uninformative priors and the other with informative priors derived from literature and study observations were run. Geweke and Gelman-Rubin diagnostic statistics were used to confirm model convergence (Stock et al., 2018).

Bobcat Activity Database:

The BIT website (Bobcatsintucson.net) became active in October 2020. It was a primary point of contact with Tucsonans, along with community outreach by study personnel through a variety of means including BIT contact cards, vehicle signage, and a variety of media (See Public Outreach for more detail). Interested individuals were directed to the BIT website (bobcatsintucson.net) where they could find the study email address (Bobcatsintucson@gmail.com) to report bobcat activity.

Individuals reporting sightings were asked to attach photographs of the animal sighted if available and provide their street address. A return email was sent to the individual thanking them for their observation, requesting use of photos and photo credit information, urging them to fill out the Bobcats in Tucson Attitudes and Value Survey (also available on the website), and answering any questions they might have about bobcats or the project. Citizen scientists reporting bobcat activity were also encouraged to sign up for the periodic “Bobcat Blog” which provided ongoing study information. Additionally, if the reported sighting was in the BIT capture area or involved a radio collared bobcat, the citizen scientist was provided with a map that highlighted their address and included location and other information on resident bobcats.

Information provided by the citizen scientist was entered into a spreadsheet which included the name, address, location coordinates, and other details including whether the bobcat was radio collared, and if it was a single bobcat or female with kittens. The area selected for this sampling encompassed not only the area on the West side of Tucson, where bobcat capture work was conducted, but also included Greater Tucson. Reporting for the Final Report was discontinued on May 31, 2024, but the website and contact points remain active and we will continue to record bobcat activity locations sent in by the public.

Bobcats in Tucson Attitudes and Values Survey:

Visitors to the BIT website were surveyed to determine attitudes and values of people living with bobcats in Tucson. The information also provided perspectives on how people interact with urban bobcats with both positive and negative outcomes and perceptions.

Because of the COVID outbreak, face-to-face survey strategies were abandoned in favor of a survey posted and maintained through the project website. This was also a more inclusive outcome since it allowed us to get responses from not only the capture area, but from across the Tucson Metropolitan area.

A thirty-one-question survey was developed utilizing Survey Monkey as the platform. Anyone who visited the Bobcats in Tucson website, sent in a bobcat sighting, or was contacted through project outreach efforts, was asked to complete a survey. The choice to complete the survey was self-driven and not conducted on a statistical or random basis. We acknowledge that the survey was implemented in such a way that survey participants were already interested in or had personal experience with urban bobcats in Tucson and was not a random sample of Tucsonans.

Study Outreach:

Both active and passive outreach methods were employed to best meet and maintain communication pathways with a diverse interested public. Outreach methods spanned school age children to adults and knowledgeable wildlife watchers to novice bobcat enthusiasts. Outreach efforts provided ongoing information about the project, provided Tucsonans with access points to accurate bobcat information, encouraged responsible behaviors in living with urban bobcats, and detailed ways to support project efforts. These and other elements lead to a strong study area, and even broader community support base.

BIT Team members made a concerted effort to accommodate every outreach request from news reporters, newsletter editors, Zoom presentation requests, events, face-to-face programs and individual personal communications. Special attention was given to utilizing methods that had larger multiplier impacts such as print and TV news media, high circulation publications and programs available to broader public access.

A special effort was also made to work directly with homeowners, HOAs and the many individuals that became supportive citizen scientists funneling information to the BIT Team.

RESULTS and DISCUSSION:

Capture

Between November of 2020 and December of 2023, we captured 56 different bobcats 68 times: 21 adult males, 25 adult females, 2 subadult males, and 8 unknown sex bobcats (1 subadult and 7 young of the year kittens) within the capture area (Fig. 12).

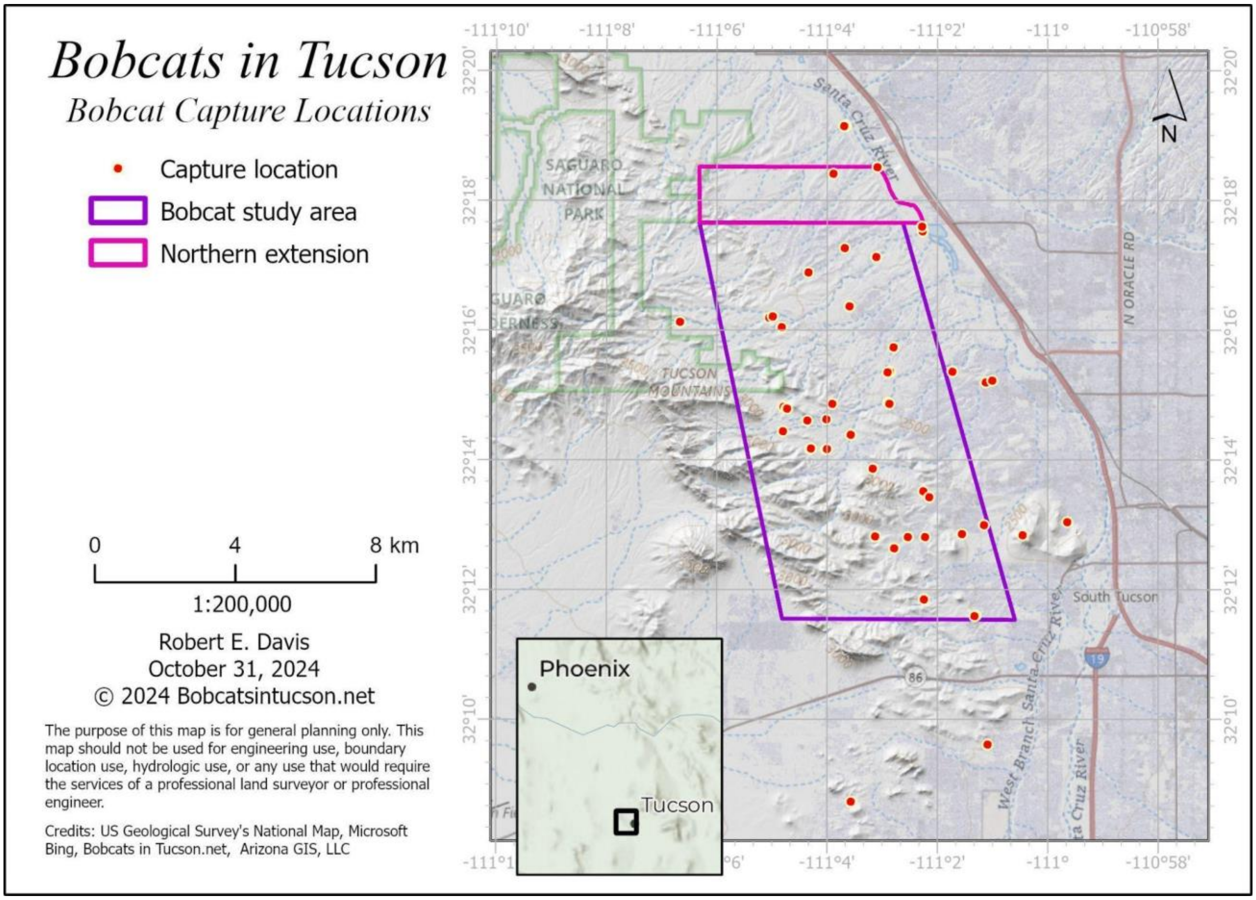


Figure 12. Bobcat Capture Locations

Thirty-eight bobcats were radio-collared including 36 adults and 2 subadults of which 14 were males and 24 were females. One female, BC #45 Emma Claire transitioned from subadult to adult while radio collared and is listed here as an adult. We radio collared all females large enough to wear a collar except one female captured on the same day as a second female who we fitted with our last available collar for that trapping period. We released without collaring 6 adult males. We prioritized radio collaring females over males because collars were a finite resource, and we wanted to maximize the number of adult females captured.

Figure 13. The Bobcats in Tucson Team with Bobcat #1 Shannan. Clockwise - Dr. Erica Giles, Cheryl Mollohan, Kerry Baldwin, and Al LeCount. Photo By Ron Day

All adult bobcats radio collared (36) were fitted with a Telonics TGW-4277 Iridium satellite collar. Two subadult bobcats were fitted with Telonics TGW-4177 Iridium satellite collars: BC #45 Emma Claire, a subadult female, and BC #48 Tippy, a subadult male, both of which were offspring of radio collared females we were attempting to re-capture. One young female BC #57 Karen (estimated age 1.5 years) was also fitted with the smaller TGW-4177 collar because she only weighed 11.4 pounds at capture.

The “adult” collars included a Telonics CRB-7 breakaway mechanism, and the “subadult” collars included a Telonics CR-5 breakaway mechanism. Subadult collars also had a cotton patch sewn into the collar as a backup for the mechanical breakaway

Note the black breakaway unit on both collars and the cotton insert on the TGW-4177 in case of a malfunction since subadult bobcats were still actively growing. On both collar types, breakaway dates were factory programmed to deploy based on a conservative estimate of battery life.

Figure 14 - Telonics TGW-4277 (top) and TGW-4177 Radio Collar (Bottom)

Figure 15. Bobcat Collars were Fitted Individually to each Bobcat

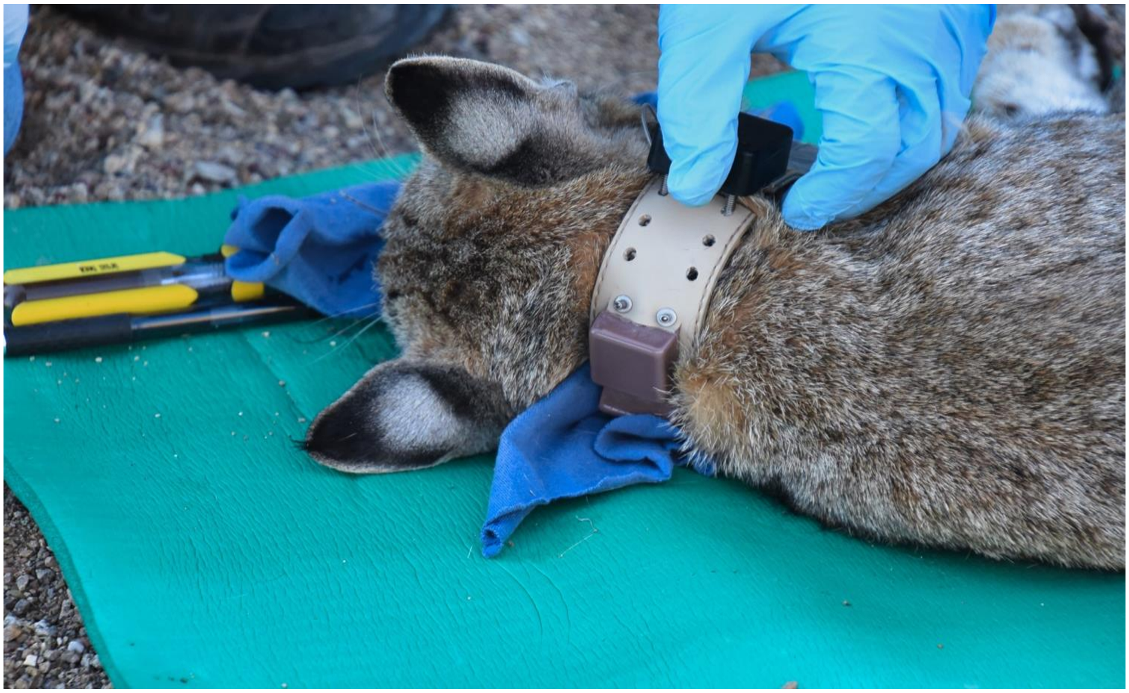


Figure 16. Fitting the Collar to the Bobcat

Six bobcats were recaptured and wore a second collar: BC # 2 Morgan, BC #12 Margaret, and BC #34 Danielle were adult females, BC #45 Emma Claire was captured as a subadult and then recaptured as an adult. BC #40 Braeden, an adult male was initially captured and collared in March of 2022. He was re-captured, and his collar changed in January of 2023. In March of 2023 the collar sent an error message, and the breakaway mechanism was deployed. This was the only collar failure we had with 45 deployments. BC #27 Wyatt was an adult male whose collar deployed and released as programmed. He was re-captured later in an area he had not used before, and radio collared as a "new" male BC #54. DNA analysis showed them to be the same individual, so data files were combined for this bobcat.

Location Analysis

We collected over 53,000 GPS locations on 38 different bobcats from November of 2020 to May of 2024 (Figs. 17 and 18).

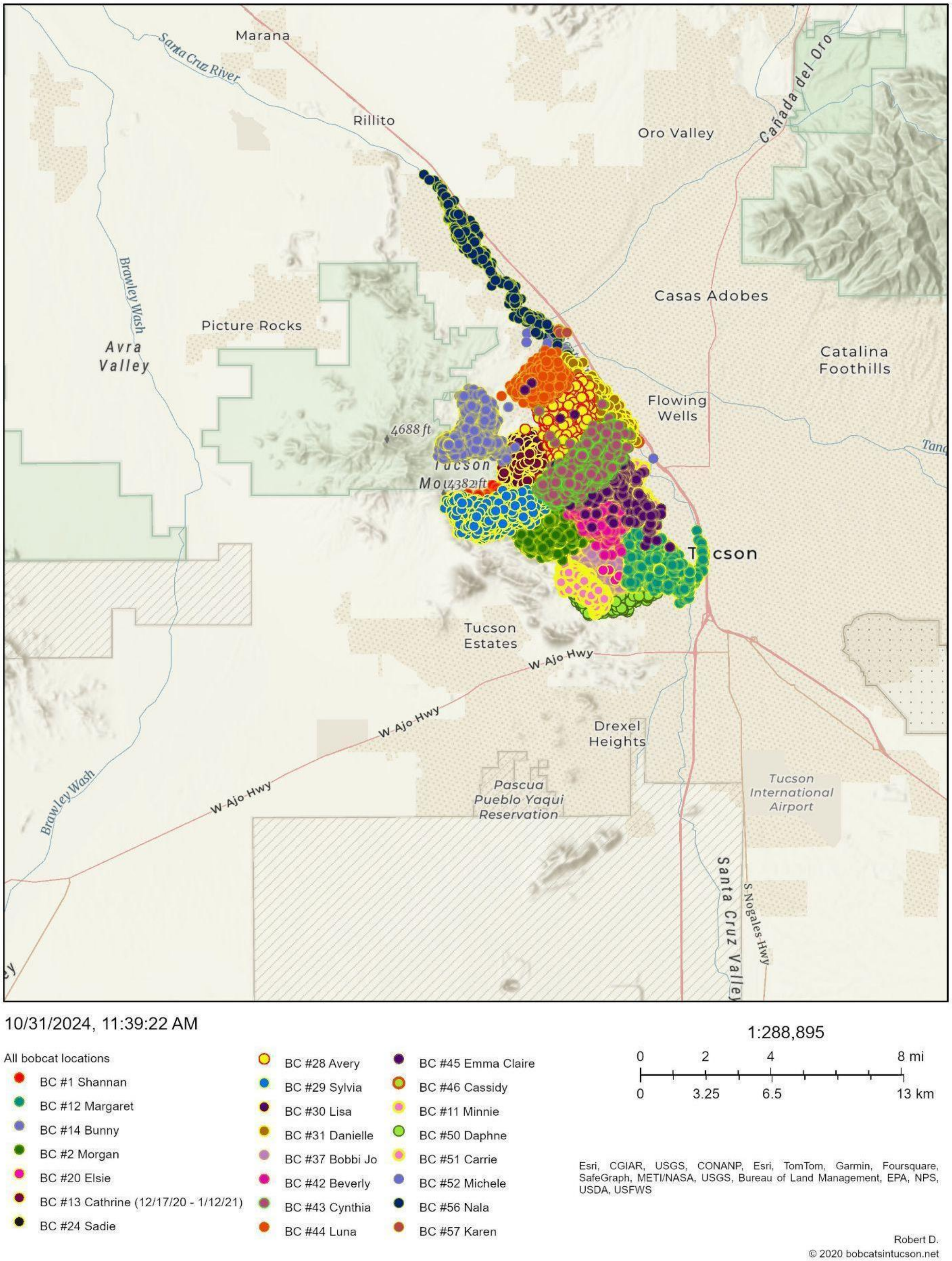


Figure 17. Radio Collared Female Bobcat Locations

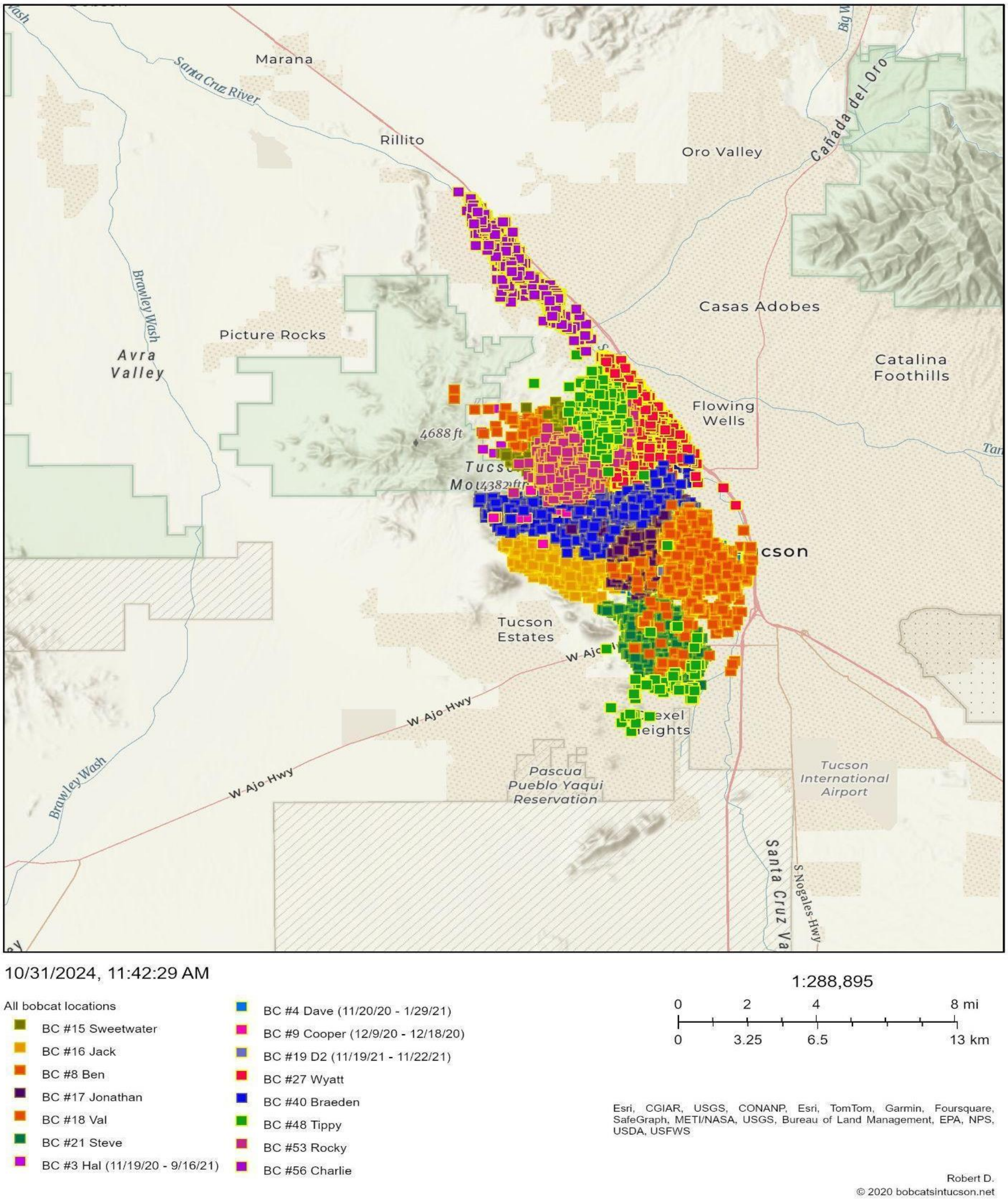


Figure 18. Radio Collared Male Bobcat Locations

Random vs. bobcat locations

The difference between bobcat locations and random points in terms of building density (F=5.14, P =0.023), distance to the nearest building (F=2984.93, P<0.001), road (F=2984.93, P<0.001), major road (F=924.68, P<0.001), wash (F=514.65, P<0.001), and park or recreational area (F=2813.98, P<0.001) were all significant.

Building density was greater at bobcat (1.52 ± 0.01 standard error [SE]) than random locations (1.48 ± 0.01 SE). This was the weakest significant difference with the lowest power (F=5.14, power for α = 0.05 was 0.62). The power for all other comparisons was ≥ 0.95. Furthermore, the distance to the nearest building and road was less for bobcat locations (building, 121.7 ± 1.08 m SE; road, 135.2 ± 1.08 m SE) than random points (building, 205.3 ± 1.08 m SE; road, 210.3 ± 1.08 m SE). However, the distance to the nearest major road was greater for bobcats (3283.7 ± 9.38 m SE) than random points (2880.25 ± 9.38 m SE), as was the distance to the nearest park or recreational area (bobcat 594.9 ± 2.31; random 421.3 ± 2.31 m SE). Conversely, the distance to the nearest wash was less for bobcat locations than random points (bobcat 99.5 ± 0.40; random 112.3 ± 0.40 m SE).

The mean building density associated with all the reported bobcat locations is 1.52 buildings per hectare (Figure 19).

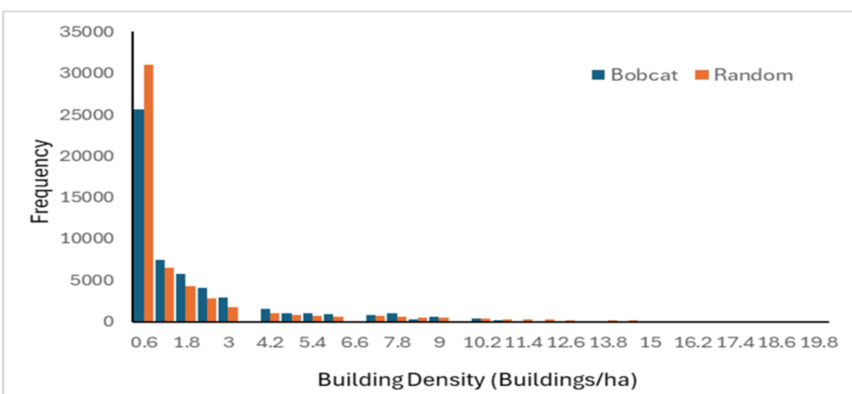


Figure 19. Mean Building Density for Bobcat and Random Locations

Building density was greater at bobcat (1.52 ± 0.01 standard error [SE]) than random locations (1.48 ± 0.01 SE). This was the weakest significant difference with the lowest

power (F=5.14, power for α = 0.05 was 0.62). The power for all other comparisons was ≥ 0.95.

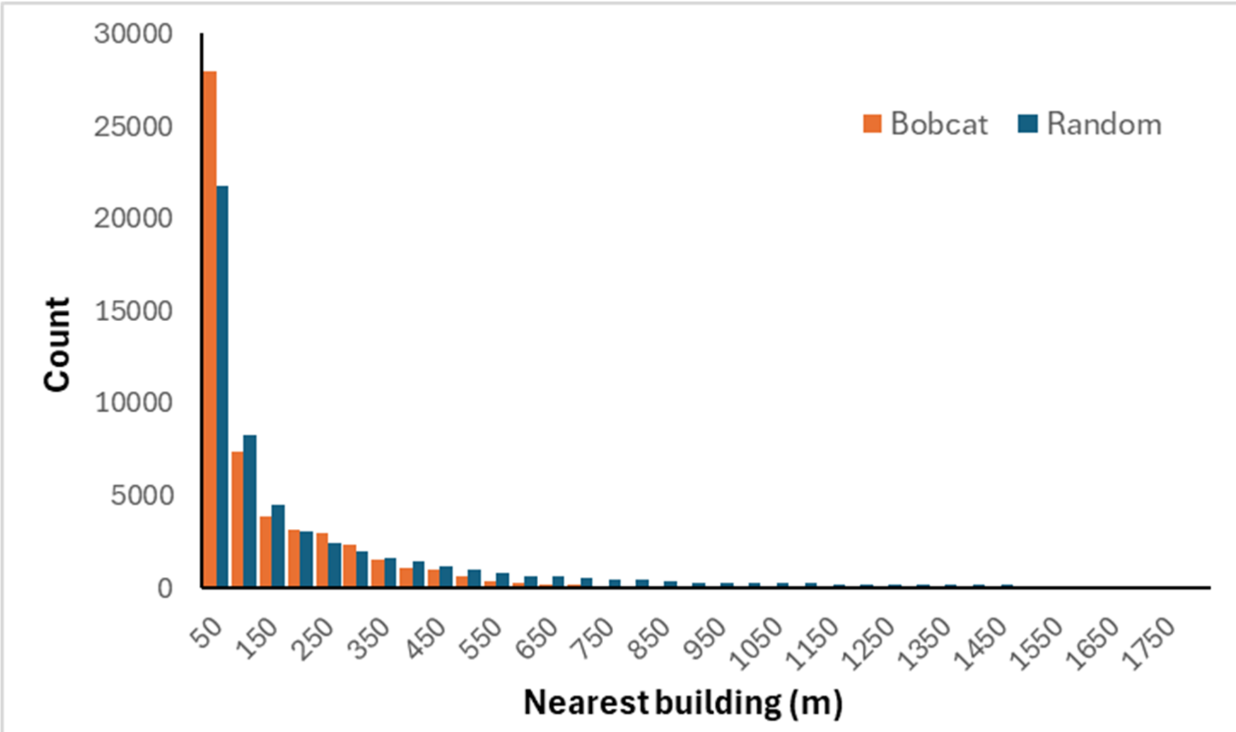


Figure 20. Distance to the nearest building for bobcat and random locations

The distance to the nearest building was less for bobcat locations (building, 121.7 ± 1.08 m SE) than random points (building, 205.3 ± 1.08 m SE) (Figure19).

Significance in both these variables (mean building density and distance to the nearest building) (Figs. 19 and 20) suggests that bobcats actively select areas near buildings and for higher building densities than are available randomly. For urban bobcats, human structures (buildings, walls, roofs) take the place of natural structures in their environment. Bobcats in urban areas in Tucson routinely hunted, rested, and denned near buildings and on roofs, and raised their kittens in backyards that usually shared a set of structural characteristics (a high block wall, a tree which provided security and sometimes roof access, and other vegetation and human structures that provided security cover for the kittens.

Bobcat #28 Avery successfully raised kittens in 2023 and 2024. In both years she utilized a backyard that included a large water storage tank that she used as a maternal den where she placed the kittens behind the water tank (Fig. 21).

Figure 21. Bobcat Avery #28' Maternal Den Site in 2023 and 2024

Note the trail camera in the foreground

Nearest road information is based on the distance, in meters, from the reported bobcat location to the nearest road (of all types) as reported by the USGS (*USGS National Transportation Dataset (NTD) for Arizona (Published 20240215) FileGDB - ScienceBase-Catalog*). The average distance to the nearest road was 135.2 meters (Figure 22). Additionally, this same data was developed but using only the larger roads (controlled access highways, secondary highway or major connecting roads, and local connecting roads). The average distance to the nearest "major" road was 3,283.7 meters.

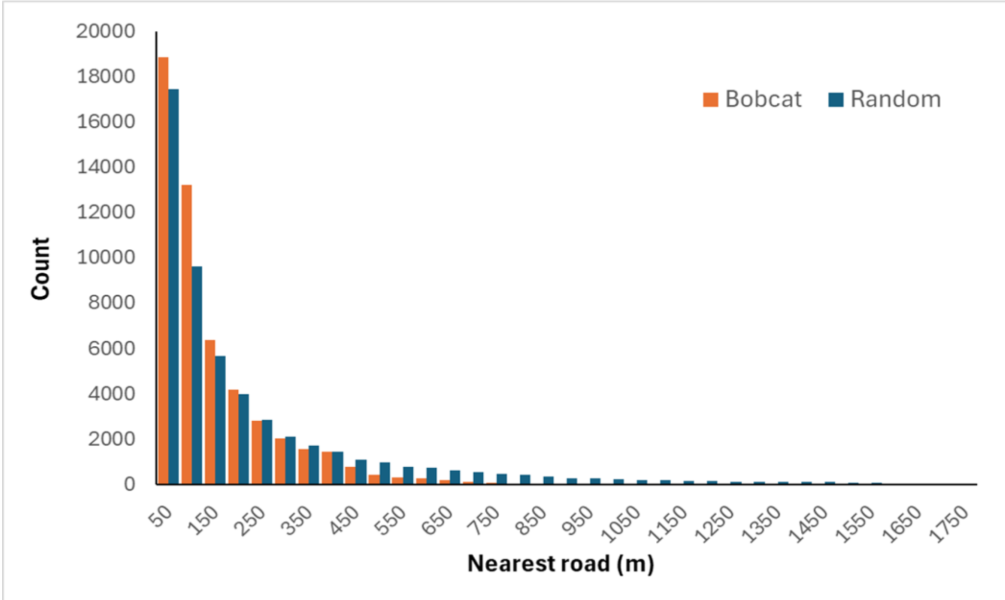


Figure 22. Distance to the Nearest Road for Bobcat and Random Locations

The distance to the nearest road was less for bobcat locations (135.2 ± 1.08 m SE) than random points (210.3 ± 1.08 m SE).

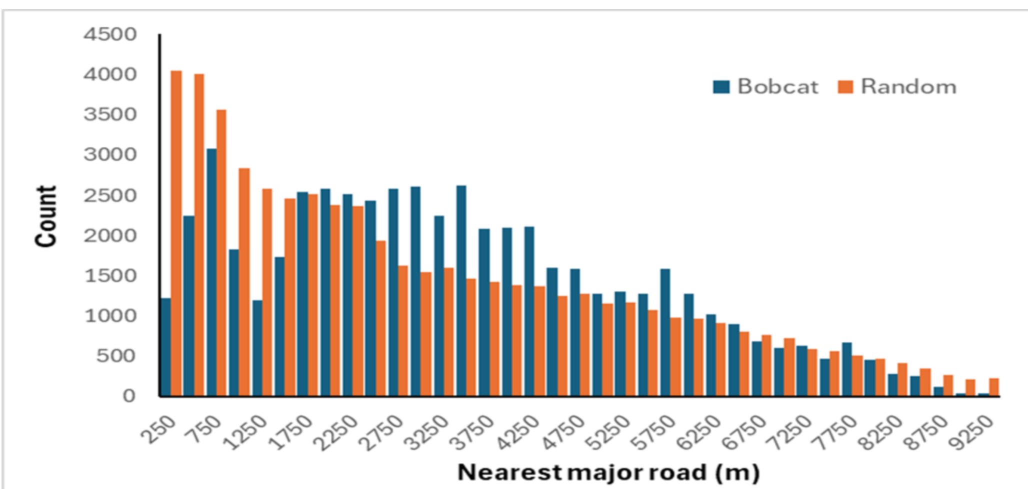


Figure 23. Distance of nearest "major" road for Bobcat and Random Locations

The distance to the nearest major road was greater for bobcats (3283.7 ± 9.38 m SE) than random points (2880.25 ± 9.38 m SE).

Radio collared bobcats avoided major roads, such as Silverbell Road, which was the eastern border for several bobcat home ranges, while crossing smaller roads as they came to them in their home range (See Bobcats and Roads section for more details).

Nearest wash information is based on the distance, in meters, from the reported bobcat location to the nearest wash (from the Pima County "Wash Layer"). The average distance to the nearest was 99.5 meters (Fig. 24).

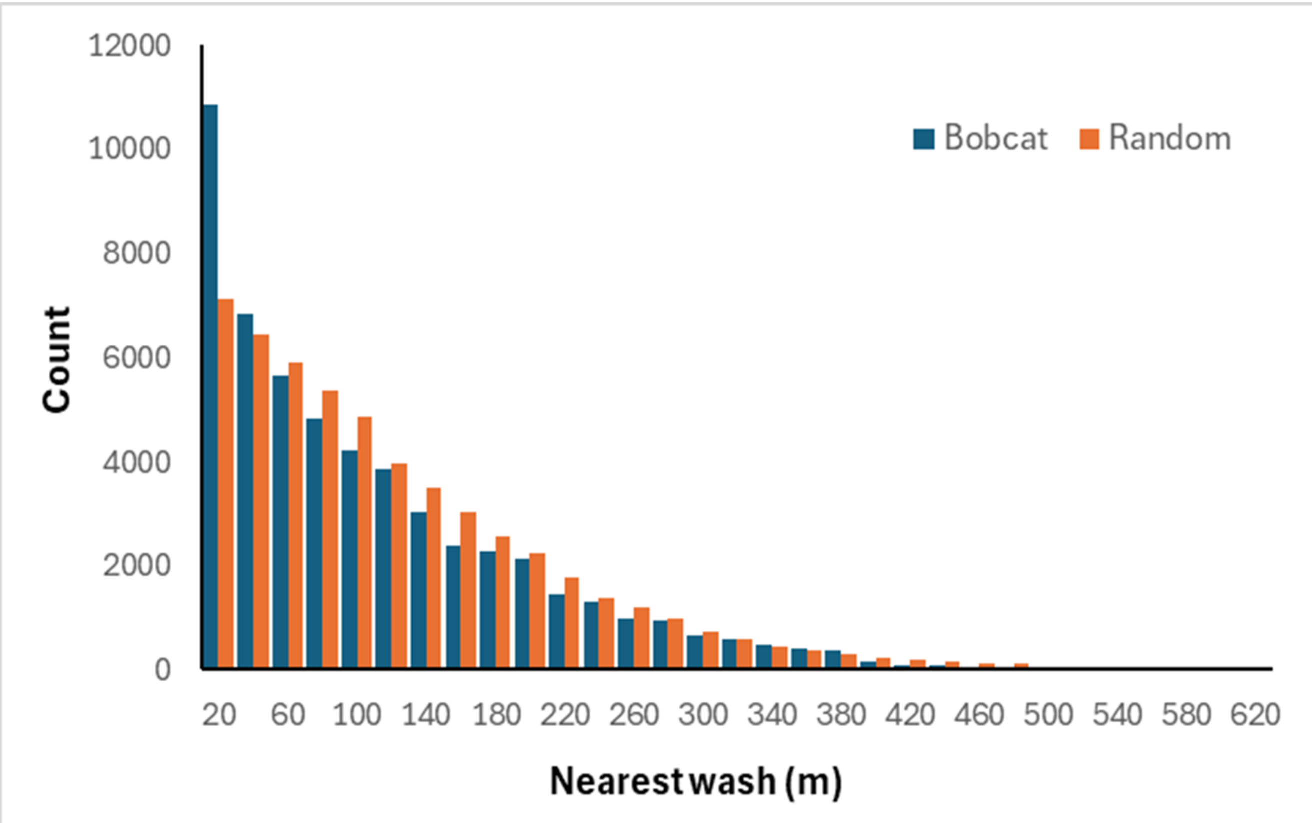


Figure 24. Distance to the Nearest Wash for Bobcat and Random Locations

The distance to the nearest wash was less for bobcat locations than random points (bobcat 99.5 ± 0.40; random 112.3 ± 0.40 m SE). We repeatedly captured bobcats in and saw evidence of use of washes as travel ways. Intact washes enable bobcats to safely travel through areas of high human activity and building densities (Fig. 25).

Figure 25. BC #37 Bobbi Jo's Use of a Wash as a Travel Way in Greasewood Park

BC #28 Avery gave birth to kittens in 2022 in an intact wash in the Agua Dulce subdivision. The Agua Dulce housing development is certified by Animal Planet and by the National Wildlife Federation as wildlife habitat. Washes were left intact without walking trails which enabled bobcats to move through the densely populated subdivision and still avoid high densities of people.

Nearest park or recreation information is based on the distance, in meters, from the reported bobcat location to the nearest park or recreation area as reported by Pima County. The average distance to the nearest park or recreation area was 594.9 meters (Fig. 26).

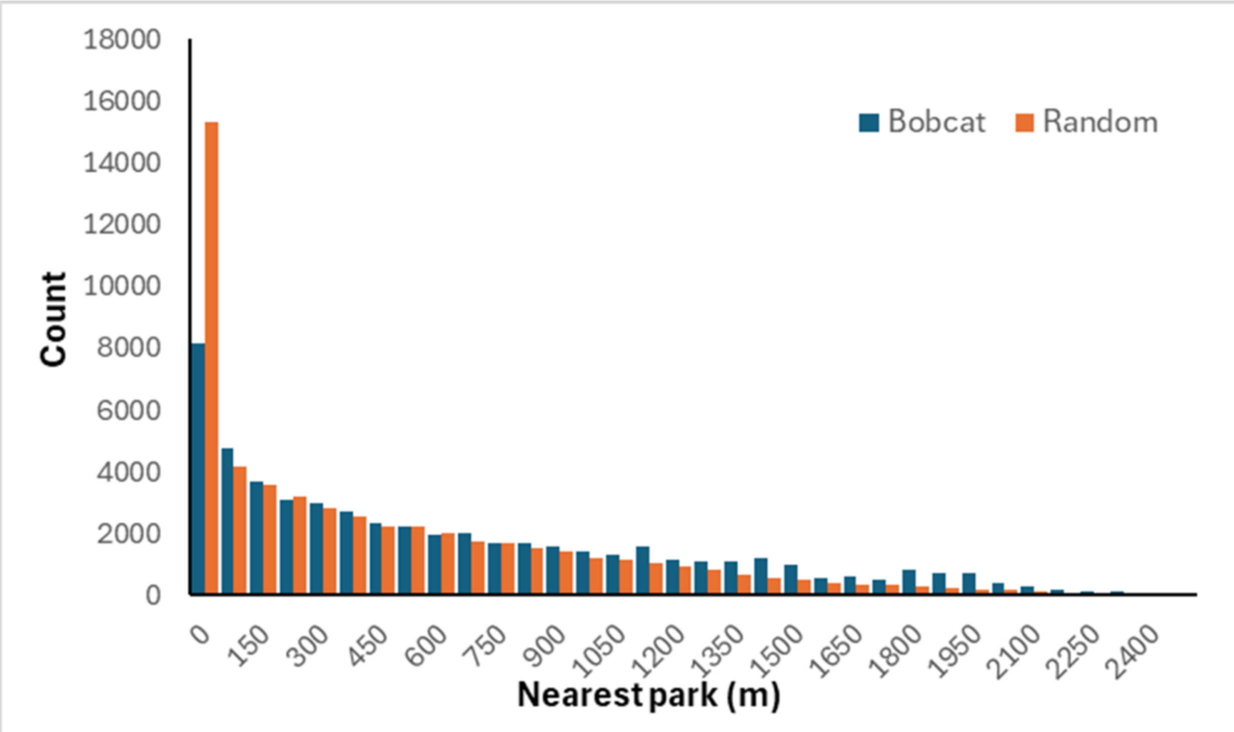


Figure 26. Distance to the Nearest Park or Recreation Area for Bobcat and Random Locations

The distance to the nearest park or recreational area was greater for bobcats than random (bobcat 594.9 ± 2.31; random 421.3 ± 2.31 m SE). This is likely a reflection of bobcats avoiding areas where many people might gather at one time (such as a ball game or soccer game) at a recreation area since this category encompasses “green space” parks with natural vegetation and developed parks.

Night brightness is based on NASA’s Visible Infrared Imaging Radiometer Suite (VIIRS) that “provides global daily measurements of nocturnal visible and near-infrared (NIR) light that are suitable for Earth system science and applications. The VIIRS DNB's ultrasensitivity in lowlight conditions enables us to generate a new set of science-quality nighttime products that manifest substantial improvements in sensor resolution and calibration when compared to the previous era of Defense Meteorological Satellite Program/Operational Linescan System's (DMSP/OLS) nighttime lights image products. Such improvements allow the VIIRS DNB products to better monitor both the magnitude and signature of nighttime phenomena, and anthropogenic sources of light emissions" (NASA VIIRS Land Science Investigator-Led Processing System). The data represent nano-wats per square-meter per steradian and are taken from November 2023.

The average nighttime brightness was 48.5 nano-watts per square-meter per steradian (Fig. 27).

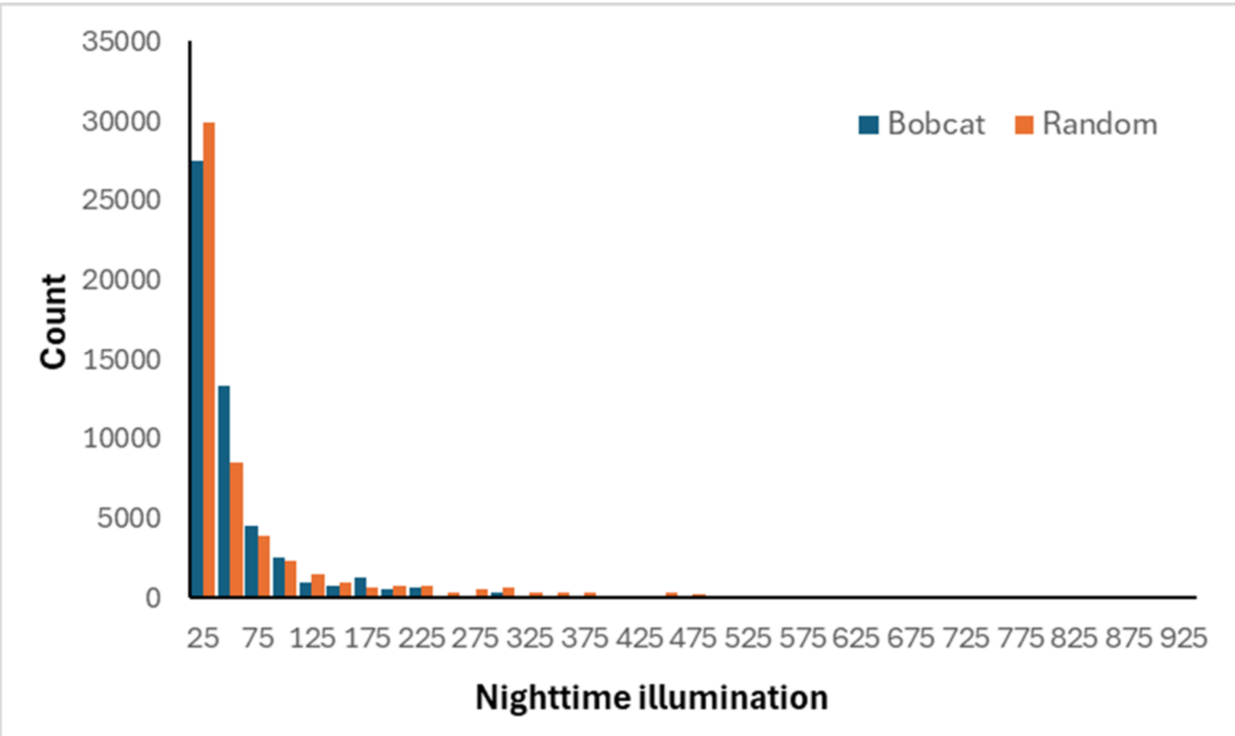


Figure 27. Distribution of Night Brightness at Bobcat and Random Locations.

Nighttime illumination was significantly lower at bobcat locations (48.5+- 41m SE) than random locations (66.4+-0.41 m SE; P<0.001)

This data appears in tabular form in the geospatial data for each of the reported bobcat locations.

Collar#	catname	Buildings per hectare	ESA_LandCover	VNB46A3_20231101	Elevation_m	PRISM_tmean_30yr...	PRISM_ppt_30yr...	nearest_Building	nearest_road
719985	BC #4 Dave (11/20/20 -...	0.74074	20	41	796.4896	20.91	287.789	27.930791	63.596071
719985	BC #4 Dave (11/20/20 -...	5.185185	10	41	799.2379	20.9	285.987	44.708935	77.268237
719985	BC #4 Dave (11/20/20 -...	0	20	26	751.8994	20.86	276.139	484.700826	474.622822
719985	BC #4 Dave (11/20/20 -...	0	20	23	778.1909	20.86	276.139	413.097783	387.384332
719985	BC #4 Dave (11/20/20 -...	0	20	23	830.7083	20.86	276.139	371.829695	262.308832
719985	BC #4 Dave (11/20/20 -...	0	20	79	853.5037	20.89	275.777	334.435823	311.292319
719985	BC #4 Dave (11/20/20 -...	0	20	23	842.3047	20.86	276.139	397.388538	239.110912
719985	BC #4 Dave (11/20/20 -...	5.185184	50	39	820.408	20.9	290.689	1.502473	39.222606
719985	BC #4 Dave (11/20/20 -...	1.481482	20	119	762.21	20.93	282.875	58.790169	70.94114
719985	BC #4 Dave (11/20/20 -...	2.962961	20	51	784.7582	20.93	282.875	25.05486	77.267735

As a check of the attributes, a point from the dataset was picked at random and the attributes were manually measured (Figure 28). All the attribute values were exactly the same.

Checked the independent variables by measuring (manually) those variables associated with Reported_bobcat_locations_and_Random_Points_Enhanced object id 22000 EpochTm 1611496805

Collar#	719988
catname	BC #1 Shannan
Buildings per hectare	0.74074
ESA_LandCover	20
VNB46A3_20231101	16
Elevation_m	813.5481
PRISM_tmean_30yr_normal	20.93
PRISM_ppt_30yr_normal	297.88199
nearest_Building	62.564669
nearest_road	120.666851
nearest_major_road	6541.325165
nearest_wash	77.888059
Nearest_park_recArea	0

Figure 28. A manual measure of the independent variables results from the dataset verified the results as accurate

Annual Survival and Mortality

Annual survival was 0.36 (95%CI = 0.17-0.54), 0.84 (95%CI = 0.17-0.54), and 0.85 (95%CI = 0.69-1.00) for years 1,2, and 3, respectively. Survival was lower in year 1 than in years 2 and 3 ($P<0.05$). Overall, there were 12 mortalities, and half of these (n=6) occurred during the first year. Additionally, there were fewer radio-collared bobcats (n=12) than during the latter 2 years. The first 3 mortalities that occurred early in 2021, the first year of the study, were all human caused, including one reported as an accidental vehicle strike, and 2 that were directly caused by humans (likely shot). The remaining mortalities in 2021 were possibly related to capture (1) and vehicle strikes (2). There were 4 mortalities in 2022 including 3 that were directly caused by humans, 2 were shot, one was likely shot, and one was a likely vehicle strike. One mortality in 2023 was a vehicle strike, while the other was unknown but likely a vehicle strike based on where the mortality occurred near a major road. Mortalities from vehicle strikes occurred in each of the three study years (3 in 2021, 1 in 2022, and 1 in 2023) but declined as the study progressed even though there were more bobcats radio collared in each successive year. Direct human caused mortalities totaled 4 in 2021 including one possible capture related mortality, declined to 3 in 2022, and to zero in 2023. As the study progressed, this decline in human caused mortalities was likely attributable to the attention in the local press about the shooting of BC #24 Sadie that occurred in September of 2022. The story, investigation, prosecution, and outcome were all reported extensively in the local newspaper and on television. It is likely this, along with other reporting on the study in general, elevated awareness of the Tucson bobcat population with Tucsonans, and perhaps discouraged individuals from shooting bobcats, or at the very least, shooting radio-collared bobcats.

Project Mortalities

During the study period, twelve mortalities were documented among the 38 radio collared bobcats. Five of the mortalities were vehicle related road fatalities. Five deaths were directly tied to human actions such as shooting of a bobcat due to potential predation on urban chickens or unfounded human safety concerns, and one mortality was possibly capture related. Only one mortality was of an unknown cause, BC # 45 Emma Claire, whose mortality was not investigated for several days because of confusion among project personnel about the location of the collar. All collared bobcats that died were examined (except for two whose carcasses were not available), collars retrieved, and, in some cases, necropsies were done looking at more detailed circumstances of death and signs of physical damage to the body.

The one mortality potentially related to capture influences (BC #19 D2) was never clearly tied to capture. The mortality occurred within two days of the capture, which had gone routinely. The project veterinarian was on-hand during all handling activity and the bobcat was monitored until fully recovered from immobilization and showed no ill effects from handling. A subsequent necropsy completed by a study veterinarian found no conclusive indicators of problems related to the capture, and there were no signs of capture myopathy.

The direct human caused mortalities usually involved shooting of the bobcat in an urban context. Some of the mortalities were investigated by Arizona Game and Fish. One incident, related to BC #24 Sadie, led to extensive and well documented news coverage. Media reporting cycled from a city-wide call for public information about details of the incident, with a $1,150 reward attached, trial and conviction in a Pima County court, to the final issuance of a Civil Assessment for loss of the bobcat to the people of Arizona by the Arizona Game and Fish Commission. The human caused incidents usually included an attempt to hide the carcass or radio collar, except for BC#17 Jonathan, a large male who was shot by the homeowner while stalking free ranging chickens in his yard. That homeowner reported it to the AZGFD who investigated and elected to not press charges. One collar which had been cut off BC #4 Dave, was found in a developed neighborhood trash dumpster near a residence with free ranging chickens which the radio collared bobcat had visited, one was buried in a vacant patch of desert with the severed head of BC #13 Cathrine, and the collar from BC #21 Steve had been cut off and tossed out along a road.

There were no natural cause-of-death mortalities documented in the study area during the project period.

Because urban development and open space patterns within the project area were mixed, road density varied greatly. Bobcats encountered roads of different sizes and traffic patterns multiple times daily. Roads crossed could be single lane dirt interior roads to 4 lane, high speed thoroughfares. Tracking data shows that bobcats moved freely across their habitats and minor roads were not seen as a major barrier. Bobcat home ranges had an average road density 9.67 km. per km. squared and averaged 97.9 kms of roads (including both major and minor roads). Radioed bobcats in the study area averaged 3050 crossings during the time they were radio collared. The 5 major road segments within the project convex core averaged just over 10,066 vehicles a day. Specific segments could be twice that number. The segment of Mission Rd./Grande Ave passing through the home ranges of several collared bobcats has a volume of over 20,000 vehicles daily annually. BC #3 Hal was tracked for just over 10 months and during that time crossed roads over 1,980 times. He was struck and killed on the 76th time he crossed Ironwood Hill Rd (Fig. 29). This major road supports a volume ranging from 3788 vehicles to over 16,800 vehicles daily.

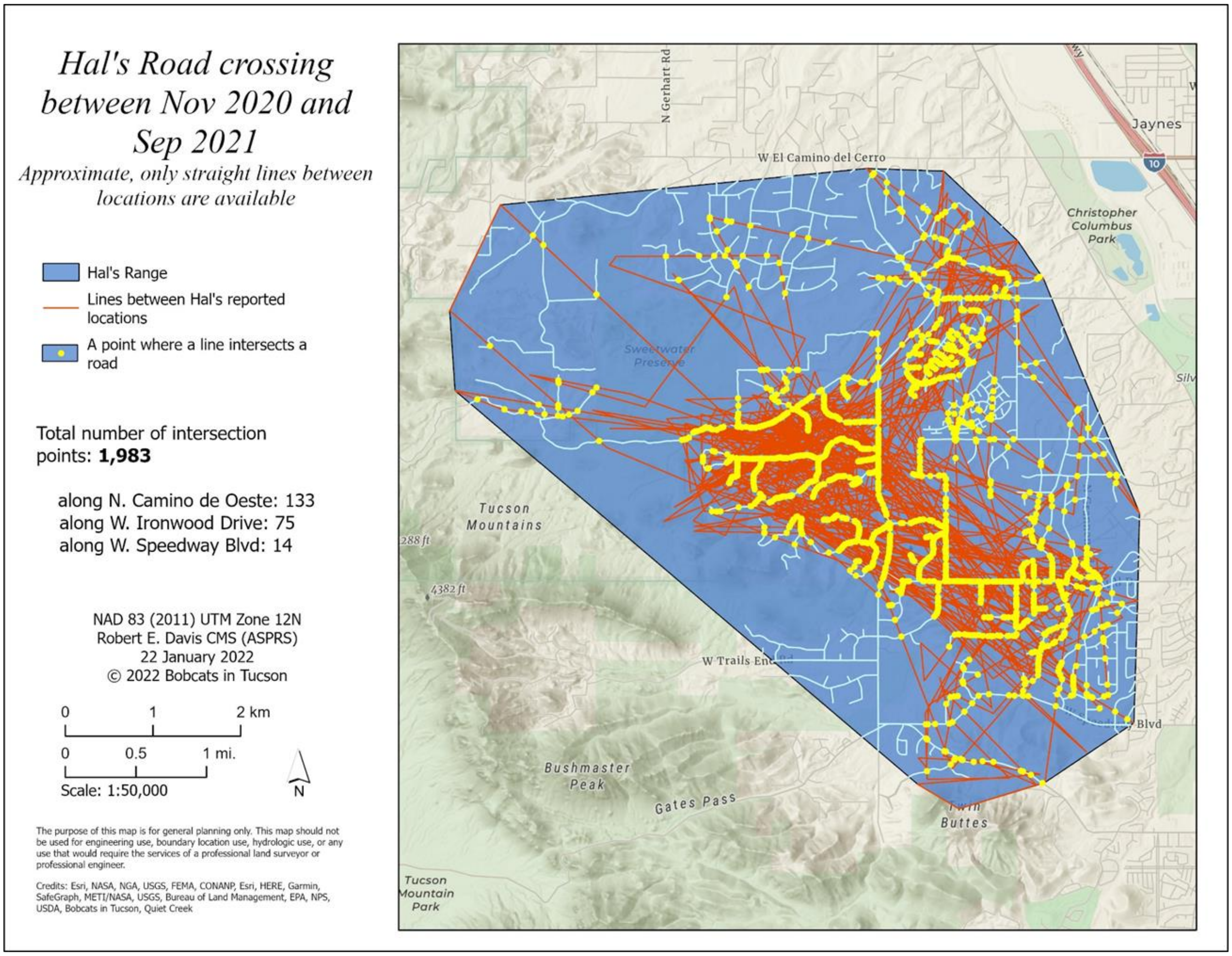


Figure 29. BC # 3 Hal Road Crossing Results

The two major causes of mortality we documented, combined, represent a significant cause-of-death reality in the mixed urban/wildlands setting. Little can be done to limit vehicle fatalities that are accidents on high volume roadways. However, the human caused killings generally show an unreasonable fear of injury to humans and pets and domestic from urban bobcats or lack of understanding of bobcat behavior. Those individuals that killed bobcats potentially preying on urban domestic livestock or pets generally placed limited value on the presence of urban bobcats. Reported and documented injuries from human and bobcat interactions are very rare. Additionally, bobcat pet conflicts appear to seldom result in significant injury to the pet, yet there are active urban myths of significant conflicts that are common among the public. Of the over 1500 bobcat activity reports we received from the public through the BIT website, only two involved negative bobcat encounters with pets, both housecats. We received no direct reports of bobcats attacking dogs.

Home Range Analysis

Thirty adult bobcats were available for home range analysis Six adult bobcats were excluded from home range analysis because they were not radio collared long enough to meet the minimum requirements for home range analysis: BC #9 Cooper (9 days radio collared), BC #19 D2 (2 days radio-collared) BC #57 Karen (3 days radio-collared) BC #46 Cassidy (35 days radio-collared), BC #52 Michele (32 days radio-collared), and BC #13 Cathrine (31 days radio-collared). All were mortalities except BC #57 Karen where a malfunction of the breakaway mechanism caused the collar to release prematurely two days after it was deployed.

Home range and core area sizes

For spatial analyses, we used 51,456 GPS locations for 30 adult bobcats (12 males, 18 females) from November 2020 to May 2024 to determine home range and core area sizes. Females' home ranges averaged 8.1 ± 4.4 km^2 (mean ± standard deviation) and ranged from 3.5 to 21.2 km^2, whereas males averaged 19.6 ± 7.6 km^2 and ranged from 11.5 to 35.4 km^2 being significantly larger than those of females (Kruskal-Wallis H = 16.2, $P < 0.001$). Similarly, females' core areas averaged 2.0 ± 1.1 km^2 and ranged from 0.6 to 4.5 km^2, whereas males averaged 4.8 ± 2.2 km^2 and ranged from 2.8 to 9.9 km^2 being significantly larger than those of females (Kruskal-Wallis H = 16.2, $P < 0.001$).

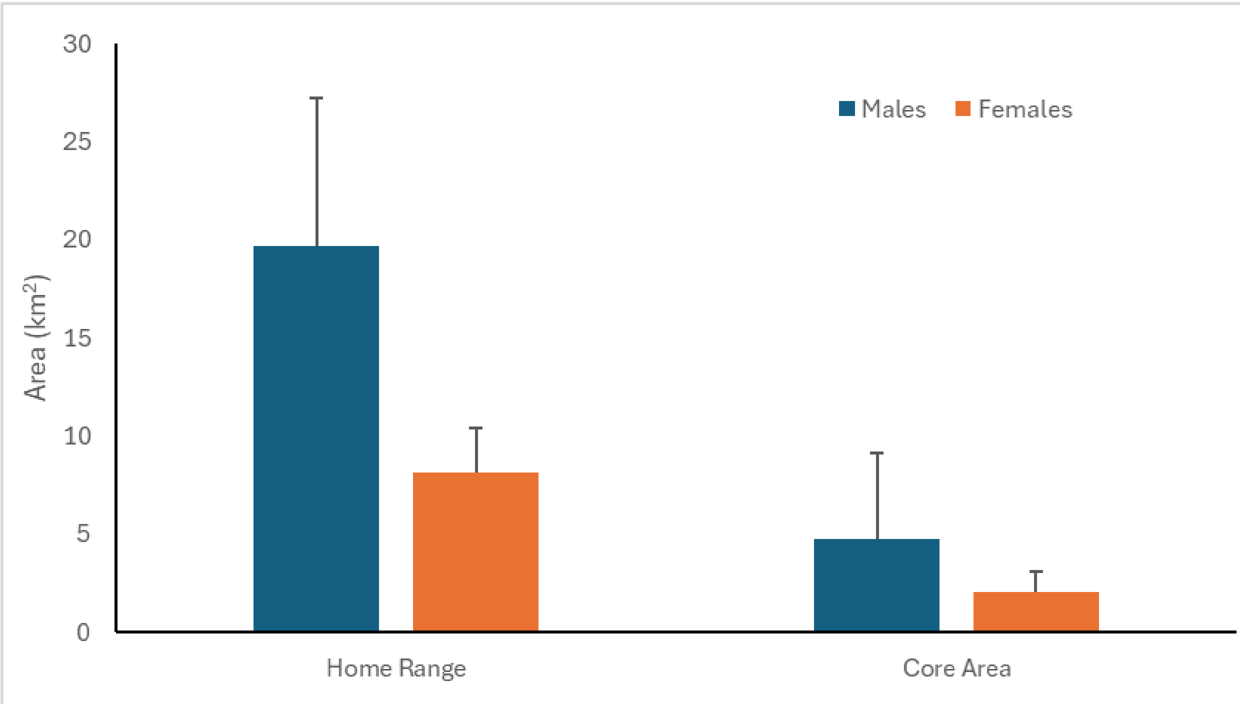


Figure 30. Male and Female Bobcat Home Range and Core Area Sizes

Shared mother-daughter home ranges

Shared mother-daughter home ranges were smaller (7.4 ± 2.2 km^2) than those that females did not share ranges (9.7 ± 6.1 km^2), but the difference was not significant (Kruskal-Wallis H = 0.095, P=0.758). The difference was not significant largely because of the variance among the home range sizes of those who did not share home ranges and could also have been affected by small sample sizes. The sharing of home ranges by mothers and daughters based on resource availability should be further investigated.

Male home ranges varied dramatically in size ranging from 11.4 to 35.4 km2, and in overlap. Bobcats #8 Ben and BC #15 Sweetwater showed a remarkable amount of overlap (Fig. 31) even though they were unrelated males.

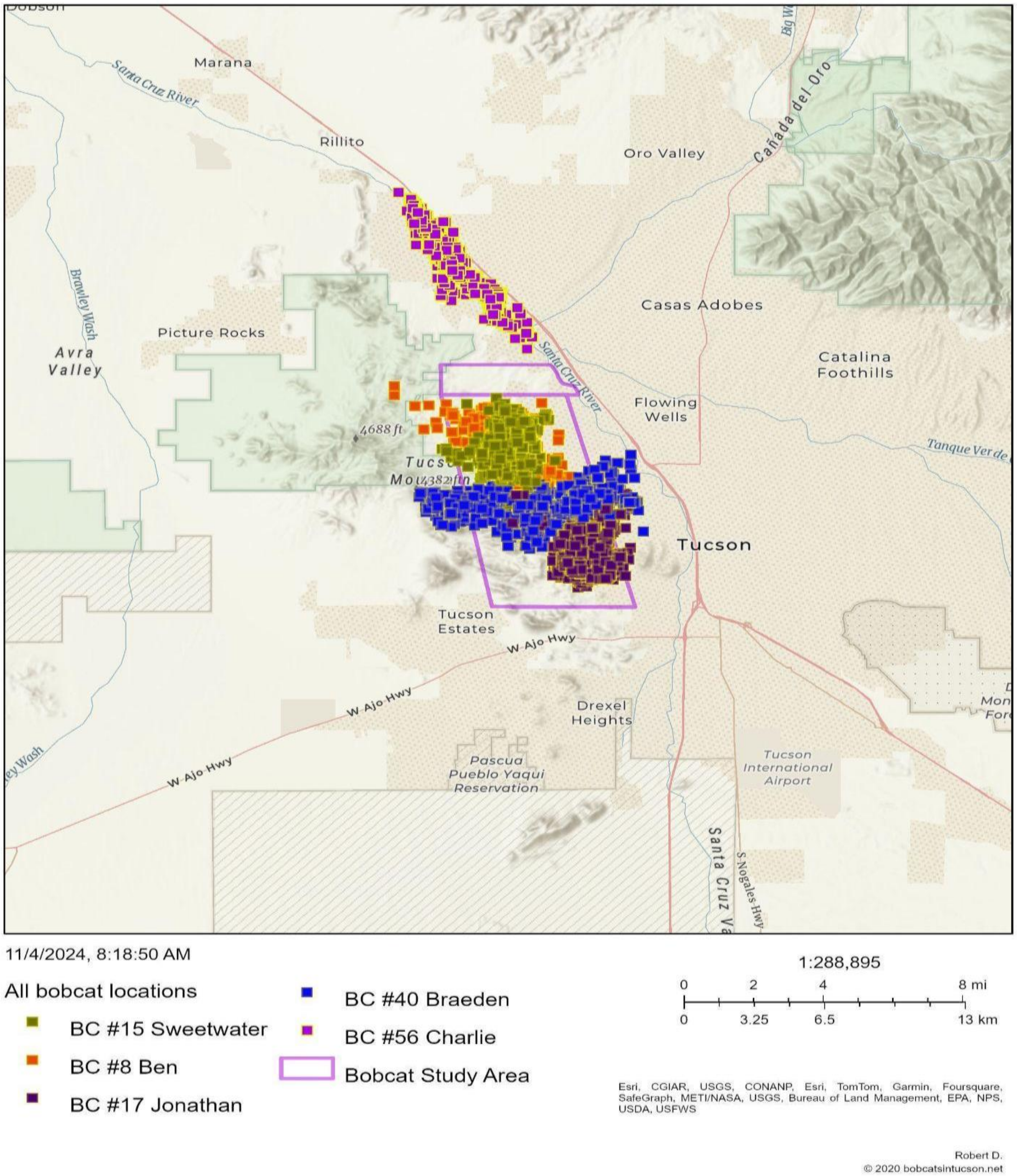


Figure 31. Select Male Location Data

Other males showed varying amounts of home range overlap versus females which showed very little overlap except for mothers and daughters. Female home range overlap is discussed in depth in the Genomic Relationships section later in this document.

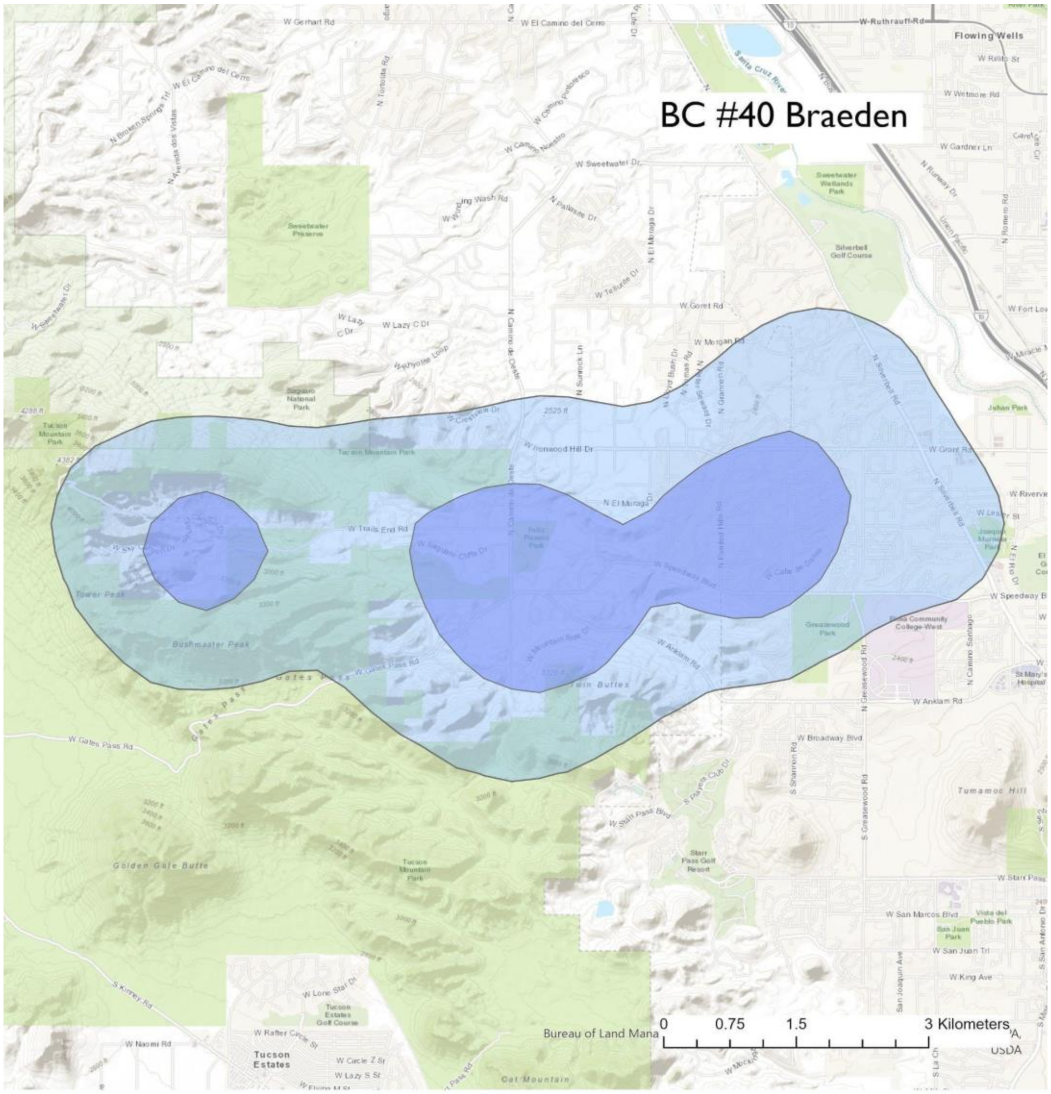


Figure 32. Home Range and Core Areas of BC #40 Braeden.

Note- Bobcat Home Range Maps vary in scale to show detail. See Figure 31 for relative sizes of male home ranges

BC #40 Braeden had the largest home range of any bobcat radio collared at 35.4km2 (Figs. 31 and 32) which is almost 3 times larger than BC #17 Jonathan (Figs. 31 and 33) who had the smallest home range of male bobcats.

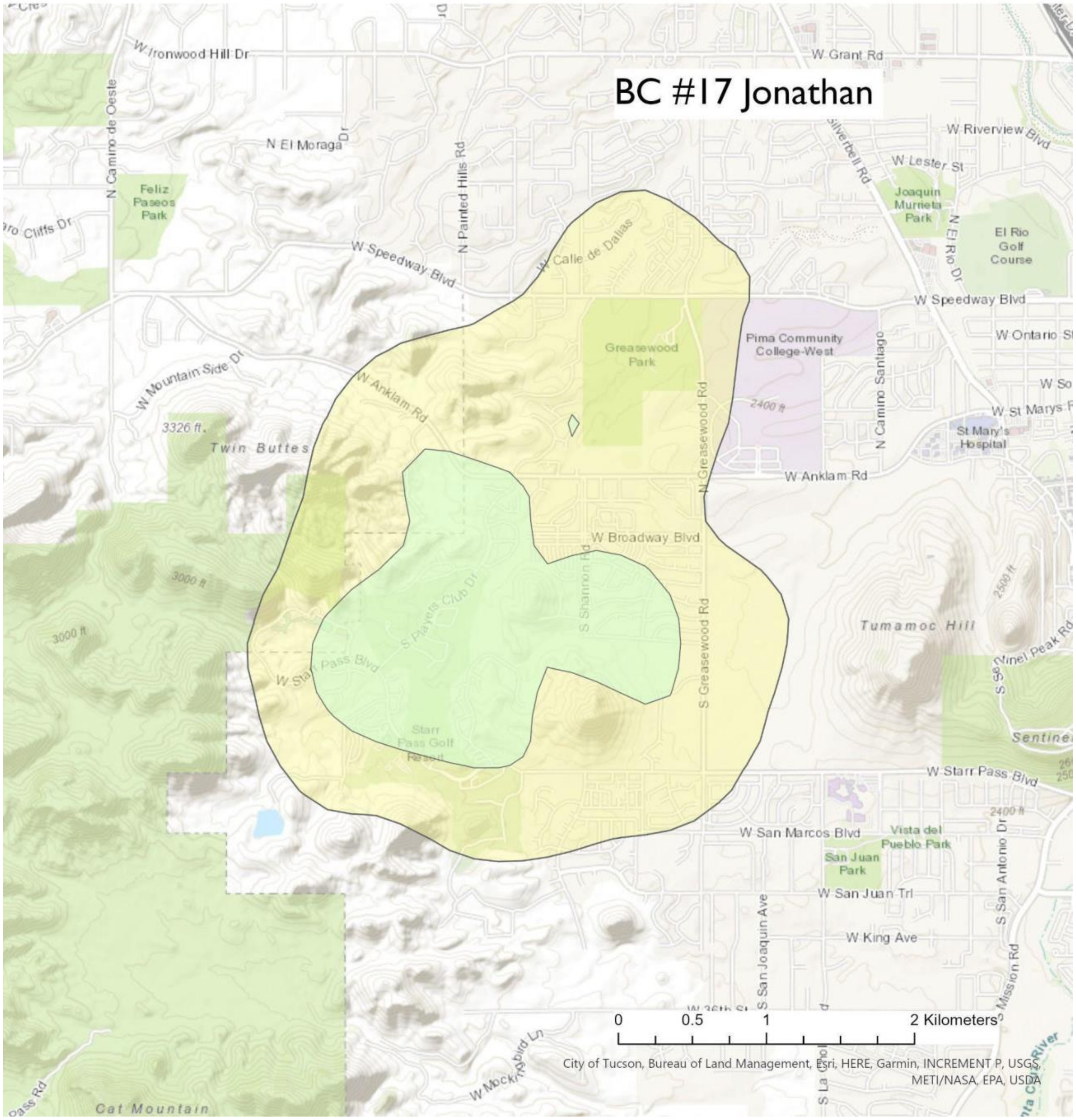


Figure 33. Home Range and Core Area of BC #17 Jonathan

BC Braeden #40 was the largest male we captured weighing 27.15 pounds. We captured and handled him twice. His initial capture weight was 25 pounds in January of 2022. We re-captured him and changed his collar in January of 2023 when he weighed 27.15 pounds. He gained weight (almost 8% of his body weight) during the first year he carried a radio collar. He was a dominant male on the study area with his home range intersecting 7 different females (Fig. 34). BC #40 Braeden utilized as part of his home range, all of the habitats in the study area from very low housing density areas on the far west side of his home range to the most highly developed areas on the east side of his home range, with the exception of golf course habitat.

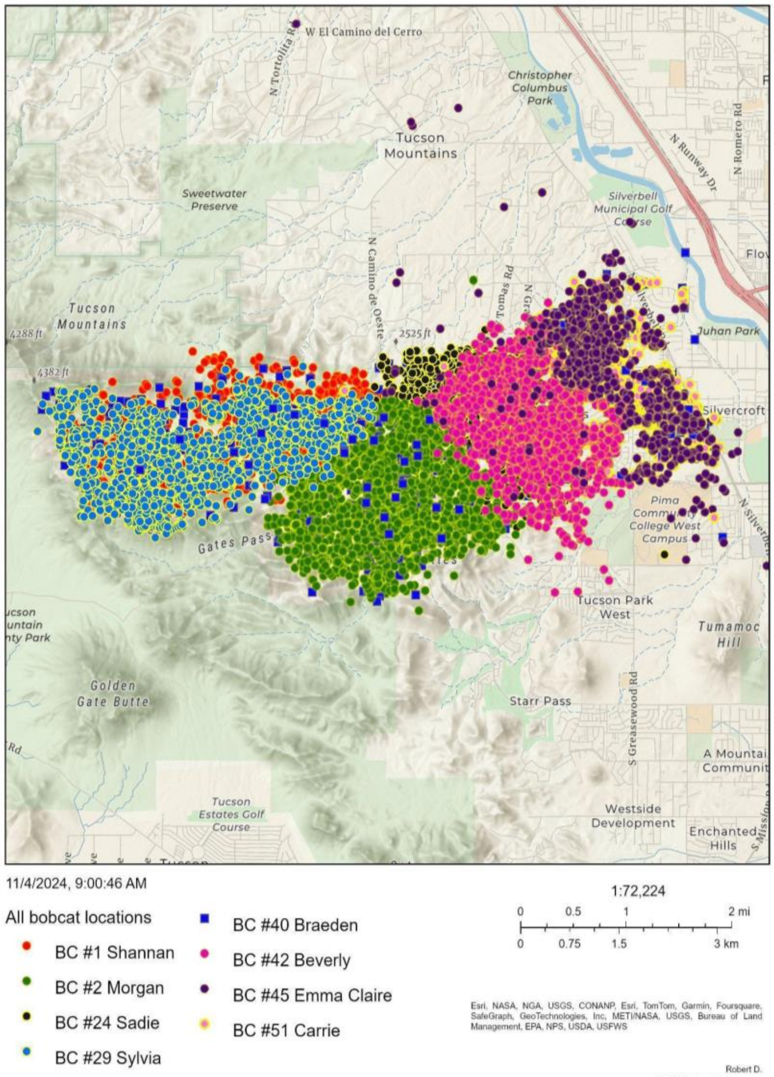


Figure 34. BC #40 Braeden's locations overlap with 7 radio collared females

The only habitat type on the study area that was not part of BC #40 Braeden's home range was a golf course. BC #13 Jonathan who had the smallest home range of all males (11.5 kilometers) (Figs. 31 and 33) which was only one third the size of BC #40 Braeden's, utilized the Starr Pass Golf Course as part of his home range, as did BC #11

Minnie, who had the smallest home range of adult females at 3.5 kms. (Figs. 35 and 36).

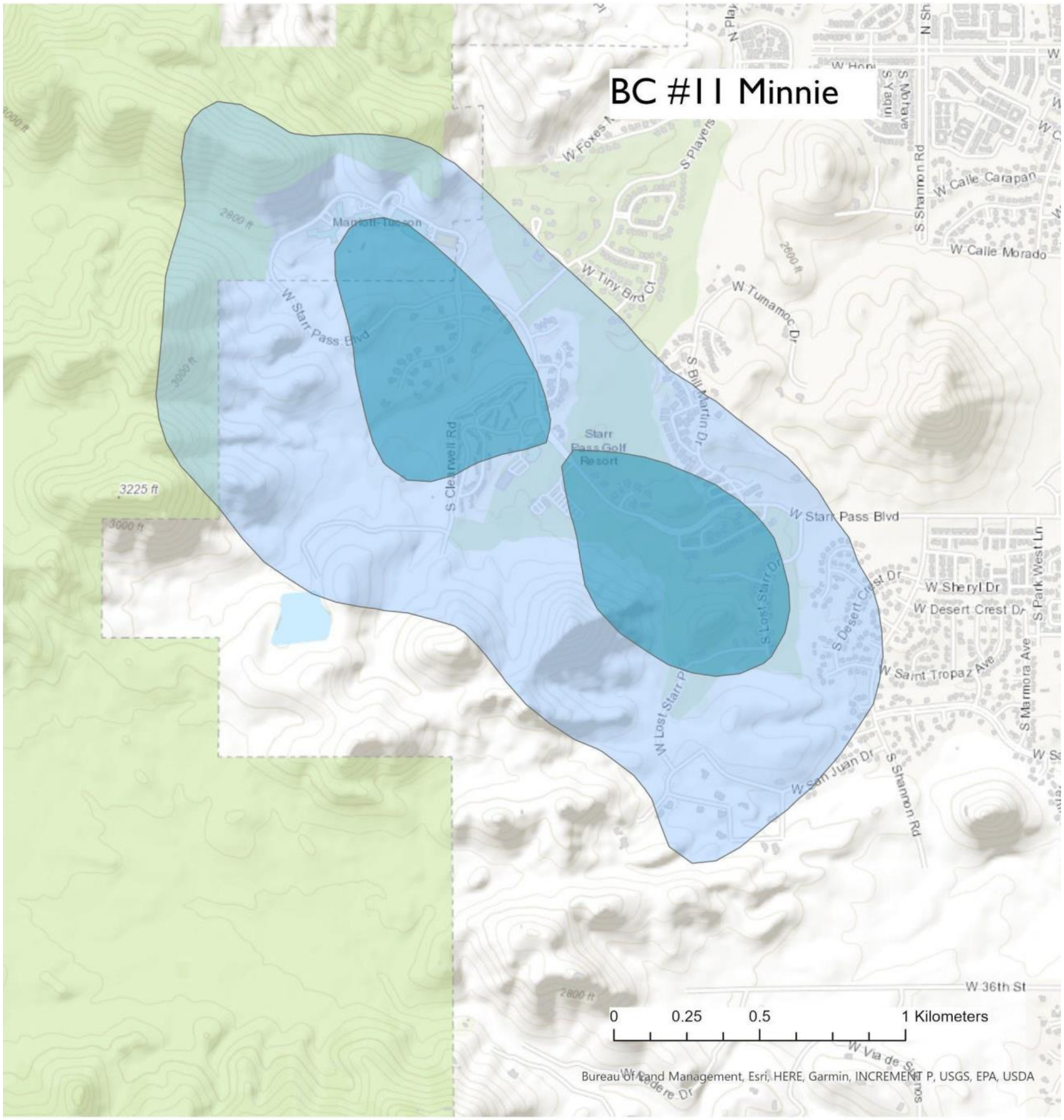


Figure 35. Home Range and Core Areas of Bobcat #11 Minnie

Note- Bobcat Home Range Maps vary in scale to show detail. See Figure 36 for relative sizes of female home ranges

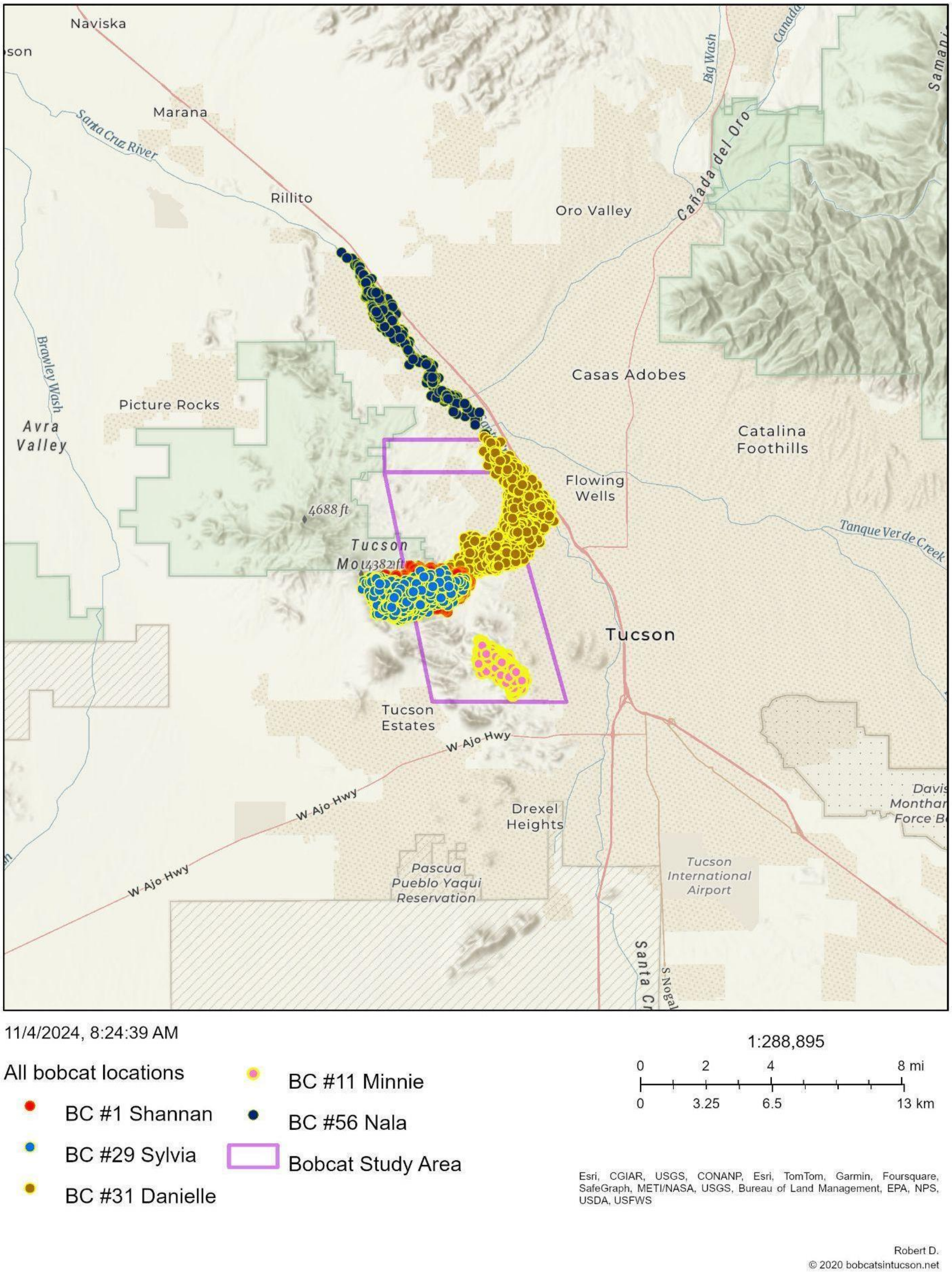


Figure 36. Select Bobcat Female Location Data

The Starr Pass Golf Course was home to 5 different bobcats over the course of the Study: BC #5 Dave, BC #11 Minnie, BC #13 Jonathan, BC #37 Bobbie Jo, and BC # 50 Daphne. BC #37 Bobbie Jo, and BC # 50 Daphne successfully raised kittens utilizing the golf course habitat. It is unclear if BC #11 Minnie successfully raised her 2021 litter of kittens (her first) before her death from a vehicle strike on Starr Pass Boulevard in the fall of 2021. Golf courses that are managed to consider wildlife can provide valuable additional habitat diversity in an urban landscape. The male and female bobcats with the smallest home ranges, respectively, both were captured on and utilized extensively the Starr Pass Golf Course.

BC #56 Nala had the largest female home range of 21.2 sq. km. of radio collared females.

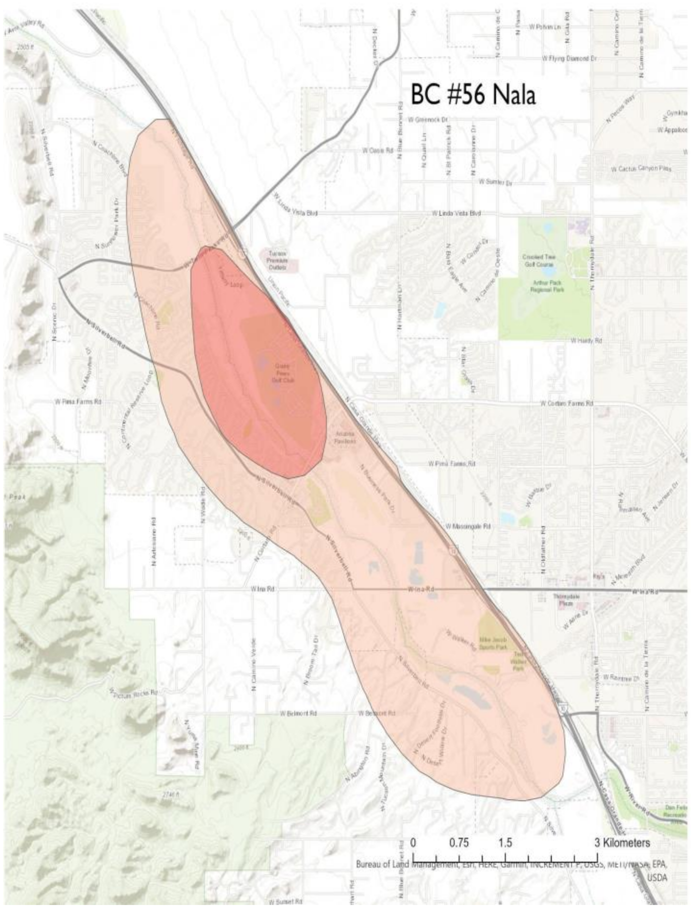


Figure 37. BC #56 Nala’s Home Range with Core Areas

Her home range and that of BC #55 Charlie (Fig. 38) were distinctly different in shape than others on the study area, being the only two radio-collared bobcats that lived primarily in and along the Santa Cruz River drainage to the north of Sunset Road.

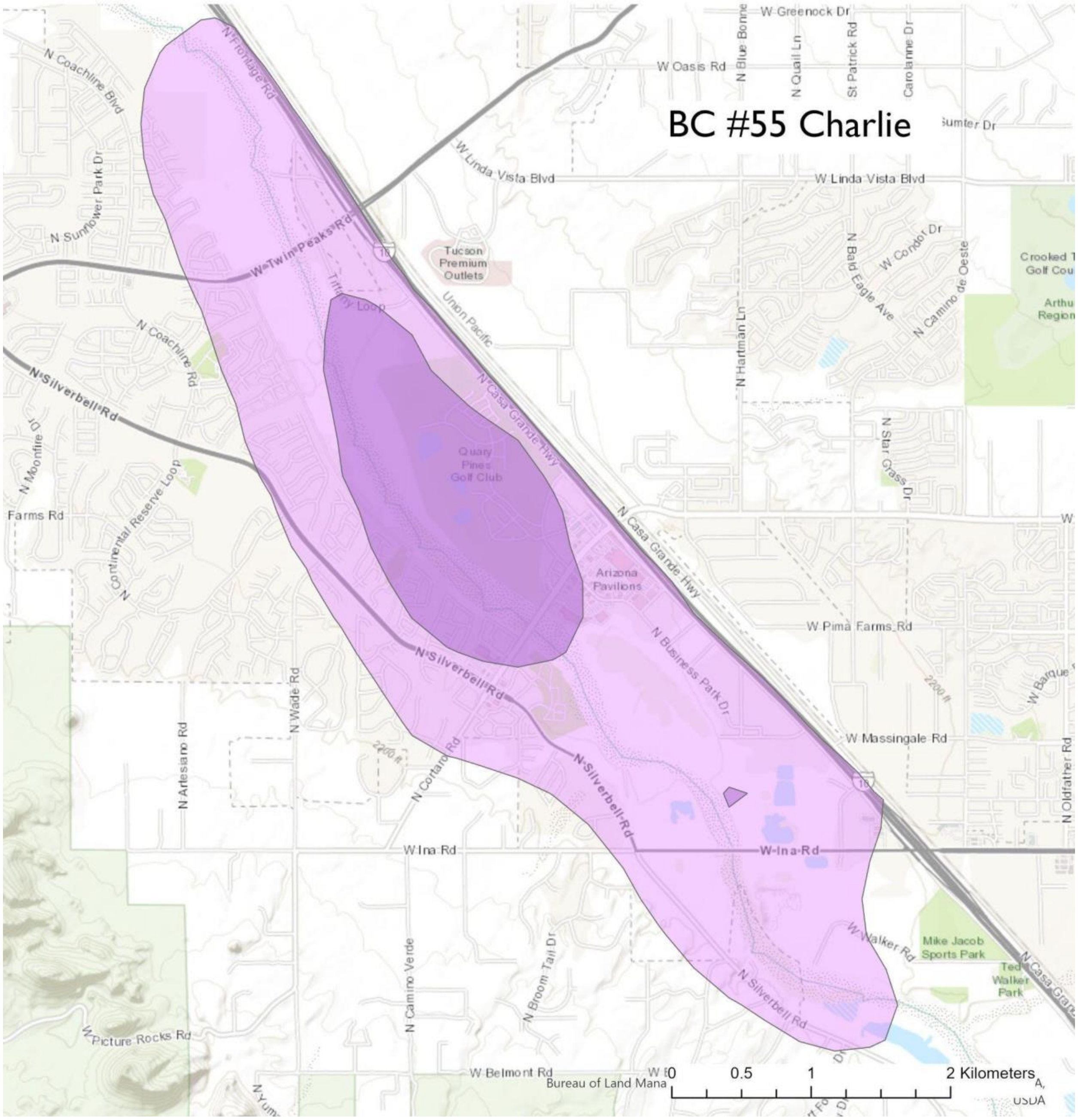


Figure 38. Home Range and Core Areas of Bobcat #55 Charlie

This area of the Santa Cruz River has well developed riparian vegetation in response to several years of high-quality effluent releases that maintain a continuous flow of water along this stretch of the river (Figure 39).

Figure 39. Mature Perennial Riparian Vegetation along the Santa Cruz River north of Sunset Road. Photo Courtesy of Claire Zugmeyer/Sonoran Institute

The linear shape of their home reflects their use of this habitat. The use of the Santa Cruz River by bobcats as it flows through Tucson should be further investigated as it offers an additional habitat type (perennial riparian vegetation), that is not available to bobcats elsewhere in the Tucson area.

Bobcats that lived south of Sunset along the Santa Cruz and utilized the Sweetwater Wetlands had to move back and forth across Silverbell Road (a major busy road) into areas of human development to meet their habitat needs (Fig. 40).

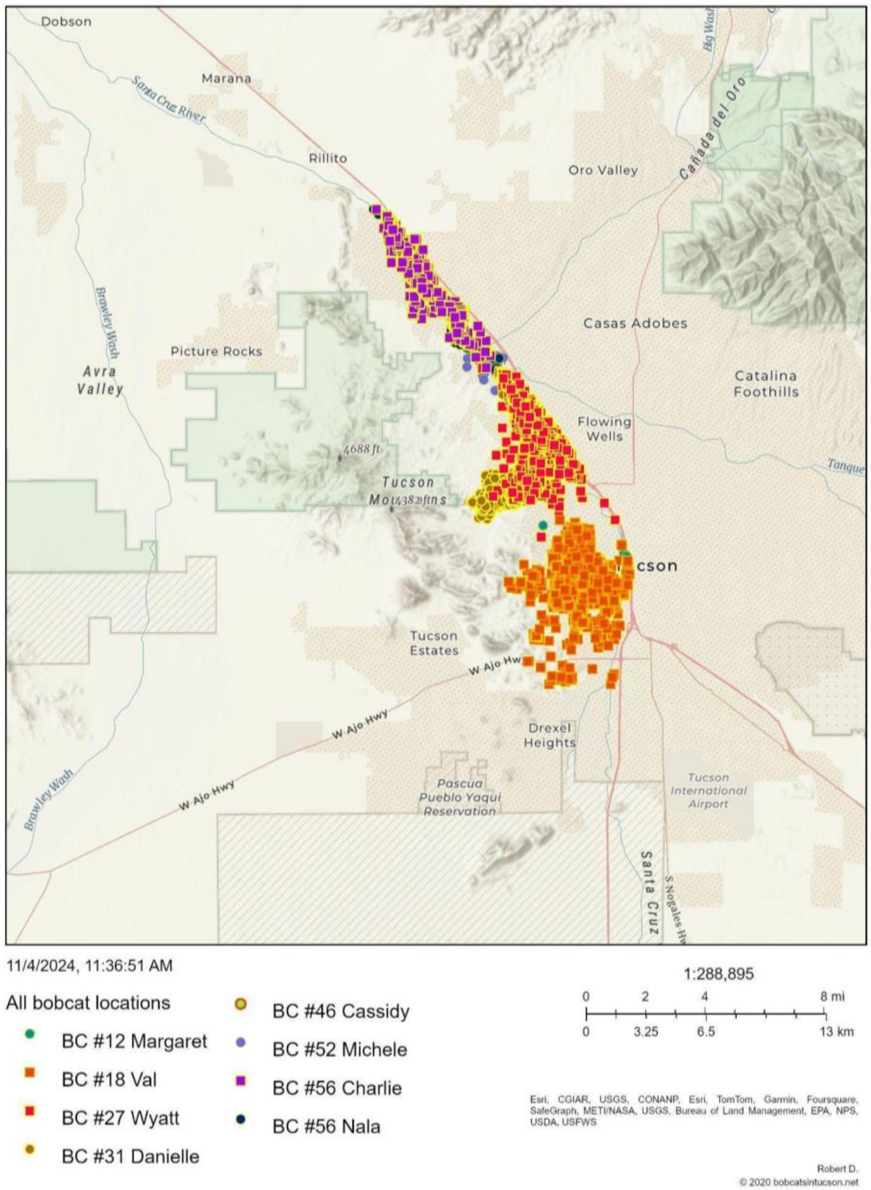


Figure 40. Radio Collared Bobcat Use of the Santa Cruz River Drainage in Tucson including BC #27 Wyatt and BC #34 Danielle

BC #52 Michele was struck and killed while crossing Silverbell within a month of being radio collared, and BC# 46 Cassidy also died from injuries near the Sweetwater Wetlands likely sustained in a vehicle strike. Bobcats # 27 Wyatt (Figs. 40 and 41) and # 34 Danielle (Figs. 40 and 42) used the Sweetwater Wetlands extensively and crossed a major road (which includes Silverbell) 1626 and 768 times respectively during the time they were radio collared.

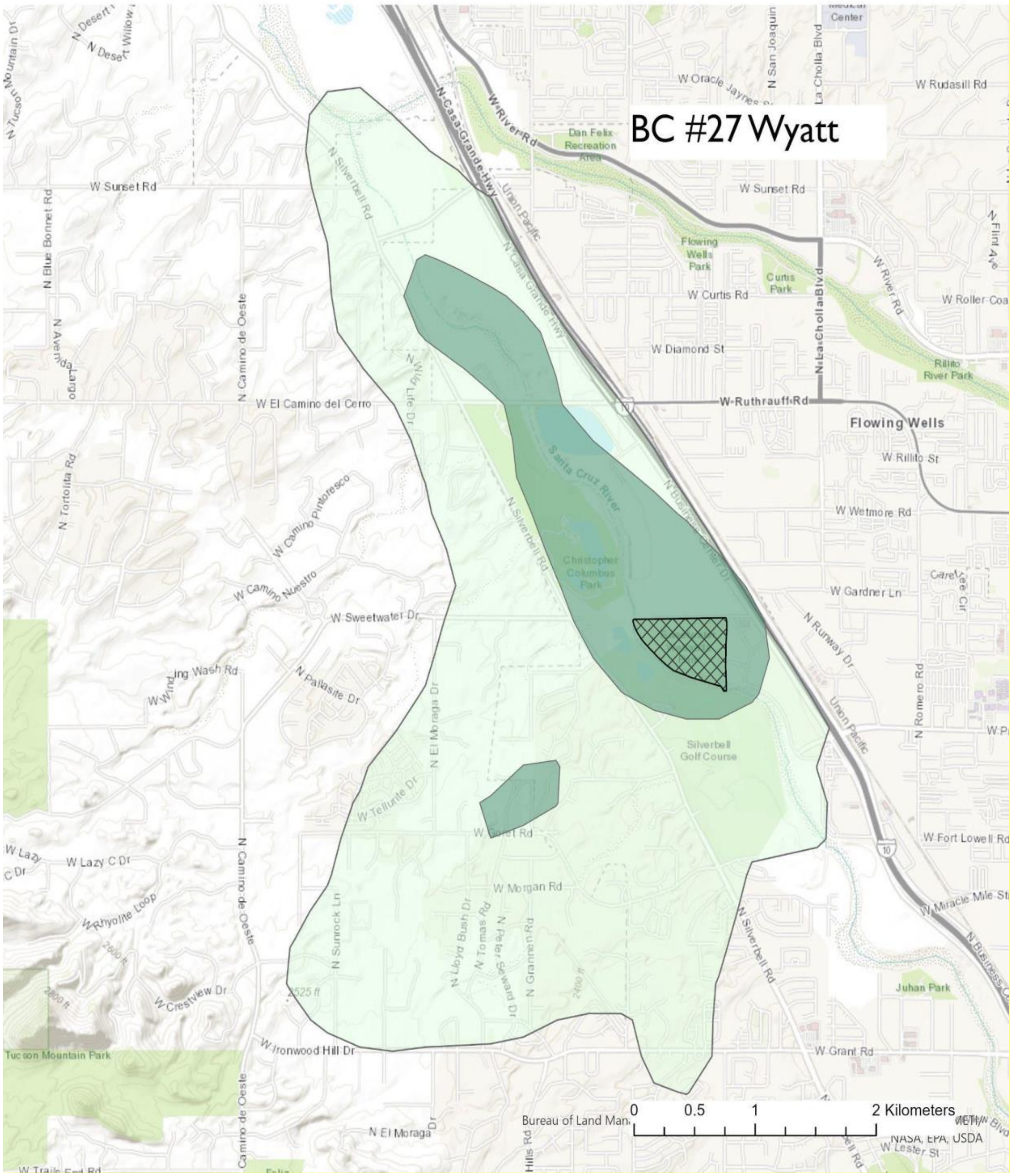


Figure 41. BC #27 Wyatt Home Range and Core Areas

with Sweetwater Wetlands Park crosshatched

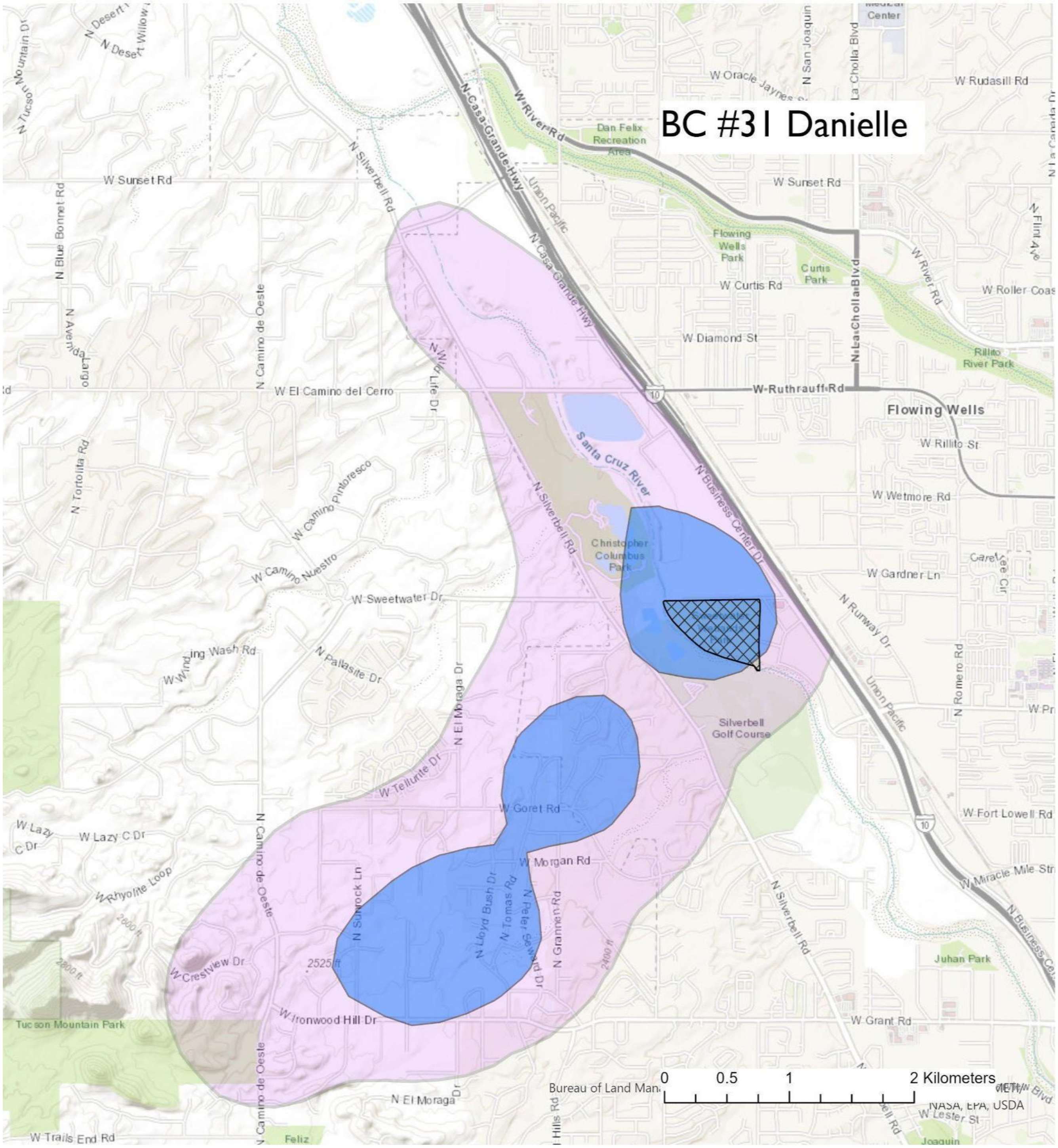


Figure 42. BC #34 Danielle Home Range and Core Areas with Sweetwater Wetland Park cross-hatched

Bobcats that utilize the Sweetwater Wetlands for its unique and food rich environment also have to utilize other habitats to meet their habitat and social needs.

Figure 43. BC #27 Wyatt hunts the Sweetwater Wetlands.

Photo by John R. Gentile

Since the habitat to the south of the Wetlands is not developed riparian vegetation (water does not routinely flow here) and the area to the east of the Wetlands adjoins Interstate 10, which is apparently a barrier to bobcats on the study area (only one bobcat BC #55 Charlie crossed under an underpass of I-10 during the study) the bobcats that use the Sweetwater Wetlands have to repeatedly cross Silverbell Road to the west to meet their needs.

Bobcats that utilize the more recently re-watered Heritage Corridor to the south include BC #12 Margaret and BC #18 Val (Figs. 31 and 36). Both bobcats live primarily on Tumamoc Hill and at Sentinel Peak Park. They utilize the Santa Cruz River as a travel way and likely for hunting, but the more recent effluent releases do not yet support an established riparian community that provides adequate cover and resources for bobcats to live there full time as they do in the northern reaches. The continued efforts to re-establish the Santa Cruz as a flowing river with a developed riparian corridor can only be beneficial to bobcats over the long term.

Female Shared Home Ranges

Individual ranges of mother-daughter pairs who shared most of their respective home ranges were smaller (7.4 ± 2.2 km^2) than those that females did not share ranges (9.7 ± 6.1 km^2), but the difference was not significant (Kruskal-Wallis H = 0.095, P=0.758). The difference was not significant largely because of the variance among the home range sizes of those who did not share home ranges and could also have been affected by small sample sizes. The sharing of home ranges by mothers and daughters based on resource availability should be further investigated.

Two subadults were also excluded from the home range comparisons: 1 male (BC #48 Tippy) who dispersed during the time he was radio collared and 1 female (BC #45 Emma Claire) who transitioned to adulthood while radio collared and was the only bobcat to wear both types of collars we deployed. In both cases these subadults were captured within their mother's home range while we were attempting to recapture her to change her radio collar.

Subadult male BC #48 Tippy was the only bobcat to disperse from the study area. He dispersed approximately 14 kilometers during the time he was radio collared (Fig. 44).

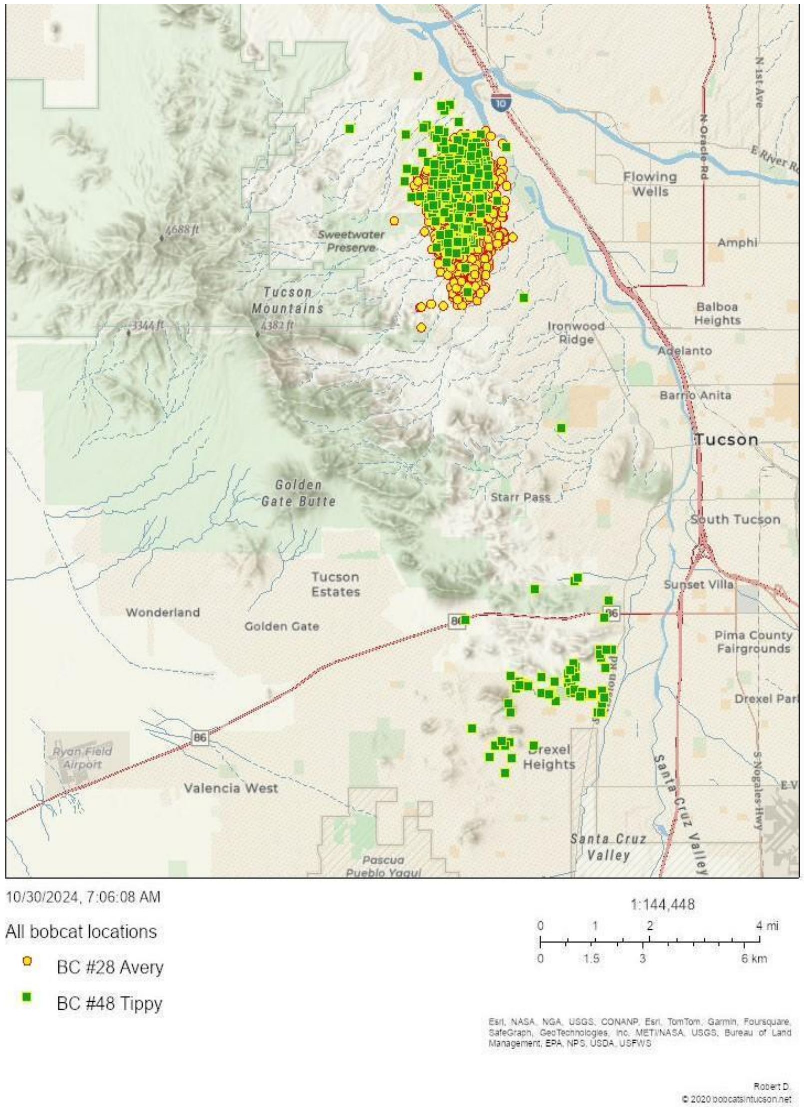


Figure 44. Location Data for subadult male BC Tippy #48 and BC Avery #28

The northern cluster represents the home range he shared with his mother from his capture in November of 2022 at approximately 10 months of age to his dispersal to the south in April of 2023 at about 15 months of age after BC #28 Avery gave birth to another litter of kittens. We received two anecdotal reports of two radio collared bobcats - one large and one smaller, growling at each other near where BC# 28 Avery gave birth to her next litter of kittens. Shortly after those reports, BC #48 Tippy began to drift to the south. His collar broke away as scheduled at the end of June 2023 within the lower cluster of locations on Figure 44. BC Emma Claire #45 was captured in November of

2022 and recaptured in December of 2023. She was a part of a litter born in early 2022. She remained largely in her mother's home range until her death in the spring of 2024.

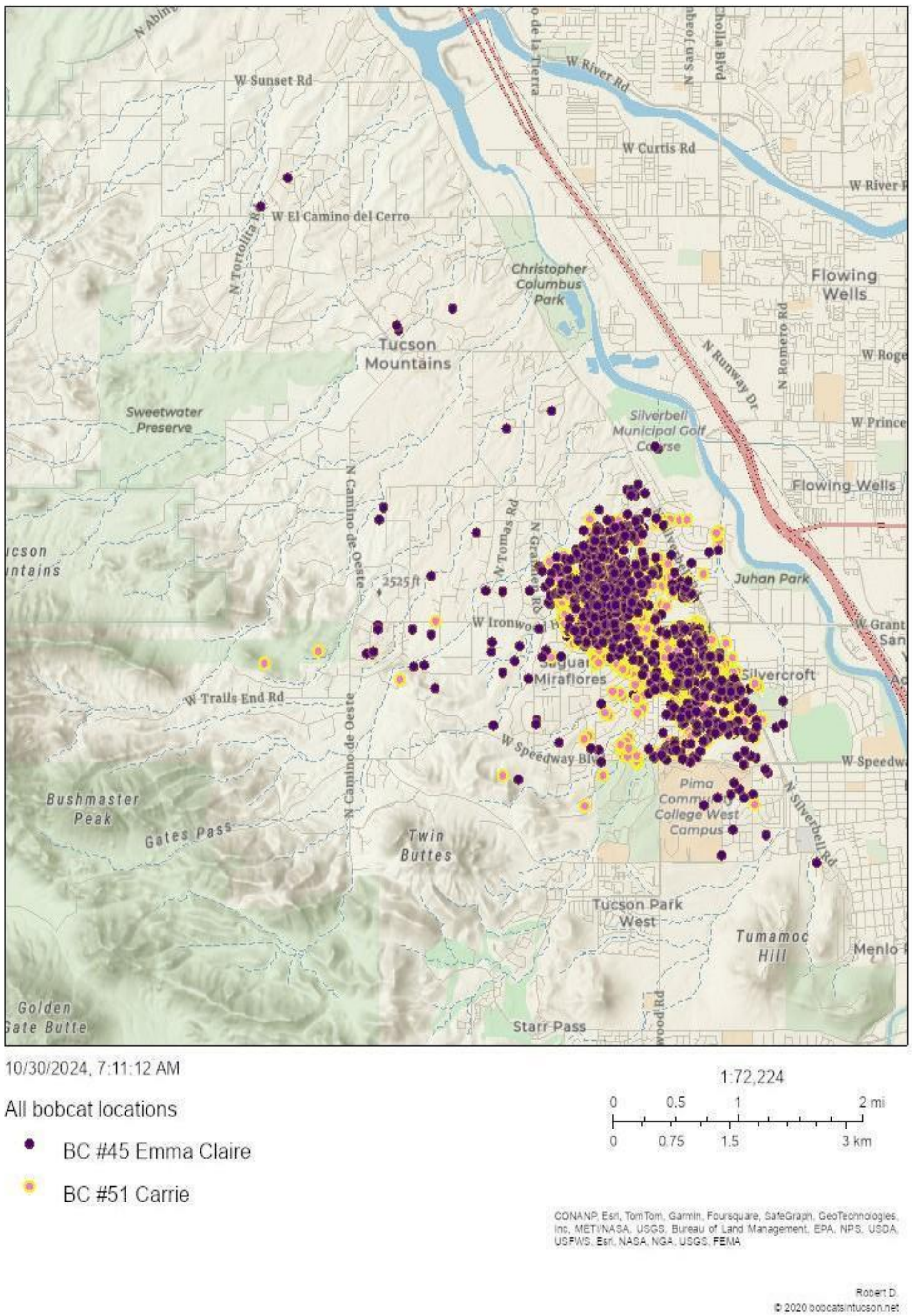


Figure 45. BC #45 Emma Claire and Bobcat #51 Carrie location data

Bobcats and Roads Analysis - by Margaret Mercer and Jesse Alston

53,683 total GPS points were collected from 38 individuals between November 18, 2020, and May 4, 2024. The length of time each collar was deployed ranged from 1 day to 2.5 years, with mean and median values of 1 year. The sampling interval ranged from 2 to 13 hours, with an average of 5.4 hours and a median of 4 hours. Three bobcats were excluded from the analysis due to insufficient data.

Road densities in bobcat home ranges averaged 9.67kms. per sq. km. with an average of 97.9 kilometers of roads per home range. The average number of road crossings per bobcat was 3050 with an average of 7.4 crossings per day. Bobcats crossed roads near structures an average of 1.3% of the time.

Crossings and the number of roads within a bobcat's range are highly correlated; for every 1 km/km squared increase in road density, bobcats crossed roads 0.85 more times per day (linear model, $p < 0.001$). Male home ranges were 2.5 times larger than female home ranges (males = 17.1 km sq., females = 6.8 km sq.), but we found no correlation between sex and the number of road crossings ($t = -0.5$, $df = 29.3$, p-value = 0.6), road density within home ranges ($t = -1.2$, $df = 30.6$, p-value = 0.23), or percentage of crossings near a crossing structure ($t = -0.09$, $df = 28$, p-value = 0.93).

Bobcats crossed roads 11% less frequently than expected by random chance. On average, each bobcat crossed roads 3,050 times during the time they were radio collared, while simulated bobcats with identical movement behaviors crossed roads 3,444 times (paired t test; $t = -2.05$, $df = 34$, p-value = 0.05) (Fig. 46a). This avoidance behavior was predominantly driven by major roads—bobcats crossed major roads 26% less frequently (474 crossings) than in simulations (643 crossings; paired t test; $t = -3.3$, $df = 34$, p-value = 0.002) (Fig. 46b). They crossed minor roads 8% less frequently than expected, but the effect was not strong ($p = 0.1$) (Fig. 46c). Simulated results are an average of 1000 simulations per bobcat. Simulations accounted for both home range size and the length of time collars were deployed. The number of actual road crossings per bobcat varied widely between individuals (50 to 8,447 for all roads, 0 to 2,020 for major roads).

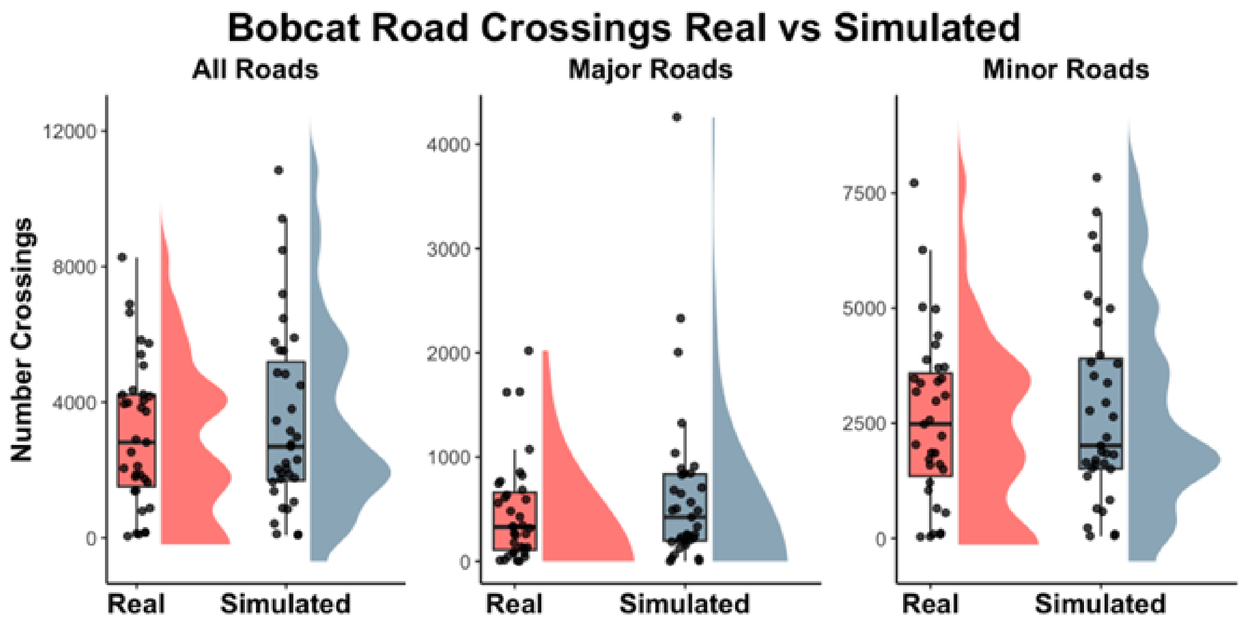


Figure 46 (a-c). Bobcats crossed roads less frequently ("real") than anticipated ("simulated")

This was the case for all roads, with most of the variation driven by major roads. We did not find strong evidence that bobcats search for or use culverts or bridge underpasses to cross roads. The mean distance from each point where a bobcat crossed a road to the nearest crossing structure was 1,804 meters (95% CI 1,796 to 1,812), compared to 1,989 meters (95% CI 1,974 to 2,004) for simulated bobcats. On average, bobcats crossed roads within 7 meters (the average GPS error) of crossing structures 1.3% of the time (95% CI 0.2% to 2.4%). Simulated paths crossed roads near crossing structures 0.4% of the time (95% CI 0.2% to 0.6%). Two bobcats were outliers, using crossing structures at rates of 16% and 11%. When they were excluded, the rest of the bobcats used crossing structures 0.6% of the time (95% CI 0.2% to 0.9%). 11 out of 35 bobcats (31.4%) never crossed a road within 7 meters of a crossing structure.

The two outliers, BC #55 Charlie and BC #56 Nala were both bobcats that had linear home ranges that primarily followed the Santa Cruz River drainage to the north of Sunset Road. They were passing under three major road bridges and overpasses as they traveled up and down the Santa Cruz (Ina, Cortaro, Twin Peaks). Both bobcats spent the majority of their time in the Santa Cruz River Basin (Figs. 37 and 38) did not actually cross roads, (but rather passed under them), as often as many bobcats who lived in dispersed or more concentrated built-up areas.

No evidence was found that home range size varied in response to road densities. As road density increased, there was no evidence that home range size changed (linear model, $p = 0.47$) (Fig. 47).

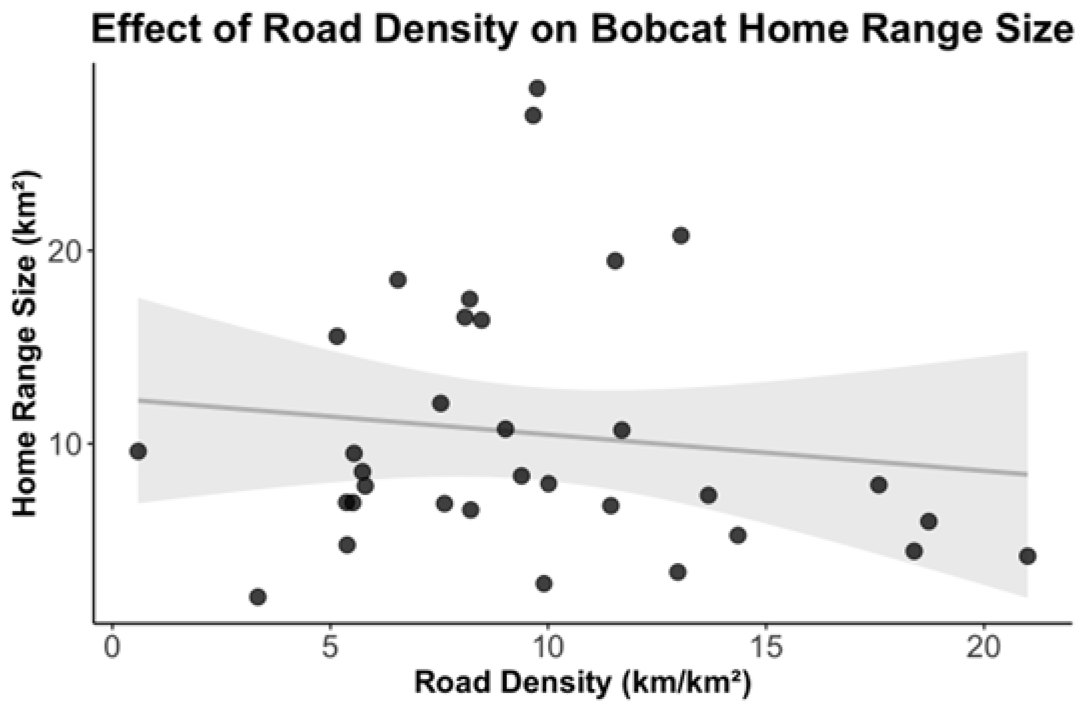


Figure 47. Effect of Road Density on Bobcat Home Range Size

Road density within a bobcat's home range has no appreciable effect on bobcat home range size.

REPRODUCTIVE TIMING AND KITTEN REARING

Bobcats utilize a polygynous reproductive strategy. Females are seasonally polyestrous (Gashwiler et al. 1961, Crowe 1975,) and may cycle up to three times if breeding is not successful, with the estrous cycle lasting about 44 days (Crowe 1975). Bobcat females typically produce one litter year, although if a litter is lost shortly after birth, females can quickly re-enter estrous to breed again and produce another litter (Beeler 1985, Stys and Leopold 1993). Bobcats have been documented producing young in all months of the year. Kittens are born semi-altricial and helpless, their eyes are closed, and they cannot regulate body temperature (Stys and Leopold 1993). Kittens typically remain in or near a den site until they begin traveling with the mother at approximately 3 months of age (Bailey 1974, Winegarner and Winegarner 1980) but begin emerging from the den in 33-42 days and begin to eat solid food soon after (Stys and Leopold 1993).

As obligate carnivores, bobcats and all members of the *Lynx* genus must select habitats with adequate prey abundance and hunting and security cover to meet their needs. Both selection stresses increase dramatically for a female with kittens; her nutritional needs increase sharply until the kittens are weaned at approximately 3 months (Sunquist and Sunquist 2002) and probably peak in the second month before kittens begin eating solid food (Sunquist and Sunquist 2002).

Bobcat females typically keep kittens at a den site until the kittens are large enough to travel with the female (8-10 weeks). A female exhibiting denning and kitten rearing behavior (returning repeatedly to the same location) until kittens are large enough to travel with her, is reliable evidence that she raised at least one kitten to independence from the den.

REPRODUCTIVE ATTEMPTS

Seventeen different adult females attempted reproduction (BC # 46 Cassidy, BC # 52 Michele, BC #13 Cathrine, BC # 45 Emma Claire, BC #56 Nala and BC #57 Karen) were not radioed long enough to document reproduction. All females attempted reproduction in each year they were radio collared.

Three females did not appear to have successfully raised any kittens during the study: BC #24 Sadie attempted and lost 2 litters of kittens in 2022. BC #30 Lisa attempted to den in both 2022 and 2023, lost kittens in 2023, and used a natal den sporadically for 60 days in 2022 but it is doubtful that she raised any kittens (this reproductive attempt was excluded from analysis). BC#1 Shannan lost kittens at 86 days in 2021 and did not successfully re-den. She was denned with kittens when her collar came off in 2023. BC #1 Shannan was BC #29 Sylvia’s mother and the mother of a young male we caught and released without radio collaring in 2020.

The remaining 14 females all reproduced successfully to raise at least one verified kitten or were likely to have raised at least one kitten based on the den record during the time they were radio collared: 82% of eligible females successfully reproduced during the study raising at least one kitten and 7% (BC #1 Shannan) had successfully raised kittens before being radio collared. It is unclear if BC #30 Lisa was successful in raising kittens. BC #24 Sadie did not successfully raise kittens during the study.

REPRODUCTIVE TIMING

We documented 24 denning attempts for kitten rearing from March 22 to May 5th during the spring kitten season (Fig. 48) and 7 den attempts outside of the spring kitten season during the study. Seventy seven percent of den attempts occurred during the spring kitten season.

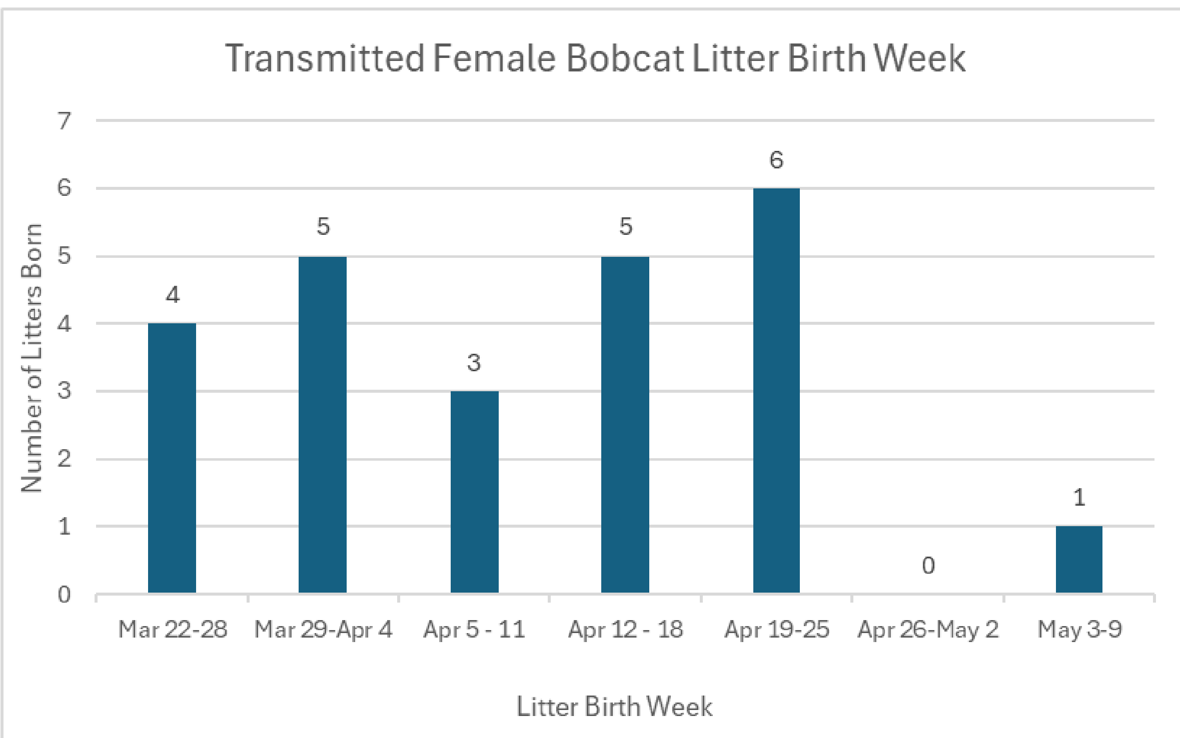


Figure 48. Birth of Spring Litters of Radio-Collared Females

An additional 5 attempts (16%) were 2nd litter attempts after kittens were lost in the spring denning season. Two attempts (6%) occurred out of sync with the spring kitten season, with one litter each born in January and February for a total 31 total attempts in 2021, 2022, and 2023.

Figure 49. Bobcat #28 Avery with two male young of the year kittens born out of sync with the spring kitten season in January of 2022. Photo Courtesy of Chris Wesselman.

Based on eight years of observations on captive bobcats in Mississippi, Stys and Leopold (1993) reported average length of gestation as 65.8 days from the first breeding attempt, and 61.7 days from the last breeding attempt. By backdating 63 days from birth of kittens on the Tucson study area 23 of 24 or 96% of successful winter breeding activity of radio collared females in Tucson occurred between the third week in January and the third week in February (Fig. 50)

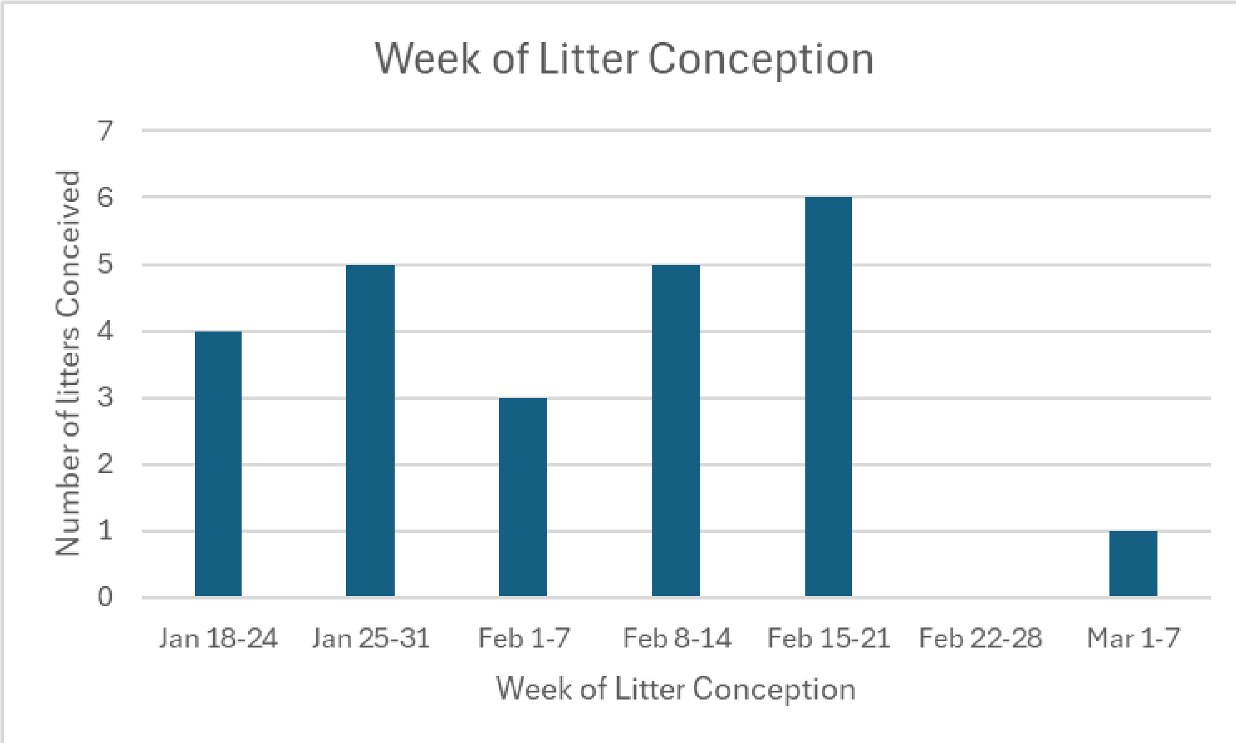


Figure 50. Week of Litter Conception for 24 Bobcat Litters 2021-2023 Born in the Spring Kitten Season

Overall, 24 of 31 or 77% of successful conception (leading to a litter being produced) occurred during the late winter breeding season, while two out of sync litters, born in January and February respectively, would have been conceived in November and December. Successful breeding attempts after litters were lost in the late spring and summer would have occurred in March and May respectively. While bobcats can and do breed and produce kittens at all times of year, we saw a definite peak in breeding activity in late January through most of February that led to most litters of kittens (77%) being born in late March to early May.

Six of 24 (24%) of breeding activity leading to the birth of kittens occurred in the third week of January, and 1 of 24 (6%) occurred the last week in February. Ninety four percent of successful breeding attempts took place between the third week in January and the third week in February. McCord and Cardoza (1982) suggested that the bobcat breeding season probably varies with latitude, longitude, and prey availability but most bobcat breeding probably occurs in February and March (Anderson and Lovallo 2003). Most of the breeding in the Tucson bobcat population took place during the month of February.

REPRODUCTIVE SUCCESS

Nineteen kittens from 12 litters (38%) were verified with visual or photographic evidence to have survived to when the female no longer uses a den.

Figure 51. Photo verification of reproductive success - Bobcat #34 Danielle with young of the year kitten October 22, 2023. Photo Courtesy of Brian Ward

Six litters (19%) with at least one kitten each surviving were likely successful based on the den record of the female for a total of 18 or 57% verified successful reproductive efforts.

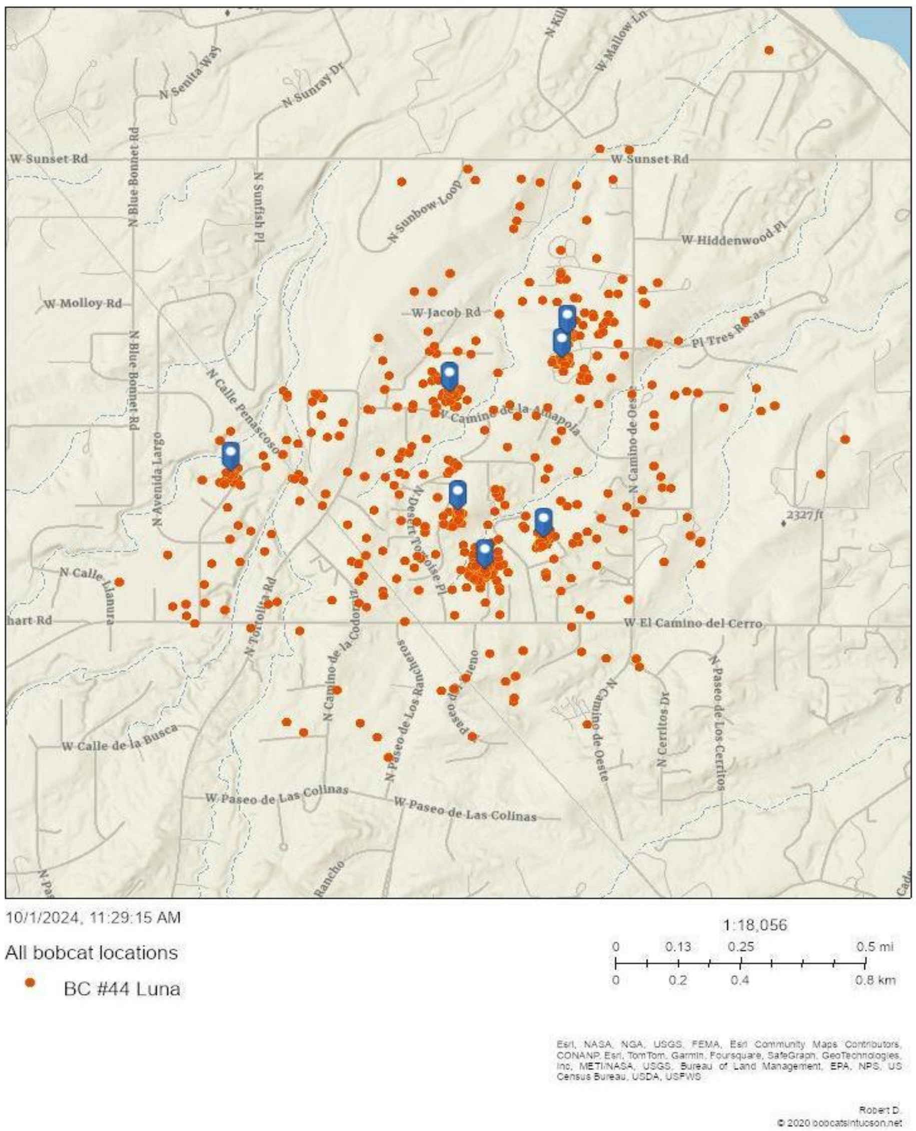


Figure 52. 2023 Den Record of BC #44 Luna

BC #44 Luna kept kittens at the natal den (farthest south of markers) for 17 days and maternal den use (6 markers) for 63 days or 80 days of total den use. Kittens were 11+ weeks old when she no longer used a den. Photographic evidence of 2 surviving kittens provided 11/18/2023 by a citizen scientist and verified with GPS location data. Kittens were moved 278-2061' from den to den.

Seven litters (23%) were lost while at the natal or maternal den. The reproductive success of the remaining 6 denning attempts (20%) is uncertain. An additional 6 spring reproductive attempts were in progress when the female's collar broke away and came off as scheduled. Of those 6, at least 3 successfully raised at least one kitten based on visual or photographic evidence provided by citizen scientists: BC #28 Avery in 2023 raised 3 kittens, BC #14 Bunny raised at least 1 kitten in 2022, and BC #50 Daphne raised one kitten in 2024. In addition, BC #28 Avery raised 2 kittens and BC #37 Bobbie Jo raised at least 2 kittens in 2024. This brings the total verified kittens that survived at least until the female no longer uses a den to 28 among radio collared females from 2021-2024.

Figure 53. BC Daphne with her 2024 young of the year surviving kitten.

Photo by Katie Ray

Photographic evidence of reproductive success provided by a citizen scientist after the female was no longer radio collared.

Included in these totals are two females that denned and gave birth to kittens out of sync with the spring kitten season: BC #20 Elsie who was captured late in 2021, had kittens on 2/6/22 and appeared to raise at least one kitten based on den use (91 days) plus 51 days of intermittent den use. BC #28 Avery was pregnant with relatively well-developed kittens when captured in January 2022. She gave birth to kittens about 1/24/2022 and successfully raised two kittens. These “out of sync” births were likely second or even third tries at raising a successful litter the previous year since both females gave birth the following year within the spring kitten season, and both were old enough to have had kittens previously.

Five females lost litters and attempted a second litter during the study.

- BC #29 Sylvia gave birth to her first litter of kittens at approximately two years of age on 4/12/2022. She quit returning to the den site about 5 days after the kitten(s) were born suggesting that she lost that litter. She produced a second litter on 7/14/2022. We do not have visual confirmation that she raised her second litter, but it is likely since she utilized dens for 74 days to when kittens would have been 10 plus weeks old, and able to travel with her.
- BC #2 Morgan denned on 3/26/2022 and continued to return to the den site for 41 days where she successfully raised a kitten in 2021. She then moved the kitten(s) to a maternal den for 9 days then stopped utilizing a den. The kitten(s) were likely lost at 50 days. She did not re-den or successfully produce a second litter.
- BC #14 Bunny denned at a house and gave birth to kitten(s) on about 3/22/2021. She stopped returning to the den site 9 days later suggesting she had lost that litter. She gave birth to another litter about 5/28/2021 in a large culvert. She was flooded out of the culvert on July 3rd during the first monsoon storm of the season. After that she moved the kittens often, only remaining at a spot for 2 days or so before moving kittens again. We received photographic confirmation of her with 2 large kittens from a citizen scientist whose home she visited in December 2021.
- BC #24 Sadie denned at a house 5/5/2022. She moved the kitten(s) after 3 days to a maternal den 258’ away at another house. She stopped returning to the maternal den four days later suggesting that she had lost that litter. She gave birth to another litter of kittens on or about 7/16/2022 at the same house where

her first natal den was. She stopped returning to this den site after 18 days suggesting she had also lost this second litter. She did not attempt to re-den.

- BC #1 Shannan lost her 2021 litter at 86 days on 7/21/2021. She was documented exhibiting breeding behavior with an adult male on 7/31 but did not successfully re-den.

To summarize, 5 females lost first litters, three females attempted to re-den. The other two females likely attempted second litters but lost the litters before a den site could be identified. Of those second litters, two females, BC #29 Sylvia and BC #14 Bunny appeared to successfully raise a second litter of kittens. BC #30 Lisa lost her April 2023 litter after 14 days at a natal den and did not appear to re-den.

DEN USE

Natal Dens

We documented 31 natal dens from 2021 through 2023. Fifteen of those dens were in wildlands habitat, typically in areas of high, steep, rugged habitat.

Figure 54. BC #2 Morgan Natal Den Site 2021, 2022, 2023

In many cases, such as with BC #2 Morgan, she did not utilize this type of habitat routinely until she denned with kittens. From her capture in November 2020 to when she gave birth to kittens in April of 2021 only 3% of her locations were on Dos Picos (the mountain pictured above). Most of her time was spent in dispersed housing in her home range. Use of the Dos Picos habitat increased to over 40% of her locations during denning from April through August. She successfully raised one female kitten at this den in 2021.

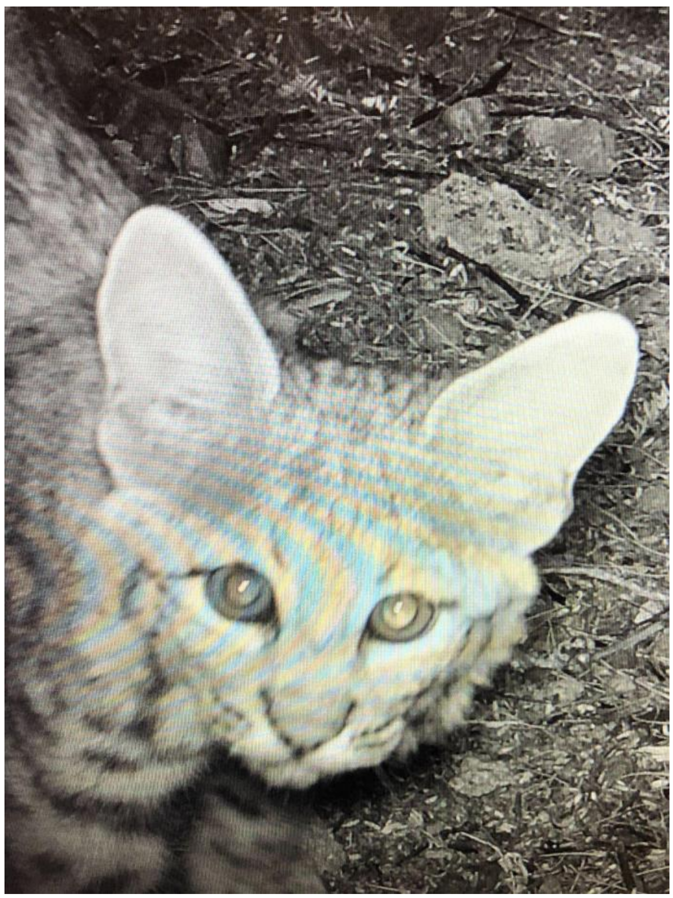


Figure 55. BC #2 Morgan's 2021 Female Kitten

Nine natal dens were located at houses (Fig. 56). We were uncomfortable closely approaching houses to determine exactly where the female had kittens hidden for fear of disturbing the female in a dangerous environment or causing her to move the kittens which were typically very small. Instead, we circled the property with radio telemetry equipment until we were sure at which house she was denned. We monitored her via her satellite GPS location data in hopes of minimizing disturbance.

Figure 56. BC #24 Sadie's Kitten Den

She attempted to raise 2 litters here in 2022. Both were unsuccessful.

Two natal dens were in native vegetation in dispersed housing. One natal den was in native vegetation in a wash in a subdivision, and one den was in native vegetation at Sweetwater Wetlands. One den was in a culvert in dispersed housing in native vegetation.

Female bobcats utilize a variety of structures for natal dens including, caves, abandoned mine shafts, hollow logs, rock crevices or shelters, brush piles, dense thickets of vegetation, abandoned buildings and beaver lodges (Bailey 1974, Brainerd 1985, Lovallo et al. 1993, Griffin 2001, Roberts 2007). Lovallo (2007) working in Pennsylvania, located natal den sites in rock crevices (5), brush piles (4), and a hollow log. Bailey (1974) reported that bobcats in Idaho moved kittens to secondary or maternal dens up to 5 times.

We documented 56 maternal dens from 2021-2024. Twenty-five maternal dens occurred at or near a house, most often in a backyard with a wall, ample vegetative cover often with a large tree, and often a water source and bird feeders (Fig. 57).

Figure 57. One of BC #28 Avery's 2022 maternal kitten dens.

She successfully raised 2 male kittens in 2022.

Figure 58. BC #28 Avery's 2022 Kittens (Photo by Shavon)

Twenty-one maternal dens were in wildlands habitat like the steep, rocky inaccessible habitat used for wildlands natal dens (Fig. 59). Seven dens were in natural vegetation near a house or building, and three occurred on the roofs of houses (Fig. 59).

Figure 59. BC Avery #28 used 3 different roof dens in 2022 in the same neighborhood.

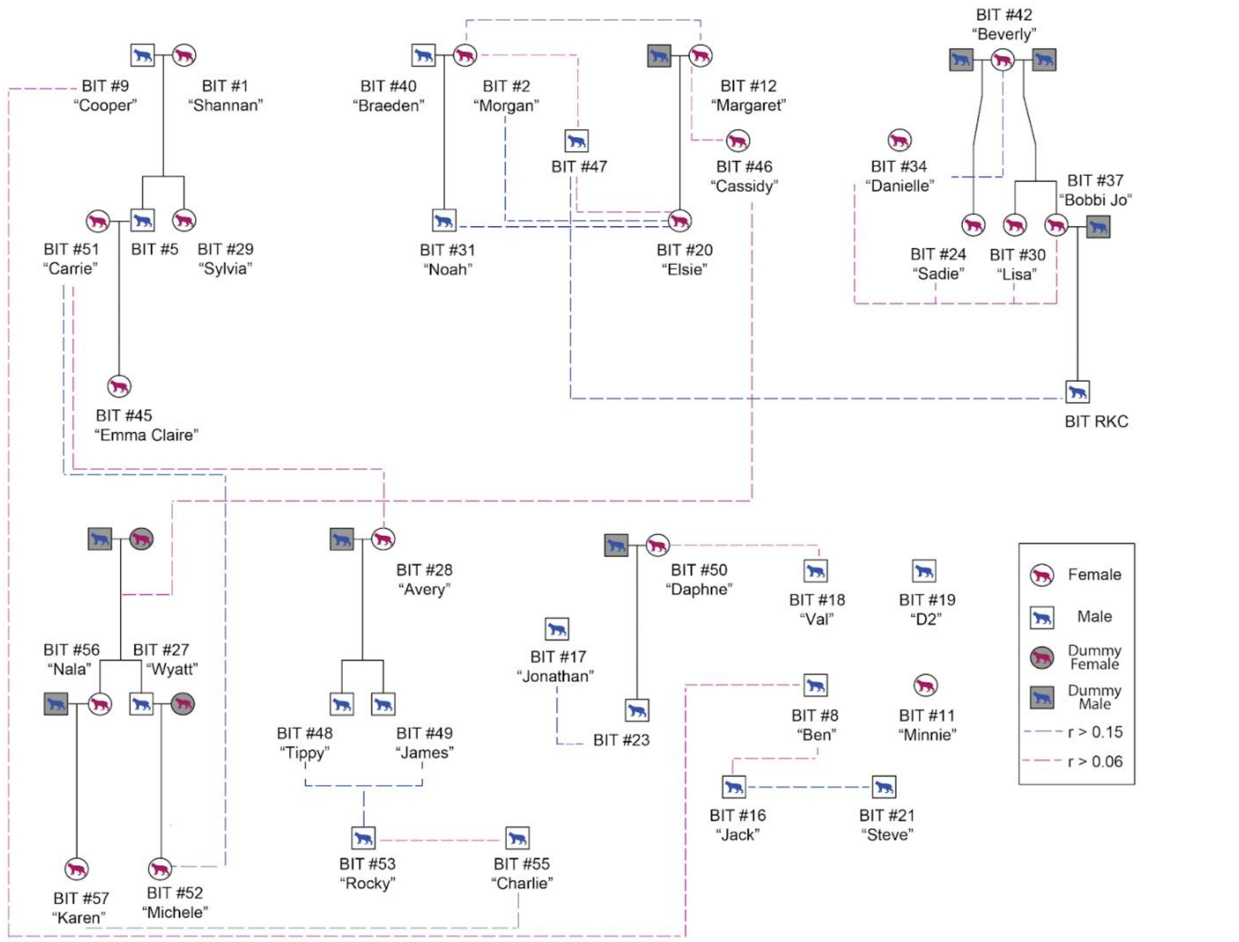
Total den use based on a complete den record (n=15) ranged from 36-241 days and average 111 days.

Genomic Analysis of Relationships - by Natalie Payne

We obtained a final dataset of 27,922 SNPs in 32 individuals post-filtering. Population structure results supported the assumption that all 32 individuals are members of a single population, with individual segregation in the PCA driven by relatedness. Mantel tests revealed significant correlations between geographic and genetic distances for the population as a whole and each sex considered separately, with the strongest correlation among females ($r = 0.238$, $P = 0.01$). Using the R program *related*, we observed low levels of relatedness among most individuals in the population, with 17 pairs identified as corresponding to first-degree relationships, having relatedness between approximately 0.4 and 0.5. In agreement with the Mantel tests showing stronger isolation by distance among females, the highest mean relatedness was observed among female pairs.

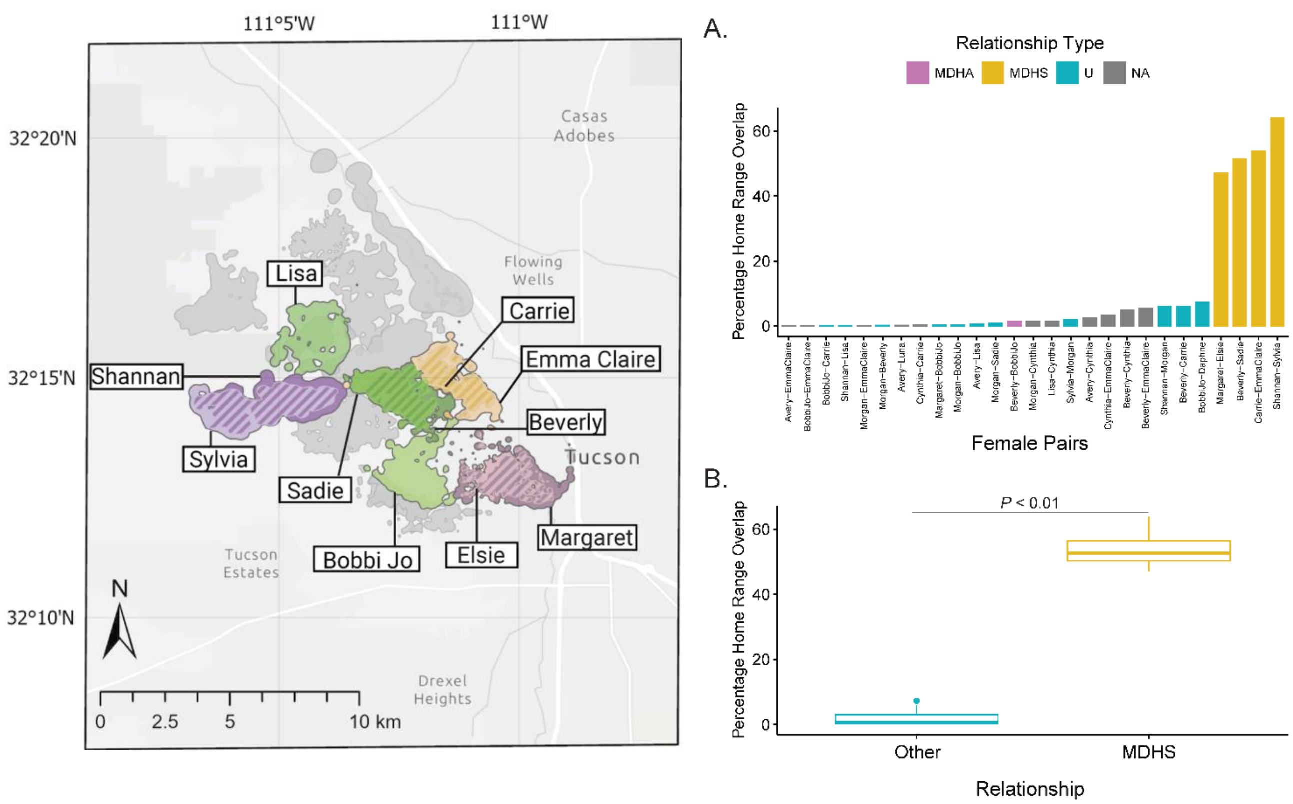
We reconstructed initial pedigrees for seven familial units using the R package *sequoia*. In total, six genotyped individuals were assigned as mothers (37.5% of genotyped females), and three were assigned as fathers (18.8% of genotyped males). A total of 11 genotyped individuals were identified as offspring in the pedigrees (34.4% of genotyped individuals), including five males (31.3% of genotyped males) and six females (37.5% of genotyped females). The largest full sibship detected was two individuals, which occurred in three of the pedigrees.

A second sequencing effort included samples from five additional BIT bobcats (BC #45 Emma, BC #55 Charlie, BC #56 Nala, BC #57 Karen, and BC Roadkill C). BC #54 was also included but determined to be a replicate sample of BC #27 Wyatt (relatedness of approximately 1.0); hence, data from BIT #54 was excluded from downstream analyses. We incorporated the data from the five new individuals into our pedigrees using *sequoia*, revealing the identification of grandparents within the BIT dataset for the first time. These consisted of BC #1 Shannan and BC #9 Cooper, paternal grandparents of BC #45 Emma Claire, and BC #42 Beverly, maternal grandmother of BC Roadkill C (RKC). We confirmed an additional mother-daughter pair, BC #56 Nala and BC #57 Karen, respectively. Although we did not have sufficient collar data to evaluate mother-daughter home range sharing for this pair, notably, the two individuals were captured in the same trap one day apart in December 2023.



Final pedigree reconstruction from the R package sequoia. Solid black lines indicate pedigree relationships, while unresolved distant relationships are shown with dashed lines according to relatedness values calculated with the R package related. "Dummy" individuals refer to non-genotyped individuals inferred to exist as parents for genotyped offspring. (Note: All BIT references are BC in the text.)

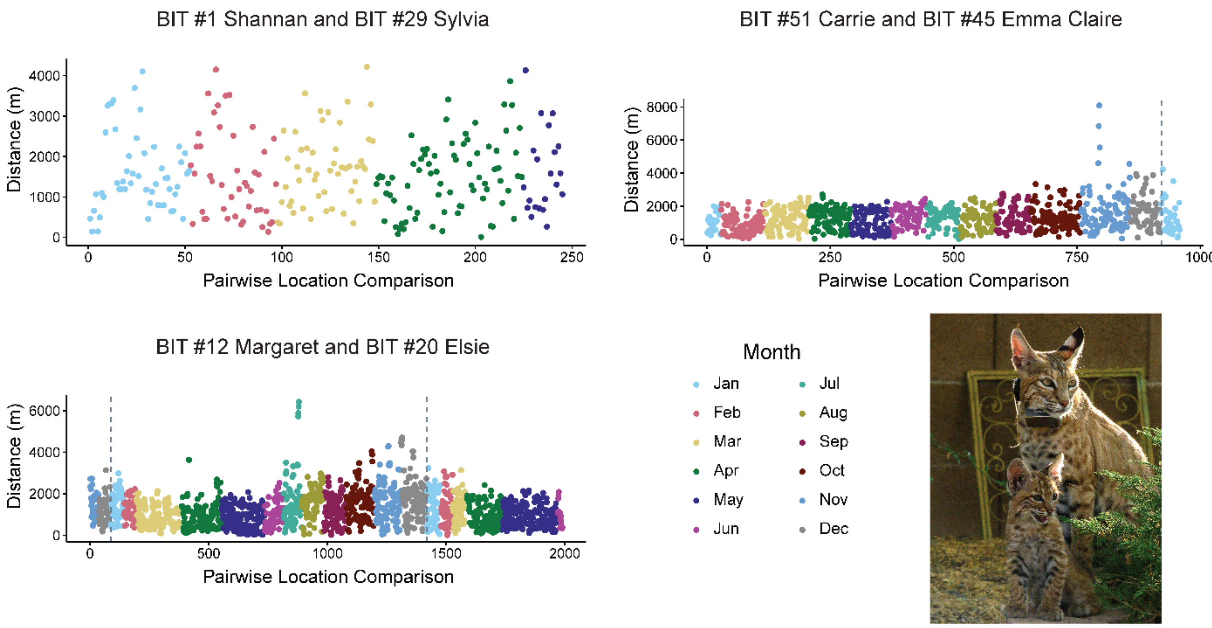
Comparisons of home range (95% KDE) overlap between females revealed the highest overlap among mother-daughter pairs. We found each mother shared a high home range percentage with one daughter, when at least one daughter was able to be identified; these pairs are denoted mother-daughter home range sharing (MDHS) pairs. We identified three MDHS pairs based on relationships observed from genotype data (in the initial ddRAD library), and a fourth pair was identified based on field observations, with the daughter (BC #45 Emma Claire) collared as a subadult and with only the mother (BC #51 Carrie) being genotyped. The parent-offspring relationship between BC #51 Carrie and BC #45 Emma Claire was later confirmed after the sequencing of our supplemental ddRAD library. These four MDHS pairs shared an average of 54.1% combined home ranges (range: 47.2 – 63.9%), significantly higher than overlap of adjoining non-MDHS pairs (*P* = 0.001). Other females (unrelated or unknown relationship based on analyses with the initial ddRAD library) which had adjoining home ranges tended to share only home range edges, not exceeding 7.24% overlap. Only



one mother (BC #42 Beverly) had more than one daughter identified; two of her three daughters did not constitute MDHS pairs with their mother, although they established adjacent home ranges (denoted mother-daughter home range adjacent, MDHA). There was no overlap for one of the MDHA pairs (with daughter BC #30 Lisa), and minimal overlap (1.30%) for the other MDHA pair (with daughter BC #37 Bobbi Jo).

Home range sharing among mother-daughter pairs. (Left) Map of 95% kernel density estimate (KDE) home ranges for all female's part of a known mother-daughter *relationship. Each mother overlaps extensively with one of her daughters, while the other two daughters (Lisa" and "Bobbi Jo) established home ranges adjacent to their mother (Beverly). Home ranges of other females (with the exception of one that shifted home range, (BC #34 Danielle) are shown in the background (unlabeled). (Right, "A") Bar plot showing percentage of combined home range overlap for female pairs in adjacent or shared home ranges. Mother-daughter home range sharing (MDHS) pairs share much higher portions of home ranges, compared to mother-daughter home range adjacent (MDHA) pairs, unrelated (U) pairs, and pairs of unknown relationship due to missing genotype data (NA). Relationships are based on analyses conducted with the initial ddRAD library. (Right, "B") Box plot comparing home range overlap between MDHS pairs and other female pairs. Here, "Other" refers to MDHA and unrelated female pairs, as pairs of unknown relationship were removed prior to the Wilcoxon rank sum test. MDHS pairs shared a significantly higher percentage of home ranges than non-MDHS females (P = 0.001).*

We additionally observed fine-scale spatiotemporal overlap for the MDHS pairs (excluding BC #42 Beverly and BC #24 Sadie from the analysis, since #24 Sadie was shot prior to BC #42 Beverly being collared). Home range overlap using 50% KDE ranged from 9.2% to 23.9% (average 16.4%). Further, weekly 95% KDE overlap largely remained stable over time. This trend was reflected in the comparison of daily pairwise distances; only one pair (BC #51 Carrie and BC #45 Emma Claire) had a significant increase in distance over time (adjusted $R^2 = 0.04$, $P < 0.0001$), although this is likely due partly to large outlying distances in November 2023, which subsequently stabilized. Each MDHS pair had GPS points within close spatiotemporal proximity. For example, we detected adjacent den sites within approximately 65 m for BC #12 and BC #20 during May 2022; further, these individuals were recorded as less than 2 m apart on the same date and time during February 2023. The minimum distance between points for BC #1 Shannan and BC #29 Sylvia (< 9 m) was recorded at the same date and time in April 2022, and the minimum distance between BC #45 Emma Claire and BC #51 Carrie (<24 m) was recorded at the same date and time in July 2023.



Distances in meters between each daily pair of points for temporally overlapping mother-daughter home range sharing (MDHS) pairs. Numbered pairs are ordered over time across the x-axis. Each dashed vertical line indicates the start of a new year. The photo inset shows BC #28 Avery, along with a kitten (Note: All BIT references are BC in the text.) Photo by Christopher Wesselman, 2022.

Food Habits Analysis - By Alexandra Diane Burnette

Hair samples of bobcats captured in Tucson produced a mean (± SE) $\delta^{15}N$ signature of 10.58 ± 0.23‰ and a $\delta^{13}C$ signature of -17.47 ± 0.16‰

Our Bayesian mixing model indicated that the diet of bobcats in Tucson consisted of ~11 ± 10% non-domesticated avian sources (e.g., doves, quail) and 85 ± 10% lagomorphs (Fig. 60). Dogs, cats, and chickens were each estimated to comprise less than 2% of their diet (Fig. 60) (Table 1).

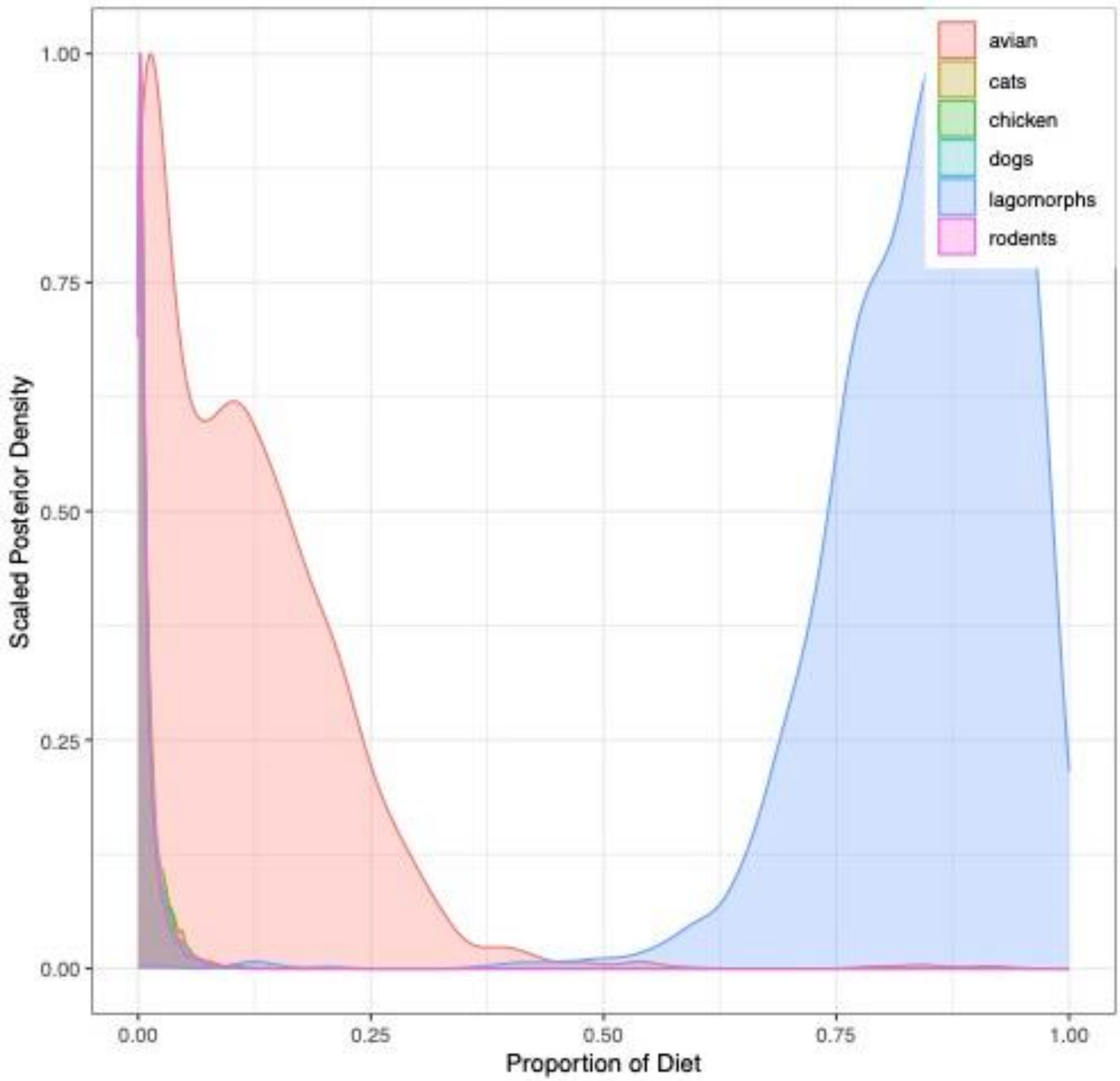


Figure 60. Posterior density plot derived from Markov chain Monte-carlo mixing models showing the predicted proportion of suburban bobcat diet for each included prey item.

Table 1. Summary of model output showing mean, standard deviation (SD), and credibility intervals for estimated dietary proportion comprised of each prey source.

	Mean	SD	2.50%	5%	25%	50%	75%	95%	97.50%
Epsilon 1	0.31	0.12	0.14	0.15	0.22	0.29	0.37	0.54	0.62
Epsilon 2	0.57	0.22	0.24	0.27	0.42	0.54	0.69	0.99	1.10
avian	0.11	0.10	0.00	0.00	0.03	0.10	0.17	0.28	0.32
cats	0.01	0.02	0.00	0.00	0.00	0.01	0.02	0.04	0.05
chickens	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.04	0.06
dogs	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.04	0.05
lagomorphs	0.85	0.10	0.64	0.68	0.79	0.86	0.92	0.97	0.98
rodents	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.04	0.06

Bobcats, Pets and Urban Livestock

Throughout the 4 years of the study, we received no direct reports of bobcats attacking or killing dogs, and only 2 reports of bobcats attacking cats, one of which involved a feral cat, even though we received over 1200 bobcat activity reports. Anecdotally, we received hundreds of bobcat “stories,” but again, we did not receive any first-hand reports of bobcats killing pets. The results of the food habits analysis provide additional support to what we already suspected based on our experiences over the past 4 years: unprovoked bobcats in Tucson rarely attack or kill pets. Coyotes, which are much more numerous on the Tucson urban landscape than bobcats, routinely kill pets in what their owners consider “safe” backyards. Coyotes can and do routinely scale 6-foot walls. In many cases, we suspect that bobcats get blamed for coyote attacks. Tucson is a predator rich environment. Any unattended pet is always at risk.

Even though at least 2 of the radio-collared bobcats in the study died because they were believed to be stalking chickens, our results show that domestic poultry is also a very small part of the urban bobcat diet in Tucson. We cannot expect bobcats to discern between domestic poultry placed in their home range by people, and wild birds. It is the responsibility of the urban livestock owner to safeguard their animals from bobcats and other predators. We can change our behaviors or circumstances, bobcats cannot.

Bobcat Activity Database

People learned about the website in various ways. Some discovered it by simply searching the internet, while others learned about it from another individual. Most discovered the website by reading newspaper articles on the project, or from speaking programs conducted by project personnel. 1,256 people submitted bobcat sightings, of which 845 (67%) were outside the study area on the west side of Tucson designated for intensive capture work (Fig. 61)

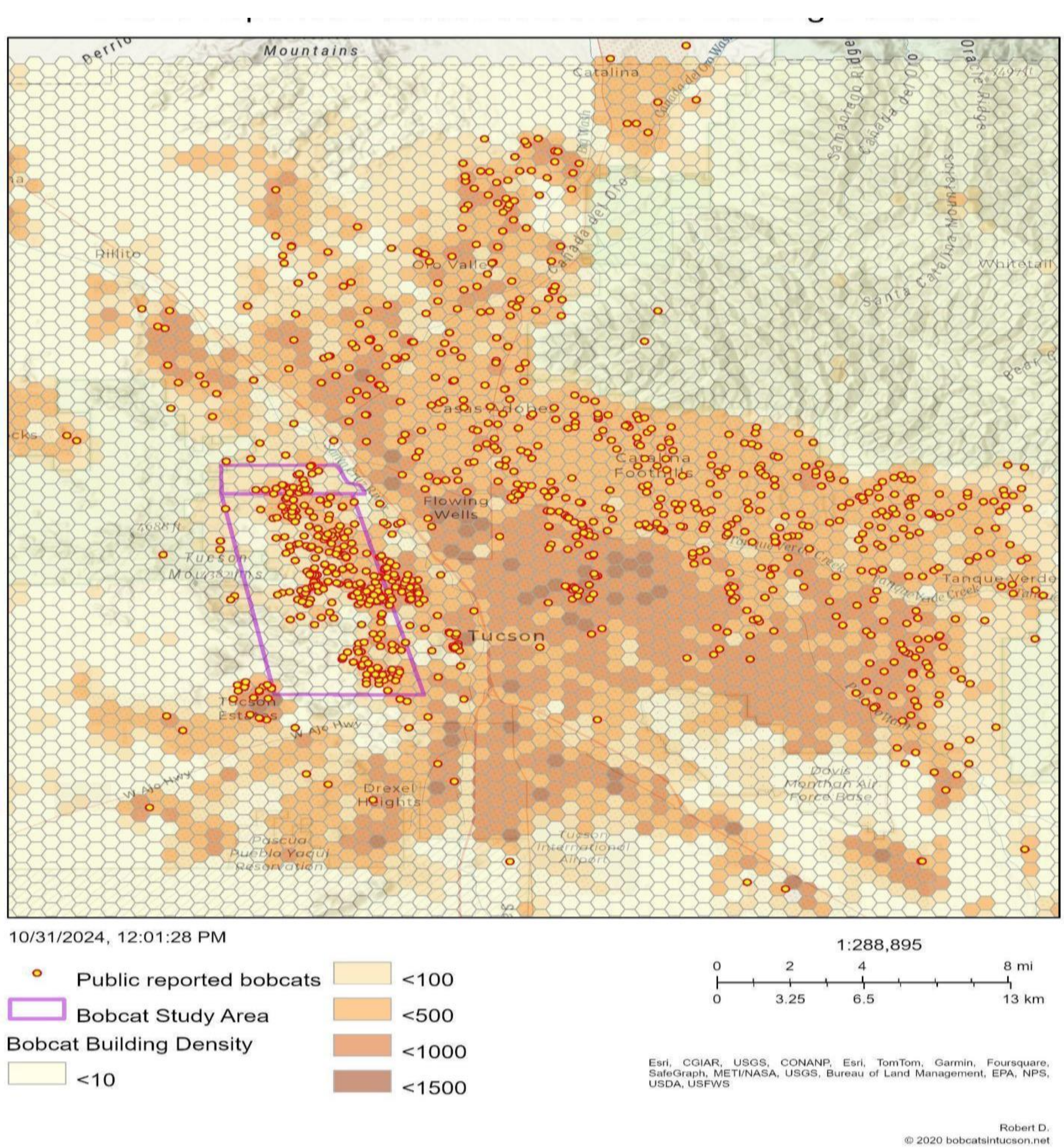


Figure 61. Public Reported Bobcat Locations and Building Densities

Seven-hundred twenty-three individuals (57%) also attached one or more photographs or videos to their reported sighting. To document bobcats in various urban situations, some individuals that attached good quality photographs to their observation were asked for permission to use their photo on the bobcatsintucson.net web site. No individual declined.

Providing a site where Tucson residents could report their bobcat sightings proved to be a very effective method for determining how widespread bobcats were in Tucson. As expected, numerous sightings occurred along the interface between urban and wildland areas, but it also documented that bobcats occurred across Tucson, from areas of scattered housing to areas that had building densities between 1000 and 1500 structures per square km. (Fig. 61). We suspect that the area of occurrence of urban bobcats in Tucson is still underrepresented. Anecdotal information from a retired Arizona Game and Fish Biologist (Gerry Perry Personal Communication 2024) who now contracts to remove wildlife from Davis Monthan Air Force Base has confirmed that bobcats do occur there, even though we did not get location reports from there or the surrounding area. The minimum convex hull to include public reported bobcat locations in Tucson equaled 1444.8 sq. km (Fig. 61a). If the two large areas without locations are removed the area equals 1110.0 sq. km. It is likely bobcats occur in these areas as well but are under-reported.

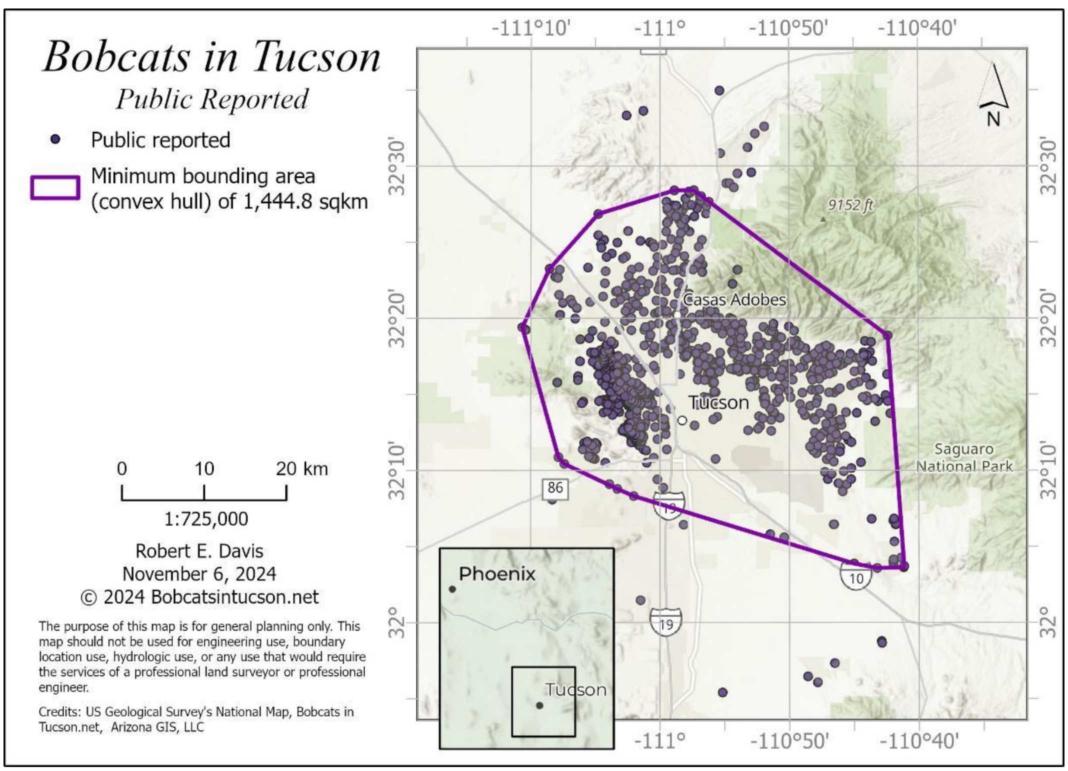


Figure 61 a. Bobcat Occurrence in Tucson based on public bobcat activity reports sent into the Bobcats in Tucson website (bobcatsintucson.net).

The occurrence of bobcats in the densest category of building classification (<1500 per sq. km.) in central Tucson near the Arizona Inn and other historic neighborhoods suggests that bobcats can and do survive and flourish in these areas as well.

Providing a contact point for Tucson residents to report their bobcat sightings also generated an unplanned Citizen Science cadre of very interested and dedicated residents. Many people only reported one observation, but others reported five or six sightings scattered over the time the web site was available. Some individuals also sent in copies of journals they had been keeping for years before this project was initiated, and other individuals reported starting journals of their sightings.

Bobcats in Tucson Attitudes and Values Survey

The survey collection period lasted from October 2, 2020, through June 1, 2024. The initial survey sample was capped at 1,500 completed surveys. The greatest response period was in 2021. Thirty-four percent of the surveys came from within the study area and adjacent areas west of I-10. Another 52% came from the north and east side of Tucson in habitats like the primary study area.

The surveys took an average of approximately 7 minutes to complete. Over 72% of surveys were fully completed. Four questions, numbers 13,16,18 and 31, allowed the respondent the opportunity to add comments. Over 750 comments were posted. Most in a positive addition to the subject question and offered to provide further information and photographs of urban bobcats.

A cloud analysis of mentioned terms in specific question responses illustrated some common themes: concerns about living with bobcats centered on predation on urban chickens, potential conflicts with dogs and children, with more significant concerns expressed about conflicts with javelina and coyotes. In another example, urban chicken issues appeared again as well as concerns over potential conflicts with pets, young children, potential diseases and negative human interactions. In the main survey, question number 17, only 7% of the respondents reported that they had an issue or knew someone directly who had had a negative interaction with an urban bobcat. Much of the “conventional wisdom” that surrounds the Tucson urban population seems to based on second or third hand information or urban myth.

Appendix 1 contains a summary of the overall survey responses. By 2/1/2023 and 1215 completed surveys summarized, the reporting numbers did not change significantly. Of special interest were the many questions that illustrated a very positive perspective of living with and seeing urban bobcats and solid support of bobcat conservation activities. Over 86% said seeing a bobcat is something they hope will happen, and only 5% of respondents hope it never happens.

Over 86% of the respondents feel seeing a bobcat in the neighborhood is a positive experience. Only 1% would have a strong fear of seeing a bobcat. Ninety-three percent of the respondents have seen a bobcat in their neighborhood. Fifty-nine percent have seen a bobcat from 1-5 times in the past year and 22% over 10 times. Eighty-six percent reported the bobcat was in their yard. Sixty percent have seen females with kittens in the past 5 years.

Several other interesting response summaries further point out the strong support for urban bobcat conservation. Ninety-four percent say they would be willing to make minor changes in personal behavior to support urban wildlife in their neighborhoods. Seventy-eight percent would be an advocate to neighbors for wildlife. 91% already do not use rodenticides to control mice and packrats on their property.

Clearly, the results of the BIT Attitudes and Values survey were overwhelmingly positive and supportive of urban bobcats. A few respondents (less than 10%) express some fear of living with bobcats. Their stated fears are not supported by our data and are based largely on misinformation and urban myth.

Study Outreach:

Public outreach was a major component of the Bobcats in Tucson Study. We wanted to keep the public informed and provide ways for them to stay engaged with the project. Our website was developed and active for the 43 months of the project and we plan to keep the website active for at least 3 additional years.

During the 43 months of the study, the study website (bobcatsintucson.net) had over 76,000 hits resulting in over 1,250 public reported bobcat sightings, and 1,500 completed “Living with Bobcats in Tucson” Attitudes and Values surveys. During the study we published 36 blogs with 372 subscribers. The project also maintains a dedicated email address <bobcatsintucson@gmail.com> to facilitate the exchange of active bobcat locations and communication updates with individual citizens. Both the website and email will remain active after study completion.

The environmental reporter and a photographer at the Arizona Daily Star, the daily Tucson newspaper, were invited to the handling and radio collaring of BC #15 Sweetwater. This resulted in a front-page story, in color, above the fold, in a Sunday edition. Over the next 3 years this reporter wrote several other feature stories about the BIT project.

A producer at the local PBS contacted us about filming an “Arizona Illustrated” segment featuring BIT in the spring of 2024. The resulting episode, 19, is archived on the Arizona Illustrated streaming site.

Because the project vehicles were often seen repeatedly in neighborhoods during capture efforts and other study activities, 11”X17” magnetic door signs were made with a bobcat photo, and study information including the website address. Over the course of the project, the signs generated a surprising number of unsolicited conversations with people in grocery store parking lots, at gas station pumps, drive through lines, etc. People had positive bobcat stories or sightings and wanted to share them with team members.

BIT contact cards were given to people with whom we had interactions. This included people we met because of the magnetic car door signs, the homeowners where we captured bobcats, their neighbors and friends who came over to see what was happening when we were setting traps or had captured a bobcat, and people who attended programs etc. In 2021 we produced “I Love Urban Bobcats” bumper stickers (with our web address) and gave them to these same people.

From about the midpoint of the project, one of our very active citizen scientists took the initiative to respond to reports of bobcat incidents or sightings on the web based "Nextdoor" platform in our study area. She encouraged users to go to the BIT website. She tracked her efforts and documented over 32 original posts and 12,198 comments or reactions back from users through the remainder of the project.

Some additional outreach activities included 16 in-person presentations at HOA annual meetings, during the Santa Cruz River Research Days conference, to students participating in the Camp Cooper Center for Environmental Education programs, to members of the Safari Club International Arizona Chapter, etc. The BIT team also helped to develop the "Tale of Two Cats" program funded by a Heritage Grant for Environmental Education for the Catalina School District at the Sunrise Drive Elementary School. Team members also participated in 12 Zoom presentations for members of the Tucson Mountain Association Board of Directors, for Pima County Natural Resources Department, for Tucson City Water Zoom to discuss the fencing issues at Sweetwater Wetlands, Sky Island Alliance, Arizona Sonoran Desert Museum Annual Meeting Keynote address, and more. Some of these Zoom meetings only had 10-30 attendees, but many of them had more than 200 participants.

Two team members were on a panel during a live AZPM presentation of the Arizona Illustrated video, "Bobcats Among Us" (Season 24, Episode 19) about the BIT project. About 150 people attended the presentation. There were 23,000 live views of the program, which does not include people streaming on YouTube or other social media platforms.

CONCLUSIONS AND RECOMMENDATIONS

By almost all measures, the urban bobcat population in Tucson appears to be thriving. Most females in the study successfully raised young, and we verified at least 28 kittens that survived to leave the den from 2021 to 2024. The population appears to be stable based on the .84 and .85 survival rates for the second and third year of the study, and we found no evidence of unoccupied home ranges. However, the first-year survival rate of .36 is concerning and unsustainable for a population. Half of the mortalities we documented over the course of the study (6 of 12) occurred in that first year. As the study progressed both types of mortality (human caused and vehicle strikes) declined. It is impossible to tell if the high mortality rate in the first year of the study was the norm prior to the Bobcats in Tucson Study and declined in the subsequent years because of this new focus on the Tucson bobcat population. The focus on bobcats during the study might have made people more reluctant to shoot bobcats overall, or at least radio collared bobcats, and to watch for bobcats while driving. The large number of mortalities in that first year might have also been an anomaly. It is impossible to know without additional research.

An average survival rate of .845 over the last two years of the study suggests that most animals in the population are living at least long enough to produce offspring, and likely long enough for females to successfully raise kittens in more than one year. All adult females in the study attempted to reproduce in each year they wore a radio collar.

We documented 4 females who were sharing their home range with adult daughters (one female BC #45 Emma Claire) transitioned to an adult in the spring of 2024 while radio collared, but did not live long enough to have kittens. Additionally, BC #56 Nala was the mother of BC #57 Karen who were both captured in the same cage in successive days in the fall of 2023. Unfortunately, BC #57 Karen’s collar malfunctioned and released prematurely 3 days after she was captured so we were unable to document their shared habitat use. The other daughters who shared home ranges with their mothers (BC #29 Sylvia, BC #20 Elsie, and BC #24 Sadie) all successfully raised kittens over the course of the study, while sharing their mother’s home range. One other daughter (BC #37 Bobbie Jo) who lived in an adjacent home range to her mother BC #42 Beverly, successfully raised kittens during the study, while it is doubtful that her sister BC #30 Lisa was successful in raising kittens during the study.

It is likely that more females in the study also had daughters sharing their home ranges. We captured BC #29 Sylvia and BC #20 Elsie in their respective mother's home range (BC #1 Shannan and BC #12 Margaret) while attempting to re-capture and change collars on these mothers. We only actively worked to re-capture 3 females to change collars and found daughters in 2 of those 3 home ranges, suggesting that other adult females may also have daughters sharing their home ranges. It is interesting to note that the shared home ranges were not significantly different in size than other female home ranges. While we often consider home range size an indicator of habitat quality, this finding suggests that other factors, such as the stability of the population and social interactions also contribute to home range sizes. Additional research where all members of a given area are radio collared is needed to truly understand how prevalent home range sharing among mothers and adult daughters is in bobcat populations and what impact it has on bobcat management.

We did not have empty home ranges in any areas we trapped. Female home ranges adjoined each other with little overlap among non-related females and fit together like "puzzle pieces" in our study area which included the range of habitats available to bobcats from pristine Sonoran Desert to low and medium density dispersed housing (ranging from 0 to >500 buildings per square kilometer to highly urbanized areas with >500 and <1000 buildings per square kilometer. Areas with the highest densities (>1000 and <1500 buildings sq. km.) are underrepresented on our study area since such development occurs primarily to the east of I-10 in central Tucson. We did document bobcats using such areas of high urbanization from Citizen Scientists reporting bobcat activity to the website (Figure 61).

The smallest male and female home ranges occurred on the Starr Pass Golf Resort. A predominance of native vegetation and largely intact washes and travel ways, combined with grass areas on the Golf Course, provided bobcats with abundant hunting, security cover, and food resources. Habitat quality was enhanced because of mitigation efforts between the Golf Course and Pima County when the Resort Hotel was planned, establishing wildlife corridors on the property. In addition, in houses surrounding the golf course numerous backyard water sources (pools, water features, and wildlife water) provide water for bobcats and prey species such as rabbits and doves. An abundance of bird feeders in resident back yards also attracts doves and other birds. We received numerous reports from residents in Starr Pass and from other areas of bobcats hunting under bird feeders. The Starr Pass Golf Course is certified by Audubon International as an Audubon Cooperative Sanctuary. This program for Golf Courses guides the facilities in protecting natural resources and enhancing the environmental quality of their property. Participants work on projects to improve wildlife habitats, conserve resources, and engage in sustainable practices. Golf courses can provide valuable added diversity for bobcats and other wildlife in urban environments, especially if managed with a positive focus on wildlife.

Bobcats on the Starr Pass Golf Resort. Photos Courtesy of (Left) Romy Fouad (Right) David Chipman

Areas of the study area with low to medium building density (<10 to >500 per square kilometer) with primarily native vegetation and largely intact washes and travel ways (which occur across much of Greater Tucson) provided high quality habitat for bobcats in Tucson. This combined with many residents' propensity to provide backyard wildlife water and food, in the form of bird feeders, attracts and concentrates birds (especially doves) on the ground. This provides quality hunting opportunity for bobcats, making much of Greater Tucson high quality bobcat habitat. Remarkably, the 2 females who lived primarily in the highest density housing areas in the study area (>500 and <1000 buildings per square kilometer) and with the highest density of roads not only survived but thrived, successfully raising kittens in multiple years.

BC # 28 Avery successfully raised kittens until they were able to leave the den and travel with her in 2022, 2023, and 2024, even though she lived in a highly urbanized area and was second only to BC # 51 Carrie in level of development in her home range. In each of the three years she was monitored she utilized the Sweetwater in the Wetlands Agua Dulce housing development which is bordered by Camino de Oeste, El Morago, and Sweetwater Roads in west Tucson, and is part of BC #28 Avery’s home range and the BIT study area. This development is recognized by the National Wildlife Federation with Community Wide Certification as Wildlife Habitat. Washes (common areas) in the subdivision are intact without walking trails. Native vegetation prevails and common areas were developed with significant input from Pima County to ensure respect and preservation of natural open areas and drainages and assist in maintaining intact wildlife corridors in line with Pima County’s Sonoran Desert Conservation Plan. Agua Dulce provides a model for developments in the future to allow bobcats and other wildlife to move more freely through areas of dense development. Recently, Pima County recognized Agua Dulce as a low impact development (LID) Case Study Site.

Based on over 1250 bobcat activity reports received at the BIT website during the study, bobcats have by and large seamlessly integrated into neighborhoods across greater Tucson. Almost 90% of the 1500 respondents to the BIT “Living with Bobcats” Attitudes Survey say living with bobcats is a positive experience. In addition, the continued high levels of interest and participation in the study by hundreds of Citizen Scientists across Tucson suggests that many in Tucson value bobcats as part of their urban environment. It is truly a remarkable situation that many (if not most) Tucsonans at the very least see bobcats in their neighborhood, and in some cases, get to watch them raise and care for kittens in their backyards.

Vehicle strikes led to the deaths of 5 bobcats (13% of radio-collared individuals) over the course of the study. Radio collared bobcats in Tucson crossed roads (all different kinds of surfaces) an average of 7.4 times per day or over 3000 times on average during the time they wore a radio collar. Of the 5 confirmed vehicle strike mortalities, at least 2 of those occurred on secondary roads with relatively low-speed limits (Trail's End and Starr Pass Boulevard) while the other 2 known mortality locations were on more major roads (Ironwood Hills Road and Silverbell Road). Signage on roads, such as Ironwood Hills Road, to warn drivers to slow down and watch for wildlife as they approach wash crossings would be valuable. When visibility is obstructed until drivers are descending into a wash, wildlife crossing such roads are in extreme danger. We believe that "Watch for Bobcats" signs would be especially valuable in getting drivers' attention on these and other roads, since most Tucsonans are aware of the Tucson bobcat population and have a positive connection to bobcats.

It was disturbing to learn as part of the study that as many bobcats were killed by people (5) as died from vehicle strikes. Only one of the 5 incidents was reported to the Arizona Game and Fish Department (BC #17 Jonathan) shown on the next page, who was shot and killed by a homeowner because the bobcat was stalking free-ranging chickens on his property. The individual was not prosecuted even though to our knowledge the bobcat had not attacked any chickens on the property and the individual had not suffered a loss of property (loss of property is the point where it is legal for someone to kill a bobcat in defense of property.)

Bobcat #17 Jonathan. Photo by Kathy McLean

At least one of the other mortalities (BC #4 Dave) was also likely due to his attempting to prey on free ranging chickens. This was never confirmed since his body was never found; his collar was cut off and thrown in a dumpster. Location data placed him at the property of an individual who warned his neighbors he would shoot any neighborhood dogs who attempted to prey on his chickens.

To expect a member of the cat family, the most highly evolved and specialized of the carnivores as a group, to not attempt to prey on free-ranging chickens or other urban livestock in their home range is unrealistic. Bobcats cannot discern between wild prey and domestic animals placed in their path by people. Individuals who choose to have chickens and other urban livestock should be required to keep them penned in predator proof coops and runs. It should be illegal for property owners to kill bobcats for preying on free ranging or uncontained poultry. Humans can adjust their behaviors, bobcats cannot.

Bobcats remain in their home ranges throughout their lives and generally do not have the option to “move elsewhere”. Moving a bobcat from its home range is not a valid management action in areas with resident bobcat populations such as greater Tucson and surrounding wildlands areas. Translocated bobcats are released in areas unknown to them and likely occupied by other bobcats. The re-located bobcat will either try and return to its former home range, or be in a conflict with the resident bobcat, neither of which leads to a positive outcome. All home ranges were occupied in our study area and at least 28 kittens survived to travel with the female during the study. If a resident is killed, that home range will very quickly be occupied by another bobcat such as one of the 28 we know were produced on the study area during the study, which in time will lead to either another dead bobcat - either by direct shooting by the landowner of the subsequent resident, or by the bobcat trying to return to the home range it has occupied its entire adult life.

One individual was prosecuted and convicted in a very high-profile case (BC #24 Sadie). The other 2 bobcat deaths were also likely illegal. Bobcat #13 Cathrine was found with her head severed and buried with the collar. Bobcat #21 Steve’s body was never retrieved; the collar was recovered after it had been cut off and thrown by the side of the road. It is unfortunate some individuals are unable to appreciate the uniqueness of urban bobcats integrating into neighborhoods across Greater Tucson, and instead act out of anger or malice.

The large number of bobcats killed by humans directly (5) was also disturbing because in general the residents of Tucson we encountered were very appreciative of having bobcats in their neighborhoods. The response to this study was overwhelmingly positive. We rarely met an individual unwilling to allow us to capture bobcats on their property, or who expressed negative attitudes towards bobcats. Well over 2,000 Tucsonans participated in the study by either making monetary donations, completing the “Living with Bobcats” Survey, contributing bobcat activity reports or allowing us to capture bobcats on their property.

We saw no evidence that bobcats in Tucson have become habituated to humans except for at Sweetwater Wetlands Park where photographers regularly approach and closely follow bobcats who are attracted to the area by the abundant food supply and unique wetland habitat. Bobcats by nature are not fearful animals, choosing to rely on their camouflaged coats and stealthy behavior to avoid humans. Bobcats that live in the Tucson area cannot behaviorally "become invisible" as bobcats in wildlands habitats can. People and people-built structures such as houses, walls, and roads are encountered daily, often many times daily, by Tucson bobcats. It is their home. They are very aware of human activities and monitor them closely, but do not have the choice of avoiding all contact with humans.

Females raising kittens in Tucson backyards often return year-after-year to the same houses. These are "bobcat friendly" human residents who are willing to share space with a bobcat mother raising her family. Such residents are often rewarded with the remarkable experience of up-close viewing of the interactions of the mother and her kittens, something rarely if ever observed in a wildland setting. People who experienced this, as we did, are often humbled by the level of care and concern that bobcat mothers routinely show their kittens. It was a reminder that our 2 species are in fact, not so different in what we care about. She is simply doing the best she can to raise her family, just as we do.

Sadly, female bobcats attempting to raise kittens who choose a house that is not "friendly" are often trapped and re-located, leading to the same issues discussed earlier about translocating bobcats. Property owners who make this choice should be made aware that they have likely contributed to the death of the female and kittens. In most cases, simply causing a disturbance by making loud noises, and even repeatedly making direct eye contact with a female bobcat will cause her to move the kittens to a different location.

We believe that the remarkably seamless integration of bobcats across Tucson with very little conflict overall should be a point of pride for the city. We are unaware of a situation elsewhere where bobcats live across most of a large urban area/city rather than just on the wildlands/urban interface. It is a remarkable situation that provides the people of Tucson with a rare glimpse into the life of one of the fiercest and wildest of our native wildlife species. Since bobcats are not legally hunted or trapped in the Tucson area, they should be viewed as the remarkable Watchable Wildlife resource they are and appreciated and managed accordingly, rather than only being seen as a complication or a problem. This is a disservice to the bobcats and humans that value and appreciate them.

Additional research is warranted in Central Tucson where bobcats have successfully integrated into the densest of neighborhoods, and in the Santa Cruz River Basin, especially as riparian habitats continue to expand in the Heritage Corridor and elsewhere.

It has been an honor for us to work with this remarkable animal and the people of Tucson who so graciously assisted our efforts on behalf of the bobcats of Tucson.
The Bobcats in Tucson Team.

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Appendix 1. Bobcats in Tucson Attitudes and Values Survey Summary

8/23/22- n= 1215 Responses **6/1/24- n= 1500 Responses**

Question: Based on the following study area boundaries: Where do you live?

20%-**22%** of responses were from inside the study area, 50%-**52%** from the North and east side of Tucson.

Question: Do you think urban bobcats are common in urban and suburban Tucson?

90%-**90%** think bobcats are common in urban Tucson.

Question: Have you seen bobcats in your neighborhood?

93%-**93%** have seen bobcats in their neighborhood.

Question: How often in the past year?

60%-**59%** 1 to 5 times and 23%-22% more than 10 times in the past year.

Question: Have you ever seen a female with kittens in your neighborhood?

42%-**43%** have seen females with litters

Question: How many in the past five years?

50%-**52%** 1 litter over the past 5 years. 8%-**8%** have seen 5 or more litters over the past 5 years.

Question: Was the bobcat on your property?

86%**-86%** have seen bobcats on their property

Question: If no, approximately how far from your house was it?

48%-**46%** have seen bobcats next door.

Question: Seeing a bobcat in my neighborhood is (or would be) positive, negative or neutral?

87%-**86%** think seeing a bobcat in the neighborhood is positive.

Question: Seeing a bobcat in my neighborhood is (or would be) something I hope happens, something I hope never happens or something that does not matter?

84%-**86%** say seeing a bobcat is something they hope will happen and 5%-**5%** hope it never happens.

Question: Which statement best describes how you feel about living with urban wildlife?

42%-**42%** purchased home location because there are opportunities to see native wildlife. 1%-**2%** do not care to see native wildlife. 79%-**78%** like to see all types of native wildlife.

Question: I believe bobcats living in urban areas are a public safety hazard?

82%-**82%** do not believe urban bobcats are a public safety hazard. 7%-7% do and 12%-**12%** do not know.

Question: If answered yes to question 14 then why?

23%-**23%** think they injure people, especially children. 67%-**64%** feel they kill pets and domestic livestock, 20%-**18%** think they carry diseases like rabies and 12%-**10%** because they prey on urban wildlife they like to watch.

Question: Have you or someone you know directly had a negative interaction with an urban bobcat in Tucson?

7%-**7%** of respondents say they have had an issue, or know someone who directly had a negative interaction, with an urban bobcat.

Question: What would be your fear factor of having bobcats in your immediate neighborhood?

59%-**59%** would have no fears of a bobcat in their immediate neighborhood, 1%-**1%** would have a strong fear and 24%-**24%** some concern.

Question: How knowledgeable are you about bobcat life history and current status?

68%**-68%** have some knowledge of bobcat natural history, 25%-**25%** no knowledge and 7%-**7%** are very knowledgeable.

Question: Where do you get most of your information on local wildlife?

67%-**66%** of respondents get most information on local wildlife from the Arizona Sonora Desert Museum, 63%-**63%** online and 41%-**41%** from Arizona Game and Fish.

Question: Do you use rodenticide (poison) to control mice, rats or packrats at your home?

92%**-91%** do not use rodenticides to control mice, rats or packrats at their home or property. If yes, 81%- **81%** say used outside.

Question: Would you be willing to make changes in your personal behavior in order to support urban wildlife in your neighborhood?

95%-**94%** say they would be willing to make changes in personal behavior to support urban wildlife in their neighborhood. 6%- **6%** would not.

Question: If yes, things I would be willing to do?

74%-**74%** would keep pets leashed or in a shelter safe from urban wildlife, 78%-**78%** would be an advocate to neighbors for wildlife, 83%-**83%** would avoid using rodenticides and 55%-**55%** would contribute to urban wildlife conservation efforts.

Question: If you had the opportunity to contribute to a local organization dedicated to research, projects, and public outreach efforts aimed at conserving bobcats in the Tucson area, what might that annual contribution look like?

21%-**22%** would not contribute to a local organization dedicated to research, projects and public outreach efforts aimed at conserving bobcats in Tucson, 11%-**10%** would contribute $10, 23%-**23%** $20, 27%-**26%** $50, 14%-**14%** $100, and 5%-**5%** over $100.

Question: Do you support governmental agencies spending tax dollars to support projects to conserve and protect urban bobcat habitat around the edges of Tucson's developed core?

95%**-95%** support governmental agencies using taxpayer funds to support projects that protect urban bobcat habitat around the edges of Tucson's developed core.

Question: How old are you?

12%-**11%** were respondents between 20-40 years old, 25%-**25%** 41-60, 59%**-59%** 61-80 and 4%-**4%** over 80.

Question: How many years of formal education do you have?

55%-**55**% of the respondents had over 16 years of formal education, 32%-**32%** 16, 12%-**12%** 12 and 1%-**1%** 8 years.

Question: Do you identify your gender as male, female or other?

64%-**64%** of the respondents self-identified as female and 35%-**35%** male.

Survey conducted from 10/2/20 until 6/1/24. N= 1,500

Respondents added 757 comments to responses on open-ended questions 13, 16, 18 and 31.

There was a 72% full survey completion rate.