MOVEMENT PATTERNS OF COYOTES AND BOBCATS RELATIVE TO ROADS AND UNDERPASSES IN THE CHINO HILLS AREA OF SOUTHERN CALIFORNIA

A Thesis
Presented to the
Faculty of
California State Polytechnic University, Pomona

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
In
Biological Sciences

By
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2001

SIGNATURE PAGE

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ACKNOWLEDGEMENTS

This research project was made possible by the constant support, guidance, hard work, and dedication of a number of people. First, I would like to especially thank my advisor, Glenn Stewart, for his faith in my abilities and allowing me liberty in attaining my thesis. Also, a warm thank you to my other committee members, David Moriarty, who always happily provided statistical advice and continual reminders of “if it was easy then everyone would be doing it”, and Gary Carlton, for allowing me latitude in class during trapping sessions and providing helpful comments.

I owe a debt of gratitude to a wonderful group of individuals: Kevin Crooks, Eric York, and Chris Haas. In addition to securing the funding for this work, Kevin provided indispensable guidance that was above and beyond the call of duty, especially towards the end of this project. Eric was absolutely instrumental in the success of this research. In particular, he had the professionalism (without too much laughter) and patience to train the “Rook” in capture techniques and field biology. I am especially grateful to Chris. Aside from teaching me to read carnivore tracks, he was invaluable as a field assistant and was responsible for keeping me focused, levelheaded, and somewhat good-natured as I wrote.

At the beginning of this work, Ray Sauvajot of the National Park Service generously offered the support of his personnel to train me in the finer art of radio telemetry – thank you. Thus, thanks to H. Sharon Kim for her radio telemetry expertise and confidence in my skills. Also, I would like to extend an enormous thank you to my field assistants: Eric Askew, Kirsti Dean, Shalene George, Kim Kindt, Mike Rathbun, Karen Raymond, and Jeremy Walling. Without their enthusiasm and hard work, this project would not have been possible.

Additionally, I appreciate Andre and Albert Bello, the California Department of Transportation (Paul Gonzales), California State Parks (Geary Hund), Green River Golf Course, Hart Brothers Livestock (Slim and Donna Hart), Orange County Water District (Brian Baharie), Prado Recreation Dog Activities (Don and Janet Richardson), Raahague's Pheasant and Shooting Club (Mike Raahague), and the U. S. Army Corp of Engineers (Carvel Bass) for allowing me access to their property. Other individuals that significantly contributed to the success of this work include: Robert Fisher of the U.S. Geological Survey-BRD, Rich Hunter of Talon Associates, Inc., Brian Mitchell from the University of California-Berkeley, Lee Montoya of the California Department of Fish and Game, Robert Shanaberger from California State Parks, Jeff Tracey from the University of California-San Diego, and Russell Williams from the California Department of Transportation.

This research was funded by the California Department of Transportation through a cooperative agreement with the Mountains Recreation and Conservation Authority.

Finally, hugs and kisses to Zeke and Kiah (who have patiently waited for "let's go for a walk!"). But, most of all, I want to extend my most heartfelt thank you to my family – Yolanda and Stan, my grandparents (who are true inspirations and I hope I've made them proud); John and Mike, my brothers (who are quite sure that I will forever be in school); and Britni, my niece (you go girl!). Their constant love and support has made this thesis possible, and I dedicate it to them.

ABSTRACT

Roads are major barriers to animal movement and are a principal cause of habitat fragmentation in which mammalian carnivores are particularly vulnerable. Roadway underpasses are intended to increase road permeability and restore habitat connectivity. Yet, few studies have examined the movement of individuals within a population in relation to both roads and underpasses, especially in an urban environment. Therefore, I examined home range characteristics, underpass use, and vehicle-related mortality patterns of coyotes (*Canis latrans*) and bobcats (*Felis rufus*) primarily along California Route 71 (CA 71) from November 1997 through February 2000. I captured and radio-tracked 29 coyotes and 4 bobcats, and fitted an additional 24 coyotes with dog collars. Telemetry data were augmented by remotely triggered camera surveys at the underpasses.

Home range sizes for 15 coyotes (1.23-54.19 km^2, 95% ADK) and three bobcats (3.41 to 15.26 km^2, 95% ADK) were highly variable. Mean core-use area sizes (50% ADK) comprised an average of 15.0% and 17.1% of the mean home range sizes for coyotes and bobcats, respectively. The small sample size of three bobcats excluded them from most analyses. For coyotes, core-use area sizes increased as home ranges became larger. Although home range sizes among all coyote age classes were similar, juveniles had smaller core-use areas than yearlings and adults. While coyote residents had smaller home ranges than transients, their core-use area sizes did not differ. Coyote home range and core-use area sizes were similar between sexes, home range location, and road crossing behavior. For those individuals located adjacent to CA 71, 54% of the coyotes and 50% of the bobcats had core-use areas that overlapped the road. Buffer zone use

along the road was highly variable among individual coyotes and bobcats. In fact, when coyotes were grouped by demographics, only the male yearlings, male adults, and non-crossers had similar, but not identical, patterns of buffer zone use. Home range length/width ratios differed only for home range location, with coyotes residing east of CA 71 having home ranges considerably more linear than coyotes to the west.

From the radio-collared individuals with home ranges described and located near CA 71, 62% of the coyotes and 100% of the bobcats, plus six dog-collared coyotes, used the underpasses. Coyotes used underpasses significantly more than bobcats. Both species used the underpasses with equal frequency between years and among seasons. Yet, coyote frequency of underpass use appeared to be suppressed by traffic volume. The probability and frequency of underpass use for coyotes was similar for sexes, ages, social status, and home range location. Also, coyote density explained 34% of the variability observed in coyote frequency of underpass use. Along CA 71, no bobcats were road killed, but significantly more coyotes were killed where wildlife fencing was absent, in southbound lanes, and juveniles and yearlings were killed significantly more than adults.

My results suggest that roadway underpasses can be effective tools in permitting movement of individuals within their home range if they survive to become educated in the dangers of crossing over roads. However, in the absence of properly installed wildlife fencing, underpasses do not appear to facilitate the movements of dispersing individuals, which can be detrimental to the viability of populations in fragmented landscapes. Also, the current condition of the wildlife fencing probably confounded the assessment of those factors (demographic and environmental) expected to have influenced the use of the underpasses.

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CHAPTER 1

HOME RANGE CHARACTERISTICS AND SPATIAL PATTERNS OF COYOTES (*CANIS LATRANS*) AND BOBCATS (*FELIS RUFUS*) IN AN ENVIRONMENT FRAGMENTED BY ROADS

INTRODUCTION

Habitat fragmentation has been identified as one of the principal threats to biodiversity worldwide (Wilcox and Murphy 1985). Aside from the direct loss of habitat, fragmentation results in the isolation of once continuous populations into smaller subpopulations (Saunders et al. 1991). Small, isolated populations fluctuate more widely as they are faced with altered microclimatic conditions, edge effects (Murcia 1995), reduced access to resources, and increased predation (Noss 1994). Consequently, they are more vulnerable to localized extinction because they are more susceptible to genetic (Gaines et al. 1997), demographic (Wauters et al. 1994, Crooks et al. 1997), and environmental stochastic events.

Roads are a primary cause of habitat fragmentation (Noss and Cooperrider 1994). They are also responsible for altering animal movement and direct mortality of wildlife through road kills (Forman and Alexander 1998). However, unlike more traditional forms of fragmentation that are usually the result of deforestation or conversion of natural habitat, which may still allow movement across the boundary, the most detrimental effect of roads is that they create absolute movement barriers and/or “filters” that allow only certain individuals across (Forman and Alexander 1998). As a result, these hard barriers can prevent recolonization of empty patches altogether (Yanes et al. 1995) or cause skewed sex ratios because of reduced emigration due to filtering (Mansergh and Scotts 1989).

Most animals are vulnerable to roads, including invertebrates (Mader 1984), amphibians (Reh and Seitz 1990), reptiles (Boarman and Sazaki 1996), birds (Reijnen et al. 1995), small mammals (Mader 1984), and ungulates (Rowland et al. 2000). However, because mammalian carnivore populations exist at low densities, have low reproductive rates, and relatively large home ranges that place them in regular contact with roads, they are particularly sensitive. In fact, the road barrier effect and associated road avoidance has been demonstrated for several species of mammalian carnivores. Wolves failed to inhabit locations with road densities in excess of 0.58 km/km^2 in Wisconsin (Thiel 1984) and grizzly bears selected for habitat with road densities less than 6.0 km/km^2 in Montana (Mace et al. 1996). Bobcats selected home ranges with lower densities of secondary highways and crossed paved roads less than expected in Wisconsin (Lovallo and Anderson 1996*b*). In North Carolina, black bears only traversed a four-lane divided highway a few times, even though it intersected 13 home ranges (Brody and Pelton 1989). In Canada, grizzly bears avoided habitat within 100 m of roads (McLellan and Shackleton 1988), wolves avoided habit within 400 m of roads (Paquet and Callaghan 1996), and coyotes avoided open areas near roads during the day (Roy and Dorrance 1985).

Roadway underpasses have received increasing attention as a way to ameliorate the barrier effect of roads and restore connectivity (Foster and Humphrey 1995, Yanes et al. 1995, Rodriguez et al. 1996). Yet, previous underpass studies have concentrated on what species use the underpasses and the landscape and structural variables influencing the use of the underpasses (Foster and Humphrey 1995, Yanes et al. 1995, Rodriguez et al. 1996, Clevenger 2000, Haas 2000, Ng 2000). Likewise, previous research on roads and carnivores has not considered the presence of underpasses (Thiel 1984, Roy and Dorrance 1985, McLellan and Shackleton 1988, Brody and Pelton 1989, Lovallo and Anderson 1996*b*, Mace et al. 1996, Paquet and Callaghan 1996). Only anecdotal evidence is available on individual carnivore home range movements relative to roads with underpasses present (Beier 1995). Therefore, my objectives were to 1) determine characteristics of home ranges and core-use areas of coyotes and bobcats and test how they vary with demographic factors (sex, age, and social status) in an environment fragmented by roads that had underpasses, and 2) to specifically evaluate the effect of those roadways on movement and spatial patterns of coyotes and bobcats.

METHODS

Study Area

The study area (Figure 1.1) encompassed about 155 km^2 of the Chino Hills and Prado Flood Control Basin (herein referred to as Prado Basin) within Orange, Riverside, and San Bernardino Counties, California ($33^o54'$N; $117^o39'$W). However, a majority of the study animals confined most of their activity to San Bernardino and Riverside counties. The climate is a warm, dry Mediterranean environment with a mean annual precipitation of 21.4 cm, primarily occurring during the wet season (Nov-Apr) (Prado Dam-World Climate Data 1998). Monthly temperatures range from a mean low of 4.2^oC

in December to a mean high of 33.3^{o}C in August (Corona-World Climate Data 1998). Elevations range from 110 to 545 m. State Route 71 (CA 71) bisects the study area into east and west halves. To the east is Prado Basin (3,925 ha), which consists of riparian and upland habitat that includes some agriculture and developed areas used largely for recreation (U. S. Army Corp of Engineers 2000). To the west are private ranch lands and Chino Hills State Park (4,577 ha) (Horn et al. 1993), dominated by riparian, coastal sage scrub, chaparral, oak and walnut woodlands, and annual grassland communities. Chino Hills State Park (CHSP) is at the eastern end of the Puente-Chino Hills wildlife corridor that extends 50 km to the west and connects with Cleveland National Forest located in the Santa Ana Mountains to the south.

In addition to CA 71, State Routes 83 (CA 83) and 91 (CA 91) further fragment the study area (Figure 1.1). CA 83 is a two-lane at-grade road connecting to CA 71 in the north (relative to the study area) and had a peak month average daily traffic (ADT) volume of 13,100 with speeds averaging 72 kph (45 mph). CA 91 is an east-west 12-lane freeway connecting with the terminus of CA 71 to the south and separating the Chino Hills and Prado Basin from the Santa Ana Mountains. The peak month ADT volume for CA 91 was 223,000 (California Department of Transportation 1999) and speeds average 120 kph (75 mph) during non-rush hour traffic.

During the summer of 1997, the California Department of Transportation (Cal Trans) reconstructed a 5-km segment of the two-lane CA 71 between CA 83 and CA 91. Prior to reconstruction, CA 71 was very similar in size and traffic speeds to CA 83, but it also included a culvert to drain water, and a vehicle underpass (underpasses 1 and 4 respectively) (Figure 1.2). Reconstruction included elevating the road, widening it to accommodate four lanes in the future, and installing guardrails, center dividers (cement walls and guardrails), 2.5 m woven-wire wildlife fencing, and an additional three wildlife underpasses and 20 water culverts. The water culverts (herein referred to as underpasses) remained dry for most of the year. The cut-and-fill areas were restored with native vegetation. However, the wildlife fencing was discontinuous along the 5-km section of freeway (Figure 1.2). During 1999, the peak month ADT volume for CA 71 was 34,500

Trapping and Telemetry

Coyotes and bobcats were captured using Victor #3 soft-catch leg-hold traps (Sterling Fur & Tool Co., Sterling, OH) during three trapping sessions in 1998: February 6 to March 6, June 6 to July 7, and October 3 to November 3. Trapping was focused along CA 71 to capture those individuals most likely to be affected by the presence of the road or using the underpasses. Upon capture, coyotes were physically restrained by placing a Velcro muzzle around the nose and hobbles around diagonally opposing front and rear legs. Bobcats were chemically immobilized with ketamine hydrochloride at 10 mg/kg of estimated body mass. Conditions permitting, each individual was ear-tagged, sexed, aged, and weighed. Standard body measurements were taken, and blood, hair, and parasite samples were collected. All bobcats and most of the coyotes (55%), depending on age and radio collar availability, were fitted with a radio collar containing a mortality sensor (Telonics, Inc., Mesa, AZ). Other captured coyotes were fitted with dog collars. Bobcats were aged by weight (Crowe 1975) and classified as either juveniles (< 1 year) or adults. Coyotes were aged by either tooth eruption or wear and condition (Gier 1968), and were classified as juveniles (< 12 months), yearlings (12-24 months), or adults (> 24 months) (Gese et al. 1996*a*). Because of the anesthetic, bobcats were placed under nearby vegetation after processing, monitored until recovery, and then released at the capture site. Coyotes were immediately released at the capture site upon removal of the muzzle and hobbles. The California State Polytechnic University, Pomona Animal Care and Use Committee approved the capture and handling procedures (protocol 97.011).

A portable receiver and hand-held Yagi antennae (Telonics, Inc., Mesa, AZ) were used to estimate the radiolocations using triangulation. An animal was typically located by one observer triangulating on the loudest signal (Springer 1979) from two to five observer stations along roads (White and Garrott 1990). The set of bearings, maintained between 30° and 160° (modified from Gese et al. 1988), was recorded in less than 30 minutes. Telemetry location estimates were generated using LOCATE II (Pacer 1990). Additional locations were obtained by opportunistic visual identification of tagged animals (Hein and Andelt 1995). Extensive vehicle searches were initially used to locate missing animals. On two occasions, when animals could not be located, aerial telemetry (Ecoscan Resource Data, Watsonville, CA) was employed; during aerial surveys we also located those animals that frequented private property where access was forbidden and location by ground triangulation was impossible (Mech 1983). However, since aerial telemetry generated only a few locations and was cost prohibitive it was only used twice.

Point and sequential sampling (Smith et al. 1981, Gese et al. 1990, Harris et al. 1990) was used from July 1998 to February 2000 to determine home-range estimates, distances from primary roads, and locations where an animal crossed a road. During point sampling, I obtained single locations for multiple animals. For sequential sampling, I recorded a series of locations on one animal during a continuous monitoring session that typically lasted six hours. Each hour, I obtained one triangulated location and took two single bearings at 20-minute intervals. A continuous session was also defined as a point location followed by a visual location within four hours (Swihart and Slade 1988). When an animal was found on both sides of CA 71, as determined from telemetry, remotely triggered cameras installed at the underpasses (CamTrak South, Watkinsville, GA; results presented in Chapter 2), or its recapture location, it was then targeted for a continuous monitoring session. So that each targeted animal was continuously radio-tracked over the entire 24-hour cycle, efforts were made to radio-track each individual at least four times (6 hours per continuous session), whereas point sampling was conducted systematically during both day and night. Day locations were those locations collected between sunrise and sunset while night locations were those collected between sunset and sunrise (United States Naval Observatory 2000).

Telemetry error was estimated by placing test transmitters at unknown distances from the observer in characteristic habitat or otherwise difficult locations throughout the study area and triangulating on the signal from three observer locations. Telemetry error tests were conducted during the day. Mills and Knowlton (1989) recommended that telemetry error tests be performed without the observer's prior knowledge to reduce bias in error estimation. However, Zimmerman and Powell (1995), using a larger sample size of 940 versus 27, refuted those results. Therefore, in this study, observers were aware that telemetry error tests were being conducted, but were ignorant of the true locations of the test transmitters. Error was determined by the location error method (LEM) (Zimmerman and Powell 1995), which is the shortest distance between the known and estimated location of the test transmitter (LEM distance). LEM distances were pooled for a single estimation of error for the entire study area. The distance from observer to transmitter (DOT distance) affects error estimation (Zimmerman and Powell 1995). Therefore, the LEM distance is a valid demonstration of the error associated with animal location estimates if there is no difference in DOT distances between telemetry error test location estimates and animal location estimates. I conducted a two-sample *t*-test to determine if DOT distances differed between test locations and animal locations. Because telemetry error test locations were estimated with just three bearings, only those animal locations estimated by three bearings were used in the analysis. DOT distances were log transformed to follow a normal distribution (Zar 1984, StatSoft, Inc. 1996).

Home Range

The Calhome home-range analysis program was used to estimate home range boundaries and size (Kie et al. 1994). Home range sizes were calculated using the minimum convex polygon (MCP) and the adaptive kernel methods (ADK) (Worton 1989). The MCP method was chosen because it is frequently reported in the literature and therefore allows for comparison between studies (Harris et al. 1990). The ADK method was chosen because it is more statistically robust, and less affected by small sample size and the choice of grid cell size, than the harmonic mean method (Gallerani Lawson and Rodgers 1997, Seaman et al. 1999). Core-use areas were defined by the 50% ADK isopleths because they remain relatively stable spatially with respect to sample size (Crooks and Van Vuren 1996). Radiolocations were pooled across seasons for the duration that an individual was monitored to estimate its home range.

Swihart and Slade (1985*a*, 1985*b*) noted that temporally autocorrelated data might result in biased estimates of home range boundaries and size. Using movement data from several species, they calculated the "time to independence" for each species, which is the time interval that sequential radiolocations were negligibly autocorrelated (Swihart and Slade 1988). The time to independence (TTI) for coyotes was ≥3.45 hours. Although bobcats were not included in Swihart and Slade's (1988) species list, I used their "hunters" linear regression equation and calculated the TTI for bobcats at ≥3.13 hours. Therefore, following Romsos (1998), a subset of point and sequential locations that were separated by >3.45 hours for both coyotes and bobcats were selected and considered independent. Schoener's t^2/r^2 ratio, which is the ratio of the mean squared distance between successive observations to the mean squared distance from the center of activity (Schoener 1981, Swihart and Slade 1985*a*), was used to test for independence within these sets of independent radiolocations (Romsos 1998). Only independent data sets that originally had ≥10 locations per individual were used (Schoener 1981, Swihart and Slade 1985*a*). Data sets that had ratios of <1.6 and >2.4 were consider temporally autocorrelated (Romsos 1998).

However, excluding autocorrelated data from home range estimates has met with some opposition, because reducing the number of locations may eliminate essential changes in behavior that are necessary to accurately describe the home range (Rooney et al. 1998, Otis and White 1999), and smaller sample sizes also affect the robustness of the home range estimation methods (i.e. kernel density estimators; De Solla et al. 1999). Therefore, home ranges and core-use areas were estimated by using all of the radiolocations and then only those considered independent. A paired-sample *t*-test was used to compare the home range estimates generated from all locations and the independent locations data sets. Home range sizes were log transformed to fit a normal distribution. If no differences were found, then all of the locations were used to estimate home ranges and core-use areas.

Area-observation (AO) curves were constructed for those individuals with >10 locations to determine if enough locations were collected to sufficiently describe their home range (Odum and Kuenzler 1955). All locations were used and entered randomly (Harris et al. 1990). Home ranges were considered to be adequately sampled when the addition of a set of five locations did not increase the 100% MCP size by > 1% (Gese et al. 1990), which indicated that the AO curves had reached an asymptote. In addition, a simple linear regression was used to determine if home range sizes were 1) a function of the number of locations used to generate the home range and 2) correlated with core-use area sizes.

Coyotes and bobcats were classified as either residents or transients. For coyotes, residents were considered to be those apparently defending an exclusive area while transients were those that traveled over a larger area and exhibited no single site fidelity (Gese et al. 1988). For bobcats, adults were classified as residents and dispersing juveniles as transients (Anderson 1987). Home ranges were defined as either east or west of CA 71 based on which side of the freeway had the larger number of locations. As determined by remotely triggered cameras or radio telemetry, animals that were detected at least once on both sides of CA 71 were categorized as “crossers”. “Non-crossers” were considered as those animals that did not cross CA 71. However, individuals that had home ranges in Telegraph Canyon in CHSP were not included in this analysis because it was unlikely they could have come in contact with CA 71. Two-sample *t*-tests were used to test for differences in home range and core-use area sizes between sexes, social status, and crossing behavior, whereas an analysis of variance (ANOVA) was used to test for differences among age classes. A Duncan new multiple-range test was used to determine which age classes showed differences in home range and core-use area sizes (Gese et al. 1988). Finally, because group variances for home range location (East/West) were heteroscedastic, a Welch's approximate *t* procedure was used for this analysis.

<u>Roads</u>

Because a linear home range may suggest that CA 71, 83, or 91 were negatively influencing coyote and bobcat movement (Stumpf and Mohr 1962), the 95% ADK home range estimates were imported to TOPO! (Wildflower Productions 1998) at the 1:12,000 scale (U. S. Geological Survey 7.5' map) for measurement of home range shape. Length was measured as the distance between the two furthest points along the home range boundary. Width was then determined as the greatest distance between two locations along the boundary that were perpendicular to the length axis (Stumpf and Mohr 1962). If a home range was bimodal (i.e. two separate areas of home range use), distances were measured to include the outer most boundaries of both polygons since it is impossible for an animal to occupy both areas without traversing the habitat between them. The home range was considered linear if the length to width ratio was greater than two (Woodward 1990). For those individuals that maintained 100% MCP home ranges within one km of CA 71, home range ratios were compared using ANOVA and two-sample *t*-tests for differences among group classifications.

Four buffer zones (0-100, 101-300, 301-700, and 701-1500 m) were delineated alongside CA 71, 83, and 91 (McLellan and Shackleton 1988, Paquet and Callaghan 1996). Using Arcview GIS 3.2 (Environmental Systems Research Institute 1999), all radiolocations within 1500 m of a road were assigned to the appropriate buffer zone. A goodness-of-fit test using the *G* statistic (Zar 1984) was used to determine if buffer zone use was proportional to availability. Expected proportional use of a particular buffer zone was calculated by dividing the area encompassed within that particular zone by the total area encompassed for all of the zones combined. The Bonferroni *z* statistic (Neu et al. 1974, Byers and Steinhorst 1984) was then used to identify how an individual used each buffer zone (i.e. under-utilized, used in proportion to availability, or over-utilized).

A heterogeneity log likelihood goodness-of-fit test (Zar 1984) was used to determine if individuals could be pooled together by demographic group (sex, age, social status, home range location, and crossing behavior) for analysis of within-group use of buffer zones. Certain groups were not analyzed because there were no individuals represented. Data were considered homogeneous and consequently pooled when $p > 0.05$. The Bonferroni *z* statistic was used to determine how the groups used the buffer zones.

Because the availability of suitable habitat can influence the use of buffer zones (McLellan and Shackleton 1988, Paquet and Callaghan 1996) along CA 71, the habitat was evaluated using GIS. Excluding urban development, the vegetative communities north of CA 91 revealed that annual grasslands dominated west of CA 71, and extended approximately 100-200 m east of CA 71, whereas southern cottonwood-willow riparian forest dominated east of CA 71. Therefore, radiolocations were pooled as either east or west of CA 71, for an additional group comparison. For this analysis, I assumed that radiolocations west of CA 71 would be distributed in proportion to the area encompassed by each buffer zone, whereas radiolocations east of CA 71 would be distributed in greater proportion within the two buffer zones closest to the road (0-100 and 101-300), if coyotes were selecting for the habitat and were not influenced by CA 71.

RESULTS

Trapping and Telemetry

Fifty-three coyotes (Tables 1.1 and 1.2) and four bobcats were captured (Table 1.3). Data on age, weight, and various morphological measurements are presented in Appendix 1.1. Because juvenile coyotes reach adult weight at about nine months old (Geier 1968), analysis of weight was separated into individuals less than one year old and individuals greater than one year old. For coyotes greater than one year old, the mean weight of males ($n = 21$) was 11.7 kg ± 0.3 SE whereas the mean weight of females ($n = 16$) was 10.3 kg ± 0.3 SE. Males weighed significantly more than females ($t = -3.359$, $p = 0.002$, $df = 35$). For comparison, Geier (1968) reported mean weights of adult male and female coyotes in Kansas as 13.9 kg and 11.8 kg, respectively. In this study, the mean weight of coyotes less than one year old ($n = 12$) was 7.0 kg ± 0.8 SE, predictably less than coyotes greater than one year old (mean = 11.1 ± 0.2 SE, $t = -6.672$, $p < 0.001$, $df = 47$). The mean weight of the adult male bobcats was 9.1 kg ± 0.5 SE ($n = 2$), and the adult female bobcat weighed 6.2 kg.

Twenty-nine coyotes and all of the bobcats received radio-collars (Tables 1.1 and 1.3). Normal operation life for the coyote collars was 20 months. However, seven and five coyotes were fitted with radio collars that had an operational life of 15 and nine months, respectively. Bobcat collars had an operational life of 15 months. Nineteen of the remaining 24 coyotes received dog collars and ear tags while the rest received ear tags only (Table 1.2). There were 28 males and 25 females coyotes captured; this included 12 juveniles, 16 yearlings, and 25 adults. Two male and two female bobcats were captured including three adults and one juvenile. When including all captures and recaptures of both coyotes and bobcats, there were 17 captures on the east and 56 captures on the west of CA 71 (Tables 1.1, 1.2, and 1.3).

Fourteen coyotes and one bobcat either slipped off their collar ($n = 2$), left the study area or lost radio contact ($n = 3$), moved to a portion of the study area where radio locations were impossible to obtain because access was forbidden by land owners ($n = 3$), or died before their home ranges could be described ($n = 7$) (Tables 1.1 and 1.3). These numbers only refer to the disposition of the animal at the time radio tracking ceased (e.g. an individual moved into to a difficult portion of the study area and could no longer be radio-tracked, but was later confirmed dead). Ten of 15 confirmed coyote deaths were due to vehicle collisions (Tables 1.1 and 1.2).

Mean radio telemetry location error for the 33 error tests conducted was 104 m, with 95% of the errors being ≤143 m. Although there was a substantial difference in sample sizes for error tests and animal locations, the DOT distance variances were homogeneous ($F = 0.539$, $p = 0.463$, $n = 513$). Furthermore, there was no difference in DOT distances ($t = -1.78$, $p = 0.076$, $n = 513$), indicating that the mean radio telemetry error estimate for the test transmitters was a credible estimate of error associated with the animal locations. Excluding visuals and capture locations, most of the animal locations were collected at distances <1000 m ($n = 692$, 82%).

Home Range

Home ranges were described for 15 coyotes and three bobcats (see Appendices 1.2-1.19) using the all locations data sets because there was no difference in home range sizes between those data sets and the independent locations data sets (Table 1.4) (100% MCP, $t = 1.935$, $p = 0.070$; 95% ADK, $t = 0.296$, $p = 0.831$; 50% ADK, $t = -0.583$, $p = 0.567$; $n = 18$). Furthermore, home range size was not correlated with the number of locations obtained for each home range estimate (100% MCP, $r^2 = 0.010$, $p = 0.692$; 95% ADK, $r^2 < 0.001$, $p = 0.975$; 50% ADK $r^2 = 0.002$, $p = 0.856$; $n = 18$). Eleven coyotes and two bobcats had home range estimates that were adequately sampled based on their area-observation curves (Figure 1.3); but of these, three coyotes (C17, C26, C43) and one bobcat (B1) had independent locations data sets that were significantly autocorrelated (Table 1.4). Additionally, two coyotes (C3 and C32) had independent data sets that were significantly autocorrelated and area-observation curves that did not asymptote (Figure 1.3 and Table 1.4). However, because mean 95% ADK home range sizes were similar for all coyotes despite removing those home range estimates that did not asymptote ($t = 0.101$, $p = 0.920$, $n = 26$), all home ranges were included for comparison among groups (Table 1.5). Still, care must be taken when interpreting these results because small sample sizes reflect low power to detect differences. Furthermore, home range estimates for those animals that did not reach an asymptote may be conservative.

Mean 100% MCP and 95% ADK estimated home range size for all coyotes were 9.79 ± 2.44 km^2 and 13.72 ± 3.92 km^2 respectively (Table 1.5); however, these estimates were highly variable (100% MCP range: 0.84 to 38.33 km^2 and 95% ADK range: 1.23 to 54.19 km^2) (Table 1.4). For residents only (n = 8), the mean 100% MCP home range size was 3.36 ± 0.62 SE while the mean 95% ADK home range size was 4.56 ± 0.94 SE. Coyotes C26, C43, and C44 had 95% ADK home ranges that were bimodal (Appendices 1.10, 1.14, and 1.15). Male and female coyotes had similar home range and core-use area sizes (Table 1.6). Additionally, there was no difference in home range and core-use area sizes between adult male and female coyotes. Although 100% MCP and 95% ADK home range sizes did not significantly differ among age classes of coyotes, 50% ADK core-use area sizes were smaller for juveniles than adults (Table 1.6). There were one to three core-use areas per animal and estimated core-use area sizes varied from 0.22 to 6.96 km^2 (Table 1.4). Core-use area sizes increased as coyote home range size increased ($r^2 = 0.475$, $p = 0.004$, 100% MCP; $r^2 = 0.458$, $p = 0.006$, 95% ADK; $n = 15$). Although core-use areas contained 50% of the locations, they consisted of just 15.0% ± 0.9 SE of the home range size. Eight coyotes had core-use areas that overlapped a primary road (see Appendices 1.3, 1.4, 1.8, 1.9, 1.10, 1.14, 1.15, 1.16).

The social structure of the radio-collared coyote population included two resident pairs or packs, C4 and his un-collared mate (Airport pair), and C7, C17, and C44 (Creek pack). Although C17 and C44 were often found hunting together in the fall, as breeding season approached C17 shifted her activities to the south of the pack's home range and C44 spent considerably more time with C7. This pair then continued to closely associate with each other through the breeding, gestation, and a portion of the pup-rearing season (until radio contact was lost with C44), indicating that they were in fact the resident breeders (Sacks et al. 1999). The remaining social structure of the population included two solitary residents (C6 and C8), two juveniles of unknown relation (C38 and C39, parents were unmarked), and seven transients. Resident coyotes had significantly smaller home ranges than transients (Table 1.6), which is not unexpected since this is inherent to their placement within each respective social group. However, core-use area sizes were similar. Finally, there was no difference in sizes of home ranges or core-use areas for home range location (East/West) or crossing behavior (Cross/Non-crosser) (Tables 1.5 and 1.6).

Home ranges were described for three bobcats (Table 1.4), but small sample size precluded any comparisons between groups. Yet, mean 100% MCP and 95% ADK home range sizes for all bobcats were 6.76 km^2 ± 2.86 SE and 8.89 km^2 ± 3.45 SE, respectively, while the mean core-use area was 1.31 km^2 ± 0.40 SE. The adult female bobcat's home range was bimodal and her core-use area overlapped CA 71 (Appendix 1.17). Bobcat core-use areas comprised 17.1% ± 2.3 SE of the home range areas.

Roads

The mean home range length/width ratio was 1.64 ± 0.14 SE for coyotes ($n = 15$) and 1.84 ± 0.26 SE for bobcats ($n = 3$). Linear home ranges were found for 20% of the coyotes and 67% of the bobcats (Table 1.4). Home ranges for the group of coyotes east of CA 71 were more linear than those home ranges for coyotes west of CA 71 ($t = 2.722$, $p = 0.016$, $n = 15$; Table 1.7). Because the sample size for bobcats was only three, they could not be grouped for comparisons.

From the 15 coyotes and three bobcats included in the buffer zone analysis, 13 coyotes and two bobcats were located near CA 71, nine coyotes and two bobcats were located near CA 83, and four coyotes were located near CA 91. However, three coyotes along CA 71, five coyotes and one bobcat along CA 83, and one coyote along CA 91 were excluded because of low sample sizes ($n < 17$). Table 1.8 shows the results for 10 coyotes and two bobcats that remained in the analysis. Except for C4 and B1, coyote and bobcat buffer zone use along CA 71 was not proportional to availability (Table 1.8). Along CA 83, two coyotes (C17 and C52) and one bobcat (B1) used the buffer zones disproportionately to availability. Along CA 91, all coyotes used the buffer zones proportional to availability (Table 1.8). Figure 1.4 shows how the individual coyotes and bobcats utilized the buffer zones around each respective road.

The heterogeneity log likelihood goodness-of-fit test showed that individuals could only be pooled within three of the coyote demographic groups along CA 71: male adults, male yearlings, and non-crossers (Table 1.9). The male adults (C4 and C44) used each buffer zone proportional to its availability. The male yearlings (C26 and C43) over-utilized the 101-300 zone, under-utilized the 701-1500 zone, and used the remaining buffer zones proportional to their availability. Finally, the non-crossers (C4 and C6) exhibited a pattern almost opposite of the male yearling group by under-utilizing the 101-300 zone, over-utilizing the 701-1500 zone, and using the remaining two buffer zones proportional to their availability (Figure 1.4). Due to low sample size, no demographic group analyses were conducted for individuals along CA 83 and 91 (Table 1.8).

After examining the individual results of the Bonferroni *z* statistic along CA 71 more closely (Figure 1.4), it appeared that some coyotes were exhibiting patterns of buffer zone use more similar to individuals from other demographic groups than within their own group. Therefore, these individuals were pooled and tested for heterogeneity. The groups I identified "a posteriori" were C4/C6/C8 because C8 had a pattern of use similar to C6 (who was part of the non-crossing coyote group), C9/C26 because they appeared to over-utilize the middle buffer zones, and C7/C17/C43/C44/C52. The latter group was assembled because, while C17, C43, and C52 tended to have more locations within the buffer zone closest to CA 71, C7, C17, and C44 were members of the same social group. The heterogeneity log likelihood goodness-of-fit test showed that the first and third groups were homogenous (Table 1.9). The Bonferroni z statistic showed that the first group appeared to avoid CA 71 while the latter group appeared to select for CA 71 (Figure 1.4). Although the two remaining coyotes, C9 and C26, appeared to have similar use patterns, they were not homogenous (Table 1.9). Yet, C26 was homogenous with C43, as the male yearling group (see above), but C43 was also homogeneous with C7/C17/C44/C52 (see above). This latter "a posteriori" group was not homogeneous when C26 was included ($G = 49.268$, $p < 0.001$, $df = 17$, $n = 213$). Because it appears that C26's use pattern strongly influenced the male yearling group use pattern (Figure 1.4), C43 remained as a member of the third "a posteriori" group.

I also grouped "a posterior" those individuals that exhibited similar responses to buffer zones along CA 83 and 91. Three coyotes along CA 83 were homogenous (C7/C17/C44) ($G = 13.531$, $p > 0.050$, $df = 8$, $n = 88$) and thus pooled together. These three individuals, when pooled, used each buffer zone in proportion to its availability (Figure 1.4). All the coyotes along CA 91 (C4/C6/C43) were homogenous ($G = 0.468$, p

> 0.999, $df = 8$, $n = 112$) and pooled. As with the pooled individuals along CA 83, these three individuals also used each buffer zone in proportion to its availability (Figure 1.4).

The bobcats, when grouped, were heterogeneous along CA 71 ($G = 13.8279$, $p < 0.005$, $n = 70$) and therefore could not be pooled. Although it appears that B1 under-utilized the buffer zones closest to CA 71 in comparison to B3 (Figure 1.4), remotely triggered camera data indicated she used the underpasses five times more frequently than B3 (Lyren, Chapter 2), which suggested that the use of the 0-100 zone was underrepresented for B1, as determined by radio telemetry.

For all of the coyote locations east of CA 71, the 0-100 zone was over-utilized, the two middle buffer zones were used in proportion to their availability, and the 701-1500 zone was under-utilized, leading to an overall trend of selecting for those buffer zones closest to CA 71 (Figure 1.4). Buffer zones west of CA 71 were used in proportion to their availability, except the 101-300 zone (Figure1.4).

DISCUSSION

Coyotes

Home range. Variation in home range size among species is primarily related to body mass and also is a function of trophic status and primary productivity. Primary productivity is strongly influenced by geographic location, particularly by latitude and annual precipitation (Harestad and Bunnell 1979). In the northern hemisphere, individuals of a species located in the northern region of their geographic range will usually have larger home ranges than individuals occupying the southern region of their range. However, variability may exist within the region, as individuals occupying drier, harsher climates will also have larger home ranges than those occupying wetter, milder climates. Finally, topographic relief (i.e. canyons and hills) (Gese et al. 1988) and habitat structure (Springer 1982, Roy and Dorrance 1985) can influence coyote home range sizes at the local scale.

In the Chino Hills and Prado Basin study area, coyote home range sizes were highly variable. The variation found here could be because they occupy habitat in an environment fragmented by urbanization. In a heterogeneous environment it would be expected that some home ranges be either larger or smaller than an average home range size as habitat quality changes across the landscape. This process is magnified when the habitat becomes fragmented, as an individual will have to either travel more or less depending on patch size, the quality of resources, and the distance between patches, to meet all its energetic requirements. Furthermore, core-use areas are presumed to contain those resources essential to the survival of an individual (i.e. prey, den sites) and therefore are of considerable importance. Although coyotes will use urban habitat within their home range, they limit the amount included in their core-use areas with a concomitant increased use of natural habitat (Romsos 1998). Therefore, a heterogeneous environment, fragmented by urban development, will likely cause coyotes to exhibit a wide range of home range sizes to compensate for the lack of continuous habitat.

In an urban environment, coyotes use large quantities of anthropogenic food resources (Middleton 1994, Quinn 1997). Anecdotal information from the public and field observations indicated that coyotes in the study area used pigeons scavenged from the Prado Recreation Dog Activities kennel, occasional domestic cats (Lyren, personal observation), and fruit to subsidize their diet. In areas with abundant food resources or during periods of high prey availability, coyotes may exhibit decreased home range sizes (Mills and Knowlton 1991). Resident coyotes in Yellowstone National Park that had numerous elk carcasses available to them in winter exhibited smaller than expected home ranges although the park is located in the northern latitudes (Gese et al. 1996*a*). Likewise, the availability of domestic sheep, which comprised 29.1% of the fresh prey weight in coyote scats, was probably an important factor contributing to the small home ranges of resident coyotes in northern California (Neale 1996). In this study, the mean home range size for resident coyotes was small, but consistent with other urban studies conducted by Atkinson and Shackleton (1991), Riley (pers. comm.; current National Park Service large carnivore study in the Santa Monica Mountains of Los Angeles, CA), Middleton (1994), and Shargo (1988) (Table 1.10). These data are in contrast to those of Quinn (1995) and Romsos (1998), but it is unclear if Quinn and Romsos discriminated between resident and transient coyotes. This, along with inconsistent methodologies and data analysis (i.e., elimination of outliers, use of area-observation curves, home range estimation methods), can produce very different home range size estimates (Smith et al. 1981, Gese et al. 1990, Laundre and Keller 1984).

Differences found in home ranges sizes between sexes and age classes within a species are generally attributed to differences in body mass (Harestad and Bunnell 1979). However, in this study, home range sizes were similar between sexes, even though male coyotes weighed more than the female coyotes. Although the difference in body mass is statistically significant, males are only 18% larger than the females, which may not be biologically significant (i.e., not a large enough of a difference to produce larger home ranges). Furthermore, coyotes are not known to be strongly sexually dimorphic; therefore, they would not be expected to demonstrate significant gender differences in home range size (Andelt and Gipson 1979, White and Ralls 1994, Neale 1996, Romsos 1998).

Home range sizes were also similar among the age classes, even though adults weighed more than juveniles. Differences in home range sizes due to body mass may not have been apparent because these coyotes occupy habitat in an arid environment. In a dry shrub-steppe environment in Washington, Springer (1982) suggested that the distribution of water had a larger effect on home range sizes than the densities or distribution of prey. Water is scarce during the summer months in the Chino Hills, though not the Prado Basin. During dry years in the Chino Hills, water is only available in Telegraph and Aliso Canyons, the Santa Ana River, and a few, randomly placed cattle troughs located on private ranch lands west of CA 71. It is around these scattered water sources that the smallest home ranges were recorded and held by resident coyotes, which included the juveniles that occupied Telegraph Canyon. However, juveniles had smaller core-use areas than either yearling or adult coyotes. A partial explanation may be because den sites are usually located close to a water source (Neale 1996), but may also be because juveniles are inexperienced at prey capture and vulnerable to negative interactions with inter- and conspecifics, which may force them to retain smaller core-use areas until they have gained more experience.

Roads. Coyote home ranges east of CA 71 were significantly more linear than those located west of CA 71. Stumpf and Mohr (1962) suggested that, although home range linearity among mammals is common, it might be “an expression of unsuitability of physical and biotic conditions in the area in which an animal lives”. Roads are prominent physical barriers to animal movement (Brody and Pelton 1989, Forman and Alexander 1998) and thus may be a source of obligatory linear home ranges (Paquet and Callaghan 1996). However, linearity may also be imposed by stream courses and lakeshores (Stumpf and Mohr 1962). Because of 1998 El Nino conditions, water was frequently retained in Prado Basin for flood control during this study, acting effectively as a lake and leaving only strips of habitat available between the water and CA 71, 83 and 91. Independently, neither barrier type (roads or water) may have been enough to impede movement and impose linearity. Collectively, however, roads and increased water levels may have caused linear home ranges, especially along CA 71 when water levels were high enough to restrict access to the lower underpasses. In fact, Kendrot (1998) made similar observations for coyotes maintaining home ranges between I-87 and Lake Champlain in New York, and Woodward (1990) concluded that woodchucks residing along the six-lane Queensway in Ontario had linear home ranges that seemed to be imposed by a combination of the “noise-vehicle barrier” and the adjacent riparian habitat. The presence of riparian habitat along the Santa Ana River north of, but paralleling CA 91, may have been the source of the linear home range for C43 west of CA 71 (Appendix 1.14).

In this study, core-use area sizes increased substantially as home range sizes became larger, suggesting that, although roads and urban development were present, the habitat was not critically fragmented immediately adjacent to CA 71. In fact, seven of 13 coyotes and one of two bobcats near CA 71 maintained core-use areas overlapping the road. However, in northern rural New York, coyotes avoided primary (equivalent to the roads in this study) and county roads in their core-use areas during the denning season (Kendrot 1998). This difference probably is the result of the underpasses underneath CA 71 that allowed coyotes and bobcats considerable freedom of movement across the landscape. In turn, relatively unrestricted movement under CA 71 likely contributed to similar home range sizes for coyotes, regardless of where they located their home range (East/West) or whether or not they crossed CA 71.

Along CA 83 and 91, buffer zone use was proportional to availability for most of the coyotes, but it was highly variable along CA 71. Homogeneity of use among the three coyotes associated with CA 83 is not surprising as they belonged to the Creek pack, which was also homogenous in their use of the buffer zones along CA 71. The lack of selection or avoidance for any zone along CA 83 may be because coyotes and bobcats do not perceive it as a threat or barrier since it is a two-lane at-grade road that supports a relatively low volume of traffic at relatively low speeds (45 mph). Although these larger predators were seen to traverse this roadway relatively easily, it was responsible for the death of one bobcat after the completion of the study and it was constantly littered with mesopredator (i.e. raccoon, skunk, and opossum) road kills. The mesopredators may have perceived the road as passable, but it is unlikely they possess the agility to safely and quickly cross a road of this magnitude. Unlike CA 83, CA 91 is a virtual barrier to movement, as it supports large volumes of traffic. CA 91 also is elevated over much of its length along Prado Basin and the Santa Ana River. Since this road is so wide and possesses few underpasses, it is unlikely that many attempts are made to cross it (only two documented coyote road kills in two years; Lyren, Chapter 2). Therefore, the buffer zones are probably utilized much like they would be if a static structure were present, the animals neither selecting for or against it.

Prior to reconstruction, CA 71 was similar to CA 83, but after reconstruction, it became more structurally similar to CA 91 because it was now elevated, with guardrails, center dividers, and wildlife fencing. However, within much of the study area, CA 71 is only two lanes, supports lower traffic volumes, and is fairly permeable because of the underpasses located in every canyon. The variability of buffer zone (space) use by coyotes along CA 71 may be due to the social organization of the population, which probably remained intact because connectivity was preserved by the underpasses (Mansergh and Scotts 1989). Coyote social structure varies widely among environments and can consist of any combination of related packs, resident pairs, solitary residents, transients, and aggregations of unrelated transients (Camenzind 1978). The proportion of residents to transients is dynamic and is influenced by prey size and abundance (Bowen 1981). Residents accounted for 53% of the radio-collared coyote population in the study area. Furthermore, the Creek pack (C7, C17, C44) comprised the majority of the individuals that selected for CA 71. Their over-utilization of the zones closest to CA 71 may be the result of long-term site fidelity that could have persisted after reconstruction because of the presence of underpasses within their home range (underpasses 1 and 4 were present prior to construction), which allowed members to maintain historical home range boundaries (Kitchen et al. 2000). In fact, the Creek pack accounted for 68% of the documented underpass crossings (Lyren, Chapter 2).

The Creek pack may have continued to maintain these boundaries due to higher prey densities along CA 71. Adams and Geis (1983) found that prey diversity and abundance is much greater in right-of-way (ROW) habitat adjacent to roads than interior habitat. An edge was also created along the ROW habitat west of CA 71 because wildlife fencing prevented cattle grazing within the ROW, leaving a strip of intermittent coastal sage scrub and annual grassland habitat. Along the east side, no cattle were present, but another edge was created as the habitat changed from the patchy coastal sage scrub-annual grassland mix to riparian forest. This combination of heterogeneous, edge habitat probably served to inflate prey densities within 300 m of either side of CA 71. The Creek pack was observed on a few occasions hunting along the interior of the western wildlife fence, which is consistent with Gibeau and Heuer (1996) who found that coyotes in Alberta quickly learned to kill big horn sheep by running them up against the wildlife fence.

Gese et al. (1996*a*) found that dominant coyotes had greater access to prey items and thus forced subordinate adults and juveniles to make additional captures on their own elsewhere. In the study area, the dominant coyotes are the residents and the subordinates are the transients. Therefore, it is possible that interactions between residents and transients are determining the use of the buffer zones. For instance, the Creek pack hunted along the interior of the fence and regularly used the underpasses. Moreover, even though their core-use area encompassed the ROW habitat, they were never found within the ROW, which would have placed them in direct contact with the freeway. Unlike the Creek pack, the remaining two transient coyotes that selected for buffer zones closest to CA 71 (C43 and C52) were frequently found within the ROW and crossing over the top of CA 71 (visual confirmation for the female, C52, and an assumption for the male since he was only documented at the underpasses twice; Lyren, Chapter 2).

Although the core-use areas for the female slightly overlapped those of the Creek pack, she appeared to avoid the residents by moving within the ROW and along CA 83 (Appendix 1.20). If she was not moving within the ROW, she was seen in the periphery of her home range (the area between her home range and core-use boundary; Sacks et al. 1999), which allowed her continued avoidance of the core-use areas of the Creek pack altogether. The ultimate fate of this female is unknown; she may have left the area. However, after making wide ranging movements over most of the southern portion of the study area, the male (C43) appeared to settle along CA 71 near CA 91, in a home range similar to the Creek pack to the north that spanned both sides of CA 71. The location was probably available because, although the home ranges of the resident coyotes at the southern end came in contact with CA 71, these residents were under-utilizing (avoiding) the buffer zones nearest the road and placing their core-use areas away from CA 71 (Appendix 1.21). Road avoidance by dominant members of a population also has been found to occur with grizzly bears where males are the dominant members and under-utilize those zones closest to roads while yearlings and some adult females with cubs over-utilized those same zones (McClellan and Shackleton 1988). The authors concluded that, since adult male grizzly bears often kill cubs and yearlings, using the habitat near the road offered a relatively safe alternative for the young bears. Similar behavior would have allowed the transient male to avoid the residents and have access to abundant prey while establishing himself as the resident spanning the southern end of CA 71. However, this section of CA 71 is responsible for numerous road kills (Lyren, Chapter 2), and the established residents may have learned to avoid the road either directly by nonfatal encounters with vehicles or indirectly by social interactions with conspecifics (Mumme et al. 2000). Unfortunately, the transient male was eventually struck and killed by a vehicle within his core-use area on CA 71.

Bobcats

Home range. Mean home range size for bobcats in this study corresponds with the latitudinal trend suggested by Harstad and Bunnell (1979) and Anderson (1987), with smaller home ranges in the southern latitudes (Table 1.11). However, these home ranges were considerably larger than those from the other southern California studies (Riley, pers. comm.; Lembeck and Gould 1979). This may be partially explained by the local habitat structure. Bobcats have been reported to prefer habitats with dense understory (Lawhead 1984, Rolley and Ward 1985). Indeed, Litvaitis et al. (1986) found a significant relationship between thicker understory and increasing prey density that was inversely correlated with bobcat home range size. Furthermore, Anderson (1990) reported that bobcats selected areas with > 55% vertical cover (excluding herbaceous cover) for their day time resting sites, which he felt was important for protection from the weather and predators, such as coyotes, that were responsible for several bobcat mortalities. However, the habitat in the eastern portion of Telegraph Canyon and near CA 71 is primarily annual grasslands, interspersed with patches of oak and walnut woodlands, coastal sage scrub, and riparian habitat, potentially producing larger home ranges equivalent to those in northern California (Neale 1996, Riley 1999) and southeastern Arizona (Lawhead 1984). Bobcats there occupied habitats similar to those in this study, unlike the thick chaparral habitat where Riley (pers. comm.) and Lembeck and Gould (1979) reported very small home ranges. Chaparral is found in the western portion of Telegraph Canyon where Haas and Crooks (1999) reported some of the highest relative abundances of bobcats across the Puente-Chino Hills wildlife corridor. Thus, in that area bobcats may be expected to have smaller home ranges.

Roads. The male bobcat (B4) in Telegraph Canyon and the adult female (B1) had linear home ranges (Appendices 1.17 and 1.19). This female and the other male bobcat (B3) were found to use the buffer zones along CA 71 and CA 83 (Appendices 1.17 and 1.18). Lovallo and Anderson (1996*b*) reported that bobcats crossed unpaved roads in proportion to their availability, but avoided paved roads, which included secondary highways and paved light-duty roads. Primary roads, such as CA 71, were not included in their analysis because they were largely unavailable within their study area. Therefore, it seems unlikely that the home range of the Telegraph Canyon male bobcat would be linear strictly due to a barrier effect imposed by the unpaved, light-duty roads present within CHSP. However, bobcats are more active during the day than coyotes (Neale 1996), and the extensive use of these roads by mountain bikers, hikers, and park personnel may have caused this animal to avoid the roads that completely bordered his home range. The female bobcat also had several light-duty unpaved roads within her home range, but these roads supported minimal activity. Haas (2000) reported that bobcats might be sensitive to urban areas because the relative abundance of bobcats decreased in locations where human activity increased. Therefore, the presence of high-density residential housing (> 4 single family homes/ha) between the female bobcat's northeast home range boundary and CA 71, terminating at underpass 27 (Appendix 1.17), may have been responsible for directing her movements. In fact, Harrison (1998) reported that bobcats were often sighted within low-density residential areas. These areas share similar features with naturally occurring open space, such as substantial vegetative cover and abundant prey (Romsos 1998). However, bobcats were rarely found within areas of high-density residential housing and, like coyotes, may tend to limit the amount of urban area included in their core-use areas (Romsos 1998). Lawhead (1984) reported that bobcats in the arid environment of south-central Arizona avoided extensive grassland habitat, but selected for riparian habitats. This is consistent with the broad habitat selection pattern exhibited by the female bobcat. She would spend large blocks of time in her northern core-use area, which consisted of coastal sage scrub and oak woodlands, and then leave, traversing annual grasslands, and head for the riparian area east of CA 71, where she would spend a few days before returning to the same core-use area. Her use of the riparian habitat, and subsequent avoidance of the urban environment, would have produced a linear home range.

Also, it is unlikely that B1 actually under-utilized the buffer zones closest to CA 71 because radio telemetry only accounted for 16% of her total recorded crossings, with the remaining crossings being documented by cameras (Lyren, Chapter 2), which would have put her in contact with the road more often. The lack of radiolocations in those zones is probably because substantial cover is scare near some of the underpasses. Thus, this may have forced B1 to move more quickly through less vegetated areas until she reached ample cover. Faster movements in those areas would have decreased my chances of locating her within those particular buffer zones. In fact, in one six-hour continuous monitoring session during the day, B1 was documented quickly approaching CA 71 from the west, crossing, and only slowing when she reached cover approximately

200 m from the road to the east. Yet, during another session at night, she was originally located within 100 m of CA 71 directly adjacent to an underpass that had abundant cover, where she remained for over four hours, resting. This is consistent with Haas (2000) that found that bobcats used underpasses significantly more when abundant native cover was immediately available. Consequently, in the absence of human disturbance, and with underpasses present to facilitate movement underneath CA 71, it is likely that buffer zone use for bobcats depends largely on the amount of native cover immediately available.

CONCLUSIONS

Home range sizes for resident coyotes in this study were similar to those found elsewhere in areas where prey is abundant due to adverse climatic conditions (i.e. heavy snow pack) or where there is access to anthropogenic food resources. Yet, because these coyotes occupy an environment fragmented by urban development, their home range sizes were highly variable with some attaining sizes similar to their wildland counterparts, as they may have been trying to compensate for the lack of continuous habitat. Also, their home ranges tended to be somewhat linear where habitat became unavailable near roads when water was present in Prado Basin. However, the presence of underpasses appears to have alleviated this adverse response and also lessened the barrier effect, as home range sizes were similar among all groups of coyotes, except for residents and transients, as is expected by definition. Furthermore, core-use areas became larger as home range size increased, with numerous core-use areas overlapping CA 71. This may demonstrate that the habitat adjacent to CA 71 is not critically fragmented. However, buffer zone use along CA 71 was highly variable. This may be because the dominant resident coyotes are dictating the use of the buffer zones, along with that of the underpasses. In contrast, buffer zones were used in proportion to their availability along CA 83 and 91, which could be because CA 83 is not being perceived as an impediment, while CA 91 is a real barrier to coyote movement.

Home ranges for bobcats in this study were larger than those from other southern California locations, perhaps because of habitat structure. Bobcats prefer habitat with dense understory (Lawhead 1984, Rolley and Ward 1985, Litvaitis et al. 1986, Anderson 1990), and dense vegetation was generally lacking where these bobcats occupied home ranges. A small sample size precluded any comparison of demographic groups and provided only limited insight in bobcat response to roads. However, bobcats are willing to cross most roads (Lovallo and Anderson 1996*b*), and in the presence of underpasses that offer a safe alternative to at-grade road crossings, it is probably not surprising that both bobcats located near CA 71 were found to use the underpasses. Furthermore, Haas (2000) found that the probability of bobcats using underpasses was positively associated with the amount of cover present around the underpasses, which also may primarily determine their use of the buffer zones. Finally, these bobcats may have had linear home ranges more as an attempt to avoid interactions with humans rather than as a response to negative effects from roads.

LITERATURE CITED

Adams, L. W., and A. D. Geis. 1983. Effects of roads on small mammals. Journal of Applied Ecology 20:403-415.

Andelt, W. F., and P. S. Gipson. 1979. Home range, activity, and daily movements of coyotes. Journal of Wildlife Management 43(4):944-951.

Anderson, E. M. 1987. A critical review and annotated bibliography of literature on the bobcat. Colorado Division of Wildlife Special Report 62. 61 p.

_____. 1990. Bobcat diurnal loafing sites in southeastern Colorado. Journal of Wildlife Management 54(4):600-602.

Atkinson, K. T., and D. M. Shackleton. 1991. Coyote, *Canis latrans*, ecology in a rural-urban environment. The Canadian Field-Naturalist 105:49-54.

Bailey, T. N. 1974. Social organization in a bobcat population. Journal of Wildlife Management 38(3):435-446.

Beier, P., and R. H. Barrett. 1993. The cougar in the Santa Ana Mountain Range, California. Final report for the Orange County Cooperative Mountain Lion Study. Berkeley: Department of Forestry and Resource Management, University of California. 104 p.

_____. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management 59(2):229-236.

_____. 1996. Metapopulation models, tenacious tracking, and cougar conservation. Pages 293-323 *in* D. R. McCullough, editor. Metapopulations and Wildlife Conservation. Island Press, Washington, D.C.

Berg, W. E., and R. A. Chesness. 1978. Ecology of coyotes in Northern Minnesota. Pages 229-247 *in* M. Bekoff, editor. Coyotes: biology, behavior, and management. Academic Press, New York.

Boarman, W. L., and M. Sazaki. 1996. Highway mortality in desert tortoises and small vertebrates: success of barrier fences and culverts. Pages 169-173 *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife mortality seminar. FL-ER-58-96. Florida Department of Transportation, Tallahassee, Florida.

Bowen, W. D. 1981. Variation in coyote social organization: the influence of prey size. Canadian Journal of Zoology 59:639-652.

Brody, A. J., and M.R. Pelton. 1989. Effects of roads on black bear movements in western North Carolina. Wildlife Society Bulletin 17:5-10.

Byers, C. R., and R. K. Steinhorst. 1984. Clarification of a technique for analysis of utilization-availability data. Journal of Wildlife Management 48(3):1050-1053.

California Department of Transportation. 1999. Traffic volumes on the California State Highway System. Available at http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/1999all.htm.

Camenzind, F. J. 1978. Behavioral ecology of coyotes on the National Elk Refuge, Jackson, Wyoming. Pages 267-294 *in* M. Bekoff, editor. Coyotes: biology, behavior, and management. Academic Press, New York.

Case, R. M. 1978. Interstate highway road-killed animals: a data source for biologists. Wildlife Society Bulletin 6(1):8-13.

Clevenger, A. P., and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology 14(1):47-56.

Conner, M., B. Plowman, B. D. Leopold, and C. Lovell. 1999. Influence of time-in-residence on home range and habitat use of bobcats. Journal of Wildlife Management 65(1):261-269.

Crooks, K.R., and D. Van Vuren. 1996. Spatial organization of the island fox (*Urocyon littoralis)* on Santa Cruz Island, California. Journal of Mammalogy 77(3):801-806.

_____, M. A. Sanjayan, and D. F. Doak. 1997. New insights on cheetah conservation through demographic modeling. Conservation Biology 12(4):889-895.

Crowe, D. M. 1975. Aspects of ageing, growth, and reproduction of bobcats from Wyoming. Journal of Mammalogy 56(1):177-198.

De Solla, S. R., R. Bonduriansky, and R. J. Brooks. 1999. Eliminating autocorrelation reduces biological relevance of home range estimates. Journal of Animal Ecology 68:221-234.

Environmental Systems Research Institute, Inc. 1999. ArcView GIS [computer program]. Version 3.2. Redlands, CA: ESRI, 380 New York Street, Redlands, CA 92373-8100, phone: (909) 793-2853, fax: (909) 307-3025, email: info@esri.com. Available at http://www.esri.com.

Forman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-231.

Foster, M. L., and S. R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23(1):95-100.

Fuller, T. K., W. E. Berg, and D. W. Kuehn. 1985. Bobcat home range size and daytime cover-type use in northcentral Minnesota. Journal of Mammalogy 66(3):568-571.

Gaines, M. S., J. E. Diffendorfer, R. H. Tamarin, and T.S. Whittam. 1997. The effects of habitat fragmentation on the genetic structure of small mammal populations. The Journal of Heredity 88:294-304.

Gallerani Lawson, E. J., and A. R. Rodgers. 1997. Differences in home-range size computed in commonly used software programs. Wildlife Society Bulletin 25(3):721-729.

Gese, E. M., O. J. Rongstad, and W. R. Mytton. 1988. Home-range and habitat use of coyotes in southeastern Colorado. Journal of Wildlife Management 52(4):640-646.

_____, D. E. Anderson, and O. J. Rongstad. 1990. Determining home-range size of resident coyotes from point and sequential locations. Journal of Wildlife Management 54(3):501-506.

_____, R. L. Ruff, and R. L. Crabtree. 1996*a*. Social and nutritional factors influencing the dispersal of resident coyotes. Animal Behaviour 52:1025-1043.

_____, _____, and ____. 1996*b*. Intrinsic and extrinsic factors influencing coyote predation of small mammals in Yellowstone National Park. Canadian Journal of Zoology 74:784-797.

Gibeau, M. L., and K. Heuer. 1996. Effects of transportation corridors on large carnivores in the Bow River Valley, Alberta. Pages 69-81 *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife mortality seminar. FL-ER-58-96. Florida Department of Transportation, Tallahassee, Florida.

Gier, H. T. 1968. Coyotes in Kansas. Kansas State College Agriculture Experiment Station Bulletin 393. 118 p.

Haas, C. D. 2000. Distribution, relative abundance, and roadway underpass responses of carnivores throughout the Puente-Chino Hills. M.S. thesis. California State Polytechnic University, Pomona. 110 p.

_____, and K. R. Crooks. 1999. Carnivore abundance and distribution throughout the Puente/Chino Hills. Unpublished report available from The Mountains Recreation and Conservation Authority, 5730 Ramirez Canyon Rd, Malibu, CA 90265. 128 p.

Harestad, A. S., and F. L. Bunnell. 1979. Home range and body weight – a reevaluation. Ecology 60(2):389-402.

Harris, S., W. J. Cresswell, P. G. Forde, W. J. Trewhella, T. Woollard, and S. Wray. 1990. Home-range analysis using radio-tracking data: a review of problems and techniques particularly as applied to the study of mammals. Mammal Review 20(2/3):97-123.

Harrison, D. J., J. A. Bissonette, and J. A. Sherburne. 1989. Spatial relationships between coyotes and red foxes in eastern Maine. Journal of Wildlife Management 53(1):181-185.

Harrison, R. L. 1998. Bobcats in residential areas: distribution and homeowner attitudes. The Southwestern Naturalist 43(4):469-475.

Hein, E. W., and W. F. Andelt. 1995. Estimating coyote density from mark-resight surveys. Journal of Wildlife Management 59(1):164-169.

Holzman, S., M. J. Conroy, and J. Pickering. 1992. Home range, movements, and habitat use of coyotes in southcentral Georgia. Journal of Wildlife Management 56(1):139-146.

Horn, M., M. Carlin, T. L. Eagan, M. Erickson, C. Jones, W. Loeffler, and G. Nishiyama. 1993. A regional landscape approach to maintaining biodiversity: protected areas in Orange County and environs. Pages 69-83 *in* J. E. Keeley, editor. Interface Between Land Ecology and Land Development in California. Southern California Academy of Sciences, Los Angeles, California.

Kendrot, S. 1998. The effects of roads and land use on home range use, behavior, and mortality of eastern coyotes (*Canis latrans*). M.S. thesis. State University of New York. 83 p.

Kie, J. G., J. A. Baldwin, and C. J. Evans. 1994. CALHOME [computer program]. Version 1.0. John G. Kie, Forestry Sciences Lab, 2081 East Sierra Avenue, Fresno, CA 93710 or Illinois Natural History Survey, 607 East Peabody Drive, Champagne, IL 61820, phone: (217) 244-0371, email: admin@nhsbig.inhs.uiuc.edu. Available at http://nhsibig.inhs.uiuc.edu/wes/home_range.html.

Kitchen, A. M., E. M. Gese, and E. R. Schauster. 2000. Long-term spatial stability of coyote (*Canis latrans*) home ranges in southeastern Colorado. Canadian Journal of Zoology 78:458-464.

Laundre, J. W., and B. L. Keller. 1984. Home-range size of coyotes: a critical review. Journal of Wildlife Management 48(1):127-139.

Lawhead, D. N. 1984. Bobcat *Lynx rufus* home range, density and habitat preference in south-central Arizona. The Southwestern Naturalist 29(1):105-113.

Lembeck, M., and G. I. Gould, Jr. 1979. Dynamics of harvested and unharvested bobcat population in California. Proceedings of the Bobcat Research Conference, National Wildlife Federation Scientific and Technical Series 6:53-54.

Litvaitis, J. A., J. A. Sherburne, and J. A. Bissonette. 1986. Bobcat habitat use and home range size in relation to prey density. Journal of Wildlife Management 50(1):110-117.

Lovallo, M. J., and E. M. Anderson. 1996*a*. Bobcat (*Lynx rufus*) home range size and habitat use in northwest Wisconsin. American Midland Naturalist 135:241-252.

_____, and _____. 1996*b*. Bobcat movements and home ranges relative to roads in Wisconsin. Wildlife Society Bulletin 24(1):71-76.

Mace, R. D., J. S. Waller, and T. L. Manley. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33:1395-1404.

Mader, H. J. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation 29:81-96.

Mansergh, I. M., and D. J. Scotts. 1989. Habitat continuity and social organization of the mountain pygmy-possum restored by tunnel. Journal of Wildlife Management 53(3):701-707.

McLellan, B. N., and D. M. Shackleton. 1988. Grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use and demography. Journal of Applied Ecology 25:451-460.

Mech, L. D. 1983. Handbook of animal radio-tracking. University of Minnesota Press, Minneapolis, Minnesota. 107 p.

Middleton, K. M. 1994. Resource use by coyotes, *Canis latrans*, and raccoons, *Procyon lotor*, at an urban-wildland interface. M.S. thesis. California State Polytechnic University, Pomona. 102 p.

Mills, L. S., and F. F. Knowlton. 1989. Observer performance in known and blind radio-telemetry accuracy tests. Journal of Wildlife Management 53(2):340-342.

_____, and _____. 1991. Coyote space use in relation to prey abundance. Canadian Journal of Zoology 69:1516-1521.

Moore, T. G., and M. Mangel. 1996. Traffic related mortality and the effects on local populations of Barn Owls *Tyto alba*. Pages 131-146 *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife mortality seminar. FL-ER-58-96. Florida Department of Transportation, Tallahassee, Florida.

Mumme, R. L., S. J. Schoech, G. E. Woolfenden, and J. W. Fitzpatrick. 2000. Life and death in the fast lane: demographic consequences of road mortality in the Florida scrub-jay. Conservation Biology 14(2):501-512.

Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. Trends in Ecology and Evolution 10:58-62.

Neale, J. C. C. 1996. Comparative resource use by sympatric bobcats and coyotes: food habits, habitat use, activity, and spatial relationships. M.S. thesis. University of California, Berkeley. 117 p.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38:541-545.

Ng, S. J. 2000. Wildlife use of underpasses and culverts crossing beneath highways in southern California. M.S. thesis. California State University, Northridge. 50 p.

Noss, R. F., and A. Y. Cooperrider. 1994. Saving Nature's Legacy: protecting and restoring biodiversity. Island Press, Washington, D.C. 416 p.

Odum, E. P., and E. J. Kuenzler. 1955. Measurement of territory and home range size in birds. Auk 72:128-137.

Otis, D. L., and G. C. White. 1999. Autocorrelation of location estimates and the analysis of radiotracking data. Journal of Wildlife Management 63(3):1039-1044.

Pacer. 1990. Locate II [computer program]. Version 1.4. Truro, Nova Scotia, Canada: Pacer, Box 1767, Truro, Nova Scotia, Canada B2N 525, phone: (902) 893-6607, email: vnams@nsac.ns.ca. Available at http://oldnsac.nsac.ns.ca/es/vnams/locate.htm.

Paquet, P. C., and C. Callaghan. 1996. Effects of linear developments on winter movements of gray wolves in the Bow River Valley of Banff National Park, Alberta. Pages 47-67 *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife mortality seminar. FL-ER-58-96. Florida Department of Transportation, Tallahassee, Florida.

Pyrah, D. 1984. Social distribution and population estimates of coyotes in north-central Montana. Journal of Wildlife Management 48(3):579-690.

Quinn, T. 1995. Using public sighting information to investigate coyote use of urban habitat. Journal of Wildlife Management 59(2):238-245.

_____. 1997. Coyote (*Canis latrans*) food habits in three urban habitat types of western Washington. Northwest Science 71(1):1-5.

Reh, W., and A. Seitz. 1990. The influence of land use on the genetic structure of populations of the common frog *Rana temporaria*. Biological Conservation 54:239-249.

Reijnen, R., R. Foppen, C. Ter Braak, and J. Thissen. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. Journal of Applied Ecology 32:187-202.

_____, _____, and H. Meeuwsen. 1996. The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. Biological Conservation 75:255-260.

Riley, S. P. D. 1999. Spatial organization, food habits and disease ecology of bobcats (*Lynx rufus*) and gray foxes (*Urocyon cinereoargenteus*) in national park areas in urban and rural Marin County, California (Golden Gate National Recreation Area). Ph.D. dissertation. University of California, Davis. 163 p.

Rodriguez, A., G. Crema, and M. Delibes. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. Journal of Applied Ecology 33:1527-1540.

Rolley, R. E., and W. D. Warde. 1985. Bobcat habitat use in southeastern Oklahoma. Journal of Wildlife Management 49(4):913-920.

Romsos, J. S. 1998. Home range, habitat use, and movements of coyotes in a southern California urban environment. M.S. thesis. Humboldt State University. 60 p.

Rooney, S. M., A. Wolfe, and T. J. Hayden. 1998. Autocorrelated data in telemetry studies: time to independence and the problem of behavioural effects. Mammal Review 28(2):89-98.

Rowland, M. M., M. J. Wisdom, B. K. Johnson, and J. G. Kie. 2000. Elk distribution and modeling in relation to roads. Journal of Wildlife Management 64(3): 672-684.

Roy, L. D., and M. J. Dorrance. 1985. Coyote movements, habitat use, and vulnerability in central Alberta. Journal of Wildlife Management 49(2):307-313.

Sacks, B. N., M. M. Jaeger, J. C. C. Neale, and D. R. McCullough. 1999. Territoriality and breeding status of coyotes relative to sheep predation. Journal of Wildlife Management 63(2):593-605.

Sargeant, A. B., S. H. Allen, and J. O. Hastings. 1987. Spatial relations between sympatric coyotes and red foxes in North Dakota. Journal of Wildlife Management 51(2):285-293.

Saunders, D. A., R. J. Hobbs, and C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5(1):18-32.

Schoener, T. W. 1981. An empirically based estimate of home range. Theoretical Population Biology 20:281-325.

Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63(2):739-747.

Shargo, E. S. 1988. Home range, movements, and activity patterns of coyotes (*Canis latrans*) in Los Angeles suburbs (California). Ph.D. dissertation. University of California, Los Angeles. 124 p.

Smith, G. J., J. C. Cary, and O. J. Rongstad. 1981. Sampling strategies for radio-tracking coyotes. Wildlife Society Bulletin 9(2):88-93.

Springer, J. T. 1979. Some sources of bias and sampling error in radio triangulation. Journal of Wildlife Management 43(4):926-935.

_____. 1982. Movement patterns of coyotes in south central Washington. Journal of Wildlife Management 46(1):191-200.

StatSoft, Inc. 1996. STATISTICA for Windows [computer program manual]. Version 5.1. Tulsa, OK: StatSoft, Inc., 2300 East 14th Street, Tulsa, OK 74104, phone: (918) 749-1119, fax: (918) 749-2217, email: info@statsoft.com. Available at http://www.statsoft.com.

Stumpf, W. A., and C. O. Mohr. 1962. Linearity of home ranges of California mice and other animals. Journal of Wildlife Management 26(2):149-154.

Swihart, R. K., and N. A. Slade. 1985*a*. Testing for independence of observations in animal movements. Ecology 66(4):1176-1184.

_____, and _____. 1985*b*. Influence of sampling interval on estimates of home range size. Journal of Wildlife Management 49:1019-1025.

_____, and _____. 1988. Relating body size to the rate of home range use in mammals. Ecology 69(2):393-399.

Thiel, R. P. 1984. Relationship between road densities and wolf habitat suitability in Wisconsin. The American Midland Naturalist 113(2):404-407.

U. S. Army Corp of Engineers. 2000. Supplemental EIS and project EIR for Prado Basin and vicinity, including stabilization of the bluff toe at Norco Bluffs. Prepared by Larry Munsey International for the U. S. Army Corps of Engineers, Los Angeles District. State Clearinghouse No. 97071087.

United States Naval Observatory. 2000. Chino, CA: W117 41, N34 01. Available at http://www.mach.usno.navy.mil/cgi-bin/aa_rstablew.

Wauters, L., A., Y. Hutchinson, D. T. Parkin, and A.A. Dhondt. 1994. The effects of habitat fragmentation on demography and loss of genetic variation in the red squirrel. Proceedings of the Royal Society of London, Series B 255:107-111.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, California. 383 p.

White, P. J., and K. Ralls. 1994. Coyote-kit fox interactions as revealed by telemetry. Canadian Journal of Zoology 72:1831-1836.

Wilcox, B. A., and D. D. Murphy. 1985. Conservation strategy: the effects of fragmentation on extinction. American Naturalist 125:879-887.

Wildflower Productions. 1998. TOPO!GPS® [computer program]. Version 1.3.0. San Francisco, CA: Wildflower Productions, 375 Alabama Street, Ste 230, San Francisco, CA 94110, phone: (415) 558-8700, email: info@topo.com. Available at http://www.topo.com.

Woodward, S. J. 1990. Population density and home range characteristics of woodchucks, *Marmota monax*, at expressway interchanges. The Canadian Field-Naturalist 104:421-428.

World Climate Data. 1998. World Climate: N33W117: Prado Dam and Corona, CA. Available at http://www.worldclimate.com/cgi-bin/grid.pl?gr=N33W17.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70(1):164-168.

Yanes, M., J. M. Velasco, and F. Suárez. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. Biological Conservation 71:217-222.

Zar, J. H. 1984. Biostatistical analysis. 2nd ed. Prentice Hall, Englewood Cliffs, New Jersey. 718 p.

Zimmerman, J. W., and R. A. Powell. 1995. Radiotelemetry error: location error method compared with error polygons and confidence ellipses. Canadian Journal of Zoology 73:1123-1133.

Table 1.1. Capture and monitoring data for 29 coyotes radio-collared in the Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to February 2000.

Animal ID #	Sex	Age	Capture Date	Capture Side[a]	Last Monitored	Status[b]
C1	M	Juv	2/11/98	E	03/15/1999	Left study area
C2	F	Juv	2/11/98	E	06/15/1998	Lost radio contact
C3	M	Adu	2/13, 10/10/98	W, W	02/02/2000	Alive
C4	M	Adu	2/13, 6/11/98	E, E	11/22/1999	Dead
C5	M	Yrlng	2/19, 2/21/98	W, W	07/02/1998	Dead[d]
C6	F	Adu	2/20, 7/4/98	W, W	01/08/2000	Alive
C7	F	Adu	2/20, 10/9/98	E, E	01/19/2000	Alive
C8	F	Adu	2/20, 10/24	W, W	12/20/1999	Alive
C9	F	Adu	2/21, 10/27/98	W, W	01/19/2000	Alive
C12	F	Adu	2/26, 2/28/98	W, W	06/11/1998	Dead[d]
C17	F	Adu	3/1, 6/17, 10/21/98[c]	E, E, E	05/24/1999	Radio failure
C19	M	Adu	3/1/98, 10/23/98[c]	W, E	10/24/1998	Dead[d]
C25	M	Juv	6/14/98	W	07/24/1998	Dead
C26	M	Yrlng	6/14, 10/9	W, W	10/06/1999	Dead[d]
C27	M	Adu	6/18/98	W	10/31/1998	Lost radio contact
C28	M	Yrlng	6/21/98	W	03/05/1999	Radio dead
C32	M	Adu	6/25/98, 7/6/98[c]	W, W	01/31/2000	Alive
C38	M	Juv	7/7/98	W	08/28/1999	Radio dead
C39	F	Juv	7/7/98	W	08/28/1999	Radio dead
C42	F	Yrlng	2/13/98	E	02/13/1998	Slipped collar
C43	M	Yrlng	10/5/98	E	05/20/1999	Dead[d]
C44	M	Adu	10/7/98	E	07/26/1999	Radio dead[e]
C45	M	Adu	10/10/98	W	3/2000	Dead
C46	F	Juv	10/11/98	W	07/26/2000	Dead[d]
C47	F	Juv	10/13/98	W	12/11/1998	Dead[d]
C50	F	Adu	10/16/98, 10/20/98[c]	E, W	02/01/1999	Dead
C51	M	Juv	10/18/98	W	01/08/1999	Slipped collar
C52	F	Adu	10/25/98	E	06/08/1999	Lost radio contact
C53	F	Juv	11/3/98	W	11/17/1999	Dead

[a] Side of CA 71 on which the individual was captured or recaptured.

[b] Welfare of individual at last monitored date (lost radio contact = unconfirmed welfare; radio failure = transmitter failed; radio dead = expiration of transmitter battery).

[c] First date: initial capture and fitting of dog collar; second date: recapture and changing of the dog collar to a radio collar; third date: recapture of radio-collared individual.

[d] Killed in vehicle collision. C45 killed 2 months and C46 killed 5 months after the end of the study.

[e] Radio transmitter should have been inoperative at this time, but this animal was also no longer being photographed at the culverts (as of 6/17/99) where he was the most frequent visitor.

Table 1.2. Capture and status data for 24 coyotes dog-collared in the Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to December 1999.

Animal ID #	Sex	Age	Capture Date	Capture Side[a]	Date Last Seen	How Seen[b]
C10[c]	M	Yrlng	2/21/98	E		
C11[c]	F	Yrlng	2/22/98	W		
C13	M	Yrlng	2/28/98	W		
C14	F	Yrlng	2/20/98	W	02/26/1999	visual
C15	F	Yrlng	2/20/98	W		
C16	F	Yrlng	3/1/98	W		
C18	M	Yrlng	3/1/98, 3/2/98	W, W	03/02/1998	recapture
C20	M	Yrlng	3/5/98	W		
C21	M	Yrlng	3/5/98	W	09/10/1998	camera
C22	F	Adu	6/9/98	W		
C23[c]	F	Juv	6/14/98	W		
C24[c]	F	Juv	6/14/98	W		
C29	M	Adu	6/22/98	W		
C30	F	Adu	6/23/98	W		
C31	F	Adu	6/24/98	W		
C33[c]	M	Juv	6/20/98	W		
C34	M	Yrlng	6/28/98	W	05/20/1999	dead[d]
C35	M	Adu	6/29/98	W	07/30/1999	camera
C36	M	Adu	7/1/98	W		
C37	F	Adu	7/2/98	W	12/21/1999	camera
C40	M	Yrlng	7/10/98	W	06/26/1999	dead[d]
C41	M	Adu	7/10/98	W		
C48	M	Adu	10/14/98	E	02/24/1999	camera
C49	F	Adu	10/14/98	W	06/21/1999	dead[d]

[a] Side of CA 71 on which the animal was captured or recaptured.

[b] How individual was last seen after initial capture. Camera indicates that the animal was photographed at the culverts.

[c] Received ear tags only.

[d] Killed in vehicle collision.

Table 1.3. Capture and monitoring data for 4 bobcats radio-collared in the Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to February 2000.

Animal ID #	Sex	Age	Capture Date	Capture Side[a]	Last Monitored	Status[b]
B1	F	Adu	2/22/98	W	01/07/2000[c]	Radio dead
B2	F	Juv	3/2/98	W	10/08/1998	Dead
B3	M	Adu	6/27, 10/17/98	W, W	12/07/1999	Radio dead
B4	M	Adu	7/7/98	W	02/03/2000	Alive

[a] Side of CA 71 on which the animal was captured or recaptured.

[b] Welfare of animal at last monitored date (radio dead = expiration of transmitter battery).

[c] Transmitter battery expired 11/20/1999, but individual was photographed at the culverts on 11/28/99, 12/4/99, and 1/7/00.

Table 1.4. Location data, Schoener's Index, group classification, and home range and core-use area estimates (km2) for 15 coyotes and 3 bobcats radio-tracked in the Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to February 2000.

							Home Range Estimate (km^2)			
Animal ID #	Point locs	Seq locs[a]	Cont sess[b]	Indep locs[c]	t^2/r^2 Index[d]	Class[e]	MCP 100%[f]	ADK 95%[f]	ADK 50%[f]	HR ratio[g]
C1	12	2	1	13	1.9	TEN	2.07	3.78	0.97	1.37
C3	30	4	2	31	1.5	TWN	24.46	29.84	6.96	1.37
C4	28	22	8	35	1.8	REN	5.98	9.11	1.76	2.82
C6	35	24	7	41	1.7	RWN	2.95	3.38	0.23	1.56
C7	30	26	5	38	2.2	REC	4.26	5.69	1.03	1.89
C8	35	20	4	40	2.1	RWC	1.72	1.77	0.46	1.21
C9	39	28	9	51	1.6	TWC	38.33	54.19	4.43	1.14
C17	19	12	5	24	1.1	REC	5.41	7.09	2.56	2.87
C26	32	11	3	37	0.8	TWC	7.69	10.17	0.74	1.54
C32	15	2	1	11	1.4	TWN	13.71	22.66	2.65	1.43
C38	23	2	1	24	1.8	RWN	2.62	3.80	0.24	1.03
C39	25	6	3	28	2.2	RWN	0.84	1.23	0.22	1.23
C43	16	12	3	15	1.1	TWC	18.07	34.17	0.32	2.38
C44	16	16	7	22	2.3	REC	3.12	4.44	1.21	1.75
C52	19	37	9	21	1.8	TWC	15.61	14.48	1.90	1.97
B1	24	22	6	32	1.2	RWC	4.05	8.01	2.04	2.16
B3	27	8	3	30	1.9	RWC	12.48	15.26	1.24	1.32
B4	28	25	7	36	2.4	RWN	3.76	3.41	0.65	2.06
Total	453	279	84	529						
mean	25	16	5	30						
SD	8	11	3	11						

[a] Sequential locations

[b] Continuous sessions

[c] Number of independent locations separated by > 3.45 hours.

[d] Schoener's ratio based on the independent locations data set.

[e] Classification of animals. The first letter refers to either Resident or Transient, the second to the location of the home range as either East or West of CA 71, and the third to Crosser or Non-crosser.

[f] Minimum convex polygon and adaptive kernel home range estimates using all locations from point and sequential sampling. The 50% ADK values are considered core-use areas.

[g] Home range ratio as length/width (linear home range is > 2).

Table 1.5. Mean 100% minimum convex polygon and 95% adaptive kernel home range sizes, and 50% adaptive kernel core-use areas for 15 radio-collared coyotes in Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to February 2000.

Group		Sample size		100% MCP (km^2)				95% ADK (km^2)				50% ADK (km^2)			
		all	rem[a]	all		rem[a]		all		rem[a]		all		rem[a]	
		n	n	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE
Female	Adult	6		11.38	5.76			14.43	8.15			1.76	0.64		
	Juv	1		0.84	0.00			1.23	0.00			0.22	0.00		
	All	7		9.87	5.09			12.55	7.14			1.56	0.59		
Male	Adult	4	2	11.82	4.77	4.54	1.43	16.18	6.12	6.12	3.00	3.14	1.31	1.48	0.27
	Yearling	3	2	9.28	4.71	12.88	5.18	16.04	9.25	22.17	12.00	0.68	0.19	0.53	0.21
	Juvenile	1	0	2.62	0.00			3.80	0.00			0.24	0.00		
	All	8	4	9.72	2.91	8.71	3.26	14.58	4.42	14.14	6.86	1.86	0.78	1.01	0.31
All sex	Adult	10	8	11.55	3.75	9.67	4.37	15.13	5.22	12.35	6.14	2.32	0.65	1.70	0.47
	Yearling	3	2	9.28	4.71	12.88	5.19	16.04	9.25	22.17	12.00	0.68	0.19	0.53	0.21
	Juvenile	2	1	1.73	0.89	0.84	0.00	2.52	1.29	1.23	0.00	0.23	0.01	0.22	0.00
Social	Residents	8	7	3.36	0.62	3.46	0.71	4.56	0.94	4.67	1.08	0.96	0.30	1.07	0.33
	Trans	7	4	17.13	4.46	19.92	6.53	24.18	6.44	28.25	10.10	2.57	0.90	1.85	0.93
Location	East	5	4	4.17	0.72	4.69	0.64	6.02	0.96	6.58	1.00	1.51	0.30	1.64	0.34
	West	10	7	12.60	3.82	12.17	5.06	17.57	5.54	17.06	7.56	1.82	0.72	1.18	0.59
Behavior	Crosser	8	8	11.78	4.33			16.50	6.47			1.58	0.48		
	Noncross	7	3	7.52	3.26	3.25	1.49	10.54	4.23	4.57	2.35	1.86	0.92	0.74	0.51
All coyotes		15	11	9.79	2.44	9.45	4.14	13.72	3.92	13.13	4.97	1.71	0.48	1.35	0.39

[a] Sample size, mean, and standard error for those groups after home ranges that did not reach an asymptote for the area-observation curves were removed (C1, C3, C32, C38; all males).

Table 1.6. Differences in 100% MCP and 95% ADK home range sizes, and 50% ADK core-use area sizes between groups of radio-collared coyotes in Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to February 2000.

Group[a]	n	100% MCP[b]		95% ADK[b]		50% ADK[b]	
		t or F[c]	p	t or F[c]	p	t or F[c]	p
Male-female	15	0.611	0.551	1.001	0.332	0.319	0.754
Male-female adults	10	0.477	0.646	0.755	0.471	1.212	0.259
Juven-yearling-adults	15	2.103	0.165	1.808	0.206	4.212	0.041[e]
Resident-transient	15	-3.625	0.003	-3.874	0.002	-1.784	0.098
East-west[d]	15	-1.335	> 0.100	-1.096	> 0.500	1.096	> 0.500
Cross-noncross	13	0.232	0.821	0.048	0.962	-0.847	0.415

[a] Differences between all groups were tested using a two-sample t-test, except an Analysis of Variance was used to test for the differences among juven-yearling-adults.

[b] See Table 1.4 for individual home range and core-use area sizes or Table 1.5 for the "all" group mean home range and core-use area sizes.

[c] Test statistic (t = Student's t, F = F statistic).

[d] Welch's approximate t procedure used to compare between groups.

[e] A Duncan's new multiple range test was performed to determine which ANOVA group means differed (juveniles, M = -1.458; adults, M = 0.452, p = 0.026).

Table 1.7 Differences in 95% ADK home range length/width ratios between groups of radio-collared coyotes in Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to February 2000.

Group[a]	95% ADK[b]		
	n	t or F[c]	p
Male-female	15	0.582	0.570
Male-female adults	10	0.687	0.509
Juven-yearling-adults	15	1.192	0.337
Resident-transient	15	0.960	0.359
East-west	15	2.722	0.016
Cross-noncross	13	0.212	0.835

[a] Differences between all groups were tested using a two-sample t-test, except an Analysis of Variance was used to test for the differences among juven-yearling-adults.

[b] See Table 1.4 for individual home range ratios.

[c] Test statistic (t = Student's t, F = F statistic).

Table 1.8. Comparisons for equality of buffer zone use[a] along California routes 71, 83, and 91 for 10 coyotes and 2 bobcats radio-collared in the Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to February 2000.

Animal ID #	CA 71			CA 83			CA 91		
	n	G	p[b]	n	G	p[b]	n	G	p[b]
C4	19	5.856	>0.100				37	1.233	>0.500
C6	45	19.036	***				52	2.654	>0.250
C7	54	10.126	**	45	6.463	>0.050			
C8	52	16.492	***						
C9	45	19.663	***						
C17	31	36.257	***	17	8.379	*			
C26	36	34.217	***						
C43	19	21.324	***				18	6.418	>0.050
C44	32	10.016	*	15	3.773	>0.250			
C52	41	51.364	***	26	13.902	**			
B1	43	5.940	>0.100	24	24.422	***			
B3	27	12.211	**						

[a] Buffer zones were 0-100, 101-300, 301-700, and 701-1500 meters.

[b] Statistically significant probabilities are denoted by asterisks: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Probability values > 0.05 indicate that the buffer zones were used proportional to their availability. See Figure 1.4 which shows how the buffer zones were used by the remaining individuals.

Table 1.9. Individual radio-collared coyotes combined by demographic group to determine if all individuals within that group used the buffer zones similarily along California route 71 in the Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to February 2000.

Group	CA 71			
	n	G	DF	p[a]
Demographic				
All coyote	374	184.917	29	***
Female	268	128.383	17	***
Male	106	36.749	11	**
Male adult	51	11.702	5	>0.050
Male yearling	55	7.877	5	>0.100
All adult	319	140.752	23	***
Resident	233	83.067	17	***
Transient	141	57.578	11	***
East	136	23.319	12	*
West	238	151.737	17	***
Cross	310	134.535	23	***
Noncross	64	2.539	5	>0.750
A posteriori				
C4/C6/C8	116	10.632	8	>0.100
C7/C17/C43/C44/C52	177	23.316	14	>0.050
C9/C26	81	11.361	5	*

[a] Statistically significant probabilities are denoted by asterisks as: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. However, groups with probability values > 0.05 were homogeneous and individuals could be pooled, as this indicates similarity of buffer zone use. Refer to Figure 1.4 which shows how the buffer zones were used by these groups.

Table 1.10. Comparison of mean resident home range sizes (km^2) of coyote populations, ranked by the mean home range sizes for both sexes and grouped by latitude, in North America from 1975 through 2001.

Reference	Location[a]	Home Range (km^2)					
		n	Both[b]	n	Male	n	Female
North							
Springer 1982[c]	So Cen WA	20	107.8[g]	15	97.8	5	117.8
Sargent et al. 1987[c]	ND	11	61.2				
Berg and Chesness 1975[c]	No MN	50	47.2	25	68.0	25	16.0
Harrison et al. 1989[c]	Ea MN	7	46.4				
Andelt and Gipson 1979[c]	Ea NB	10	29.1	5	28.2	5	29.9
Kendrot 1998[c]	No NY	9	16.7[g]	6	18.9	3	14.4
Quinn 1995[d]	We WA	6	12.9[g]				
Roy and Dorrance 1985[c]	Cen AB Canada	12	12.1				
Gese et al. 1996*a*[f]	NW WY	49	10.3				
Pyrah 1984[c]	No Cen MT	11	8.8	8	9.7	3	7.8
Atkinson & Shackleton 1991[c]	So BC Canada	6	5.6	4	5.8	2	5.1
South							
White and Ralls 1994[c]	Cen CA	12	59.1				
Mills and Knowlton 1991[e]	No UT	20	20.1				
Romsos 1998[c]	So CA	11	14.3[g]	6	12.8	5	16.0
Holzman et al. 1992[c]	So Cen GA	12	10.1[g]	7	6.9	5	15.6
Gese 1988[c]	SE CO	48	9.3	29	9.9	19	8.6
Neale 1996[c]	No CA	7	6.6	2	7.3	5	6.3
Riley (pers. comm.) 2001[c]	So CA	39	4.5	22	6.2	17	2.8
This study[c]	So CA	8	3.4	3	3.9	5	3.8
Middleton 1994[c]	So CA	6	2.2	5	2.0	1	2.8
Shargo 1988[c]	So CA	10	1.1				

[a] Location is listed as the general area within a state or province and then the abbreviated state code or province.

[b] Both indicates the mean home range size for both sexes combined, or if separate mean home range sizes are listed for males and females, then this is an average of the mean male and female home ranges.

[c] Home ranges estimated using the minimum convex polygon method.

[d] Home ranges estimated using the adaptive kernel method.

[e] Home range estimated using the harmonic mean method.

[f] No home range estimation method was provided.

[g] Unable to determine if transient home range estimates were included.

Table 1.11. Comparison of mean home range sizes (km^2) of bobcat populations, ranked by male bobcat range sizes and grouped by latitude, in the United States from 1972 to 2001.

Reference	Location	n	Home Range (km^2) Male	Home Range (km^2) Female
North				
Major 1983[a]	We ME	9	138.6	27.5
Litvaitis et al. 1986	ME	23	91.8	32.2
Knowles 1985[a]	No Cen MT	2	83.3	17.8
Berg 1979[a]	No MN	22	62.0	38.0
Lovallo and Anderson 1996*a*	NW WI	11	60.4	28.5
Fuller et al. 1985	No Cen MN	33	53.5	40.5
Rolley 1983[a]	SE OK	22	43.2	14.8
Bailey 1972	SE ID	12	42.1	19.3
South				
Hamilton 1982[a]	MO	30	60.4	16.1
Kitchings and Story 1979[a]	Ea TN	5	42.9	11.5
Golden 1982[a]	NW NV	24	22.8	7.7
Karpowitz 1981[a]	NE UT	13	22.6	16.4
Buie et al. 1979[a]	SC	6	20.8	10.3
Conner et al. 1999	Ea Cen MS	27	15.5	7.1
Riley 1999	No CA	11[b]	13.5	5.3
Shiflet 1984[a]	MS	7	10.1	5.9
Neale 1996	No CA	9	9.7	13.2
Lawhead 1984	So Cen AZ	7	9.1	4.8
This study	So CA	3	8.1	4.1
Riley 1999	No CA	8[c]	6.4	1.3
Hall and Newsom 1976[a]	So LA	6	4.9	1.0
Marshall and Jenkins 1969[a]	We Cen SC	3	4.6	3.0
Riley (pers. comm.) 2001	So CA	35	3.2	1.6
Miller and Speake 1979[a]	So AL	20	2.6	1.1
Lembeck and Gould 1979[a]	So CA	43	2.0-6.0	1.4

[a] References taken from and follows the format of Anderson (1987). However, only those home ranges that were not an actual estimation and provided both male and female sizes were included.

[b] These estimates are for those bobcats the author consider rural bobcats.

[c] These estimates are for those bobcats the author considered urban bobcats.

[d] Using male home range size estimates, a two-sample t-test reveals that northern home ranges are larger than southern home ranges ($t = -6.001$, $p < 0.001$, $df = 23$).

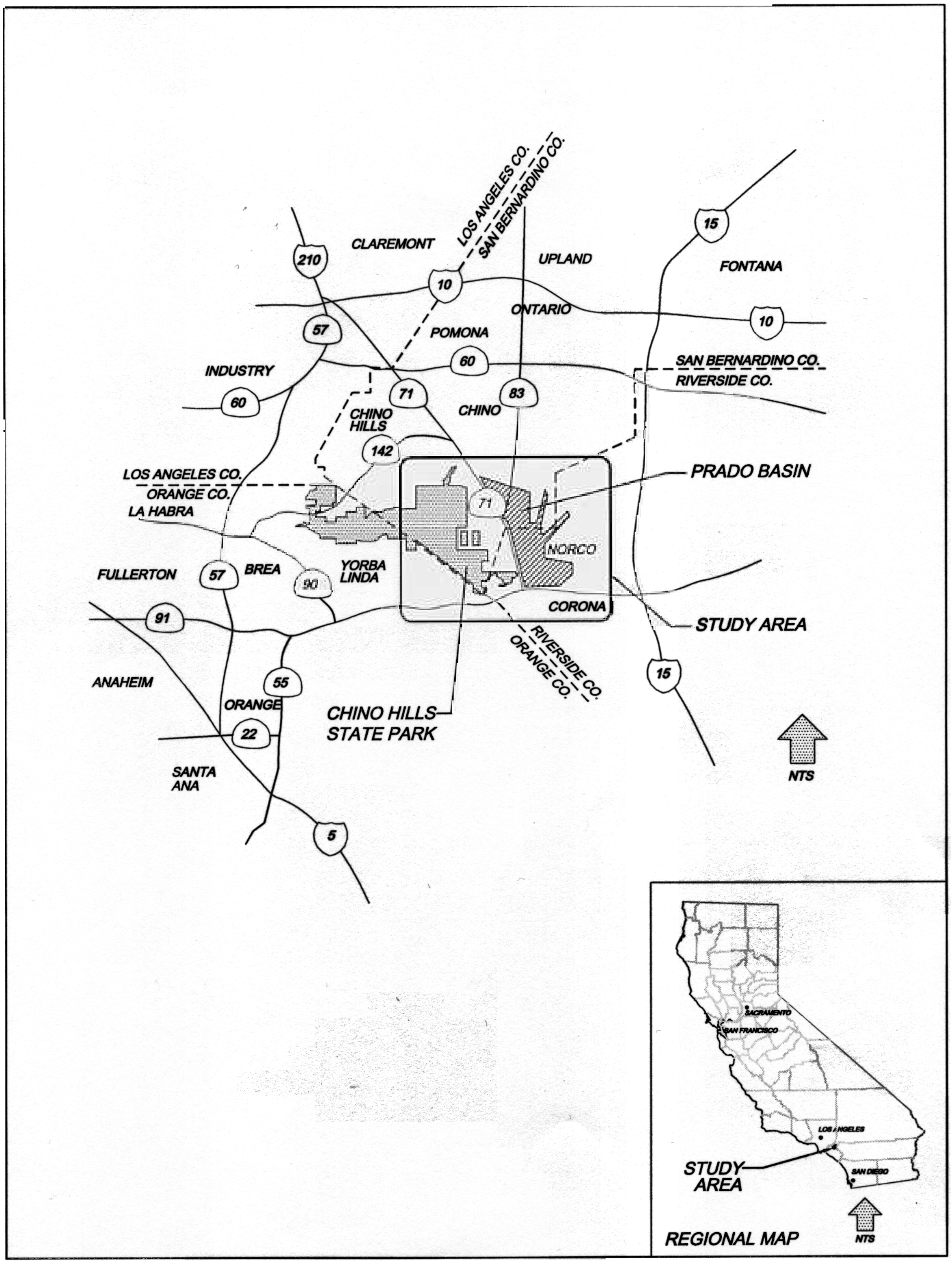


Figure 1.1. The study area.

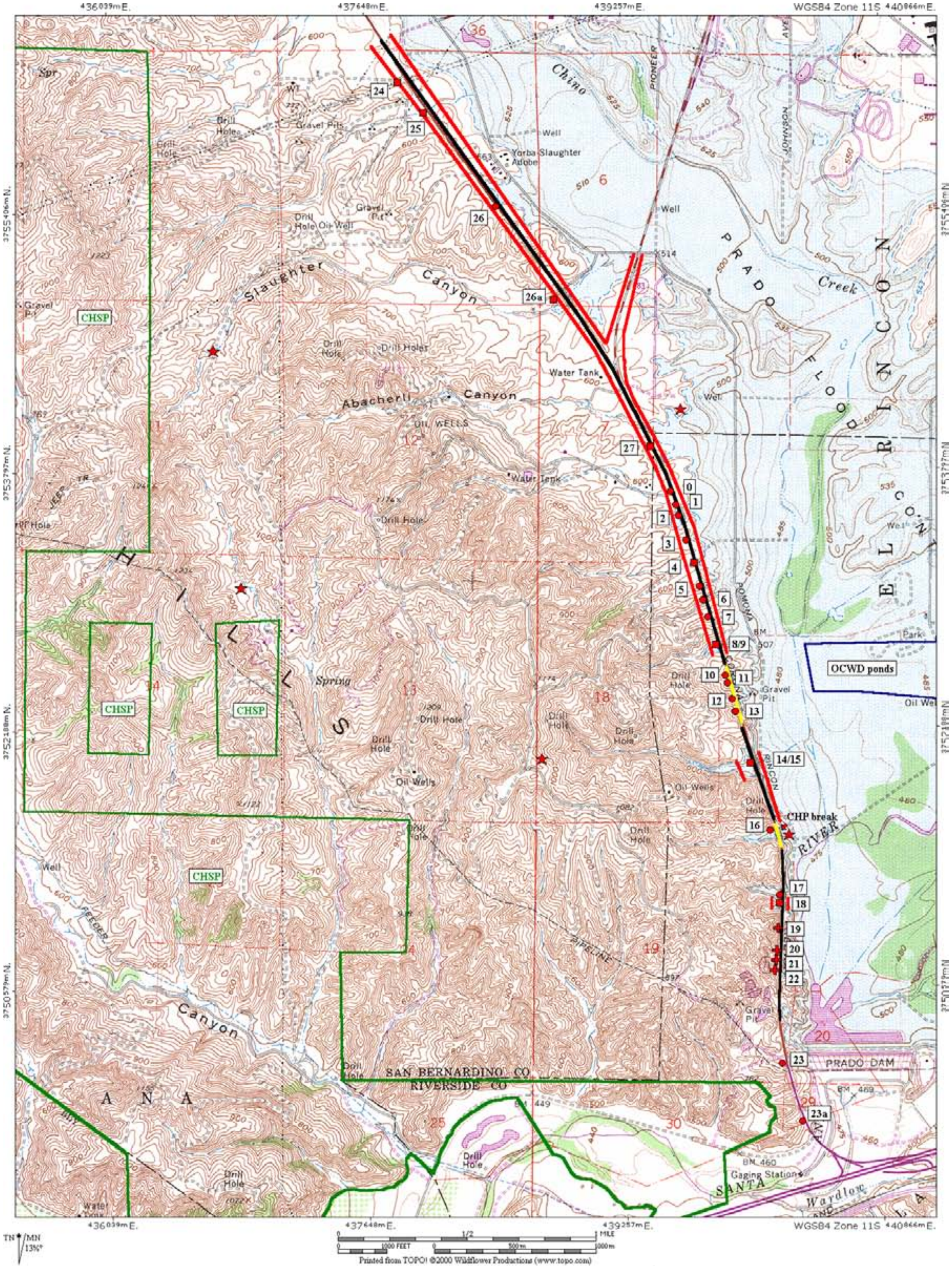
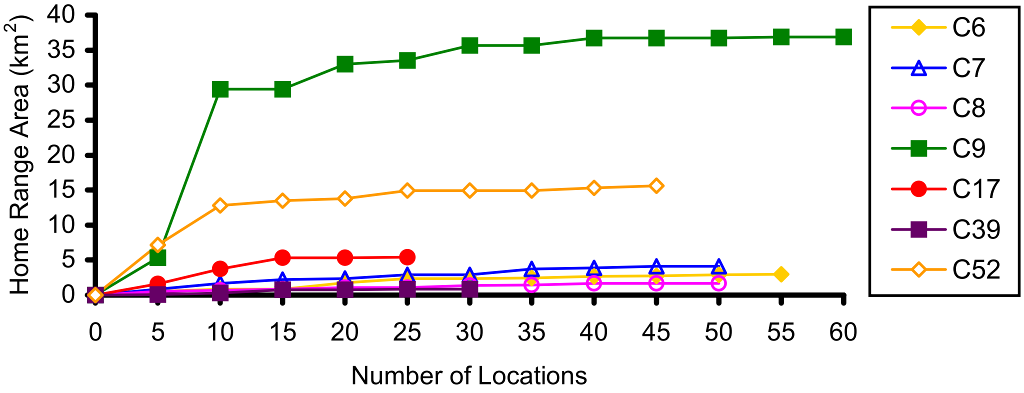
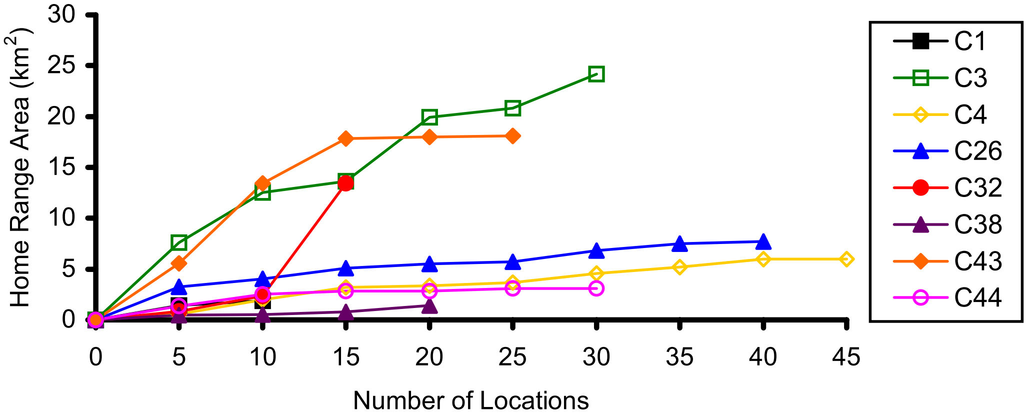


Figure 1.2. Location of wildlife underpasses 🟥, water culverts 🔴, impassable culverts ✚, cement center dividers ▬, guardrail dividers ▬, and wildlife fencing ▬ along CA 71 from Pine Avenue in the north to the interchange with CA 91 in the south. Also shown are locations of select buildings ★, Orange County Water District water filtration ponds ▬, and Chino Hills State Park boundaries ▬ for reference.

Female coyote, all locations



Male coyote, all locations



Bobcat, all locations

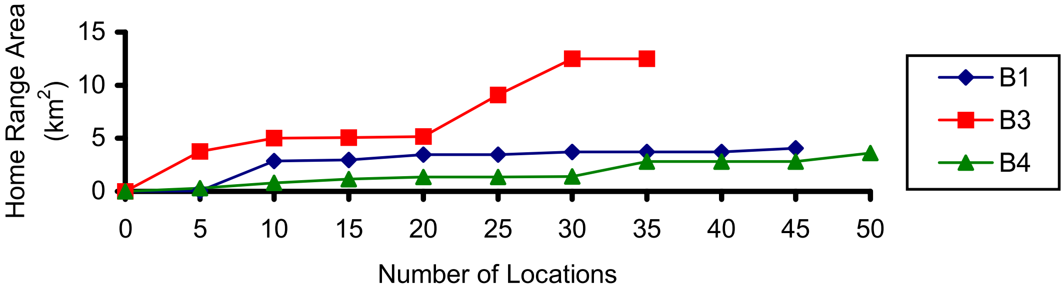


Figure 1.3. Area-observation curves using the 100% minimum convex polygon method for 15 coyotes and 3 bobcats radio-collared in the Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to February 2000. Asymptotes were not reached for C1, C3, C32, C38, and B4.

	CA 71				CA 83				CA 91			
ID #/Group	0-100	101-300	301-700	701-1500	0-100	101-300	301-700	701-1500	0-100	101-300	301-700	701-1500
Individual												
C4												
C6	▨	□	▨	■								
C7	▨	▨	▨	▨								
C8	□	▨	▨	■								
C9	▨	▨	■	□								
C17	■	▨	▨	□	▨	▨	▨	▨				
C26	▨	■	■	□								
C43	▨	▨	▨	□								
C44	▨	▨	▨	▨								
C52	■	▨	□	□	▨	▨	■	□				
B1					□	□	□	■				
B3	▨	▨	▨	▨								
Demographic												
Male adult	▨	▨	▨	▨								
Male year	▨	■	▨	□								
Noncross	▨	□	▨	■								
Locs East	■	▨	▨	□								
Locs West	▨	■	▨	▨								
A posteriori												
C4/C6/C8	□	□	▨	■								
C7/C17/C43/ C44/C52	■	■	▨	□								
C7/C17/C44					▨	▨	▨	▨				
C4/C6/C43									▨	▨	▨	▨

□ Under-utilized ▨ Proportional use ■ Over-utilized

Figure 1.4. Utilization of buffer zones (meters) along California routes 71, 83, and 91 for individual coyotes and bobcats in the Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to February 2000. Pooled data for select groups and habitat availability (Locs East and Locs West) are also included.

CHAPTER 2

FACTORS AFFECTING THE USE OF ROADWAY UNDERPASSES AND ROAD MORTALITY OF COYOTES (*CANIS LATRANS*) AND BOBCATS (*FELIS RUFUS*) ON STATE ROUTE 71 IN SOUTHERN CALIFORNIA

INTRODUCTION

Roads separate once continuous habitat and are substantial barriers to animal movement (Forman and Alexander 1998). Animals can respond by refusing to enter areas that support elevated road densities (Thiel 1984, McLellan and Shackleton 1988) or by shifting their activities away from the habitat immediately adjacent to the road (Reijnen et al. 1995, 1996; Boarman and Sazaki 1996, Mace et al. 1996, Paquet and Callaghan 1996, McLellan and Schackleton 1988). Moreover, some species are willing to cross only certain classes of roads (Brody and Pelton 1989, Lovallo and Anderson 1996), whereas others may change their crossing activity periods in response to varying traffic volumes throughout the day, as increased traffic volume increases noise levels (Reijnen et al. 1995, 1996; Forman and Alexander 1998).

Roads also cause direct mortality by collisions with motor vehicles (Forman and Alexander 1998), which can severely impact wildlife populations (Case 1978). In fact, if road kill rates exceed that of reproduction and immigration rates, wildlife populations can suffer declines (Beier 1993, Bruinderink and Hazebrook 1996, Moore and Mangel 1996, Forman and Alexander 1998). Species that are particularly vulnerable are those that exist in low densities, such as threatened and endangered species (Mumme et al. 2000), but also those with relatively large home ranges and normally low reproductive rates, such as carnivores (Knick 1990, Beier 1993, Gilbert 1996, Bangs et al. 1998).

Carnivores should be conserved not only for their inherent biological value, but also because the loss of these species can alter community dynamics (Noss et al. 1996). Thus, understanding what factors influence road kill patterns is of utmost importance. Previous studies suggest that reduced amounts of road kill are associated with particular habitat and road characteristics (Ward 1982, Bashore et al. 1985, Foster and Humphrey 1995; Evink et al. 1996, 1998, Ng 2000). Nonetheless, road mortality can increase during certain seasons (Case 1978, Feldhammer et al. 1986, Bruinderink and Hazebrook 1996), with increased traffic volume (McCaffery 1973), or can be biased towards specific sex and/or age classes with serious demographic consequences (Beier 1993, Moore and Mangel 1996, Mumme et al. 2000).

Roadway underpasses are increasingly being considered as a method to minimize road kill mortality and allow animals to move safely under roads (Ward 1982, Foster and Humphrey 1995, Yanes et al. 1995, Rodriguez et al. 1996, Crooks and Jones 1998, Clevenger and Waltho 2000, Haas 2000, Ng 2000). Although these underpasses are not habitat corridors (Beier and Noss 1998), they do connect two blocks of habitat severed by roads. When viewing connectivity at such a fine scale (Scott et al. 1999), the underpass is analogous to a corridor that is immediately embedded in a dissimilar matrix of road surface and fenced right-of-way (ROW) habitat (Beier and Noss 1998), surrounded by wildlands. These types of underpass environments are prevalent where habitat corridors are primarily intact except for the presence of a road (Beier 1996).

Because connectivity is the primary issue, principles of corridor design can be applied to movements through roadway underpasses. Overall, corridors should provide enough connectivity to prevent inbreeding depression, decrease vulnerability to demographic stochasticity, allow colonization or re-colonization of unoccupied patches, and allow individuals freedom of movement to fulfill their requirements for food, shelter, protection, and mates (Noss 1987, Simberloff et al. 1992, Rosenberg et al. 1997). The probability and frequency of corridor movement can be determined by understanding the biology of the species for which it was designed, the habitat within the corridor, and its length and width (Noss 1987). Previous studies of roadway underpasses have begun to investigate which species will use them (Foster and Humphrey 1995), during what seasons (Yanes et al. 1995, Rodriguez et al. 1996), and what landscape and structural variables determine if and how often they will be used (Ward 1982, Yanes et al. 1995, Rodriguez et al. 1996, Crooks and Jones 1998, Clevenger and Waltho 2000, Haas 2000, Ng 2000). Yanes et al. (1995) and Rodriguez et al. (1996) have suggested that frequency of underpass use is partially density dependent, with fluctuations in population density explaining more variation in crossing frequencies than either landscape or structural variables (Rodriguez et al. 1996).

Determining the effectiveness of roadway underpasses in facilitating population persistence truly depends on the probability and frequency of use by the individuals with reproductive value, because if movement of these individuals can be maintained, then so can the population (Rosenberg et al. 1997). It is not enough to just document movement through underpasses, but movement into the matrix (over the top of the road and within ROW habitat) must also be considered (Beier and Noss 1998). Unfortunately, data on individual movement for carnivores through underpasses is limited to research conducted by Beier (1995) on dispersing juvenile mountain lions in the Santa Ana Mountains of southern California, which he later related to population viability (Beier and Noss 1998). Therefore, the purpose of my study was to evaluate individual coyote and bobcat movement through underpasses and within the matrix environment, which exposes them to collisions with vehicles. My specific objectives were to 1) determine if underpass use was density dependent; 2) determine if probability of underpass use varied with demographic factors (sex, age, social status, and home range location); 3) determine if frequency of underpass use varied with demographic and environmental (season, year, traffic) factors, and 4) determine what demographic, environmental, and roadway variables affected road kill patterns.

METHODS

Field Methods

Remotely triggered cameras have become a popular tool among researchers studying various aspects of wildlife ecology (for review see Cutler and Swann 1999). Cameras can be advantageous because they disrupt animals less than the presence of human observers and can save time and money by forgoing direct observations (Cutler and Swann 1999). In this study, remotely triggered cameras were chosen to augment radio telemetry data (Lyren, Chapter 1) at the underpasses because 1) some of the underpasses present along CA 71 were spaced closer together than the upper limit of radio telemetry accuracy (142 m); 2) it was important to provide continuous monitoring of targeted underpasses to document as many crossings as possible, since crossings may have occurred so infrequently as to be missed by radio telemetry efforts, and 3) it was necessary to confirm that marked individuals (coyotes and bobcats) crossed underneath CA 71 via an underpass rather than making at-grade (over the top of the road) crossings.

Initially, 24 underpasses were identified between CA 83 and CA 91. However, radio telemetry data revealed that coyotes were also crossing CA 71 near underpass 27 and north of CA 83, which includes underpasses 24 through 26a. Therefore, those underpasses were included in the camera-monitoring schedule (Figure 1.2, Chapter 1). It was decided that underpass 26 was probably too small to support carnivore movement, so this underpass was excluded. Underpass 0 was also excluded because it was not being used by any carnivore species, as documented by track stations conducted simultaneously with this research (Haas and Crooks 1999). An attempt was made to monitor underpass 26a, but the camera was vandalized within two days. This underpass is immediately adjacent to residential housing, a gas station, fast food restaurant, and shooting club, making it attractive to the public (Figure 1.2, Chapter 1). Underpasses 19 through 22 became filled with debris soon after CA 71 was re-opened to traffic and they were also excluded. Another water underpass, 23a, was not discovered until the completion of the study, but during the study 22 underpasses were surveyed. [See Lyren, Chapter 1 for the complete description of the study area and Haas and Crooks (1999) for underpass dimensions and associated landscape variables.]

Installation of CamTrakker cameras (CamTrak South, Watkinsville, GA) involved driving a wooden stake into the ground, usually at the west end of the underpass, and attaching the camera to the stake with a bungee cord. The camera recorded a picture when the infrared beam was broken. Cameras operated continuously during the day and night, and were programmed with a three-minute minimum delay between photos. The cameras were checked every two weeks, as time permitted, to change batteries and film.

Sampling was done randomly from November 1997 through January 2000 because cameras were often stolen (Figure 2.1). Therefore, until cameras could be replaced, the absolute number of underpasses monitored varied across time. Furthermore, when new cameras were received, an underpass often was not re-sampled until a sufficient amount of time had passed so additional loss due to theft was probably negligible. Human traffic was excessive at underpasses 4 and 15, and after the initial cameras were stolen, monitoring at these underpasses ceased.

During the trapping sessions (Lyren, Chapter 1), captured coyotes and bobcats were each individually marked with unique ear tags and radio or dog collars (coyotes only) so they could be identified when they passed through an underpass. Each picture of a coyote or bobcat, collared or non-collared, was considered one pass. If possible, collared animals were individually identified. Pictures of animals that could not be individually identified were excluded from individual totals. The date and time, which were imprinted on most photos, underpass location, and travel direction were recorded for every picture.

Road kill was also monitored when cameras were checked and during radio telemetry from November 1997 through February 2000. Monitoring occurred along CA 71, between Pine Avenue and CA 91, and on CA 91, between Green River Road and Auto Center Drive. Each coyote or bobcat victim was sexed and aged, if possible, and its location marked by GPS. The dates, specific location relative to the road (north or southbound lanes), presence of wildlife fencing, and type of center divider (none, guardrail, cement wall) were also recorded.

Statistical Methods

For each underpass, an underpass index was calculated to determine if the indices were density dependent. Only underpasses that were visited by coyotes and/or bobcats were considered. Three indices were calculated for each underpass: a coyote index, a bobcat index, and a combined coyote and bobcat index termed the carnivore index to represent the total carnivore activity. I used the following equation for the underpass indices (Haas 2000):

$$I_j = p_j/n_j$$

where, I_j = index of species activity at underpass j,

p_j = number of passes by a species, collared or non-collared, at underpass j,

n_j = number of days that the camera was active at underpass j.

However, because the first camera date did not coincide with the first capture date and road mortality caused significant losses of collared individuals, a subset of the camera data was used. Cameras were installed at the underpasses beginning 20 Nov 97, but the first individual was not captured and collared until 11 Feb 98, which is a difference of 84 days, including the first camera and first capture day. Therefore, 84 days were added to the last date that an individual was captured, which was 3 Nov 98. The subset of camera days that were used to calculate underpass indices was 20 Nov 97 through 25 Jan 99.

The total number of individuals using the underpass was calculated by summing the number of radio- and/or dog-collared individuals photographed at each underpass. A collared individual was counted only once regardless of how many times it was photographed at a particular underpass.

All underpass indices were log transformed to assume a normal distribution and for coyotes the number of individuals was square root transformed (Zar 1984). A Pearson-product moment correlation was used to determine if underpass indices were correlated with the number of coyote individuals that were photographed at each underpass. Because the number of individuals for bobcats and carnivores could not be transformed to assume a normal distribution, a Spearman rank correlation was used for those analyses between bobcat or carnivore individuals and the underpass indices.

Probability of underpass use was determined for coyotes only, as the small sample size of two bobcat individuals did not allow them to be grouped for comparison. Coyotes were grouped demographically by sex, age, social status, and location of home range. The categories within the sex group were male and female. Age was divided into two categories, juveniles/yearlings and adults. Social status was defined as either resident or transient. Home range location was determined by which side of CA 71 an individual had the greatest number of radio telemetry locations, east or west. Both radio- and dog-collared coyotes were used in the sex and age analyses. Social status and home range location could not be determined for dog-collared coyotes. Therefore, only radio-collared coyotes were included in those analyses. To determine if the probability of underpass use differed between the categories within the demographic groups, I assumed that individuals within each category had an equal chance of using the underpasses. A

Yates-corrected chi-square goodness-of-fit test was used to determine if the probability of underpass use along CA 71 differed between the categories of a group.

Differences in crossing frequency of radio-collared animals along CA 71 were also tested among the same coyote groups. Three types of crossing frequencies were calculated using the following methods: 1) camera surveys at the underpasses, 2) radio telemetry locations, and 3) and integration of camera surveys and radio telemetry. The camera crossing frequency was determined by using the underpass index equation (Haas 2000) as follows:

$I_c = p_c/n_c$

where, I_c = index of individual c activity at underpasses,

p_c = total number of passes by individual c,

n_c = combined number of days a camera was active at underpasses used by individual c between its capture date and the last day individual c was monitored (Lyren, Chapter 1).

The second crossing frequency was determined by radio telemetry using two different field methods. The first method involved triangulating on an individual and generating a location estimate (Lyren, Chapter 1). This location estimate was then mapped using TOPO! (Wildflower Productions 1998) at the 1:12,000 scale (U. S. Geological Survey 7.5’ map) to determine on which side of CA 71 the individual was located. The second method included driving transects along CA 71 from Pine Avenue to CA 91 in blocks of six hours from 0-6:00, 6:00-12:00, 12:00-18:00, and 18:00-24:00. During these sessions, the observers would stop the vehicle at predetermined locations along CA 71, record every individual they located, and determine if the individual was either east or west of the road. The date and time of each location were also recorded. These were not triangulated locations, but simply directional locations. All triangulated and directional locations for both coyotes and bobcats were then placed in chronological order for each individual. When an individual was found in the opposite direction from its previous location, it was recorded as one crossing. These crossing were summed to yield the total crossings (passes) detected by telemetry. For each individual, a sampling day was defined as each day where radio telemetry confirmed on which side of CA 71 the individual was located. If an individual was located more than once per day, it was only recorded as one sampling day. Obviously this method accounted for both underpass and at-grade crossings across CA 71. Again, the telemetry crossing frequency was determined by using the underpass index equation as follows (Haas 2000):

$$I_t = p_t/n_t$$

where, I_t = index of individual t activity across CA 71,

p_t = combined number of passes by individual t, as determined by radio telemetry

n_t = total number of sampling days.

The camera and radio telemetry data were then integrated with each other and arranged in chronological order to determine the third crossing frequency. Again, when an individual was found opposite from its previous location, it was recorded as one crossing. However, if two camera crossings were detected in succession and the individual was heading in the same direction, the second camera crossing was considered two crossings of CA 71. For instance, consider a set of chronological data that reads camera east and camera east, where camera east means that the individual was heading east when it was photographed, the individual crossed once from west to east (camera photograph showing individual heading east), and crossed once again from west to east (second camera photograph). Obviously, the individual made an undocumented crossing between the two camera photographs, as it is impossible to be heading east twice without having been west of CA 71 for some period of time. Thus, this individual would be recorded as making three crossings. This "integrated" crossing frequency was also calculated using the underpass index equation (Haas 2000) as follows:

$I_i = p_i/n_i$

where, I_i = index of individual i activity across CA 71,

p_i = total number of passes by individual i,

$n_i = n_c + n_t$ by individual i.

Differences in crossing frequency may also be a function of how many underpasses are available to an individual within its home range. Therefore, each individual's 95% ADK home range (Lyren, Chapter 1) and the location of each underpass along CA 71 were imported to TOPO! at the 1:12,000 scale. The number of available underpasses for each individual were those underpasses located within the individual's 95% ADK home range area, with the exception of underpasses 0, 19, 20, 21, 22, and 26a (see above). Two individuals, C8 and C44, were documented using underpasses outside of their 95% ADK home range. This occurred because underpass crossings were not included in any of the home range estimates, as they would have biased the estimates with cameras continuously monitoring an underpass. The 95% ADK home range for C8 only included underpass 16, but cameras documented her using underpasses 8 and 18. Therefore, those underpasses between 8 and 18 were included in her total available underpasses. The 95% ADK home range for C44 included underpasses 1 through 12, and underpass 27 (north of underpass 1; Figure 1.2, Lyren, Chapter 1), but cameras documented him using underpass 13, which was therefore included in his total available underpasses. The total available underpasses within the home ranges acted as the covariate for one-way fixed effects Analysis of Covariance testing for differences in crossing frequencies among coyote groups.

A paired-sample *t*-test was used to test for the difference in frequency of underpass use between the populations of collared and non-collared coyotes and bobcats using the 20 Nov 97 through 25 Jan 99 subset of camera data. Indices were calculated similar to the I_j underpass index above. However, for each underpass, one index was calculated for collared individuals and another index was calculated for non-collared individuals, each over the same number of days that the camera was active at the underpass.

Because frequency of underpass use was not any different between collared and non-collared coyotes ($t = -0.270$, $p = 0.791$, $n = 15$) or bobcats ($t = -0.098$, $p = 0.924$, $n = 9$; α probability = 0.05 unless otherwise stated), all photographs of collared and non-collared coyotes and bobcats, from 16 Dec 97 through 15 Dec 99 (two complete biological years), were used to determine if crossing frequency differed among seasons. Following Gese et al. (1988), seasons were divided as: breeding (16 Dec-28 Feb), gestation (1 Mar-15 May), young rearing (16 May-31 Aug), and dispersal (1 Sept-15 Dec). Because the majority of bobcat litters are born during April and May (Anderson 1987), bobcat activity was also divided among these same seasons. The underpass index equation, $I_j = p_j/n_j$ (Haas 2000), was used to calculate an index of activity, with underpasses acting as replicates within each season, resulting in an unbalanced design. A one-way random effects model Analysis of Variance (ANOVA) was used to determine if frequency of underpass use differed between coyotes and bobcats. Also, a two-way mixed model ANOVA was used to determine if frequency of underpass use was any different between years and among seasons for coyotes and bobcats, separately.

In addition, one-way Analyses of Variance and Covariance (ANCOVA) were used to determine how traffic volume affected the frequency of underpass use for both species. Coyotes (Andelt and Gipson 1979, Smith et al. 1981) and bobcats (Anderson 1987) are primarily nocturnal, although some bobcat activity is focused around dawn and dusk. Thus, the night was divided into two halves, from 18:00-24:00 and 0-6:00. The California Department of Transportation (1998) conducted hourly traffic counts along CA 71 for 18 full days during April and July 1998. This was used to calculate mean hourly traffic volumes. The one-way ANOVA was used to determine if traffic volumes and frequency of underpass use differed during the night for coyotes and bobcats. The one-way ANCOVA was then used to determine if the frequency of underpass use differed during the night when accounting for the traffic volume.

Road killed individuals were categorized within various groups for analysis. Age was again divided into two groups, juveniles/yearlings and adults. This was done to compare those groups that were most likely dispersers (juveniles/yearlings) and those that were not (adults). Seasons were combined into two groups. One group was defined as the breeding and dispersal season, because movement is usually greater during these seasons. The second group was defined as the gestation and young-rearing seasons, because females usually remain closer to den sites (Laundre and Keller 1984, Anderson

1987) during these seasons. Individuals were also grouped by traffic direction to determine if the road kills occurred more often in northbound or southbound lanes. The effect of wildlife fencing on road kill mortality was determined by grouping individuals that were killed where fencing along the roadway was present and where it was not. This analysis was also conducted for the center dividers. A second center divider analysis was conducted to determine if more road kills occurred where there was a center guardrail, cement wall, or no divider present. The Yates-corrected chi-square goodness-of-fit test was used for all group comparisons except divider type, as there were three categories for that analysis (guardrail, cement wall, or none).

RESULTS

Fourteen coyotes and two bobcats were documented using the underpasses either by remotely triggered cameras or radio telemetry (Table 2.1). This included eight male and six female coyotes, which were comprised of one juvenile, three yearlings, and 10 adults. The male and female bobcats were both adults. Eight coyotes and both bobcats had radio-collars while the six remaining coyotes had dog collars.

Collared (radio- and dog-collared) coyotes accounted for 29% (*n* = 122 crossings) of the entire coyote underpass crossings (*n* = 419 total crossings) documented by cameras (17 photographs of collared coyotes could not be verified to individual). Also, collared coyotes crossed primarily at underpasses 1, 7, 8, 11, 13, 18 and 27, but all coyote crossings, collared and non-collared, occurred primarily at underpasses 1, 4, 8, 24, 25, 27. Cameras documented 124 total crossings by bobcats. Radio-collared bobcats accounted for 23% (n = 28 crossings) of those crossings (two collared bobcat photos could not be verified to individual). Also, radio-collared bobcats crossed primarily at underpasses 1, 8, 12, 14, 16, 17, but all bobcat crossings, collared and non-collared, occurred primarily at underpasses 1, 7, 8, 13, 14, and 16. Radio telemetry documented an additional 110 coyote and 6 bobcat crossings across CA 71 (Table 2.1). After integrating both methods, collared coyotes accounted for 274 crossings and radio-collared bobcats for 46 (Table 2.1), which is certainly a conservative estimate since radio telemetry could not be employed 24 hours per day and cameras were not active at all underpasses during the entire study (Figure 2.1).

Both bobcats and all collared coyotes, except C26, C37, and C52 (Table 2.1), used the underpasses from 20 Nov 97 through 25 Jan 99. There was no correlation between the underpass indices and the number of individuals using each respective underpass for bobcats ($r_s = -0.452$, $p = 0.222$, $n = 9$) or carnivores ($r_s = -0.183$, $p = 0.498$, $n = 16$). However, the number of individual coyotes using an underpass was positively correlated with the underpass indices ($r^2 = 0.344$, $p = 0.022$, $n = 15$) suggesting that 34% of the observed variation in underpass use for coyotes is due to density. Thus, a higher underpass index implied that there were a greater number of coyotes using the underpass.

Probability of underpass use for collared coyotes did not differ between the sexes ($\chi^2 = 0.357$, $p > 0.500$, $n = 14$), social status ($\chi^2 = 0.125$, $p > 0.500$, $n =8$), or home range location ($\chi^2 = 0.625$, $p > 0.250$, $n =8$; Table 2.1). Even though it was not statistically significant, adult coyotes exhibited a greater tendency to use underpasses than the juveniles and yearlings ($\chi^2 = 2.643$, $p > 0.100$, $n = 14$; Table 2.1).

As determined by cameras, the frequency of underpass use did not differ between years or among seasons for either coyotes or bobcats, which included both collared and non-collared individuals (Table 2.3, Figures 2.2 and 2.3). Yet, coyotes used the underpasses more frequently than bobcats ($F = 14.885$, $p < 0.001$, $df = 94$). Coyotes used the underpasses at a mean of 1.9 ± 4.27 SD days (date imprinted on 409 photographs) between underpass crossings, whereas bobcats used the underpasses at a mean of 6.5 ± 13.23 SD days ($n = 120$) between underpass crossings. However, the density of bobcats along CA 71 probably is fairly low. In fact, the ratio of collared bobcats to collared coyotes was 1:7, which is similar to their integrated crossing frequency ratio of 1:10 (Table 2.1). When combined, all coyotes and bobcats crossed CA 71 via the underpasses at a mean of once every 2.9 ± 7.56 days.

The camera, telemetry, and integrated frequency of underpass use indices were similar for all radio-collared coyote groups (Table 2.2). Although the differences were not significant, the camera indices suggested that the residents, and those coyotes located east of CA 71, where using the underpasses to cross CA 71 more frequently than the transients and coyotes located west of CA 71. However, the telemetry and integrated indices showed the opposite, with the transients and coyotes located west of CA 71 crossing CA 71 more frequently (these two indices do not distinguish between underpass or at-grade crossings).

Traffic volumes were higher during the first half of the night from 18:00 to midnight ($F = 12.461$, $p = 0.005$, $df = 10$). Coyotes used the underpasses more frequently during the second half of the night from midnight to 6 a.m. ($F = 10.411$, $p = 0.009$, $df = 10$), whereas frequency of underpass use was similar during both halves of the night for bobcats (*F* = 0.148, *p* = 0.709, *df* = 10). Traffic did appear to have an effect on frequency of underpass use for coyotes, because when traffic was held as the covariate, frequency of underpass use no longer differed during the night (*F* = 0.111, *p* = 0.747, *df* = 9; Figure 2.4). When including traffic as a covariate, bobcats still exhibited the same pattern, using the underpasses with equal frequency during the entire night (*F* = 0.658, *p* = 0.804, *df* = 9; Figure 2.5).

No bobcats were road killed during this study. However, two were road killed immediately following, in March and April. One was struck on CA 83 at Pine Avenue, and the other in the southbound lanes of CA 71 adjacent to underpass 25.

Road kill was the cause of death for 7 of the 12 radio-collared coyotes that were confirmed dead. Five of those seven killed by vehicles were struck on CA 71 (Figure 2.6). Three dog-collared coyotes were also killed on CA 71 (Figure 2.6). Therefore, road kill was responsible for 67% (*n* = 10) of the confirmed radio and dog-collared coyote deaths (*n* = 15). In addition, 10 unmarked coyotes were killed on CA 71 and two were killed on CA 91 during this study (Figure 2.6). A significantly higher number of the coyotes were killed where wildlife fencing was absent and in the southbound lanes of CA 71 (Table 2.4, Figure 2.6). Thus, a paired-sample *t*-test was used to determine if coyotes used the underpasses significantly more heading in one direction than the other, as this may have offered a partial explanation to why more individuals were killed in the southbound lanes. Although more coyotes were photographed at the underpasses heading east than heading west, the difference was not significant (*t* = 1.017, *p* = 0.323, *n* = 19). Juvenile and yearling coyotes (< 2 years) were killed significantly more often than the adults (Table 2.4).

DISCUSSION

Underpass Use

Overall, coyotes used the underpasses 237% more than bobcats. However, trapping efforts to fit coyotes and bobcats with radio collars suggested that the density of bobcats located adjacent to CA 71 was low. In fact, 14 collared coyotes and two collared bobcats used the underpasses (62% of the radio-collared coyotes and 100% of the radio-collared bobcats within the immediate vicinity of CA 71). Their underpass use, as documented by the cameras, accounted for 29% and 23%, respectively, of collared and non-collared underpass crossings. Although these proportions of underpass use are similar, the ratio of individual captured coyotes to bobcats is not, suggesting that density of bobcats was indeed low and a higher frequency of underpass use by coyotes should be expected.

Yanes et al. (1995) and Rodriguez et al. (1996, 1997) have suggested that crossing rates are density dependent. However, they did not test these assumptions directly, but only inferred this conclusion by detecting significant increases in crossing indices during months or in habitats where relative abundances were expected to be greater. A significant relationship between the number of individuals using the underpasses and the magnitude of the underpass index was not found for bobcats or the combination of bobcats and coyotes in this study area. Again, this is probably a result of low bobcat density. Because the number of bobcats along CA 71 was small, the probability that an individual bobcat would use an underpass was low and, therefore, the power to detect a relationship was low. Nonetheless, my data do clearly show that for coyotes, variation in underpass indices are partially due to changes in density.

The probability than an individual will use an underpass is highly dependent on its chances of locating the underpass, choosing to use it, and then making a safe passage through (Rosenberg et al. 1997). Because males are predominantly the dispersing sex among mammals (Van Vuren 1998), it would seem likely that males have a greater chance of coming into contact with the underpasses than females. However, there was no difference in probability of underpass use among the sexes for coyotes.

Likewise, age class was not significantly different for coyote probability of underpass use, but juveniles and yearlings were killed on CA 71 significantly more than adults. In addition, C. Haas (unpublished data) reported that only one juvenile was recorded at track stations placed at both ends of the underpasses and operated concurrently with this study. However, once coyotes are about eight months old, they reach adult proportions (Gier 1968) and would be indistinguishable from adults at track and camera stations. If juveniles accompanied parents through the underpasses prior to eight months old and when track stations were not operating, it is unlikely that cameras would have documented their presence either, as it is probable that the parents would lead their young through the underpasses and the camera would have snapped a picture as soon as the lead individual broke the infrared beam, missing any individual following, juvenile or adult. Side-by-side travel was possible at the larger underpasses (4, 15, 18, 24, and 25), but unfortunately camera theft was also a problem at these underpasses. During the period when juveniles could most likely be distinguished from adults, 15

April to 31 Dec of each year, those underpasses were only monitored 142 days of the 3701 total camera days.

Age and sex classes also were not significantly different for coyote frequency of underpass use. The most likely time that frequency of underpass use may have differed between the sexes was during late gestation and early young rearing seasons, when females usually remain closer to the dens (Laundre and Keller 1984) and the males are chiefly responsible for bringing back food. Yet, there probably was only one breeding pair in this analysis, C7 and C44. To detect differences between the sexes in frequency of underpass use, data would have to have been analyzed seasonally and probably only for breeders. The lack of differences between age classes may have been because the only two young coyotes in this analysis, C26 and C43, had their movements terminated when they were killed on CA 71. Because they did not survive throughout the entire study, it is unlikely that their true underpass crossing frequencies were known. Movements also were terminated for C17 and C52 when their transmitter batteries failed or they left the study area.

Frequency of underpass use and movement across CA 71 did not vary among seasons for coyotes or bobcats. These results are consistent with Yanes et al. (1995) who found no seasonal variation in crossing rates of carnivores (red foxes, wildcats, and genets) at underpasses, and with Gese et al. (1988) and Neale (1996) who found that coyote home range sizes, which are an expression of how individuals use their home ranges, did not fluctuate seasonally. However, their results are not in agreement with Holzman et al. (1992) who found that home range sizes for coyotes in Georgia were smaller during gestation season. Moreover, the results of Rodriguez et al. (1997), who recorded greater crossing rates during the respective young rearing and dispersal seasons for both red foxes and wildcats, are in direct conflict with Yanes et al. (1995), although both conducted research on crossing rates of carnivores (among other taxa) at railway and culvert underpasses on the Iberian Peninsula, Spain. In southeastern Alberta, Woelfl and Woelfl (1997) also recorded a higher number of coyote visitations at baited scent stations during the dispersal season. Inconsistencies between the Spain studies may have been caused by differences in their sampling methodologies. Yanes et al. (1995) only sampled once a season for four days while Rodriguez et al. (1996, 1997) sampled 15-22 days during each month, which probably offered more power to detect trends among seasons. My results may be inconsistent with Woelfl and Woelfl (1997) because they used baited stations to detect relative abundances, whereas my camera stations at the underpasses were not baited, so natural movement patterns could be detected. Other confounding issues in this study include unequal sampling across underpasses and among seasons because of camera theft and differential road kill of juveniles and yearlings on CA 71 that otherwise would have been present at the underpasses during dispersal season.

For bobcats, Koehler and Hornocker (1989) and Rucker et al. (1989) both detected seasonal influences in bobcat activity. Bobcats in Idaho (Koehler and Hornocker 1989) responded to seasonal changes by locating themselves in warmer areas of their home ranges in winter, as determined by slope aspect, terrain, and cover. Since the climate in southern California remains mild for most of the year, it is unlikely that bobcats would change their frequency of underpass use in response to changing weather conditions. In Arkansas, females had greater movement rates during the summer than males (Rucker et al. 1989), even though the summer season was also when two of the three females exhibited their smallest home ranges. This coincides with the young-rearing season when females may be restricting their home range sizes, but are using them more intensively (Bailey 1974) because they are solely responsible for protecting the young and providing them with food. In this study area, if the female (B1) did breed during both years, she may have exhibited seasonal differences in frequency of underpass use by restricting her home range to her primary core-use area, which was located in Abacherli Canyon and did not include CA 71 (Lyren, Chapter 1). Because she had an adequate crossing sample size (n = 38) and was suspected to have bred (she was photographed with male B3 at underpass 17), I tested her seasonal frequency of movement across CA 71 using a chi-square goodness-of-fit test, with the expectation that she used the underpasses equally among the four seasons. She did indeed move across CA 71 more frequently during the dispersal season and less frequently during the remaining three seasons ($\chi^2 = 12.947$, $p = 0.005$, $df = 3$). As with coyotes, it may be that only breeding individuals alter their frequency of underpass use with seasons.

Individual movement patterns may have a notable effect on yearly (and presumably seasonal) frequency of underpass use and movement across CA 71. From the beginning of the 1998 to the end of 1999 (eight total seasons) a downward trend is visible for coyotes (Figure 2.2), and counter intuitively, the 1999 dispersal season showed the lowest frequency of underpass use of any season. Paquet and Callaghan (1996) noted that when the dominant breeding female wolf from the Healy Creek pack died, the use of the Healy Creek underpass declined significantly the next year. In 1999, C17 and C44, the two coyotes that were responsible for 64% of the underpass crossings (Table 2.1), stopped using the underpasses in May and July (young-rearing season), respectively. It was the next season when the frequency of underpass decreased notably. Although road kill was not significantly different between 1998 and 1999 along CA 71, twice as many coyotes were killed in 1999, which in combination with the decreased underpass use by C17 and C44 may have produced the downward trend. Because the frequency of underpass use is partially density dependent, the number of coyotes that used the underpasses during the 1999 dispersal season was probably low.

Coyotes and bobcats are usually found to be nocturnal in their diel activity patterns, with some peaks in activity near dawn and dusk (Andelt and Gipson 1979, Smith et al. 1981, Anderson 1987). However, in areas that are intensively used by humans (Griffiths and Van Schaik 1993, Clevenger and Waltho 2000) or where animals are exploited (Neale 1996), it has been suggested that a tendency towards nocturnal behavior may be the result of animals attempting to avoid direct contact with humans. In fact, in coastal southern California, Romsos (1998) noted an inverse relationship between mean hourly movement rate for coyotes and mean hourly traffic volume. However, he did not determine if the relationship was a result of the traffic volume or if it was simply the normal activity pattern of coyotes in a human-dominated landscape. In this study, coyotes were not only primarily nocturnal (no peaks in activity at dawn and dusk), but also their frequency of underpass use appeared to be suppressed by the increased traffic volume from 18:00 to midnight. Although it could not be determined from my data if nocturnal behavior was primarily a response to traffic volume, with underpass avoidance as the secondary response, coyotes located in the rural Tenaja Corridor in southern California are primarily crepuscular in their activity patterns (R. Fisher and K. Crooks, unpublished data). Therefore, the full effects of traffic on the frequency of underpass use for coyotes may actually be a shift towards nocturnal movement and, at night, decreased activity when traffic is heavier.

Bobcats were inconsistently active at the underpasses with no particular nocturnal or crepuscular rhythm. Like coyotes, this may also be an overall response to traffic volume, but with no predictable shifts in activity patterns. This is not consistent with Foster and Humphrey (1995) who reported that bobcats crossing under I-75 in southwestern Florida were largely nocturnal. Furthermore, although bobcats in northern California were not using underpasses, they were primarily nocturnal and unexploited, unlike the coyote population in the study (Neale 1996). Finally, in the Tenaja Corridor, bobcats also were found to be nocturnal (R. Fisher and K. Crooks, unpublished data). The difference between bobcat activity in my study and the other studies may be because a larger proportion of the bobcat population was sampled in each of the other three studies.

Based on field observations and a cursory review of photographs taken of non-collared bobcats, it appears that as few as four to five bobcats may have used the underpasses along CA 71. Thus, activity patterns at the underpasses may change quickly if there is a high level of turnover in the bobcat population adjacent to CA 71. Two bobcats were killed after the completion of this study, which probably changed the crossing rate dynamics. However, prior to the death of these bobcats, underpass use may also have been intermittent while bobcats tried to adjust to the amount of coyote activity through the underpasses, as coyotes have been known to kill bobcats (Palomares and Caro 1999).

Road Kill

In this study, the most significant source of mortality for coyotes was vehicle collisions. The lack of continuous wildlife fencing along CA 71 and its absence along CA 91 was the principal factor determining where an individual was killed. Previous research has indicated that coyotes will use underpasses when convenient, but otherwise will cross roadways at will, especially where wildlife fencing is irregular (Gibeau and Heuer 1996). If wildlife fencing is installed properly, it can be an effective tool to guide movements of coyotes. For example, Roof and Wooding (1996) found that coyotes were willing to walk > 25 m alongside wildlife fencing installed down both sides of Florida State Route 46. Even where wildlife fencing was present along CA 71, the fencing failed at many locations for the same reasons listed by Foster and Humphrey (1995): gaps left underneath the fencing due to improper construction, soil erosion by water, vandalism, vehicle accidents, and cattle. Coyotes seem especially adept at exploiting weaknesses in fencing and finding alternate ways to cross fencing (Thompson 1978). Moreover, Thompson (1978) remarked that even after he observed coyotes crossing under, over, or through a fence at a particular location, he was unable to find any physical evidence (e.g. hair, tissue, dig marks) that an individual did so. In fact, C52 was visually observed on many occasions crossing underneath the wildlife fencing in locations where the fencing appeared to be flush to the ground. Upon closer examination, there was no observable evidence that C52 had in fact passed underneath the fencing. The ultimate fate of C52 could not be determined, and because most coyotes were killed where the wildlife fencing was absent, it is unknown how many coyotes actually breached the fencing by various methods, instead of just attempting an at-grade crossing where fencing was absent.

The wildlife fencing was discontinuous, but it was uniform in its installation on both sides of CA 71. Thus, it is unlikely that it contributed to the disproportionate number of coyotes killed in the southbound lane. Rodriguez et al. (1997) found that underpass crossings for wildcats were biased in one direction. That is, wildcats were using the underpasses twice as much to cross west to east than east to west, which could contribute to unequal road kills in a particular traffic direction (lane), as animals returned via the top of the road. In this study, some underpasses were used more to cross in one direction than the other, but many of these underpasses were not monitored continuously. Consequently, it is likely that individuals used unmonitored underpasses for their return trip, since crossing direction was generally similar for coyotes. Yet, if there were higher densities of coyotes on the west side, then it may be possible that individuals were getting struck when they made their first attempt to cross at-grade from west to east. If this were true, then any biases in crossing direction may not have been detected when viewing only total successful underpass crossings.

Other plausible explanations for coyotes being killed more frequently in the southbound lane may be that coyotes loiter in that lane longer or driver visibility differs between north and southbound lanes. As coyotes cross from east to west, the steep slope upwards from Prado Basin onto CA 71 may be advantageous because it forces them to move slower and allows them to assess their surroundings before entering the northbound lane. Traffic in the southbound lane may be obscured by the presence of the center divider, causing a blind crossing. Also, at the south end of CA 71 where the center divider is absent, there are four lanes of traffic to negotiate and visibility may be reduced as the road curves east to meet with CA 91. When coyotes cross west to east, their rate of movement may be quicker and they can assess traffic easier since they are probably coming down one of the hills. If there is no traffic they will probably cross the southbound lane successfully. Yet, if traffic is intermittent and traveling at high speeds, which is often the case late at night and when coyotes are primarily active, their chance of getting across the southbound lane is probably slim. Bashore et al. (1985) suggested that drivers travel at faster speeds when they can see a substantial distance down the road, increasing the chances of hitting an animal emerging from a blind spot along the road. This may be more likely in the southbound lane because the Chino Hills to the west offer plenty of locations for a coyote to remain hidden from view until it has stepped onto the road.

My capture records indicated that the ratio of juveniles/yearlings to adults was roughly 1:1, and if these records were accurate, then road kills should have occurred in the same ratio. In contrast, juveniles and yearlings were killed on CA 71 three times more often than adults. This probably is because these younger individuals are naïve (Moore and Mangel 1996) and often less cautious. Even if a juvenile had been raised near the road, there was little evidence of juveniles accompanying adults through the underpasses (see above), which would have provided them with experience prior to dispersing from their natal home ranges. Mumme et al. (2000) suggested that mortality due to vehicle collisions decreased with increasing juvenile experience. They specifically found that if a juvenile Florida scrub-jay lived beyond 90 days, whether it was fledged adjacent to the road or not, it was never found dead on the road at a later date. However, it is unknown how many times a juvenile made contact with the road and/or vehicles within those 90 days, which is probably the most crucial factor determining survivorship along roads.

In my study, C26, C43, and C47, all young animals, were all photographed at an underpass once or twice before finally being killed on CA 71. At about 8 months old, the juvenile, C47, was found at underpass 7 two days prior to being killed adjacent to underpass 12. One of the yearlings, C26, was captured within 300 meters of underpasses 1 and 10 in June and October 1998, respectively. He was then photographed at underpass 9 in February 1999 and killed adjacent to culver 26a in October 1999. It was apparent from continuous radio tracking, camera, and mortality data that C26 was looking for a way to disperse across CA 71, because in between his contacts with the road, he would move west for awhile, only to return to spend a great deal of time at various locations close to the road. When the yearling C43 was released after capture in October 1998, he immediately darted west through underpass 17. Although radio contact could not be immediately established, in November 1998 the camera at underpass 14 documented him heading west again. C43 was finally located about 8 km west of his capture site, west of CA 71. After investigating Featherly Park, areas south of CA 91, and areas near the campground in Lower Aliso Canyon of Chino Hills State Park, he returned to his capture site and began crossing CA 71 via the roadway.

Other collared yearlings that were not photographed at the underpasses prior to being killed on CA 71 include C5, C34, and C40 (Lyren, Chapter 1). Although C5 was captured west of CA 71, he was killed in the northbound lane of CA 71 adjacent to the gate for the Santa Ana River Trail. It appeared that he was heading back west prior to being struck and killed. The other two yearlings were also captured west of CA 71, but were killed in the southbound lane. The movements of these three coyotes, in addition to the fact that the remaining collared coyotes were not documented at the underpasses, supports the learning curve pattern suggested by Ward (1982) and Mumme et al. (2000) and implies that a larger number of successful contacts with underpasses and/or non-lethal contacts with vehicles may be needed before an individual is finally educated and survivorship is increased.

Road kill mortality may have either a compensatory or additive effect on a population. If the effect is compensatory, road mortality occurs instead of some other form of mortality (e.g. hunting, predation, disease), which given that the population is stable, would not cause the population to decline (Forman and Alexander 1998). If the effect is additive, then road mortality occurs in addition to other types of mortality and may possibly affect population viability (Moore and Mangel 1996, Forman and Alexander 1998). It may not be important to determine if road kill mortality has an additive or compensatory effect, because simply, no radio-collared juvenile or yearling managed to disperse across CA 71 successfully. Moreover, track stations only recorded one juvenile at the underpasses, and during 1999, when C7 and C44 were suspected to have bred, C7 was only documented using the underpasses in February whereas C44 stopped using them in June. This means that there was only a slight chance that juveniles accompanied them through the underpasses.

Although underpasses are not corridors in the strictest of definitions, underpasses are now being viewed as an important tool in reconnecting two habitat patches severed by a road, especially in an urban environment such as southern California where opportunities for corridors are limited. The glue that ties corridors and underpasses together is connectivity. It has been stated that it is not necessary to demonstrate the demographic effects of corridors as long as animals use corridors in such a way as to provide connectivity, and that without corridors connectivity would be reduced (Beier and Noss 1998). The same may be said for underpasses. Connectivity would be reduced in this area without the use of underpasses because, as roads become wider and larger, they act as absolute barriers (Lyren, Chapter 1). Yet, my data show that, although adult coyotes are using the underpasses for movements within their home range and connectivity has been conserved for those types of movements, adults may be failing to educate their young. Moreover, with the wildlife fencing in it current condition along CA 71, little guidance is provided to the uneducated juveniles and/or yearlings, which means that the underpasses are not facilitating dispersal movement.

In particular, the section south of underpass 18 has become a chronic mortality sink (Figure 2.6). This section was never fenced. Several additional factors are likely responsible for aggravating the road kill situation. First, 1998 El Nino conditions swept dirt and debris into underpasses 19 through 22, making them impassable to wildlife and leaving only underpasses 23 and 23a open for movement, but there was no evidence that coyotes used underpass 23 (Haas and Crooks 1999). This probably is because, as they were traveling parallel to the road heading south, they were crossing CA 71 at the first available location, which was near the gravel pit entrance. Second, human traffic along the Santa Ana River Trail may have forced coyotes to move their activity from the trail towards the road to reduce chance encounters with humans (Griffiths and Van Schaik 1993, Clevenger and Waltho 2000). Finally, resident coyotes located along the south end of CA 71 seem to have shifted their core-use areas away from the road, thus creating what appears to be an open territory spanning the road (Lyren, Chapter 1).

CONCLUSIONS

Ultimately, the success of underpasses in conserving connectivity depends on the proper installation of wildlife fencing. Despite fencing across the expected primary travel routes along CA 71, numerous coyotes were road killed. This suggests that fencing must be continuous along the entire road that fragments wildlife habitat to prevent animals from finding less suitable alternate crossing locations. Until they have become accustomed to using underpasses, the young animals are especially vulnerable to vehicle-related mortality because they are inexperienced. In addition to the variables examined in this study, other environmental, landscape, or roadway variables may be determining road kill patterns, since a disproportionate number of coyotes were killed in the southbound lane of CA 71.

Furthermore, the current condition of the wildlife fencing may have confounded the assessment of those factors expected to have influenced the use of the underpasses. With the exception of the frequency of underpass use being density dependent for coyotes and the effects of traffic volume, most of the demographic and environmental variables did not seem to affect the probability or frequency of underpass use for coyotes and bobcats. Traffic volume appeared to have suppressed the frequency of underpass use for coyotes and may have contributed to the pattern observed for bobcats. Until the wildlife fencing is installed properly, it will be difficult to determine if the underpasses are facilitating the movements of resident and dispersing animals alike or what factors affect the use of underpasses. Moreover, wildlife fencing in a condition like that found along CA 71 can create a mortality sink, which may jeopardize population viability.

LITERATURE CITED

Andelt, W. F., and P. S. Gipson. 1979. Home range, activity, and daily movements of coyotes. Journal of Wildlife Management 43(4):944-951.

Anderson, E. M. 1987. A critical review and annotated bibliography of literature on the bobcat. Colorado Division of Wildlife Special Report 62. 61 p.

Bailey, T. N. 1974. Social organization in a bobcat population. Journal of Wildlife Management 38(3):435-446.

Bangs, E. E., S. H. Fritts, J. A. Fontaine, D. W. Smith, K. M. Murphy, C. M. Mack, and C. C. Niemeyer. 1998. Status of gray wolf restoration in Montana, Idaho, and Wyoming. Wildlife Society Bulletin 26(4):785-798.

Bashore, T. L., W. M. Tzilkowski, and E. D. Bellis. 1985. Analysis of deer-vehicle collision sites in Pennsylvania. Journal of Wildlife Management 49(3):769-774.

Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. Conservation Biology 7(1):94-108.

_____. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management 59(2):228-237.

_____. 1996. Metapopulation models, tenacious tracking, and cougar conservation. Pages 293-323 *in* D. R. McCullough, editor. Metapopulations and Wildlife Conservation. Island Press, Washington, D.C.

_____, and R. F. Noss. 1998. Do habitat corridors provide connectivity? Conservation Biology 12(6):1241-1252.

Boarman, W. L., and M. Sazaki. 1996. Highway mortality in desert tortoises and small vertebrates: success of barrier fences and culverts. Pages 169-173 *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife mortality seminar. FL-ER-58-96. Florida Department of Transportation, Tallahassee, Florida.

Brody, A. J., and M.R. Pelton. 1989. Effects of roads on black bear movements in western North Carolina. Wildlife Society Bulletin 17:5-10.

Bruinderink, G., and E. Hazebrook. 1996. Ungulate traffic collisions in Europe. Conservation Biology 10(4):1059-1067.

California Department of Transportation. 1998. Report of detail all vehicle hourly count. Available from California Department of Transportation, District 8, Traffic Division, 464 West 4th Street, San Bernardino, CA 92401. Report OTM32520.

Case, R. M. 1978. Interstate highway road-killed animals: a data source for biologists. Wildlife Society Bulletin 6(1):8-13.

Clevenger, A. P. and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology 14(1):47-56.

Crooks, K. R., and D. Jones. 1999. Monitoring program for carnivore corridor use in the Nature Reserve of Orange County. Unpublished report available from The Nature Reserve of Orange County, 300 North Flower, Santa Ana, CA 92075.

Culter, T., and D. E. Swann. 1999. Using remote photography in wildlife ecology: a review. Wildlife Society Bulletin 27(3):571-581.

Evink, G. L., P. Garrett, D. Zeigler, and J. Berry, eds. 1996. Proceedings of the Transportation Related Wildlife Mortality Seminar. FL-ER-58-96, Florida Department of Transportation, Tallahassee, Florida. 351 p.

_____, _____, _____, and _____, eds. 1998. Proceedings of the International Conference on Wildlife Ecology and Transportation. FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida. 263 p.

Feldhammer, G. A., J. E. Gates, D. M. Harman, A. J. Loranger, and K. R. Dixon. 1986. Effects of interstate highway fencing on white-tailed deer activity. Journal of wildlife management 50(3):497-503.

Forman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-231.

Foster, M. L., and S. R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23(1):95-100.

Gese, E. M., O. J. Rongstad, and W. R. Mytton. 1988. Home-range and habitat use of coyotes in southeastern Colorado. Journal of Wildlife Management 52(4):640-646.

Gibeau, M. L., and K. Heuer. 1996. Effects of transportation corridors on large carnivores in the Bow River Valley, Alberta. Pages 69-81 *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife mortality seminar. FL-ER-58-96. Florida Department of Transportation, Tallahassee, Florida.

Gier, H. T. 1968. Coyotes in Kansas. Kansas State College Agriculture Experiment Station Bulletin 393. 118 p.

Gilbert, T. 1996. An overview of black bear roadkills in Florida 1976-1995. Pages 322-336 *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife mortality seminar. FL-ER-58-96. Florida Department of Transportation, Tallahassee, Florida.

Griffiths, M., and C. P. Van Schaik. The impact of human traffic on the abundance and activity of periods of Sumatran rain forest wildlife. Conservation Biology 7(3):623-626.

Haas, C. D. 2000. Distribution, relative abundance, and roadway underpass responses of carnivores throughout the Puente-Chino Hills. M.S. thesis. California State Polytechnic University, Pomona. 110 p.

_____, and K. R. Crooks. 1999. Carnivore abundance and distribution throughout the Puente/Chino Hills. Unpublished report available from The Mountains Recreation and Conservation Authority, 5730 Ramirez Canyon Rd, Malibu, CA 90265. 128 p.

Holzman, S., M. J. Conroy, and J. Pickering. 1992. Home range, movements, and habitat use of coyotes in southcentral Georgia. Journal of Wildlife Management 56(1):139-146.

Knick, S. T. 1990. Ecology of bobcats relative to exploitation and prey decline in southeast Idaho. Wildlife Monographs 108:1-42.

Koehler, G. M., and M. G. Hornocker. 1989. Influences of seasons on bobcats in Idaho. Journal of Wildlife Management 63(1):197-202.

Laundre, J. W., and B. L. Keller. 1984. Home-range size of coyotes: a critical review. Journal of Wildlife Management 48(1):127-139.

Lovallo, M. J., and E. M. Anderson. 1996. Bobcat movements and home ranges relative to roads in Wisconsin. Wildlife Society Bulletin 24(1):71-76.

Mace, R. D., J. S. Waller, and T. L. Manley. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33:1395-1404.

McCaffery, K. R. 1973. Road-kills show trends in Wisconsin deer population. Journal of Wildlife Management 37(2):212-216.

McLellan, B. N., and D. M. Shackleton. 1988. Grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use and demography. Journal of Applied Ecology 25:451-460.

Moore, T. G., and M. Mangel. 1996. Traffic related mortality and the effects on local populations of Barn Owls *Tyto alba*. Pages 131-146 *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife mortality seminar. FL-ER-58-96. Florida Department of Transportation, Tallahassee, Florida.

Mumme, R. L., S. J. Schoech, G. E. Woolfenden, and J. W. Fitzpatrick. 2000. Life and death in the fast lane: demographic consequences of road mortality in the Florida scrub-jay. Conservation Biology 14(2):501-512.

Neale, J. C. C. 1996. Comparative resource use by sympatric bobcats and coyotes: food habits, habitat use, activity, and spatial relationships. M.S. thesis. University of California, Berkeley. 117 p.

Ng, S. J. 2000. Wildlife use of underpasses and culverts crossing beneath highways in southern California. M.S. thesis. California State University, Northridge. 50 p.

Noss, R. F. 1987. Corridors in real landscapes: a reply to Simberloff and Cox. Conservation Biology 1(2):159-164.

_____, H. B. Quigley, M. G. Hornocker, T. Merrill, and P. C. Paquet. 1996. Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology 10(4):949-963.

Palomares, F., and T. M. Caro. 1999. Interspecific killing among mammalian carnivores. The American Naturalist 153(5):492-508.

Paquet, P. C., and C. Callaghan. 1996. Effects of linear developments on winter movements of gray wolves in the Bow River Valley of Banff National Park, Alberta. Pages 47-67 *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife mortality seminar. FL-ER-58-96. Florida Department of Transportation, Tallahassee, Florida.

Reijnen, R., R. Foppen, C. Ter Braak, and J. Thissen. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. Journal of Applied Ecology 32:187-202.

_____, _____, and H. Meeuwsen. 1996. The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. Biological Conservation 75:255-260.

Rodriguez, A., G. Crema, and M. Delibes. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. Journal of Applied Ecology 33:1527-1540.

_____, _____, and _____. 1997. Factors affecting crossing of red foxes and wildcats through non-wildlife passages across a high-speed railway. Ecography 20:287-294.

Romsos, J. S. 1998. Home range, habitat use, and movements of coyotes in a southern California urban environment. M.S. thesis. Humboldt State University. 60 p.

Roof, J., and J. Wooding. 1996. Evaluation of the S.R. 46 wildlife crossing in Lake County, Florida. Pages 344-351 *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife mortality seminar. FL-ER-58-96. Florida Department of Transportation, Tallahassee, Florida.

Rosenberg, D. K., B. R. Noon, and E. C. Meslow. 1997. Biological corridors: form, function, and efficacy. BioScience 47(10):677-687.

Rucker, R. A., M. L. Kennedy, G. A. Heidt, and M. J. Harvey. 1989. Population density, movements, and habitat use of bobcats in Arkansas. The Southwestern Naturalist 34(1):101-106.

Scott, J. M., E. A. Norse, H. Arita, A. Dobson, J. A. Estes, M. Foster, B. Gilbert, D. B. Jensen, R. L. Knight, D. Mattson, and M. E. Soulé. Pages 19-37 *in* M. E. Soulé and J. Terbough, eds. Continental Conservation: scientific foundations of regional reserve networks. Island Press, Washington, D.C.

Simberloff, D., J. A. Farr, J. Cox, and D. W. Mehlman. 1992. Movement corridors: conservation bargains or poor investments? Conservation Biology 6(4):493-504.

Smith, G. J., J. C. Cary, and O. J. Rongstad. 1981. Sampling strategies for radio-tracking coyotes. Wildlife Society Bulletin 9(2):88-93.

Thiel, R. P. 1984. Relationship between road densities and wolf habitat suitability in Wisconsin. The American Midland Naturalist 113(2):404-407.

Thompson, B. C. 1978. Fence-crossing behavior exhibited by coyotes. Wildlife Society Bulletin 6(1):14-17.

Van Vuren, D. 1998. Mammalian dispersal and reserve design. Pages 369-393 *in* T. Caro, editor. Behavioral ecology and conservation biology. Oxford University Press, New York.

Ward, A. L. 1982. Mule deer behavior in relation to fencing and underpasses on Interstate 80 in Wyoming. Transportation Research Record 859:8-13.

Wildflower Productions. 1998. TOPO!GPS® [computer program]. Version 1.3.0. San Francisco, CA: Wildflower Productions, 375 Alabama Street, Ste 230, San Francisco, CA 94110, phone: (415) 558-8700, email: info@topo.com. Available at http://www.topo.com.

Woelfl, S., and M. Woelfl. 1997. Coyote, *Canis latrans*, visitations to scent stations in southeastern Alberta. The Canadian Field-Naturalist 111:200-203.

Yanes, M., J. M. Velasco, and F. Suárez. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. Biological Conservation 71:217-222.

Zar, J. H. 1984. Biostatistical analysis. 2nd ed. Prentice Hall, Englewood Cliffs, New Jersey. 718 p.

Table 2.1. Demographic classification, total number of culverts within the 95% ADK home range, and number of crossings of CA 71 by individual collared coyotes and bobcats in the Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, March 1998 to January 2000.

					Crossings					
Animal ID #	Sex	Age[a]	Class[b]	Culv[c] HR	Cam[d] Cross	Cam[e] Days	Tel[f] Cross	Tel[g] Days	Integ[h] Cross	Culverts Used[i]
Radio-collared coyotes										
C7	F	Adu	RE	13	4	681	4	75	11	8 11 12
C8	F	Adu	RW	11	8	468	0	77	10	8 18
C9	F	Adu	TW	23	3	497	33	63	36	8 18
C17	F	Adu	RE	19	33	973	7	33	63	1 2 4 6 7 8 27
C26	M	Yrlng	TW	18	1	170	3	57	4	9
C43	M	Yrlng	TW	11	2	242	14	28	17	14 17
C44	M	Adu	RE	14	34	720	15	46	73	1 7 8 10 13 27
C52	F	Adu	TW	19	1	12	34	31	34	13
Dog-collared coyotes										
C21	M	Yrlng			2				3	18
C35	M	Adu			4				6	8 17
C37	F	Adu			6				9	10
C47[j]	F	Juv			1				1	7
C48	M	Adu			5				6	7 9 17
C49	F	Adu			1				1	14
Radio-collared bobcats										
B1	F	Adu	RW	17	22	2084	6	47	38	1 2 7 8 10 14 16 17
B3	M	Adu	RW	19	4	803	0	46	8	8 9 12 17
Total				164	131	6650	116	503	320	
mean				16.4	8.2	665.0	11.6	50.3	20.0	
SD				3.98	11.11	582.0	12.61	17.47	22.43	

[a] Age classes for coyotes: <1 yr = juvenile, 12-24 mos = yearling, >2 yrs = adult; bobcats: >1 yr = adult.

[b] Classification of individuals. The first letter refers to either Resident or Transient and the second to the location of the home range as either East or West of CA 71.

[c] Number of culverts within each individual's 95% ADK home range.

[d] Number of photographs of the individual crossing at culverts underneath CA 71.

[e] Number of days that cameras were active at culverts used by the individual between its capture date and last monitored date.

[f] Number of passes across CA 71by each individual as determined by radio telemetry.

[g] Number of days that individual was located via radio telemetry and a direction could be determined.

[h] Number of camera and radio telemetry passes across CA 71 integrated as a total number of crossings.

[i] The culverts that individuals used to cross underneath CA 71 as documented by the cameras.

[j] C47 was radio-collared, but she was killed 36 days after capture on CA 71. Therefore, because her home range, social, and location status could not be described, she was considered a dog-collared individual. Her camera days = 21, while she was only monitored by telemetry for one day.

Table 2.2. Differences in frequency of underpass use along CA 71 for demographic goups of radio-collared coyotes (n = 8 individuals), as determined by camera and telemetry indices, separately and integrated, in Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, March 1998 to February 2000.

Group[a]	Category	Camera[b]			Telemetry[c]			Integrated[b]		
		Culv[d]	Mean[e]	F[f]	Culv	Mean	F[f]	Culv	Mean	F[f]
Sex	Male	14.3	-4.328	0.083	14.3	-1.586	0.005	14.3	-3.052	0.002
	Female	17.0	-4.037		18.5	-1.259		17.0	-2.796	
Age[g]	Yearling	14.5	-4.966	1.457	14.5	-1.819	0.732	14.5	-3.402	0.170
	Adult	16.5	-3.873		17.6	-1.231		16.5	-2.721	
Social	Resident	14.3	-3.911	0.459	15.3	-1.867	0.523	14.3	-3.337	0.326
	Transient	17.8	-4.382		17.8	-1.048		17.8	-2.446	
Location[h]	East	15.3	-3.858	0.296	15.3	-1.867	0.523	15.3	-3.117	0.056
	West	16.4	-4.319		17.8	-1.048		16.4	-2.756	

[a] The sex, age, and location groups are unbalanced (see Table 2.1 for classification of individuals).

[b] Effect *df* = 1 and error *df* = 5.

[c] Effect *df* = 1 and error *df* = 4 because C8 was removed since she was not recorded crossing CA 71 by radio telemetry.

[d] Culverts within 95% ADK home range were used as the covariate. The average number of culverts is shown.

[e] All camera, telemetry, and integrated indices were log transformed.

[f] One-way fixed effects Analysis of Covariance. All probability values were non-significant ($p > 0.05$).

[g] Because only radio-collared coyotes were used in this test, age is categorized as either yearling or adult.

[h] Location relative to CA 71, either east or west, as determined by where the individual has the greatest number of telemetry locations.

Table 2.3. Differences in frequency of underpass use along CA 71 between years and among seasons for all coyotes and bobcats, as determined by camera indices in Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, December 1997 to December 1999.

Group[a]	Category	Coyote[b]			Bobcat[c]		
		Mean[d]	MS	F[e]	Mean[d]	MS	F[e]
Year	1998	-1.786	2.503	2.057	-2.656	<0.001	<0.001
	1999	-2.226			-2.658		
Season[f]	Breeding	-1.613	2.398	2.237	-1.715	1.967	1.642
	Gestation	-1.746			-2.953		
	Young rearing	-2.133			-2.898		
	Dispersal	-2.536			-3.061		
Year x Season			1.072	0.881		1.198	1.732
Error			1.217			0.691	

[a] Unbalanced two-way mixed model Analysis of Variance with year as a random effect and season as a fixed effect.

[b] Year *df* = 1, season *df* = 3, year x season *df* = 3, and error *df* = 52.

[c] Year *df* = 1, season *df* = 3, year x season *df* = 3, and error *df* = 28.

[d] All indices were log transformed.

[e] All probability values are non-significant ($p > 0.05$).

[f] Seasons = breeding (16 Dec-28 Feb), gestation (1 Mar-15 May), young rearing (16 May-31 Aug), and dispersal (1 Sept-15 Dec).

Table 2.4. Demographic, environmental, and roadway variables related to coyote road kill patterns along CA 71 and CA 91 in Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, November 1997 to January 2000.

Group[a]	Category	f[b]	X^{2c}
Fence present	Yes	3	9.850**
	No	17	
Divider present	Yes	13	1.850
	No	7	
Divider type[b]	None	7	0.099
	Guardrail	6	
	Cement wall	7	
Traffic direction[c]	Northbound	3	7.177**
	Southbound	14	
Sex	Male	8	1.417
	Female	4	
Age	Juvenile/Yearling	10	3.846*
	Adult	3	
Season[d]	Disp/Breeding	9	1.214
	Gest/Young rear	5	

[a] Yates correction for continuity was used for all groups except Divider type.

[b] Observed frequencies. Individuals were expected to be killed equally between (or among) categories.

[c] Statistically significant probabilities are denoted by asterisks as: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[d] Traffic direction was for CA 71 only.

[e] Seasons were dispersal/breeding [(1 Sept-15 Dec)/(16 Dec-28 Feb)] and gestation/young rearing [(1 Mar-15 May)/(16 May-31 Aug)].

	YEAR/MONTH																											
	1997		1998												1999												2000	
CULV	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	**MO/C**
1						▨	▨	▨	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	21
2								▨	▨	▨	▨	▨	▨	▨		▨	▨		▨	▨	▨	▨	▨	▨				15
3	▨	▨						▨	▨	▨	▨								▨	▨								8
4		▨			▨	▨	▨	▨																				5
5								▨	▨	▨									▨	▨	▨							6
6	▨	▨	▨	▨	▨	▨	▨	▨		▨			▨	▨	▨	▨	▨			▨	▨	▨	▨	▨	▨	▨	▨	22
7								▨	▨		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	19
8		▨	▨	▨	▨	▨	▨	▨		▨	▨	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	24
9	▨	▨	▨	▨	▨	▨			▨	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	24
10									▨								▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	12
11												▨							▨	▨								3
12									▨			▨							▨	▨	▨							5
13									▨			▨							▨	▨								4
14	▨	▨	▨	▨	▨	▨	▨		▨	▨	▨	▨	▨	▨		▨	▨	▨										16
15					▨	▨		▨	▨																			4
16	▨	▨			▨	▨			▨	▨			▨	▨		▨	▨	▨						▨	▨	▨		14
17	▨	▨							▨	▨		▨	▨	▨	▨	▨		▨	▨	▨	▨							13
18	▨	▨	▨		▨			▨	▨		▨		▨			▨	▨	▨										11
24																▨	▨											2
25																▨	▨	▨	▨	▨								5
26																▨												1
27																▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	12
C/MO	7	9	5	4	8	8	5	10	14	10	8	9	9	9	5	14	13	11	14	15	11	8	8	9	8	8	7	

Figure 2.1. Monthly sampling effort per culvert along CA 71, San Bernardino and Riverside Counties, November 1997 to January 2000. MO/C pertains to the number of months that the culvert was sampled while C/MO pertains to the number of culverts sampled within that month. A month was shaded, which means sampled, regardless of the total number of days sampled within that month.

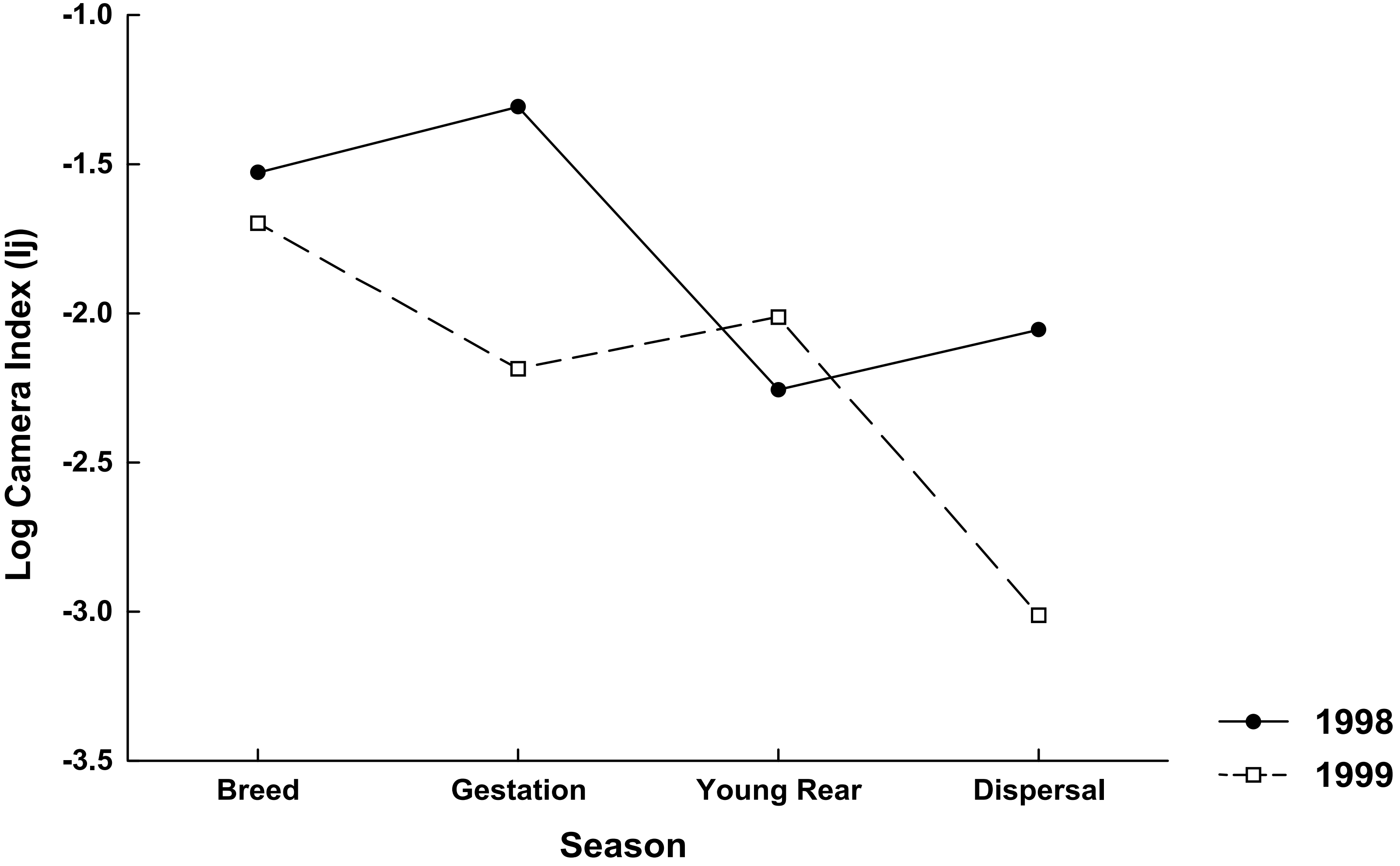


Figure 2.2. Mean frequency of underpass use between years and among seasons for coyotes in Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA. Yearly and seasonal differences are not significant (Table 2.4).

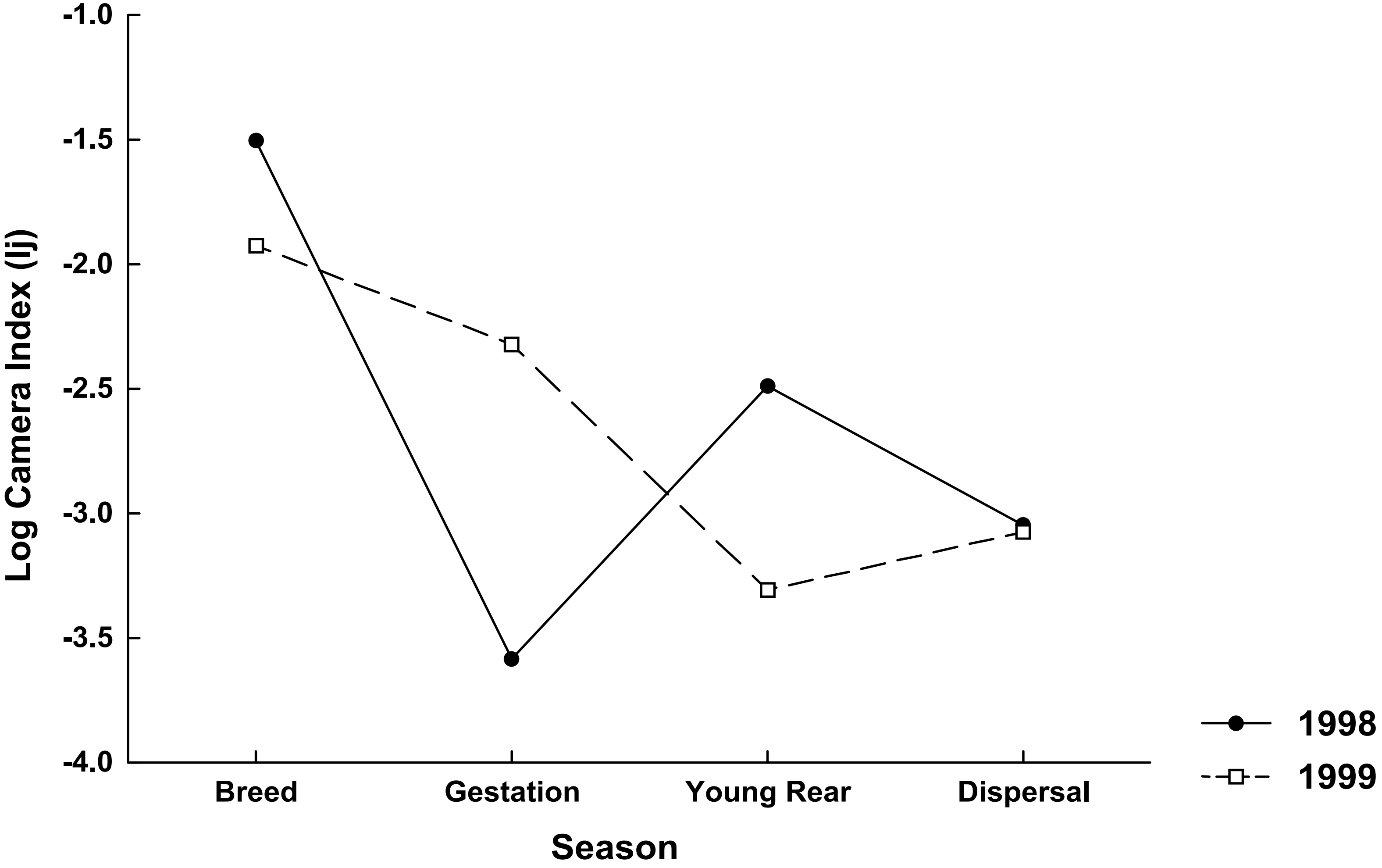


Figure 2.3. Mean frequency of underpass use between years and among seasons for bobcats in Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA. Yearly and seasonal differences are not significant (Table 2.4).

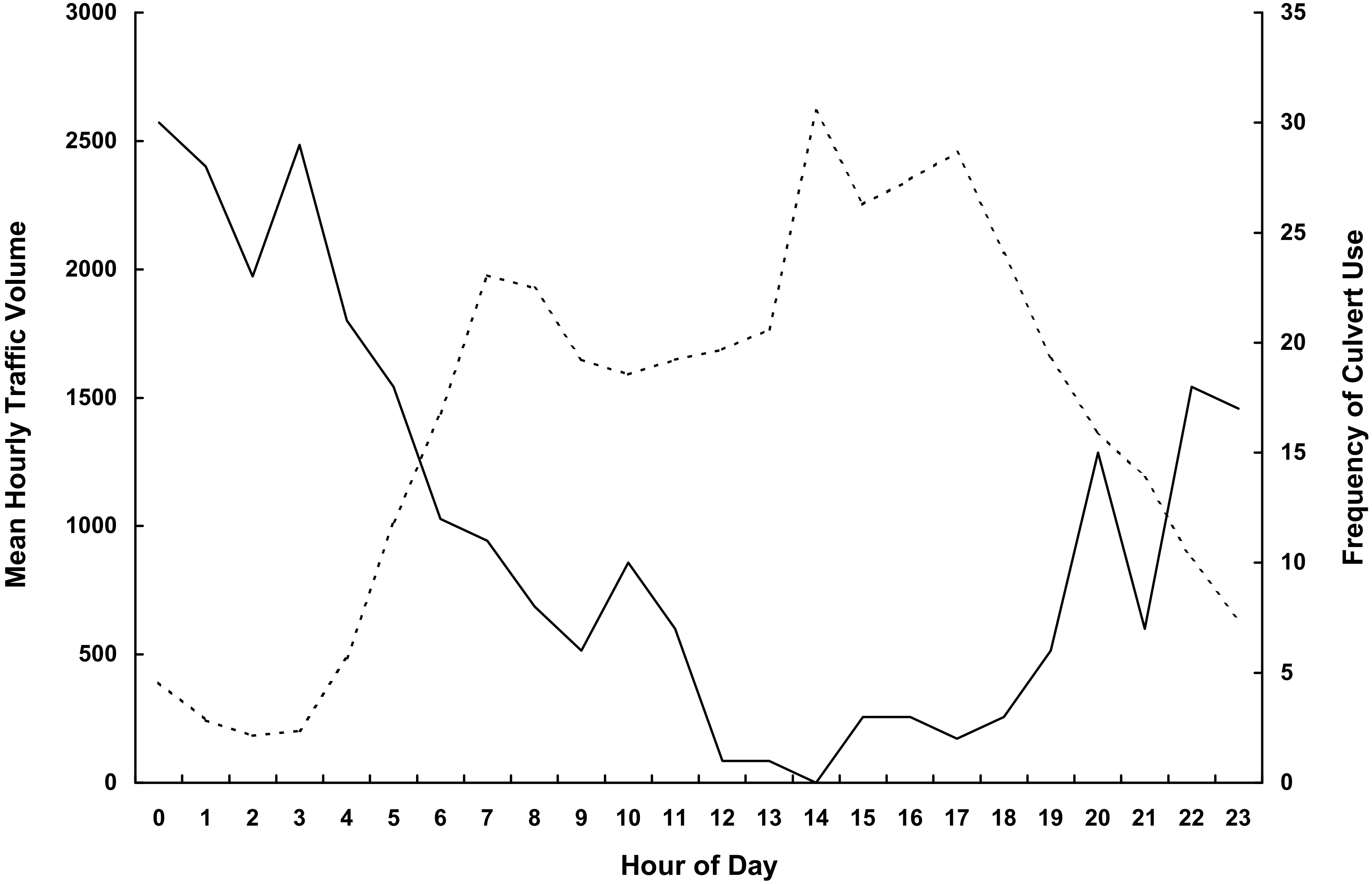


Figure 2.4. Hourly frequency of culvert use relative to mean hourly traffic (dashed) for coyotes (solid) in Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA. 279 coyote photographs were imprinted with the time stamp.

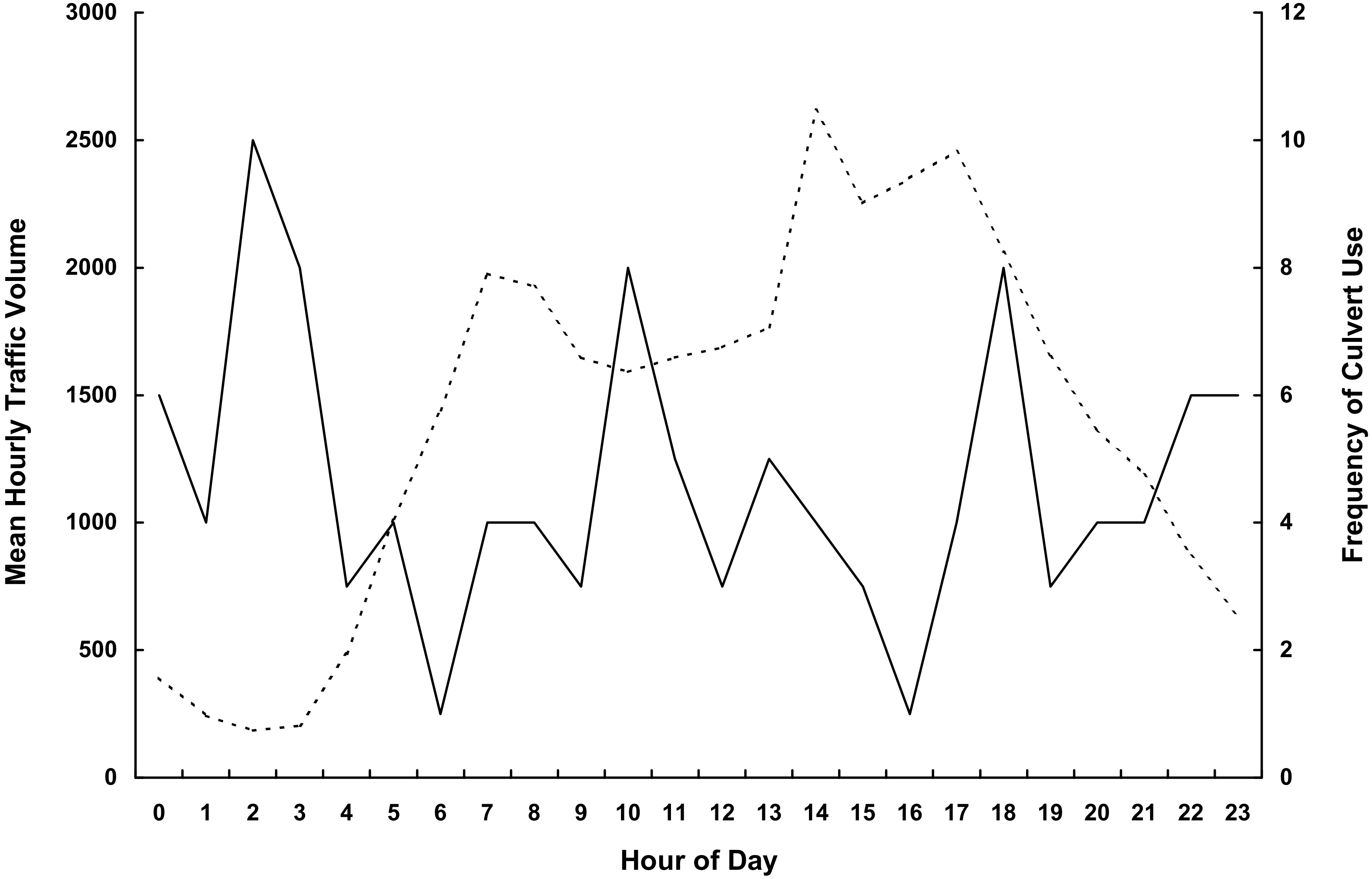


Figure 2.5. Hourly frequency of culvert use relative to mean hourly traffic (dashed) for bobcats (solid) in Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA. 111 bobcat photographs were imprinted with the time stamp.

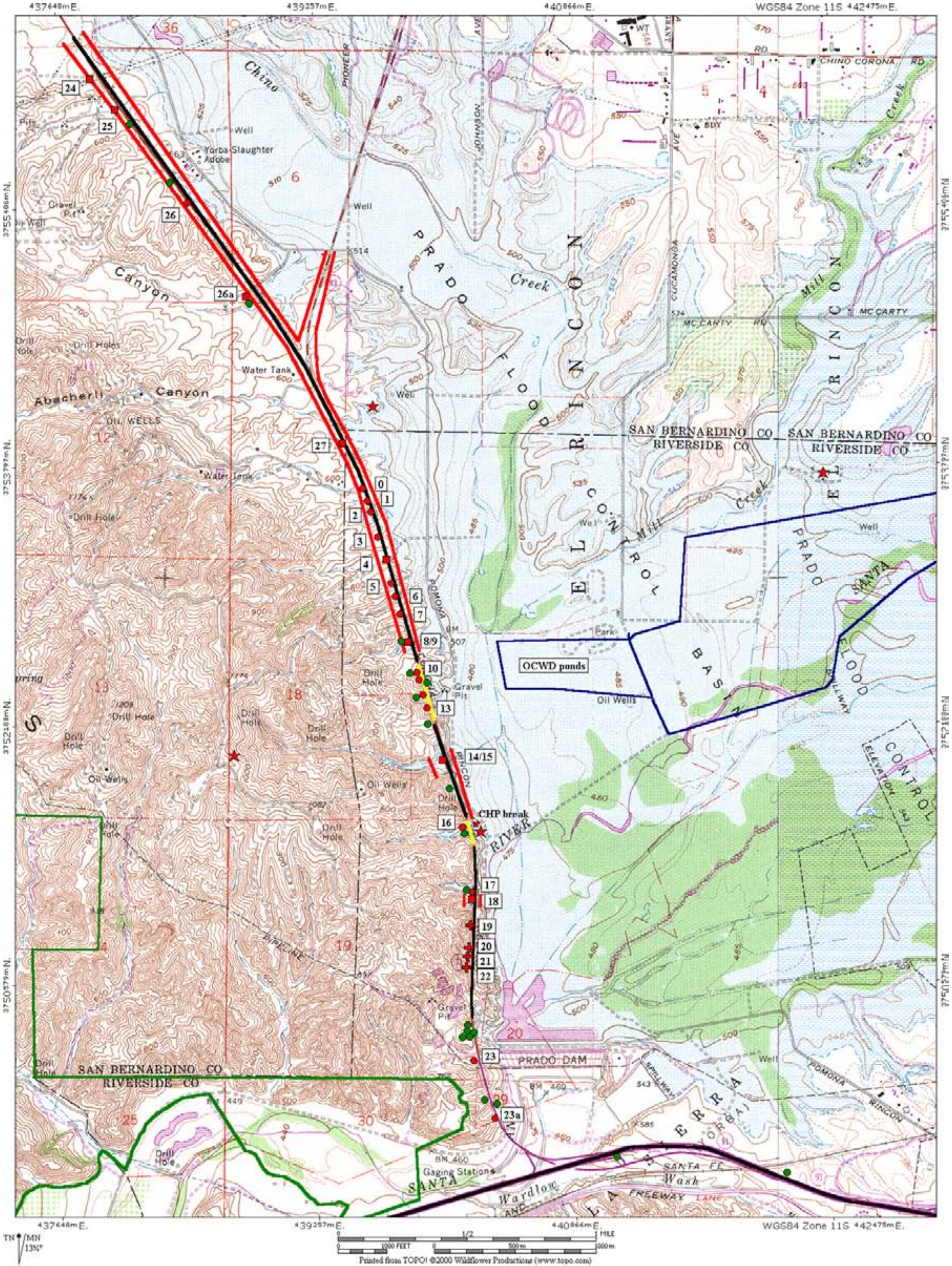


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Figure 2.6. Road kill locations (●) of coyotes (n = 20) along CA 71 and 91, November 1997 to January 2000. Locations are marked on the side of the road that indicates the appropriate traffic lane in which the individual was killed. The coyote killed at 26a was considered to have been killed where wildlife fencing was absent, as firefighters removed a large section of fencing to extinguish a fire. See Figure 1.2 (Chapter 1) for a description of the other map objects.

Appendix 1.1. Mean age, weight, and various body measurements of coyotes and bobcats grouped by species, age, and sex captured in the Chino Hills and Prado Basin, San Bernardino and Riverside Counties, CA, February 1998 to November 1998.

		Age (yrs)		Weight (kg)		Head (cm)[a]		Neck (cm)		Chest (cm)[b]		Body (cm)		Tail (cm)		Ear (cm)		Foot (cm)[c]	
Group	n	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
Coyote																			
Adu Male	12[d]	4.1	1.46	12.0	1.26	33.9	1.41	29.7	2.06	49.9	3.27	84.1	17.14	34.1	4.59	12.0	0.73	18.1	0.89
Adu Fem	13[e]	4.1	1.71	10.1	1.17	32.3	1.64	27.7	2.03	46.3	3.38	80.6	15.09	31.6	5.28	11.3	0.85	17.5	1.05
Yrlng Male	11[f]	1.6	0.32	11.2	1.36	33.3	2.32	28.5	2.33	45.3	3.77	90.8	8.00	31.7	1.96	12.0	0.58	17.7	1.06
Yrlng Fem	5[g]	1.9	0.11	10.2	1.36	32.1	0.45	27.4	0.81	44.6	2.21	85.5	3.85	29.1	2.21	11.0	0.35	17.8	1.07
Juv Male	5[h]	0.4	0.30	6.7	2.57	27.8	3.50	22.0	4.34	37.7	4.62	74.1	12.88	26.6	4.89	11.2	1.90	16.5	1.24
Juv Fem	7[i]	0.5	0.26	7.2	3.03	28.5	2.53	22.2	4.62	40.0	6.90	73.9	14.49	23.4	7.29	10.2	1.46	16.1	1.74
Bobcat																			
Adu Male	2	Adu[j]		9.1	0.64	28.6	1.70	22.0	0.28	40.8	0.21	76.0	3.39	17.2	0.49	7.4	0.64	16.2	0.72
Adu Fem	1	Adu[j]		6.2		27.0		21.6		NT[k]		NT		NT		NT		NT	
Juv Fem	1	Juv[j]		5.1		23.5		19.0		27.2		69.0		13.5		7.0		16.1	

[a] Head circumference measured over the widest part of the skull at the zygomatic arches.

[b] Chest circumference measured during inhalation.

[c] Hind foot length.

[d] Sample size differed for Tail (n=11) and Ear (n=10) measurements.

[e] Sample sized differed for Ear (n=9) measurements.

[f] Sample size differed for Weight (n=9); Chest, Body, Tail, and Foot (n=10); and Ear (n=8) measurements.

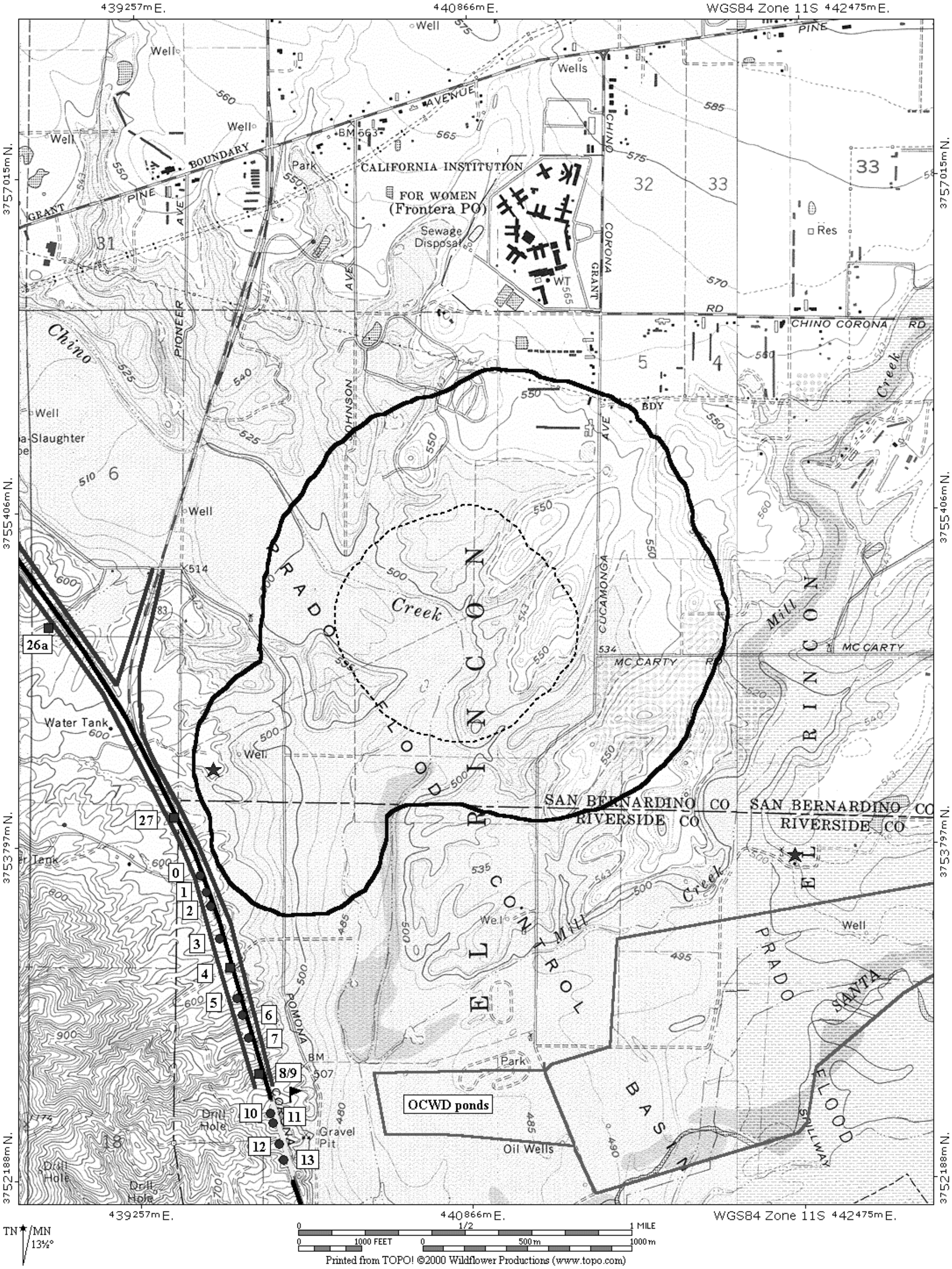
[g] Sample size differed for Weight, Head, Chest, Body, Tail, and Foot (n=3); Neck (n=4); and Ear (n=2) measurements.

[h] Sample size differed for Ear (n=4) measurements.

[i] Sample size differed for Ear (n=6) measurements.

[j] Bobcats were not aged to a specific year, but merely classified as either adult or juvenile.

[k] NT indicates the measurement was not taken.



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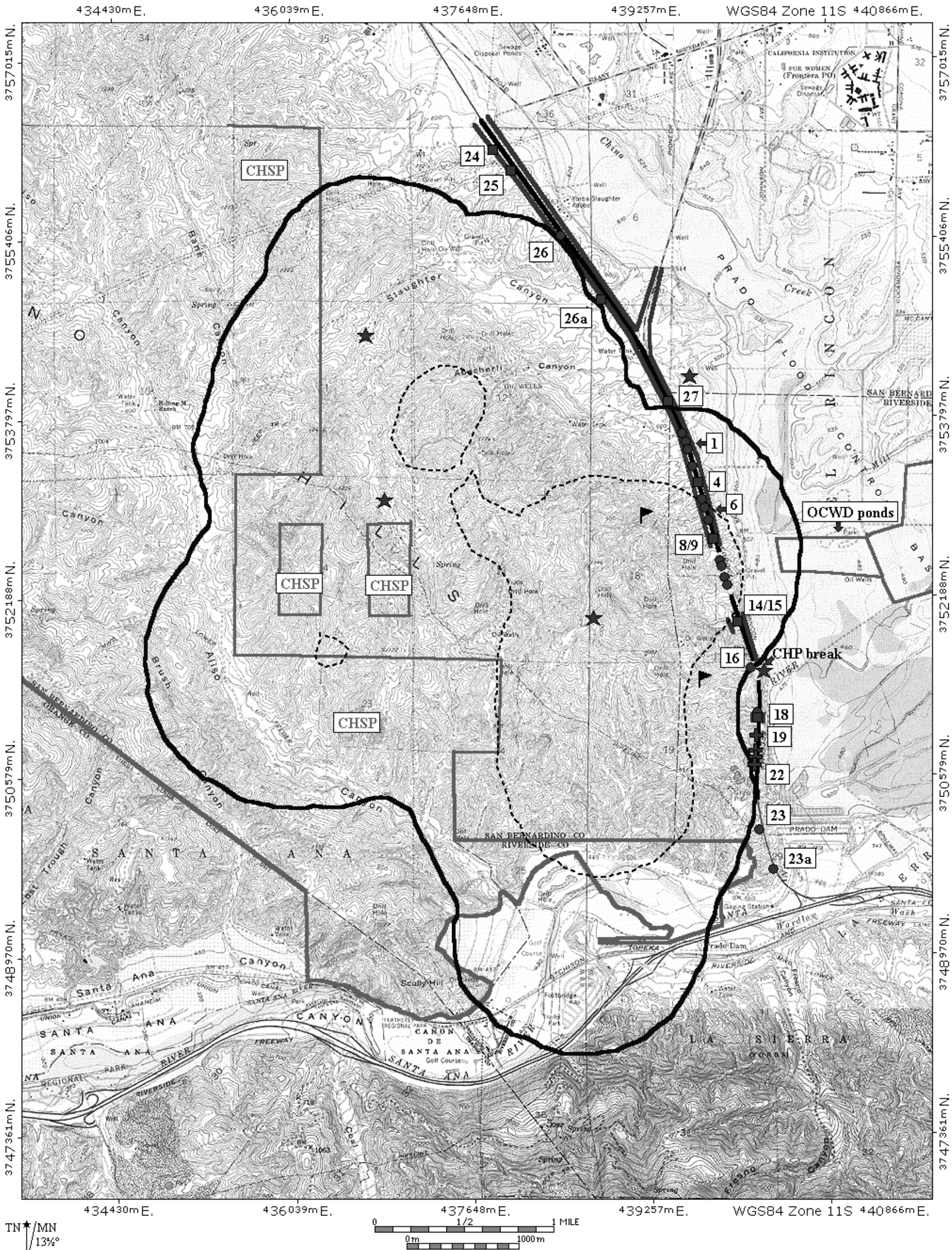
Appendix 1.2. 95% adaptive kernel home range (▬) and 50% adaptive kernel core-use area (········) for C1 from February 1998 to March 1999. Capture location (n = 1) is marked by a flag near culverts 8/9. AO curve did not asymptote.



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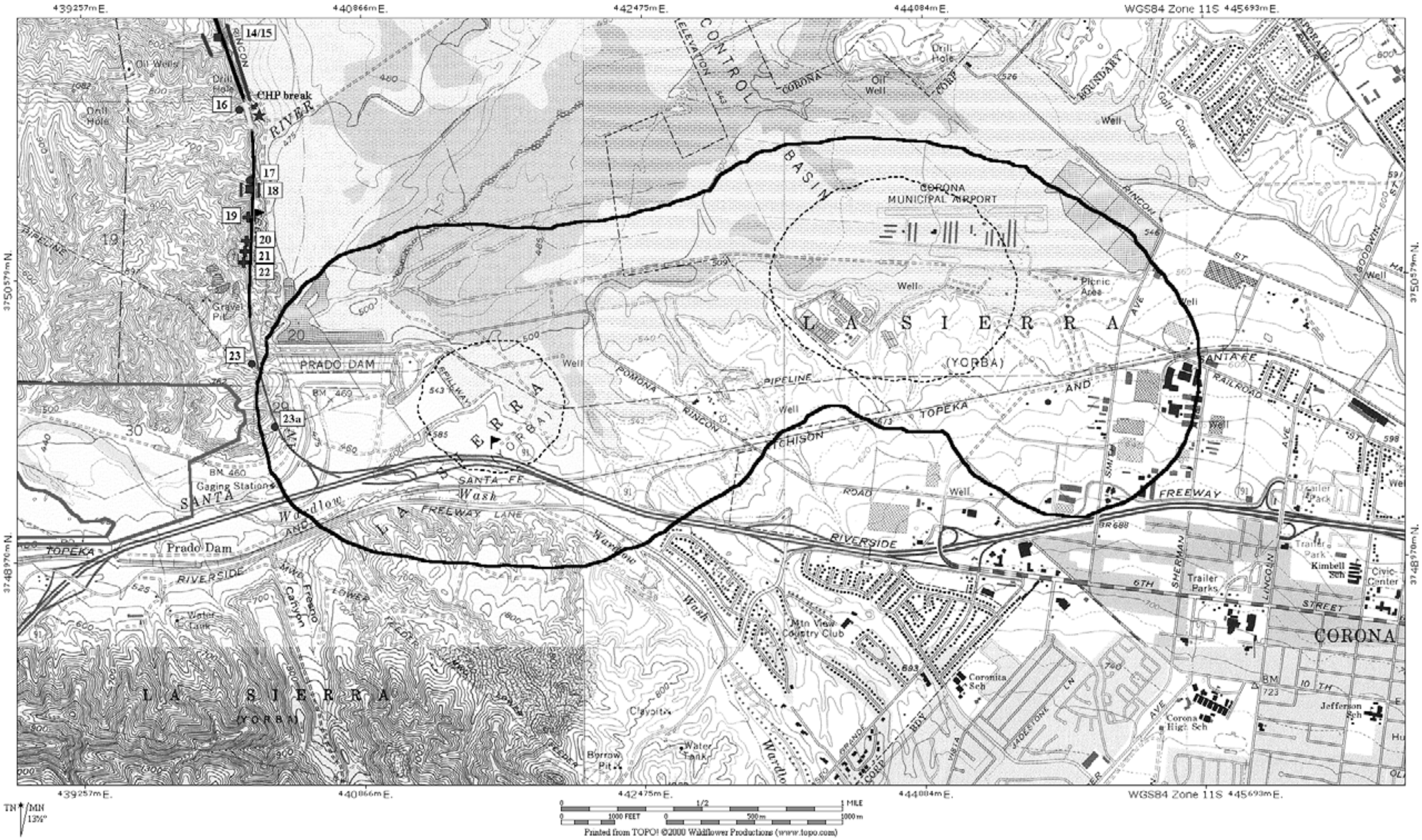
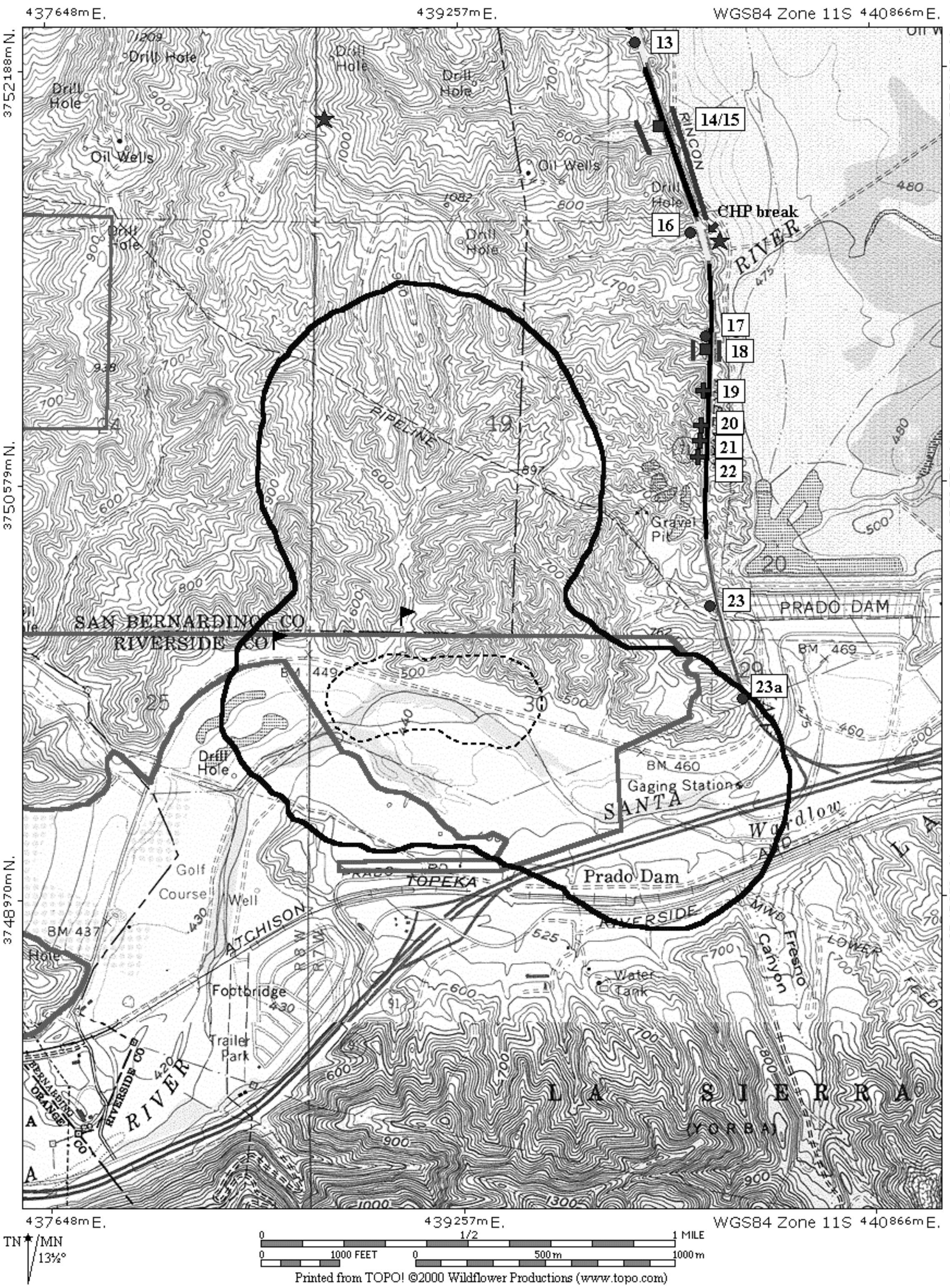
Appendix 1.3. 95% adaptive kernel home range (━━━) and 50% adaptive kernel core-use area (┅┅┅) for C3 from February 1998 to February 2000. Capture locations (n = 2) are marked by flags. AO curve did not asymptote.



Appendix 1.4. 95% adaptive kernel home range (▬▬) and 50% adaptive kernel core-use area (┈┈┈) for C4 from February 1998 to November 1999. Capture locations (n = 2) are marked by flags. The location outside of the polygons is directly east of culvert 19.



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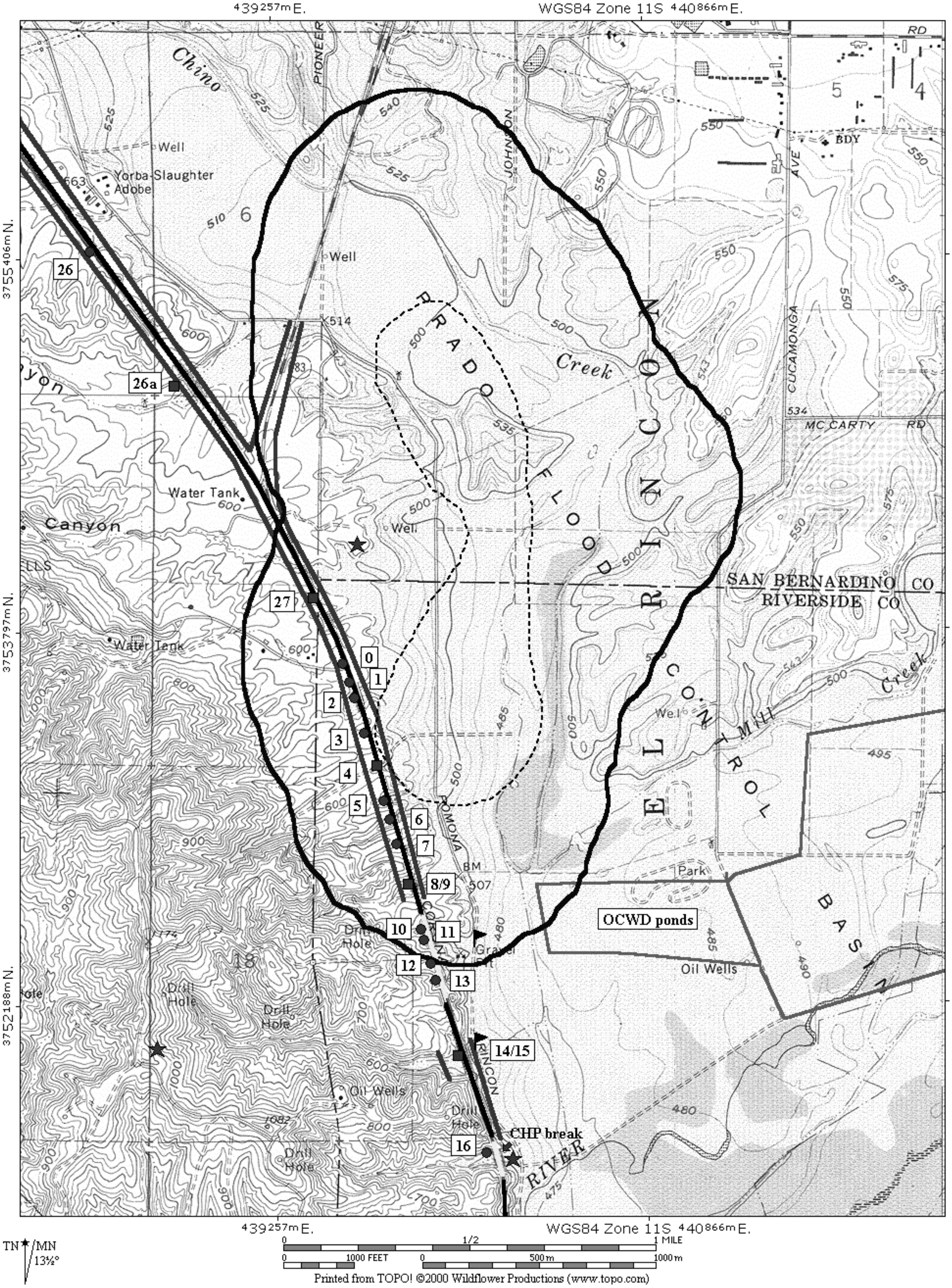
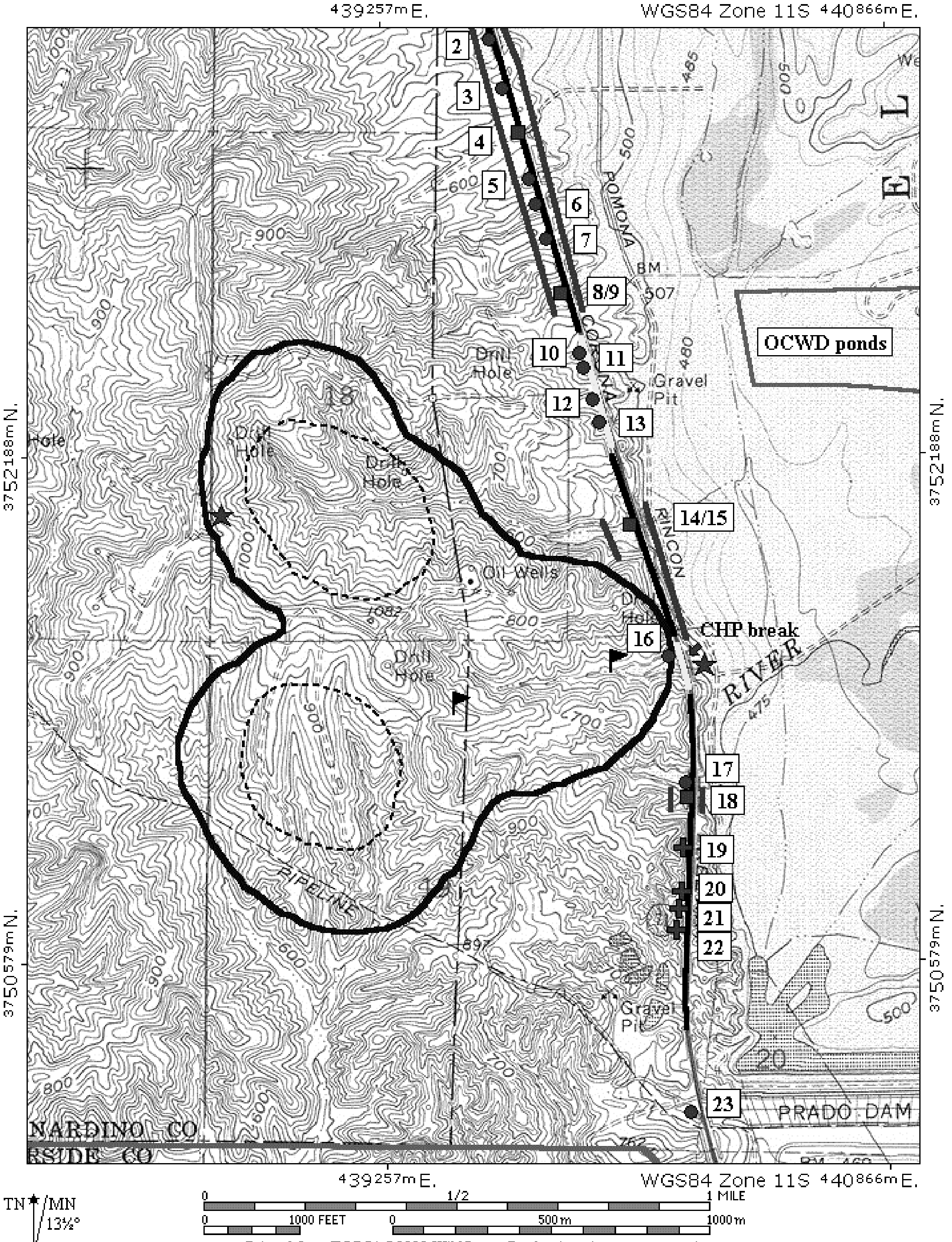
Appendix 1.5. 95% adaptive kernel home range (▬) and 50% adaptive kernel core-use area (┅) for C6 from February 1998 to January 2000. Capture locations (n = 2) are marked by flags.



Appendix 1.6. 95% adaptive kernel home range (▬) and 50% adaptive kernel core-use area (·······) for C7 from February 1998 to January 2000. Capture locations (n = 2) are marked by flags. The location outside of the polygons is near culverts 14/15.



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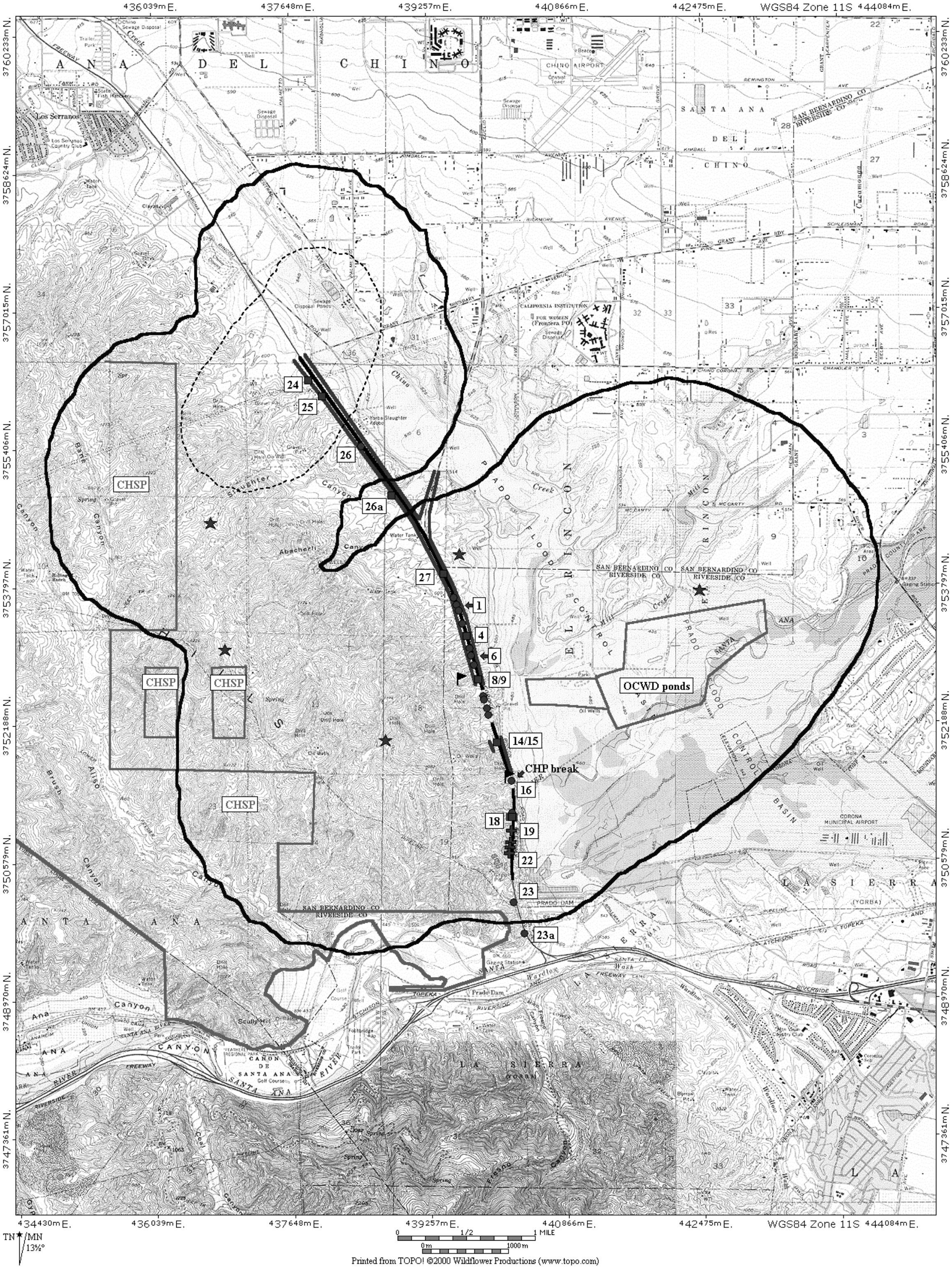
Appendix 1.7. 95% adaptive kernel home range (━━━) and 50% adaptive kernel core-use area (┅┅┅) for C8 from February 1998 to December 1999. Capture locations (n = 2) are marked by flags.



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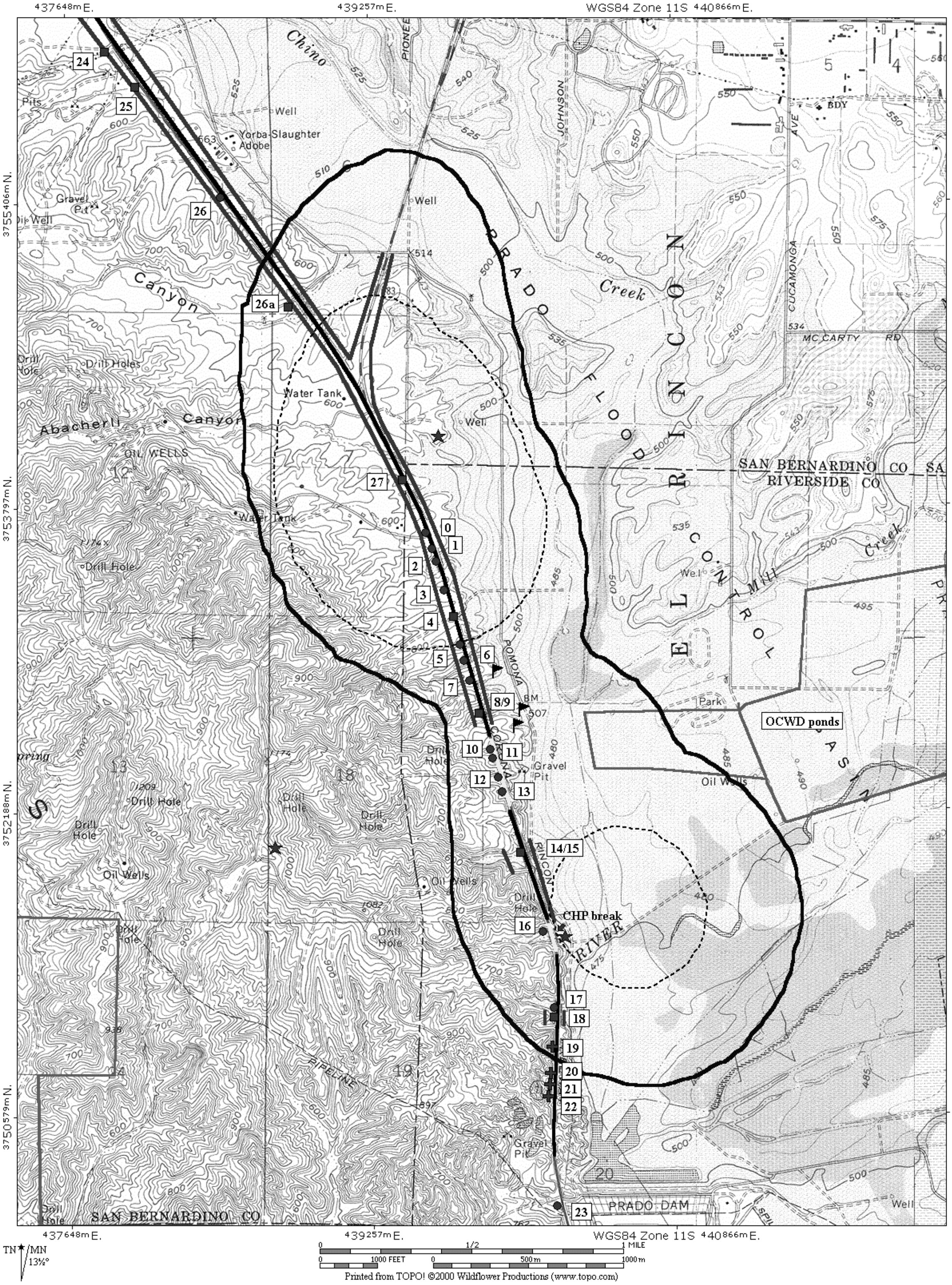
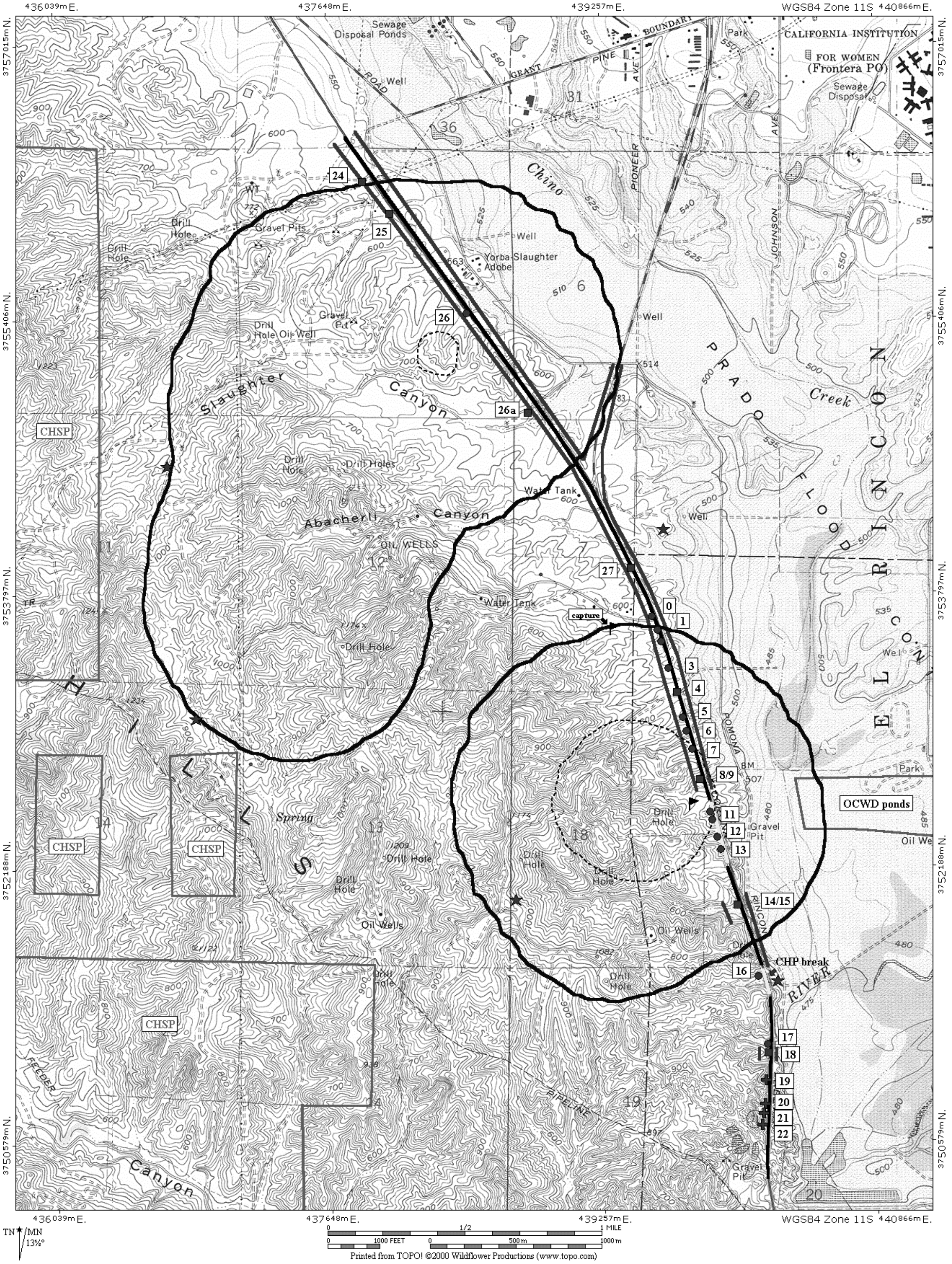
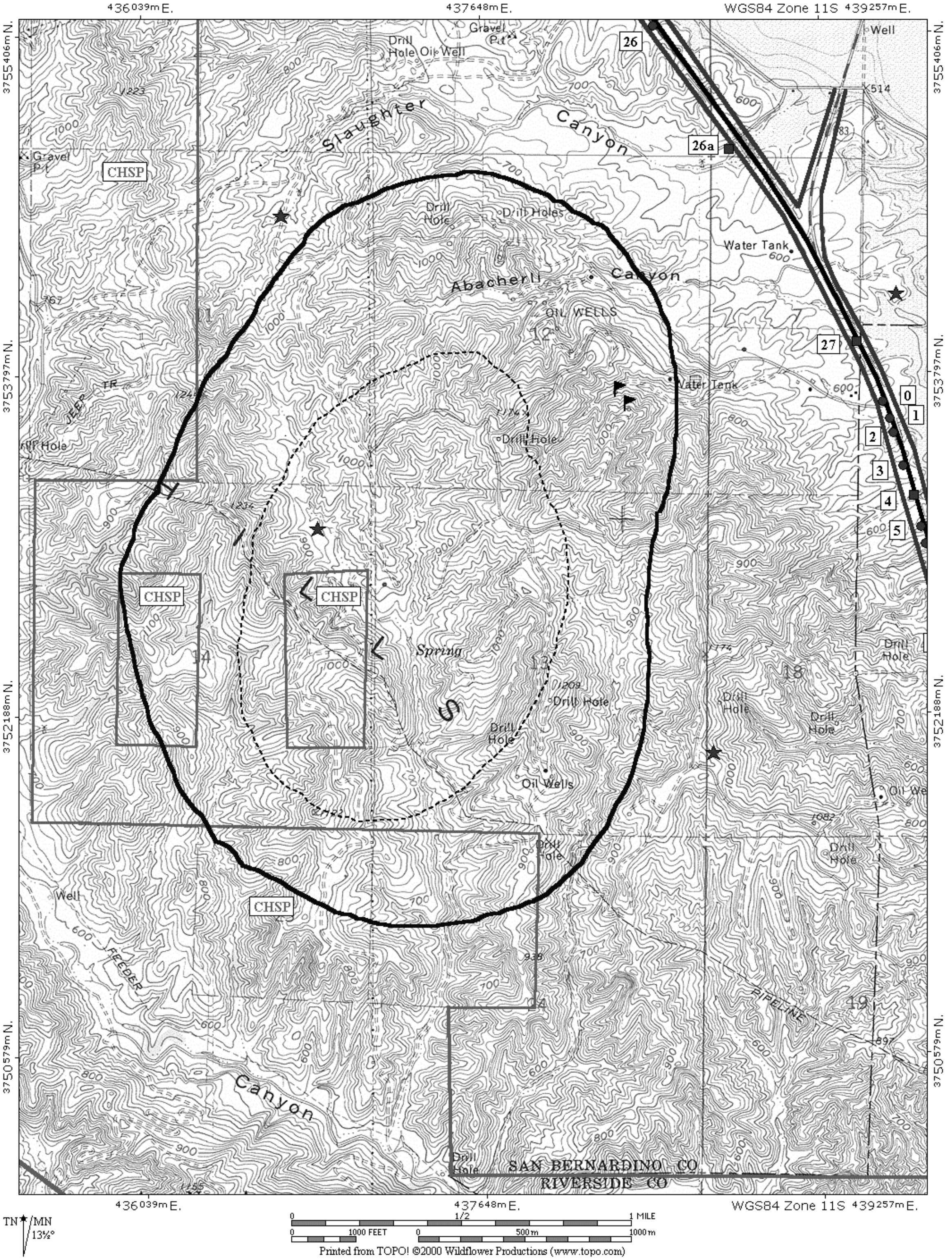
Appendix 1.8. 95% adaptive kernel home range (━━━━) and 50% adaptive kernel core-use area (┅┅┅┅) for C9 from February 1998 to January 2000. Capture locations (n = 2) are marked by flags. One location is directly west of culvert 16 while the other is near culverts 8/9.



Appendix 1.9. 95% adaptive kernel home range (▬) and 50% adaptive kernel core-use area (┅) for C17 from March 1998 to May 1999. Capture locations (n = 3) are marked by flags.



Appendix 1.10. 95% adaptive kernel home range (▬) and 50% adaptive kernel core-use area (┅) for C26 from June 1998 to October 1999. Capture locations (n = 2) are marked by flags. One location is near culvert 1 on the polygon boundary.



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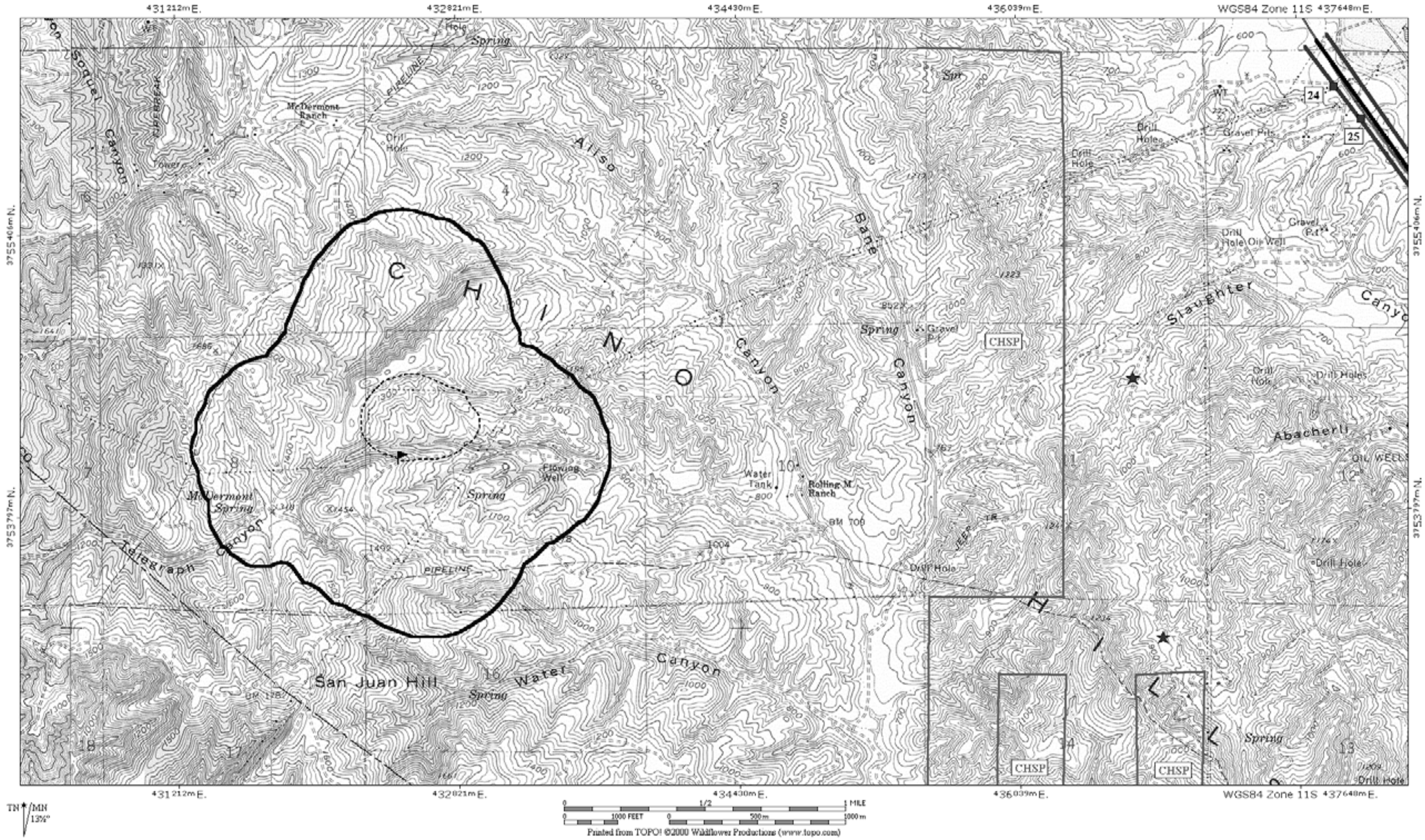
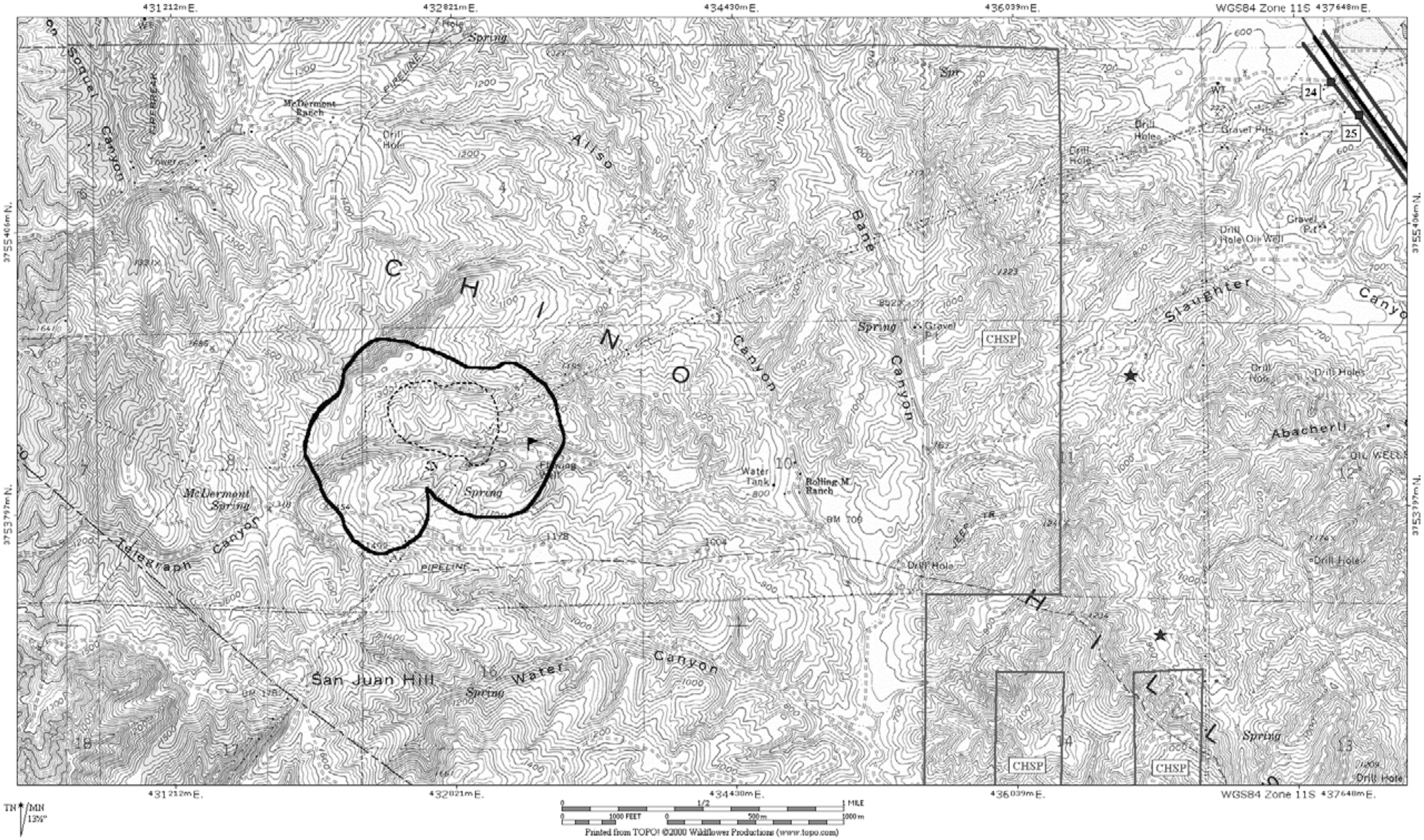
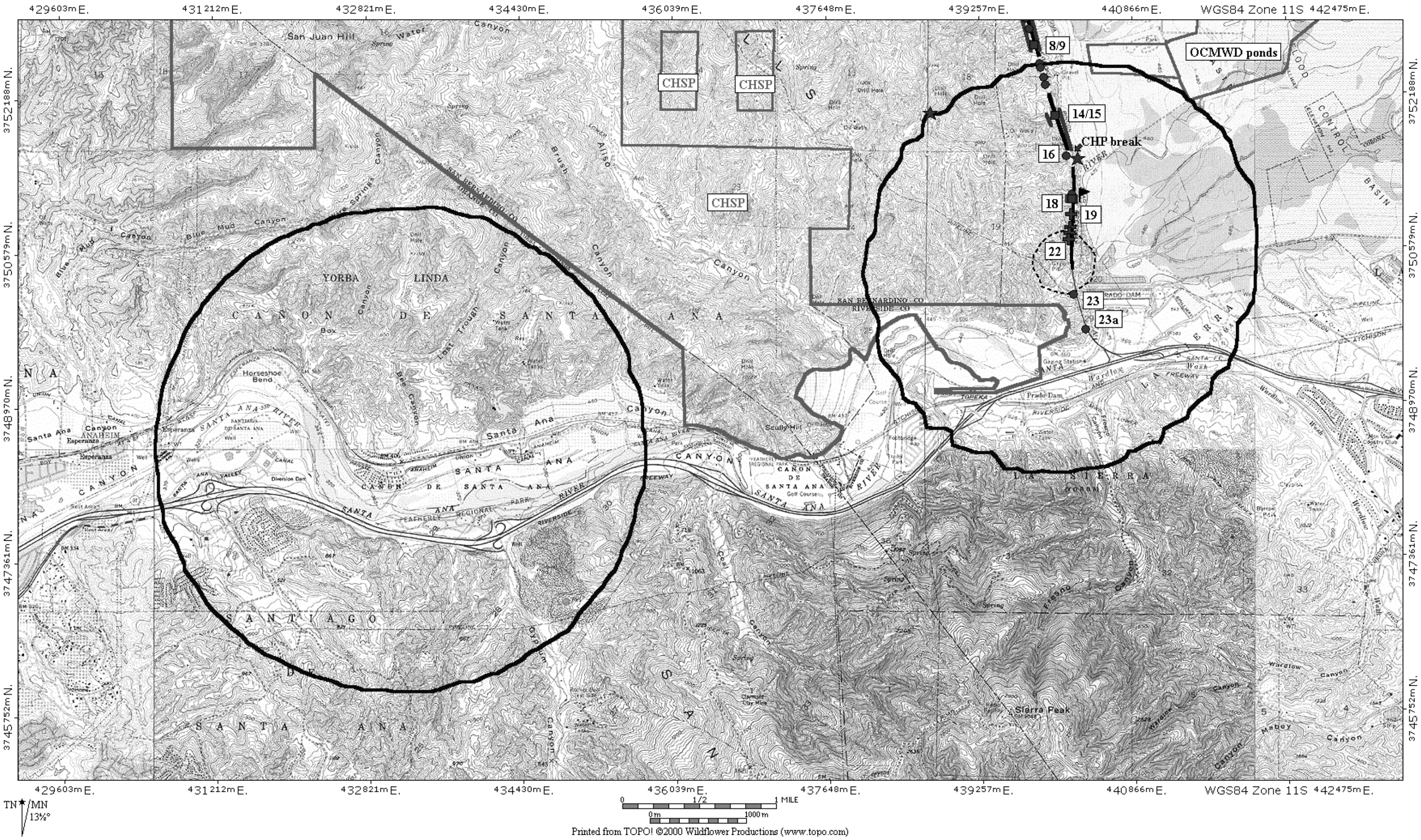
Appendix 1.11. 95% adaptive kernel home range (━) and 50% adaptive kernel core-use area (⋯) for C32 from June 1998 to January 2000. Capture locations (n = 2) are marked by flags. AO curve did not asymptote.



Appendix 1.12. 95% adaptive kernel home range (▬) and 50% adaptive kernel core-use area (……) for C38 from July 1998 to August 1999. Capture location (n = 1) is marked by a flag. AO curve did not asymptote.



Appendix 1.13. 95% adaptive kernel home range (▬) and 50% adaptive kernel core-use area (⋯⋯) for C39 from July 1998 to August 1999. Capture location (n = 1) is marked by a flag.



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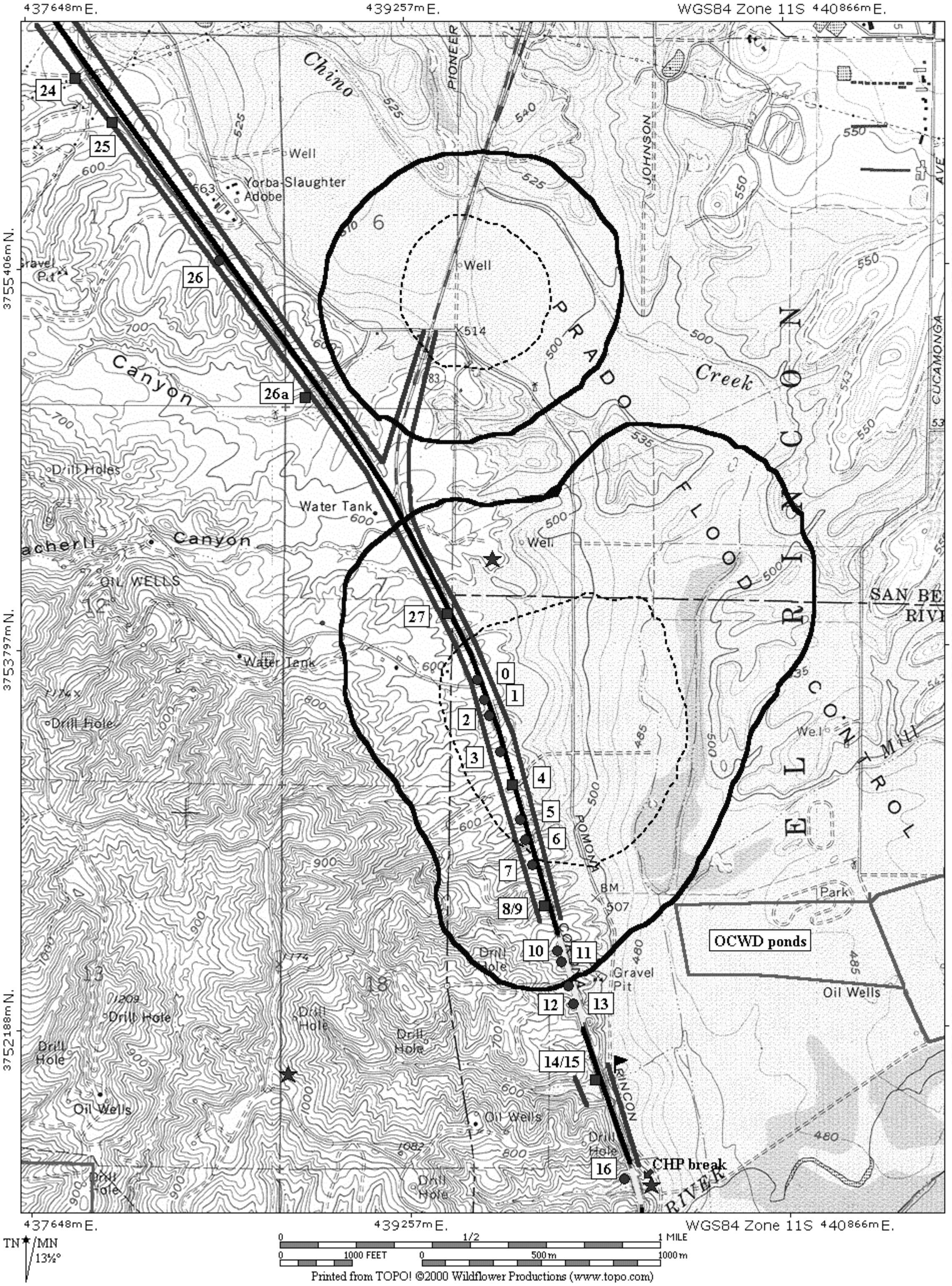
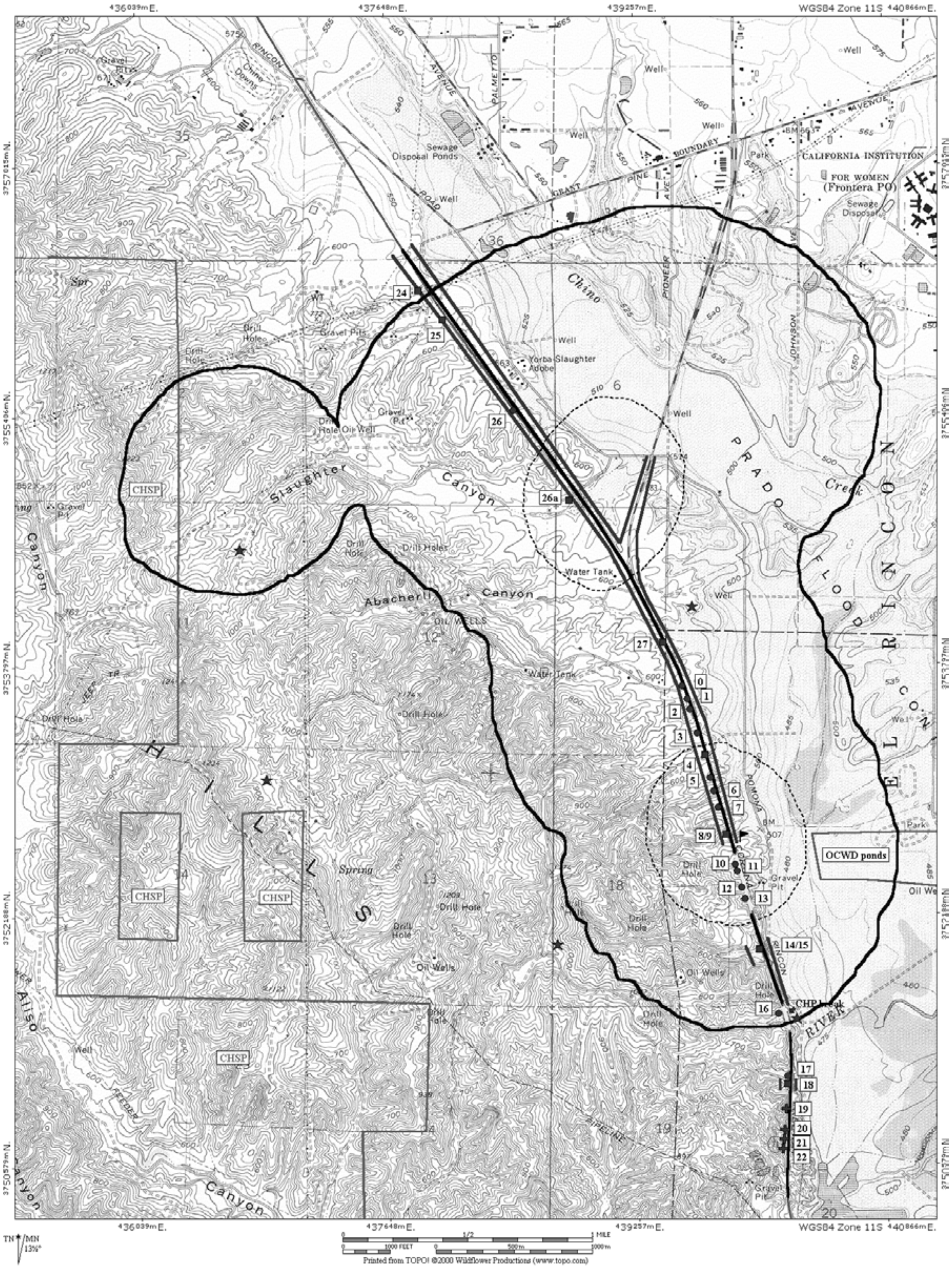
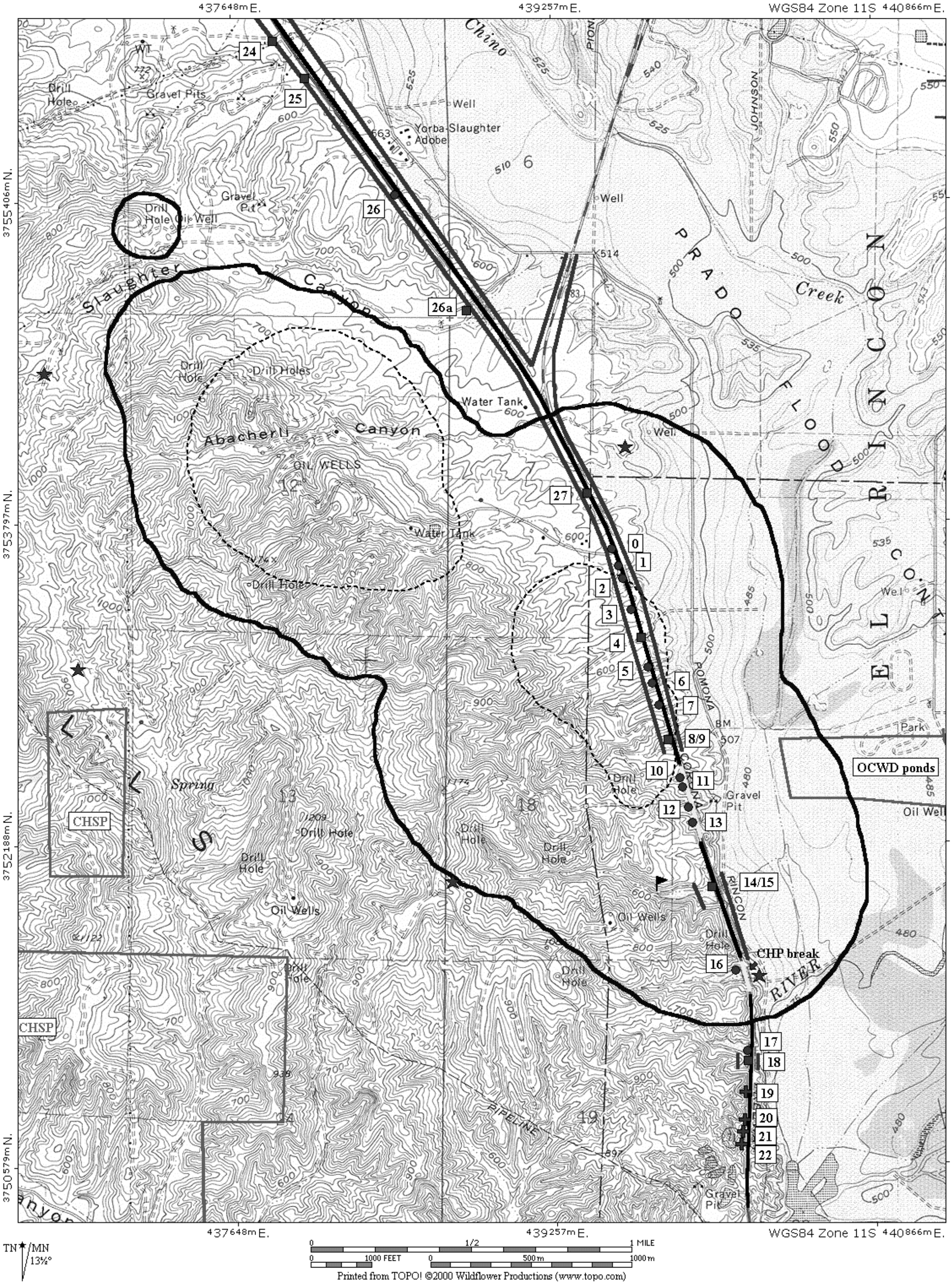
Appendix 1.14. 95% adaptive kernel home range (▬) and 50% adaptive kernel core-use area (⋯⋯) for C43 from October 1998 to May 1999. Capture location (n = 1) is marked by a flag directly east of culverts 17 and 18.



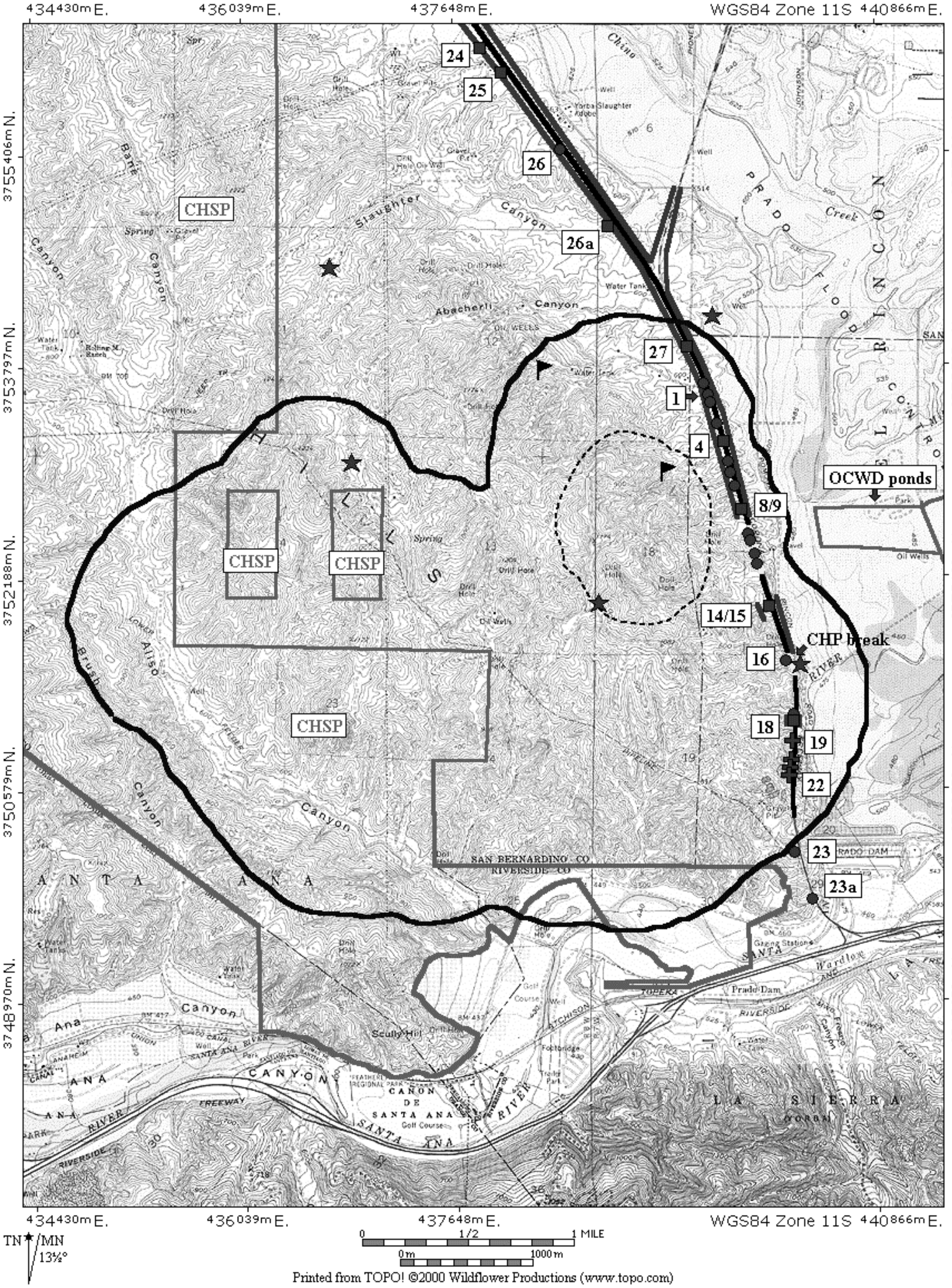
Appendix 1.15. 95% adaptive kernel home range (▬) and 50% adaptive kernel core-use area (┈┈) for C44 from October 1998 to July 1999. Capture location (n = 1) is marked by a flag near culverts 14/15.



Appendix 1.16. 95% adaptive kernel home range (▬) and 50% adaptive kernel core-use area (┅) for C52 from October 1998 to June 1999. Capture location (n = 1) is marked by a flag east of culverts 8/9.



Appendix 1.17. 95% adaptive kernel home range (▬▬) and 50% adaptive kernel core-use area (⋯⋯) for B1 from February 1998 to November 1999. Capture location (n = 1) is marked by a flag.



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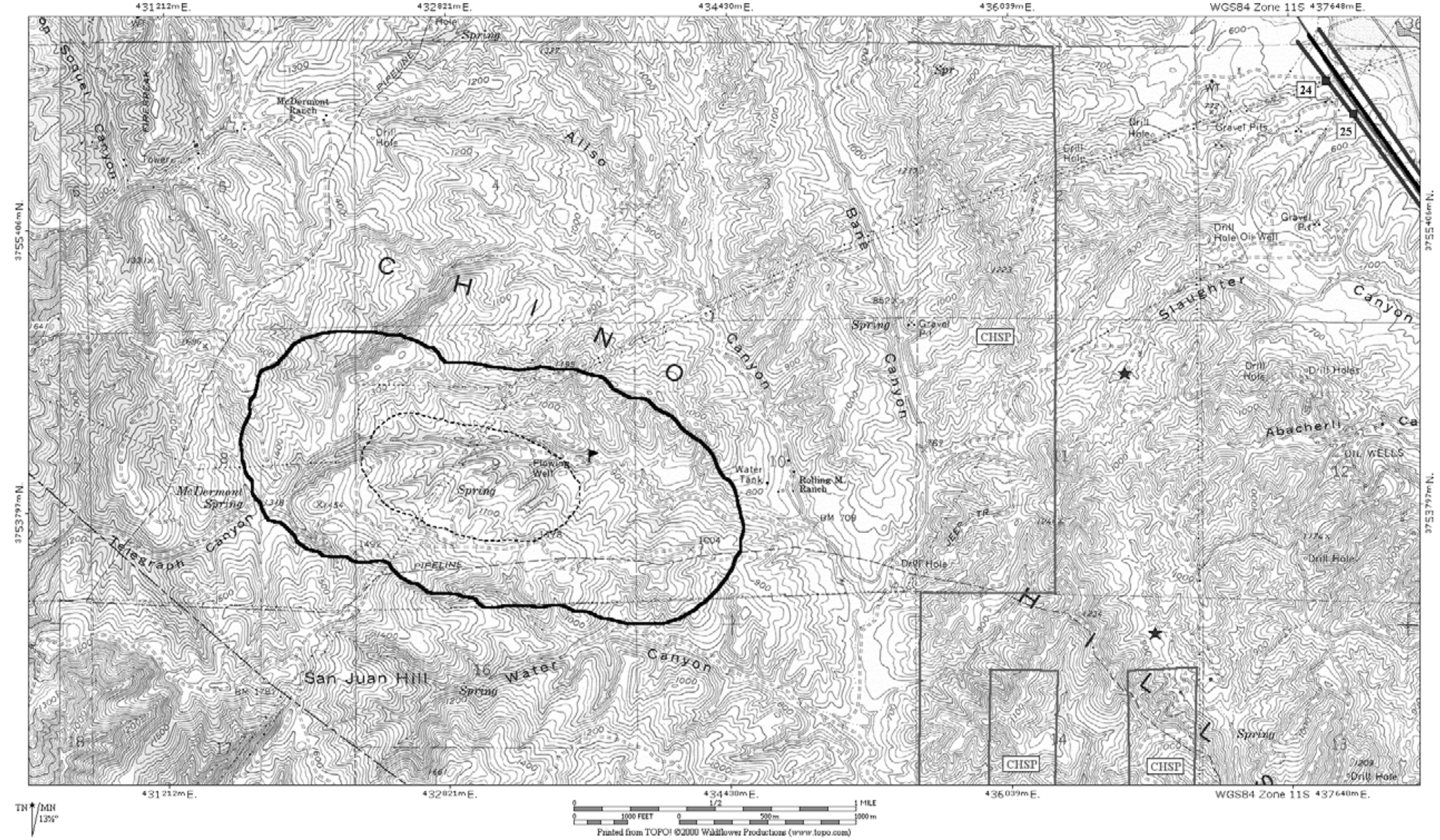
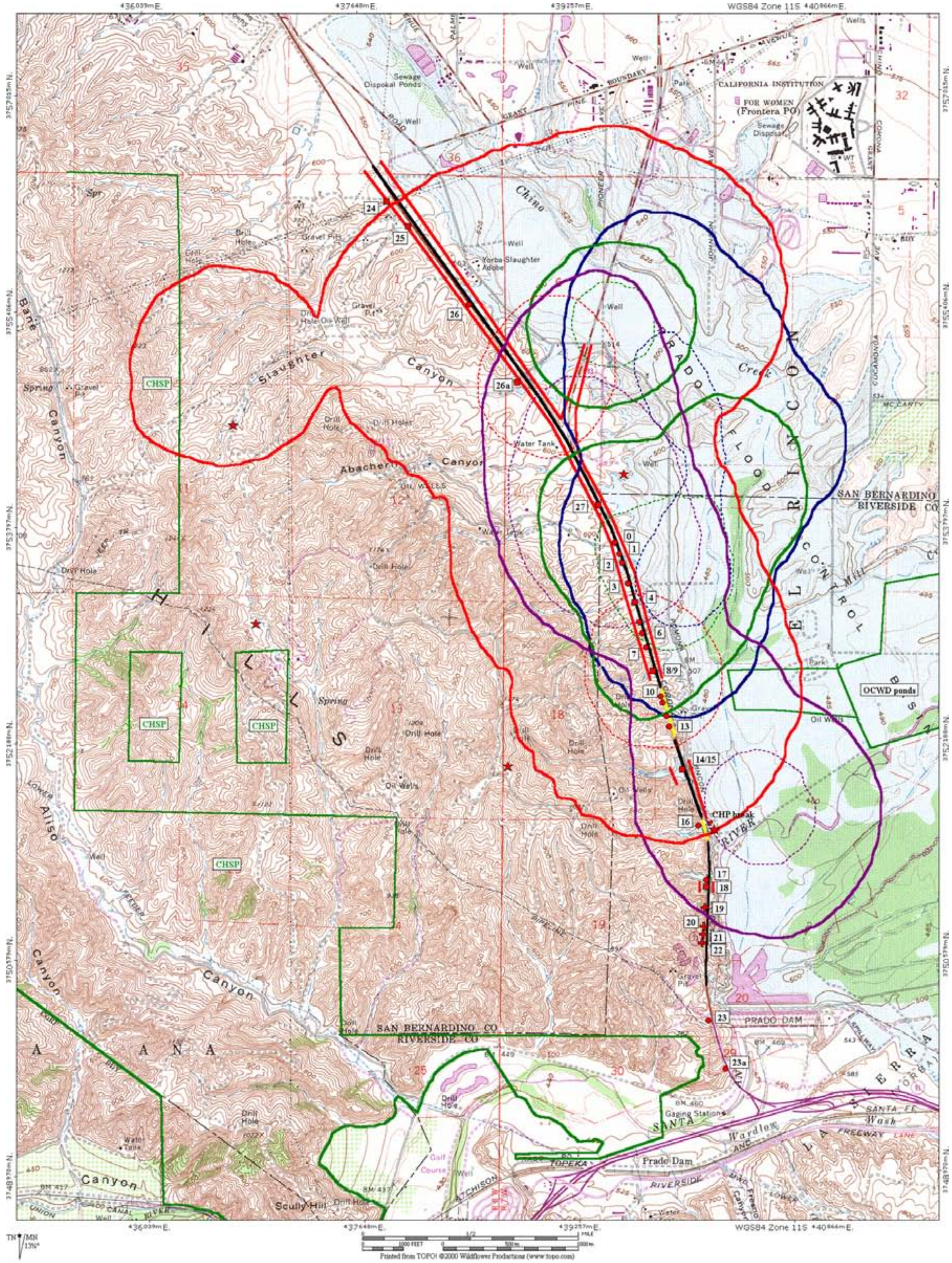
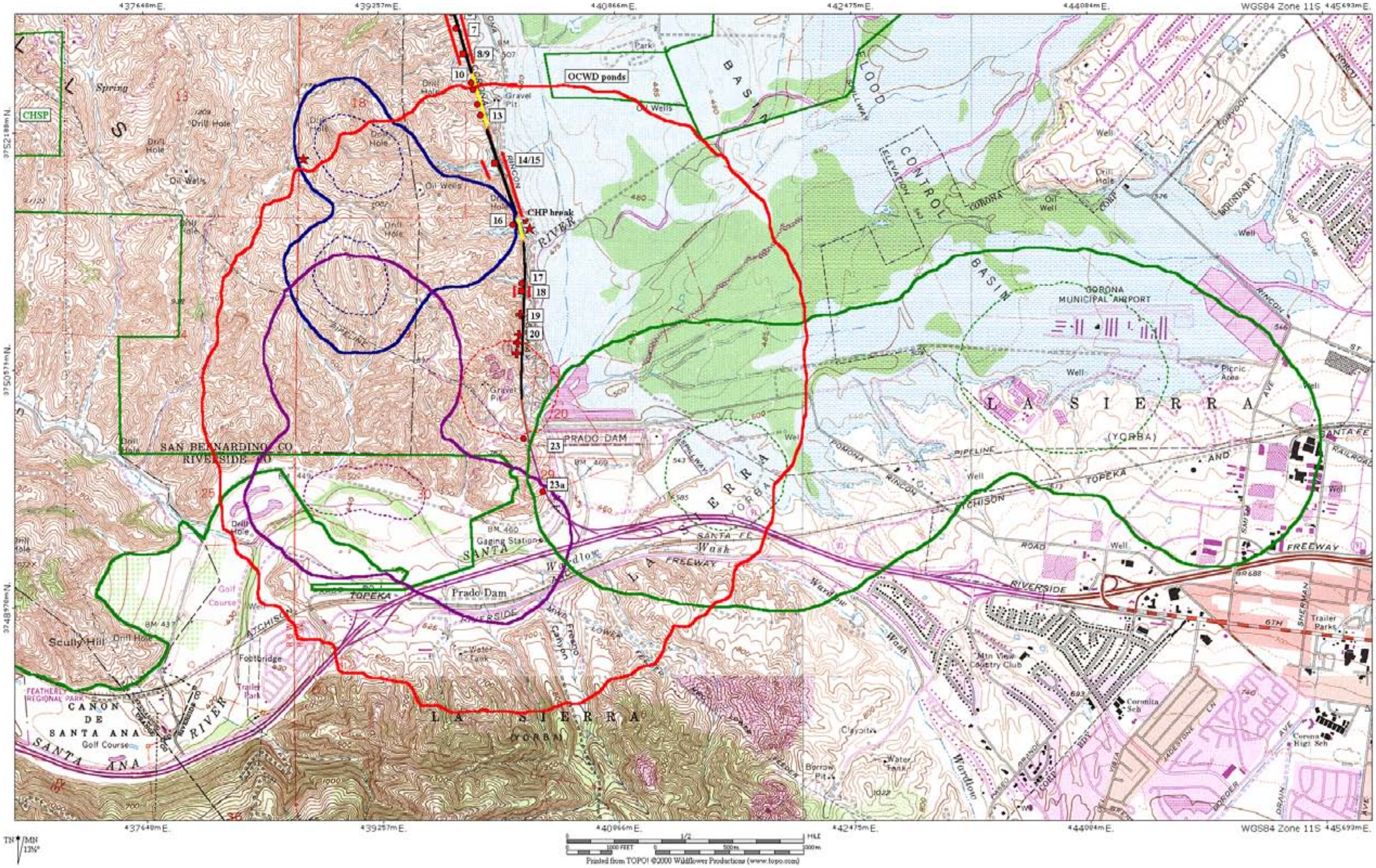
Appendix 1.18. 95% adaptive kernel home range (▬▬▬) and 50% adaptive kernel core-use area (········) for B3 from June 1998 to December 1999. Capture locations (n = 2) are marked by flags.



Appendix 1.19. 95% adaptive kernel home range (▬) and 50% adaptive kernel core-use area (┈┈┈) for B4 from July 1998 to February 2000. Capture location (n = 1) is marked by a flag. AO curve did not asymptote.



Appendix 1.20. 95% adaptive kernel home range (solid) and 50% adaptive kernel core-use area (dashed) for C7 (blue), C17 (purple), C44 (green), and C52 (red) from February 1998 to January 2000 in the Chino Hills and Prado Basin.



Appendix 1.21. 95% adaptive kernel home range (solid) and 50% adaptive kernel core-use area (dashed) for C4 (green), C6 (purple), C8 (blue), and C43 (red) from February 1998 to January 2000 in the Chino Hills and Prado Basin.