Carnivore Activity and Movement in a Southern California Protected Area, the North/Central Irvine Ranch

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U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER

Carnivore Activity and Movement in a Southern California Protected Area, the North/Central Irvine Ranch

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Carnivore Activity and Movement in a Southern California Protected Area, the North/Central Irvine Ranch

Abstract

Connectivity and wildlife corridors are essential for biodiversity conservation in fragmented landscapes, and large carnivores are ecologically pivotal species whose status can be indicative of functional connectivity of ecosystems. Our primary research goals were 1) to assess movement patterns of wildlife in the North/Central Irvine Ranch (NIR), with a focus on large carnivores, and 2) to identify and monitor key movement corridors for large carnivores near potential arterial roads that are proposed to cross the NIR, including the Jamboree Road extension and North Lake Road construction. In Phase 1 (summer 2002-fall 2003), we completed track and remotely-triggered camera surveys to evaluate distribution, relative abundance, and movement patterns of wildlife species. Track and camera transects detected nine wildlife species each throughout the study area, including the three target species [(mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), coyote (*Canis latrans*)] as well as six non-target species [(mule deer (*Odocoileus hemionus*), gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), spotted skunk (*Spilogale gracilis*), and the non-native opossum (*Didelphis virginiana*)]. Track and camera surveys also detected various human recreationists, as well as domestic animals including dogs (*Canis familiaris*) and horses (*Equus caballus*). In addition, we conducted GPS (Global Positioning System) radio telemetry surveys on 10 bobcats, 6 males and 4 females, within the study area. In Phase 2 (fall 2003-summer 2005), we conducted radio telemetry surveys on six more bobcats, two males and four females, within the study area. In addition, we carried out radio telemetry surveys on three adult female mountain lions. With the exception of one mountain lion, we successfully retrieved all collars and downloaded the stored location data. In total, we recorded 4469 high-resolution GPS locations for bobcats ($\overline{X}$ = 279 locations; range = 181 to 359 locations per individual) and 3118 GPS locations for mountain lions ($\overline{X}$ = 1039 locations; range = 371 to 1637 locations per individual). Mountain lions, and to a lesser extent bobcats, traveled widely throughout the study area; the 100% Minimum Convex Polygon (MCP) and 95% Fixed Kernel (FK) home range sizes for bobcats ranged from 1.54 to 9.42 km^2 ($\overline{X}$ = 3.62 ± 0.56 SE) and 1.34 to 13.39 km^2 ($\overline{X}$ = 3.72 ± 0.35 SE), respectively, and the 100% MCP and 95% FK home range sizes for mountain lions ranged from 97 to 181 km^2 ($\overline{X}$ = 132 ± 25.3 SE) and 83 to 125 km^2 ($\overline{X}$ = 105.4 ± 12.4 SE), respectively. Mountain lions and bobcats frequently encountered potential barriers such as urban edges and roadways. Indeed, although we recorded mountain lion and bobcat use of existing underpasses along CA-241 and Santiago Canyon Road, two of the GPS radio collared mountain lions were killed by vehicles while attempting to cross these roadways. Overall, core habitat blocks within the NIR appear to serve as critical components of a network of wildlands in the region, and with continued urban development and road construction in the area, it is critical to maintain and restore connectivity within and outside the NIR to ensure long-term persistence of carnivore populations and the systems in which they live.

Introduction

Habitat fragmentation is one of the principle threats to biodiversity (Wilcove et al., 1998), and in developing landscapes, urbanization is a leading agent of fragmentation and primary cause of species endangerment (Soulé, 1991; Czech et al., 2000). Such is the case in coastal southern California, one of the largest megalopolitan regions in North America, stretching from Santa Barbara and Los Angeles in the north through San Diego (and Tijuana) in the south. The six counties of coastal southern California contain about 25% of California's land area, but as of 2000 contained nearly 20 million people, about 60% of the state's population. From 1990 to 2000, the population of Riverside County increased by 32%, San Bernardino County by 20%, Orange County by 18%, San Diego and Ventura Counties by 13%, and Santa Barbara and Los Angeles Counties by 7-8% (U. S. Census Bureau, 2000). As might be expected, the dramatic growth of human populations and the resulting sprawl have severely fragmented native habitat in coastal southern California. Development over the past century has destroyed all but 10% of the native Mediterranean coastal sage scrub habitat (McCaull, 1994), with many of the remaining remnants of natural areas persisting as habitat islands immersed within a vast urban sea. The California south coast is one of the world's "hot-spots" of native biodiversity supporting many endemic species occurring nowhere else in the world (Myers, 1990; Wilcove et al., 1998). This rich biodiversity, coupled with massive human population growth and associated environmental impacts, has helped create an epicenter of endangerment and extinction in the region (Myers, 1990; Dobson et al., 1997; Wilcove et al., 1998;).

Preservation of landscape-level connectivity undoubtedly strengthens efforts to protect wildlife and their habitats in developing landscapes (Crooks & Sanjayan, 2006). Connectivity, the degree of movement of organisms or ecological processes among habitat patches (Taylor et al., 1993), is essential to allow for natural ranging behavior of animals among foraging or breeding sites and for dispersal of individuals from their natal ranges. Such movements may be critical to facilitate exchange of genetic material among otherwise isolated populations (Creel, 1998; Schwartz et al., 2005). Further, at large spatial and temporal scales, maintaining connectivity may be essential to allow natural range shifts in response to long-term environmental transitions, such as global climate change. Finally, connectivity is also necessary to maintain continuity of large-scale ecological processes and flow of material, energy, or nutrients. Due to the threat that habitat fragmentation poses to natural environments, connectivity conservation is increasingly becoming incorporated into land-management plans worldwide.

One of the most practical and effective measures to maintain wildlife in urban settings is establishment of linkages that permit dispersal across barriers such as roadways and developments (Noss, 1983; Noss et al., 1996). For some species, such "conservation corridors" need not be huge, elaborate structures (although usually larger is better). Amphibians, reptiles, birds, rodents, and small to medium-sized predators (e.g., opossums, raccoons, foxes, bobcats, and coyotes) will use even small culverts and drainages as movement corridors (Clevenger & Waltho, 1999). Bridges or underpasses, however, are often required to accommodate movement of larger species, such as deer and mountain lions, through urban environments (Haas, 2000; Lyren, 2001; Tigas et al., 2002; Ng et al., 2004; Clevenger & Waltho, 2005). Where functional movement corridors are not retained across urban landscapes, many wildlife populations, especially carnivores, will eventually disappear.

The concept of focal species in reserve design is a central theme in large-scale conservation planning (Miller et al., 1998; Soulé & Terborgh, 1999). Focal species are chosen to symbolize ecological conditions that are critical to healthy, functioning ecosystems (Lambeck, 1997). Mammalian carnivores can be effective focal species to evaluate the degree of landscape-level connectivity, or fragmentation, in a region. Large carnivores are particularly vulnerable to extinction in fragmented habitats because of wide ranges and resource requirements, low densities, slow population growth rates, long range dispersal, and direct persecution by humans (Noss et al., 1996; Woodroffe & Ginsberg, 1998; Crooks, 2000; Crooks, 2002). Consequently, top predators may not be able to persist in landscapes that are not connected by functional movement corridors. Further, their disappearance may generate cascades that ripple down the food web (Crooks & Soulé, 1999; Henke & Bryant, 1999; Estes et al., 2001; Ripple et al., 2001). In fragmented habitats in San Diego, Crooks and Soulé (1999) suggest that extirpation of dominant predators such as coyotes can contribute to ecological release of smaller predators and increased extinction rates of their avian prey. Thus, top predators may function as keystone species - animals whose disappearance causes increases in some species and declines and extinction of others (Mills et al., 1993).

Large carnivores therefore are ecologically pivotal organisms whose status can indicate functional connectivity of ecosystems. Using mammalian carnivores in conservation planning adds a critical layer of conservation strategy that may provide a robust method for protecting other species with less demanding needs (Lambeck, 1997; Miller et al., 1998; Carroll et al., 1999). In southern California, mountain lions, bobcats, and coyotes are excellent focal species for the evaluation of connectivity across multiple spatial scales (Crooks, 2000; Crooks, 2002; Tigas et al., 2002; Riley et al., 2003; Hunter et al., 2003). Mountain lions are the largest predator remaining in the region and are particularly sensitive to habitat fragmentation (Beier, 1993; Maehr, 1997; Crooks, 2000; Crooks, 2002; Hunter et al., 2003). Mountain lions occupy ranges that encompass up to 300 km^2, travel on average 6 km per night (Beier et al., 1995), and disperse distances that average 65 km (Beier, 1995). Our ongoing carnivore surveys in southern California indicate that mountain lions only occur in large, intact landscapes and are therefore excellent indicator species of connectivity across the scale of the entire ecoregion (Crooks, 2000; Crooks, 2002; Hunter et al., 2003). In comparison, bobcats are less sensitive to fragmentation and have smaller dispersal distances and home ranges (southern California: 1.4-8.1 km^2, see Lyren 2001 Table 1.11, Riley et al. 2003) than mountain lions. Bobcats therefore can persist in smaller habitat fragments, but, like mountain lions, only those that have adequate connections to larger natural areas. Consequently, bobcats are valuable indicators of connectivity at smaller, more local, spatial scales in developing landscapes. Although coyotes are widespread and relatively abundant throughout the region, certain populations are vulnerable to localized extinction in habitat fragments that are too small, disturbed, or isolated (Crooks & Soulé, 1999; Crooks, 2002). Further, the decline and disappearance of coyotes from urban habitat fragments may contribute to increased numbers and activities of smaller predators such as domestic cats, raccoons, and gray foxes, and thus increase predation pressure on a variety of small prey species, including scrub-breeding birds (Crooks & Soulé, 1999).

Objectives

Our primary research goals were 1) to assess movement patterns of wildlife in North/Central Irvine Ranch (NIR), with a focus on large carnivores (bobcat, coyote, and mountain lion), and 2) to identify and monitor key movement corridors for large carnivores near potential arterial roads that are proposed to cross the NIR, including the Jamboree Road extension (Jamboree) and North Lake Road construction (North Lake) (see Figure 1a). The Jamboree extension involves continuing Jamboree Road north of Santiago Canyon Road through Weir Canyon and terminating at California State Route 241 Toll Road (CA-241). The North Lake Road construction entails realigning the footprint and paving the existing dirt road from the Black Star Canyon gate to a terminal point at CA-241.

To accomplish our objectives, we employed a suite of sampling techniques to evaluate wildlife movement and corridors in the NIR. Methods included track and remotely-triggered camera surveys of target species and other wildlife, and GPS (Global Positioning System) telemetry of bobcats and mountain lions. These baseline wildlife movement data can be used to assist in long-term management and monitoring plans for the area. Documentation of wildlife movement routes can also be used to identify likely road crossing locations for existing and proposed roads. In the final section of the report, we provide specific recommendations of various methodologies for long-term monitoring of carnivores in the area, as well as actions to facilitate connectivity relative to future road construction projects.

Methods

Study Area

The study area was located between the cities of Orange (Orange County) and Corona (Riverside County), California (Figure 1a). It consisted of the NIR and the Cleveland National Forest. The NIR was the primary study area situated on about 135 km^2 of the Santa Ana Mountains (33°47'N; 117°43'W). California State Route 91 (CA-91) served as the northern boundary for on-the-ground field activities. It was an east-west 14-lane freeway supporting an average annual daily traffic volume (AADT) of 265,000 vehicles during 2003 (CDOT, 2005) and separating the Chino Hills and Prado Basin from the Santa Ana Mountains. The El Toro Marine Corp Air Station (Marine Base) roughly demarcated the southern boundary of the study site.

Besides the primary roadway, CA-91, there were other primary, secondary, and undeveloped roads of interest within the study area. The primary roadways were the Foothill (CA-241) and Eastern (CA-261 and CA-133) toll roads. CA-241 was a north-south six-lane freeway where in the north it divides the NIR into areas of unequal size. Paralleling CA-241 in the south was Santiago Canyon Road (SCR), a secondary road that also divided the natural area. In addition, connecting to SCR in the south was Live Oak Canyon Road (LOC) that separated the 3,100-acre natural area of O'Neill Regional Park from the Santa Ana Mountains. For these interior roadways, undercrossings, designated for either wildlife or water, were present to increase road permeability. On CA-241, we concentrated our undercrossing survey on bridged underpasses between CA-91 and the CA-241/CA-261 connector. Along SCR, we surveyed for either bridged underpasses or water culverts that were greater than one meter high. We did not survey the rest of CA-241, CA-261, CA-133, LOC, or SCR west of CA-241 and southeast of

Silverado Canyon Road for underpasses. We identified and mapped (all GPS coordinates presented throughout this report are in WGS 84 datum) four underpasses along CA-241 and nine along SCR (Figure 1b, Table 1, Appendix 1). Although many undeveloped and unpaved roads were present in the study area, we focused on North Lake Road, which extended west from Black Star Canyon Road (that connected to SCR), bordered Irvine Lake, and crossed underneath CA-241.

The climate was a warm, dry Mediterranean environment with a mean annual precipitation of 32.6 cm, primarily occurring during the wet season (Nov-Apr) (World Climate Data, 2004a). During this study, annual precipitation for both 2002 and 2004 were below average, 2003 was above average, and 2005 was the third wettest year on record with 66.5 cm (MWDOC, 2005; NOAA, 2005). Monthly temperatures ranged from a mean low of 4.8°C in December to 29.3°C in August (World Climate Data, 2004b); however, we recorded a maximum temperature in the excess of 37.7°C during this research. Coastal sage scrub, chaparral, riparian, coastal oak woodlands, and annual grassland communities primarily dominated the NIR.

General Field Methods

We used a suite of sampling techniques to evaluate wildlife movement and corridors in the NIR. We used track and remotely-triggered camera station surveys to evaluate distribution and relative abundance of the three target large carnivore species (mountain lion, coyote, bobcat), as well as other non-target wildlife, humans, and domestic animals. To document movement patterns of bobcats and mountain lions, we used high-resolution GPS radio telemetry. We completed the research in two phases, Phase 1 from summer 2002 to fall 2003, and Phase 2 from fall 2003 to summer 2005. Phase 1 included the track and remotely-triggered camera surveys, and the first phase of bobcat GPS radio-tracking. Phase 2 included a second phase of bobcat tracking. We also radio tracked mountain lions during the second phase.

Track and Camera Surveys

Track Surveys – Track surveys with baited scent stations have been widely used as a means of monitoring carnivore activity. Following methods developed by Linhart and Knowlton (1975), track surveys can be an effective measure of distribution and relative abundance of mammalian species (Conner et al., 1983; Sargeant et al., 1998; Crooks, 2002).

We established six track transects along dirt roads throughout the property to obtain information on mammal distributions. We established four of the track transects (Blind Canyon, MWD Road, Weir Canyon, and Windy Ridge) along the proposed Jamboree Road extension. . Track surveys along the proposed Jamboree Road extension were conducted twice in 2002 and 2003 each (August 6-10 and October 15-19, 2002; August 19-23 and November 22-26, 2003). We established the remaining two track transects (Fremont Canyon, North Lake Road) along the proposed North Lake Road alignment. We sampled these transects twice during 2003 (August 19-23 and November 22-26, 2003). Each 1000-meter track transect consisted of five scent stations at approximately 250 m intervals (Table 2, Figure 2). Each scent station consisted of a 1-m^2 plot of finely sifted gypsum powder and a rock, placed in the middle of the station, baited with two artificial scent lures (Russ Carman's Pro Choice, Canine Call) every other day (Crooks, 2002). We checked the stations for tracks on five consecutive mornings. If animals visited a station, we identified tracks to species, cleared the station of tracks, and resifted the gypsum.

To obtain an index of relative abundance, we divided the number of visits by each species by the total sampling effort. This index was calculated using the equation $\mathbf{I_j = [v_j / (s_j n_j)]}$, where I_j = index of activity at transect j, v_j = number of stations that detected a species in transect j, s_j = number of stations in transect j, and n_j = number of nights that stations were active in transect j. We omitted any scent station where tracks were too difficult to read from the sampling nights. Thus, the true sampling effort was $\mathbf{[s_j n_j] - o_j}$, where o_j = number of omits in transect j. This index does not provide data on the absolute number of individuals. Instead, the index compares relative abundance of species across space and time (Conner et al., 1983; Sargeant et al., 1998; Crooks, 2002). Due to relatively low sample sizes within sampling sessions, we pooled track indices across sampling sessions and phases to derive a single track index per transect for each individual species.

Camera Surveys - Remotely-triggered camera stations have increasingly become a useful tool for recording activity of various wildlife species (Griffiths & Van Schaik, 1993; Jacobson et al., 1997; Karanth & Nichols, 1998). Cameras provide a relatively low-maintenance means of surveying wildlife populations, because researchers visit the units only to change film and batteries.

We conducted camera surveys from August 2002 to December 2003. In total, we placed 14 Camtrakker camera traps (CamTrak South Inc, Watkinsville, GA) along wildlife trails and dirt roads throughout the property (Table 2, Figures 3 & 4). We established half of the cameras stations in the Jamboree portion and the other half in the North Lake portion of the study area, and assigned each station a 4-digit number. Along the proposed Jamboree Road extension, we established camera stations #2001, 2002, 2003, and 2039 in August 2002 and added stations #2030, 2031, and 2040 in January 2003. Along the proposed North Lake road alignment, we established camera stations #2032, 2033, 2034, 2035, and 2041 in January 2003 and added stations #2037 and 2038 in June 2003. Although Camera #2032 was not mutually exclusive with either the North Lake or Jamboree portions of the study area, we considered it part of North Lake section. Each pass of an animal by the infrared sensor triggered the camera, which recorded date and time of pass on each photograph.

We periodically shifted the cameras as necessary to avoid photographs of moving vegetation or vehicular activity. We removed Camera #2003 in June 2003 due to continued vandalism. Another camera (#2037) was lost in November 2003 in a slot canyon flood.

To obtain an index of relative abundance, we divided the number of camera detections (photographs) of each species by the total sampling effort. This index was calculated using the equation $\mathbf{I_j = [v_j / n_j]}$, where I_j = index of activity at camera j, v_j = number of detections of a species at camera j, and n_j = number of nights that camera j was active. We compared camera indices among camera locations to detect relative activity levels of species across the property. We pooled the indices across phases to derive a single camera index per camera for each individual species.

GPS Radio Collars

We used GPS telemetry to document movement patterns of individual bobcats and mountain lions. All the collars in this study were Televilt GPS radio collars (Telemetry Solutions, Walnut Creek, CA) that had GPS position capability and also emitted a VHF (Very High Frequency) radio-signal, on a pre-programmed schedule. Traditional VHF radio collars allow tracking of animals as long as the collar emits a radio frequency that can be picked up by a field researcher with a receiver unit. Relative to GPS collars, VHF-only collars drain their batteries slowly and continuously. GPS radio collars deplete their battery power each time they switch on to record a location. Consequently, there is a trade-off between the expected battery life and the number of locations obtained each week with more locations per week equating to shorter battery life and vice-versa.

Bobcats: GPS Collar Programming

To our knowledge, this study was the first to utilize GPS collar technology on bobcats (or any carnivore of a similar size to bobcats). We selected the Televilt GPS-Posrec™ 120 collar, a collar small and lightweight enough for a bobcat to wear. This collar stored all the GPS data on-board. GPS data were accessible only upon retrieval of the collar, which dropped off the study animal automatically. The timing of the collar drop-off and the data collection features of the collars had to be specified when the collars were ordered from the manufacturer. In the sections below on GPS collars for bobcats, we describe details of the collar programming and data-collection schedules, which were not the same for all collars. The bobcat collars were similar in that all were expected to yield approximately the same number of GPS locations collected at regular intervals during "sampling sessions" (periods of time when a collar was on collecting GPS data and thus "sampling" bobcat space use behavior). Collar schedules varied in the number of days that sampling sessions occurred within a week, the duration and timing of sampling sessions, the length of time between collection of GPS locations within a sampling session, and the number of total weeks of data collection. VHF signals on these collars allowed for knowledge of an animal's whereabouts prior to retrieval of its collar and finding a collar in the field once it had dropped off a bobcat. Unlike the GPS locations schedule, the schedule for the VHF signal remained the same for all collars and was on from 6am-4pm Pacific Standard Time (PST) weekly on Monday, Wednesday, and Friday.

In addition to date, time, and geographic coordinates, the Posrec™ collars recorded a "fix type" for each GPS position that was based on the number of GPS satellites used in calculating the GPS "fix" or position. Fix type categories were 1D, 2D, 3D, and 3D+, with more satellites obtained, the more accurate the location. A 1D fix was an undefined location. This situation was similar to trying to determine a location from a single compass bearing, which is not possible. A 2D fix was a location acquired with three satellites with an undefined error margin due to the dimensionality of the location (i.e., although three satellites were obtained they were positioned in only two dimensions). We considered the next two fix types (3D and 3D+) ideal because the collar had acquired enough satellites and their geometry was such that the location progressed from two to three dimensions, increasing the accuracy substantially. A 3D fix was a location acquired with four or more satellites with an error margin of ±100 to 200 meters. A 3D+ fix was a location acquired with five or more satellites that had been validated with an error margin of ±15 meters. Heavy cloud cover, dense vegetation, deep canyons, and other factors could affect the fix type by influencing the accessibility of orbiting GPS satellites to the GPS collar, and these factors could prevent the collar from obtaining a scheduled location altogether.

Bobcats: Trapping and Capture

As mentioned in the "General Field Methods" section, we divided bobcat trapping and capture efforts across Phase 1 and Phase 2 of the study. Bobcats were captured using wire cage traps (24" x 17" x 43") that were modified to hold a live white dove as a lure animal. Doves were housed within a 12" x 8" x 17" enclosure built within and located at the upper back of the cage trap and inaccessible to bobcats. Each cage trap was checked morning and afternoon each day. We chose bobcat trap site locations based upon signs (e.g., tracks, feces) of bobcat presence in an area. We usually placed the cage traps along washes, wildlife trails, and dirt roadways, and situated them under tree canopy and in other shaded areas to prevent excessive sun exposure. For each trap site, we recorded the GPS location and the majority habitat type present within a 250 m radius using habitat descriptions of Mayer and Laudenslayer (1988). At trap site locations where habitat was distributed equally between two habitat types, we assigned a dual habitat type such as coastal sage scrub/coastal oak woodland.

We initially restrained captured bobcats using a push board to restrict the animal at the back of the cage trap, allowing for hand injection of chemical immobilization drugs. Our chemical immobilization drug was a combination of ketamine (10 mg/kg) and xylazine HCL (1 mg/kg). Once the bobcat was completely immobilized, we removed it from the cage, placed the animal on a blanket, blindfolded it to reduce stimulation, and monitored temperature, heart rate, and respiration at five to 10 minute intervals. Each bobcat was marked with ear tags, fitted with a GPS-Posrec™ 120 radio collar if it was above the minimum weight limit, sexed, aged, and weighed. We aged the bobcats by body mass and/or tooth eruption patterns, and classified them as kittens (0-12 months), yearlings (13-24 months), or adults (Conley, 1966; Crowe, 1975; Jackson et al., 1988). We recorded standard body measurements, and collected blood, hair, and parasite samples. At work-up completion, we neutralized the xylazine with an injection of yohimbine HCL (0.125 mg/kg) at the known weight of the bobcat, and returned the animal to the cage trap. We monitored the bobcat until it recovered from the remaining anesthetic and then released it from the cage trap at its capture site.

Bobcats: Phase 1

GPS Collar Programming – To document a variety of movements for all bobcat sex and age classes, we selected three data collection schedules for Phase 1 collars that were specific to particular age or sex classes (Table 3). All collars collected GPS data at night, so that GPS data collection would occur when bobcats would be particularly active (Tigas, 2002). The interval between GPS location collection within each sampling session was 15 minutes. We wanted to obtain frequent locations for male bobcats to document their ranging movements, as males were likely to move more often and over longer distances than females. By scheduling four sampling sessions each week, GPS collars for males lasted approximately 10 weeks. Our goal for juveniles (kittens or yearlings) was to sample their behavior over a longer period to document dispersal events and establishment of an adult territory. Therefore, we planned to sample juveniles once per week, which allowed these collars to last approximately 25 weeks. We scheduled this weekly session to coincide with the collar schedules for adult bobcats. Sampling females two times per week permitted us to have a medium duration 19-week collar that was suitable for detecting female denning activities and smaller home ranges. Our goal for bobcats was to collar 12 individuals in approximately equal numbers from each of the age and sex classes, and the collars were programmed accordingly. Although we tried to fit each captured bobcat with a collar that had the appropriate schedule for that individual based on sex and age, this was not always possible.

Trapping Effort – We set bobcat traps at 13 sites in the Jamboree section (T1A-T10A, T17A-T19A) and 19 sites at the North Lake section (T11A-T16A, T20A-T32A) with one trap per location (Table 4, Figure 5). Three of the North Lake traps (T11A, T16A, and T30A) were located west of CA-241 and were considered part of the North Lake section. Traps in the North

Lake section were in the following habitats: two traps in mixed chaparral, six in riparian, and 11 in coastal sage scrub. In the Jamboree section, we established two of the 13 traps in riparian habitat with the rest in coastal sage scrub habitat. We conducted trapping during December 11-15, 2002, January 2-19, and January 22-February 1, 2003, producing 470 trap nights (one trap set for one night equals one trap night). In addition, the remotely-triggered cameras remained in the study area during the first phase to photographically capture marked bobcats to augment the data collection from GPS collars.

Bobcats: Phase 2

GPS Collar Programming – We evaluated the bobcat GPS location data returned from Phase 1 to determine if the GPS schedules we had chosen provided us with movement distances between consecutive locations that were representative of bobcats crossing the width of a two-lane paved roadway with undercrossings. Our road model was CA-71, which has wildlife crossings that bobcats currently use and it connects to CA-91, the northern NIR study area boundary. Because the average width of CA-71 is 64 meters (range 29 to 125 m) (Haas & Crooks, 1999), we grouped the observed Phase 1 bobcat movement distances into three categories 1) less than 51 meters, 2) 51-100 meters, and 3) greater than 100 meters. We expected an equal number of movements to occur in each category. However, 48% of the movements were category 1, 20% were category 2, and 32% were category 3. To obtain more bobcat movements in category 2, representing the average width of our model road, we created a fourth GPS collar schedule to use in Phase 2 (Table 3). Since we were not targeting a particular bobcat demographic with this schedule, we wanted to continue sampling the bobcats two times per week with a medium duration schedule. Thus, we increased the time interval between GPS locations to 30 minutes during the twice-weekly sampling sessions, which allowed the collars to last approximately 18 weeks. Four collars received this programming schedule. The VHF signal continued to emit its frequency on the same schedule used in Phase 1.

Trapping Effort – We set bobcat traps at 16 new sites in the Jamboree section (2T45A-2T60A) and 12 new sites in the North Lake section (2T33A-2T44A). In addition, we re-used some trap locations established in Phase 1. For the Jamboree area, we re-used one trap location (T7A). In the North Lake area, we re-used six trap locations (T21A, T23A-T25A, T27A, and T32A) (Table 5, Figure 6). Overall, for the Jamboree area, we established two traps in habitat that was an even mix of coastal sage scrub and coastal oak woodlands, 4 in coastal oak woodland habitat, and 11 in coastal sage scrub habitat. The overall trap placement for the North Lake area was one in grasslands, three each in riparian and coastal oak woodlands, five in mixed chaparral, and six in coastal sage scrub habitat. Because most (70%) of the bobcats radio-collared during Phase 1 were located west of CA-241, we began the Phase 2 trapping efforts east of CA-241 to adequately sample the North Lake area. We conducted trapping there from October 1-10 and November 14-23, 2003 for 297 trap nights. Afterwards, we returned to the Jamboree area and trapped there from December 1-19, 2003 and January 5-15, 2004 for 342 trap nights.

From November 15-20, 2004, we also conducted 35 trap nights at two established sites (2T39A and 2T40A) and 5 new sites (2T61A-2T65A) in coastal oak woodlands and riparian habitat (Table 5; Figure 6). Altogether, there were 674 total trap nights for Phase 2. During this particular Phase 2 trapping session, we were focusing on recapturing a male yearling bobcat (B13) to remove his collar, which had failed to drop off as scheduled in April 2004. The VHF signal on his collar had also failed, and we had been unable to track him since February 2004. However, in October 2004, Orange County Water District employees spotted him with the collar still attached in the Santiago Creek streambed in the NIR. We used this sighting and the VHF telemetry data for B13 to focus our trapping effort within his apparent home range.

Mountain Lions: Trapping and Capture

We began mountain lion trapping during Phase 2 of the study. We captured mountain lions primarily using modified Aldrich foot snares, following techniques described by Logan et al. (1999). All snares were equipped with a slide stop on the cable to minimize snare closure during a capture, thus allowing non-target species (with smaller feet) to escape the snare. We checked the snares and cage trap on the same daily schedule as bobcat cage traps. The mountain lion cage trap differed from the bobcat cage traps in its size, which was 8' x 4' x 4', and the use of bait instead of lure animals. We used thawed mule deer carcasses as bait and secured them to the back of the mountain lion cage trap.

We chose mountain lion trap site locations using similar methods to bobcat trapping. However, to decrease the possibility of people encountering a potentially dangerous situation, either a snare they inadvertently sprung or a captured mountain lion, we established all snares out of sight of roads. We characterized the habitat surrounding each trap site location using the same methods we used during bobcat trapping.

We established snares and the mountain lion cage trap at 29 trap site locations within the NIR. There were never more than 16 snare site locations active at any given time (Table 6, Figures 7 & 8). Weir, Blind, Fremont Canyons, and areas north of Santiago Canyon Road, were the primary target areas for capture. Twelve of the trap site locations were located west of CA-241 with the rest located east of CA-241. We established 21 of 28 snares and the cage trap in coastal oak woodland habitat. For the remaining seven snares, we placed them as follows: two in a combination of coastal oak woodland and riparian, two in riparian, two in a combination of riparian and coastal sage scrub, and one in mixed chaparral. We conducted mountain lion trapping in several sessions during 2004 for 879 trap nights. The 2004 trapping session dates were as follows:

March 22-24	May 4-7	July 7-19
March 30-April 2	May 10-14	November 15-21
April 5-9	May 18-21	November 29–December 2
April 26-29	June 15-July 2	December 10-17

We immobilized captured mountain lions using the same combination of ketamine and xylazine HCL as bobcats, but administered the immobilization drugs via jab stick (a syringe attached to 6' pole). Once completely immobilized, we processed the mountain lions like the captured bobcats. For mountain lions, however, we fitted them with a GPS-Simplex™ radio collar and classified them as kittens (0-16 months), subadults (17-23 months), or adults following body mass, tooth eruption, and pelage criteria presented by Ashman et al. (1983). Similar to the bobcats, we neutralized the xylazine with yohimbine upon work-up completion. We then placed the mountain lions in a secluded area near the capture location and monitored them while they recovered and became mobile.

Mountain Lions: GPS Collar Programming

Collars for mountain lions were Televilt GPS-Simplex™ radio collars. These collars stored all GPS data on-board, but batches of the GPS data could also be remotely downloaded in the field. These collars experienced the same battery life trade-off as those used on the bobcats but offered more scheduling flexibility. For example, unlike the GPS-Posrec™ collars, the Simplex™ collars could obtain a variable number of locations for each day of the week. We selected two schedules for these collars, A and B, both of which collected one GPS location per hour during the scheduled sampling sessions. We chose schedule A to coincide with the programming scheme used by University of California-Davis researchers (Ken Logan and Linda Sweanor) (see also Sweanor et al., 2004) and National Park Service researchers (Seth Riley and Eric York) (see also Riley et al., 2004) involved in concurrent mountain lion projects in southern California. Schedule A collars attempted to acquire 68 locations per week with 24 locations each on Saturday and Wednesday and 4 locations each day for the remaining weekdays. At this sampling rate, the expected collar duration was 11 months. We used Schedule A twice. Schedule B recorded 148 locations per week, acquiring one location per hour for almost every hour during a week. The expected collar duration for Schedule B was 6 months (Figure 9). We used Schedule B when we had the opportunity to collar a mountain lion about 6 months before the close of this project.

The collars recorded one GPS location per hour, at 15 minutes past the hour, during the scheduled sampling sessions. The GPS-Simplex™ collars recorded locations as only two different "fix types", 2D and 3D, which were comparable to the 2D and 3D+ fix types of the GPS-Posrec™ collars that we used for the bobcat tracking. The VHF signal was active from 6am-5pm PST each day of the week except Sundays. The VHF signal with the Simplex collars was particularly important, because these collars allowed downloading GPS data through the VHF antenna. We had two options for obtaining data downloads: 1) remotely triggered downloads at any time, or 2) scheduled downloads of the previous month's data at preprogrammed times during a 2 to 3 day window of time each month. Both options required radio tracking a collared mountain lion until the receiver unit indicated that the mountain lion was within range for the download to transmit to the receiver. We selected to use Option 1, but included Option 2 because Option 1 could potentially fail. Option 1 failing was possible because it acts remotely requiring the technician to "send" the download code through the VHF antenna, the collar to recognize the code, and then perform the requested action. Conversely, Option 2 automatically sends the data without requiring the technician to "ask" the collar to release the data. Nonetheless, Option 1 allowed for much greater flexibility in obtaining downloads since we could remotely trigger them whenever conditions were optimal. As another benefit, the remotely triggered option essentially allowed for near real time data acquisition, a feature that may become increasingly important with mountain lion-human interactions.

General VHF Telemetry

Besides using the VHF signal to retrieve mountain lion data downloads, we also used the VHF radio signal to acquire locations for both bobcats and mountain lions. These VHF radio locations augmented the GPS locations in case the GPS portion of the radio collars failed. To acquire the radio locations, field technicians used a portable receiver and hand-held Yagi antenna (Telemetry Solutions) to estimate the VHF radiolocation of an animal using triangulation. A technician typically located an animal by taking bearings on the loudest signal (Springer, 1979) from two to five stations along roads (White & Garrott, 1990). The set of bearings, maintained between 40° and 120° (modified from Gese et al., 1988), was recorded in less than 30 minutes. Technicians attempted to gain radio locations from radio-collared animals two to six times per week. Using LOCATE II (Pacer, 2000), we used each set of bearings to generate each animal's VHF radiolocation estimates. If we lost an animal's VHF radio signal, we searched extensively by vehicle until it was regained. In addition, technicians obtained extra locations for an animal by opportunistic visual identification of tagged animals (Hein & Andelt, 1995).

Home Range Analyses

We used ArcView 3.3 (ESRI, Redlands, CA) with the Animal Movement Extension (Hooge & Eichenlaub, 2000) to estimate home range size and boundaries. We did not include the VHF or visual locations for either species in any analyses because there were relatively few such locations and the GPS data were more accurate. We used those locations separated by greater than 4 hours (Swihart & Slade, 1988) as independent observations to estimate home ranges. We calculated home range sizes using the minimum convex polygon (MCP) and the fixed kernel (FK) methods (Worton, 1989; Powell, 2000). We calculated 95% FK utilization distributions to represent the home range and 50% FK utilization distributions to estimate areas of core use. We overlaid the resulting utilization distribution contours for each bobcat with their event and GPS locations, movement path (see "Analyses of Movements across Road" section), and road and land cover GIS (Geographic Information System) layers. In addition, we combined all male bobcat home range and core-use areas and overlaid those with road and terrain GIS layers. We did the same for female bobcats and mountain lions (mountain lion event locations, GPS locations, and movement path with land cover were projected separately by individual). To compare male versus female bobcat home range and core-use area sizes, we used two-sample *t*-tests with statistical significance indicated at p-values < 0.050.

We constructed area-observation (AO) curves for all bobcats and mountain lions to determine if enough GPS locations were collected for sufficient home range descriptions (Odum & Kuenzler, 1955). For each animal, we first randomized their locations and then used all of their locations to construct the AO curve (Harris et al., 1990). For bobcats, home ranges were considered adequately sampled when the addition of a set of 20 locations did not increase the 100% MCP size by greater than 4% for five successive additions (following Gese et al., 1990), which indicated that the AO curves had reached an asymptote. We considered mountain lion home ranges adequately sampled when the addition of a set of 50 locations did not increase the 100% MCP size by greater than 10% for five successive additions (following Gese et al., 1990).

Analyses of Movements across Roads

We imported GPS locations into ArcView 3.3 where we joined sequential locations and constructed a movement path (route) for each radio-collared animal. Each path consisted of both "fine-scale" and "coarse-scale" moves. Fine-scale moves for bobcats occurred at either 15 or 30 minutes intervals depending on which collar we fitted to that individual. Within each sampling session, the 10-week, 19-week, and 25-week collars sampled at 15-minute intervals while the 18-week collars sampled at 30-minute intervals. For mountain lions, fine-scale moves were those separated by 1-hour intervals. Since we sampled mountain lions throughout the 24-hour period, we also identified their day and night locations by comparing each location to the daily sunrise and sunset times for that date. Although the movement path remained continuous, we identified when it switched between day and night. Whenever we did not schedule the collars to record fine-scale intervals or if the collar missed receiving a location within a fine-scale sampling session, the movement path became a coarse-scale path.

Regardless of the location's fix type or actual width of the road, when the movement path crossed a paved roadway, we considered it a road crossing. We counted both fine- and coarse-scale road crossings. We then identified the road and noted the locations immediately before and after the movement path crossed the road. For each set of crossings, we determined if the collar missed recording a location and how many, and calculated the distance and the time elapsed between the two locations.

Next, we overlaid the movement paths for bobcats and mountain lions onto a GIS road layer that depicted a possible Jamboree Road extension in the NIR to map where these felids moved relative to the possible new road extension and identify the areas where the most potential road crossings occurred. This process was done separately for each species using data from all the radio-collared individuals. After overlaying the movement paths onto a GIS map of the Jamboree Road extension, we counted the number of bobcat and mountain lion fine-scale movement paths that crossed the possible extension. We considered the intersection of a movement path and the planned road as a "road encounter." We then converted the counts of road encounters into the densities of encounters that we mapped as 15 x 15 m grids. The value in each 15 x 15 m grid cell in a road-encounter density grid was the number of road crossings within a 0.5 km radius of that cell. For example, if there were 10 bobcat movement paths across the planned road within a 0.5 km radius of a particular grid cell, then that cell was assigned a value of 10 and converted to a density as 10 / 0.250 x pi (counts per unit area). After calculating the road encounter density for bobcats and for mountain lions, we overlaid the density grids for these two species to generate a grid representing the mean road encounter density for all radio-collared felids in the study area. We used the geometric mean of the bobcat and mountain lion layers in this combined layer ([combined grid value] = square root ([bobcat grid value] x [mountain lion grid value])), because in using the geometric mean, we ensured that areas with a low density of crossings for either species had a low density in the combined grid.

Results

Track and Camera Surveys

Sampling effort for the scent stations (track transects) along the Jamboree Road Extension ranged from 94 to 100 station nights. Sampling effort for the scent stations along North Lake Road ranged from 48 to 49 station nights. Sampling effort for the camera stations along the Jamboree Road Extension ranged from 185 to 495 days, while the sampling effort for the camera stations along the North Lake Road ranged from 83 to 326 days (Table 7).

Track Surveys: Jamboree Road – Nine wildlife species were detected in the Jamboree portion of the study area, including the three target species (mountain lion, coyote, bobcat) and six non-target species (mule deer, gray fox, raccoon, striped skunk, spotted skunk, and the non-native opossum) Track surveys also detected dog and humans (Table 8). All four track transects located in this area were visited by at least six different species. We detected mountain lions along the Weir Canyon and Windy Ridge transects. Bobcats were detected along all transects, except Windy Ridge. Coyotes, gray foxes, and striped skunks were detected on all four transects. We detected mule deer along the Blind Canyon and Windy Ridge transects.

Mountain lion activity was highest along the Windy Ridge transect with three detections. Coyote activity was highest along the Weir Canyon transect and lowest along the Blind Canyon transect. Bobcat and gray fox activities were highest along the Blind Canyon and MWD Road transects. Striped skunk activity was highest along the MWD Road. We detected spotted skunks only at the Weir Canyon and MWD Road transects. In addition, we detected raccoons and spotted skunks less frequently than any other native species. Scent stations also documented several small mammals, bird, and herpetofauna species, including squirrels and smaller rodents, rabbits, lizards, and snakes.

Track Surveys: North Lake Road – Seven wildlife species were detected in the North Lake portion of the study area, including the three target species (mountain lion, coyote, bobcat) and four non-target species (mule deer, gray fox, striped skunk, and opossum) (Table 8). The two track transects located in this area were each visited by six different species. We detected mountain lions only along the Fremont Canyon transect. Track surveys detected bobcats along both the Fremont Canyon and North Lake Road transects. Coyotes, mule deer, gray foxes, and striped skunks were also detected on both transects. We did not detect raccoons and spotted skunks in this portion of the study area by this method.

Coyote and gray fox activities were highest along the North Lake Road transect. Bobcat activity was higher along the Fremont Canyon transect. Striped skunk activity was similar along the two transects with two visits per transect during the study. Mule deer visitation was one visit per transect during the study. Scent stations also documented several small mammals, bird, and herpetofauna species, including squirrels and smaller rodents, rabbits, lizards, and snakes.

Camera Surveys: Jamboree Road – Nine wildlife species were detected in the Jamboree portion of the study area, including the three target species (mountain lion, coyote, and bobcat) and six non-target species (mule deer, gray fox, raccoon, striped skunk, spotted skunk, and opossum). Cameras also recorded domestic dog, horse, and humans (Table 9). Although a considerable portion of the human visitation was due to the activity of USGS/CSU research personnel, cameras also recorded many photographs of unknown individuals. We also recorded bicycle and vehicular activity (exclusive of pedestrians) at the camera stations.

For native species, we detected seven at Camera #2030, six at Camera #2002, 2003, and 2031, and five at Camera #2039. Bobcats and mule deer were detected at all seven camera stations. We detected mountain lions, coyotes, and gray foxes at six of seven camera stations. We recorded striped skunks at three cameras. Camera #2003 was the only station where we detected raccoons, and Camera #2030 provided the only detection of a spotted skunk.

Mountain lion activity was highest at Camera #2002; we detected no mountain lions at Camera #2001. Coyote and bobcat activities were highest at Camera #2003; gray fox activity was highest at Camera #2002. We also detected several non-target species at the camera stations, including rabbits (*Sylvilagus* spp.), rodents, and bird species.

Located in south Weir Canyon, Camera #2030 had the greatest number of native species detections. All native species except raccoon were present at that camera. Mule deer accounted for 72.1% (88 of 122) of the detections; they were the native species most often (159 of 421) detected. Camera #2030 also detected the least number of humans (n = 8). Besides research personnel, humans (including vehicular and bike traffic) accounted for 34.8% (307 of 881) of the camera detections in the Jamboree portion of the study area.

Camera Surveys: North Lake Road – Seven wildlife species were detected in the North Lake portion of the study area, including the three target species (mountain lion, coyote, bobcat) and four non-target species (mule deer, gray fox, striped skunk, and opossum). Cameras also detected relatively low levels of domestic dogs and humans, which primarily were research personnel (Table 10). We recorded no bicycle or vehicular activity in this area. We did not detect raccoons or spotted skunks along North Lake by this method.

For native species, we detected six at Camera #2032, five at Camera #2034, and four at Camera #2038 and #2041. We detected mule deer at six of seven camera stations. We recorded mountain lions at five camera stations, and bobcats and coyotes at four of seven camera stations each. Two cameras detected striped skunks.

Mountain lion and mule deer activities were highest at Camera #2041; we did not detect mountain lions at Camera #2033 and #2035. Coyote, bobcat, and gray fox activities were highest at Camera #2032. We also detected several non-target species at the North Lake Road camera stations; these included rabbits, rodents, and birds.

Camera #2032 detected more species (n = 6) than the other cameras. Nevertheless, Camera #2041, located at the eastern end of Irvine Lake had the greatest number of detections. Mule deer accounted for 87% (103 of 118) of the native species detected there. Likewise, mule deer were the most often (50.0%) detected native species (169 of 338) overall. Excluding research personnel, humans accounted for 5.4% (22 of 409) of the camera activity in the North Lake portion of the study area.

Bobcats: Capture, Radio Telemetry, and Road Crossings

Capture – Overall, there were 20 individual bobcats captured during this research with 16 of them receiving GPS collars. Of these 16, there was an even proportion between sexes, whereas the age demographic upon initial capture was 2 yearlings and 14 adults (Tables 11 & 12).

In Phase 1, we captured 12 individual bobcats. Two (B2, B12) of those individuals were captured three times and one individual (B7) was captured twice, equaling 17 total captures (Table 11). B2's recaptures occurred during 2003, once on January 9 at T3A and again on January 16 at T16A. B7 was recaptured at T4A on January 11, 2003. We recaptured B12 on January 27 and 29 at T15A and T31A, respectively. Non-target species captured included gray foxes, one coyote, and one opossum. Additionally, we captured red-tailed hawks (*Buteo jamaicensis*) on two occasions. Among bobcats, the ratio of males to females was close to an even distribution with six males, five females, and one undetermined (B3 could neither be sexed nor aged). Most of the bobcats were adults (n = 9), but a kitten (0-12 months) and a yearling (13-24 months), which were considered "dispersers" (i.e., not holding a stable home range), were also captured. Ten bobcats (six males and four females) were marked with ear tags and GPS collars (Table 11). B1 was too small to collar and B3 did not respond favorably to chemical immobilization, and thus was released without gathering any additional data. We successfully retrieved all collars and downloaded all stored GPS locations from them.

From the beginning of our trapping efforts on December 11, 2002 through December 9, 2003, when we removed cameras from the field, we obtained 96 photographs of bobcats. Of those, unmarked bobcats totaled 65 photos while marked (radio-collared) bobcats totaled 31 photos. In instances where we could identify a bobcat on the photo, cameras captured 6 of 10 marked bobcats 24 times (Table 11). There were seven additional camera captures of marked bobcats at cameras #2032 and 2039, but we could not identify them as a particular radio-collared individual (Appendix 2). All camera captures of radio-collared bobcats occurred at the five camera stations located closest to CA-241 (three to the west and two east of the roadway).

During two capture efforts in Phase 2, eight individual bobcats (three males, five females) were trapped with two individuals (B13, B15) captured twice (*n* =10). We recaptured B13 and B15 in 2004, a year after their initial captures on November 20 at 2T62A and November 18 at 2T63A, as an adult and yearling, respectively (Table 12). We marked all eight bobcats with ear tags and collared six of them; two were too small to radio-collar. In total, four females and two males received collars. We successfully retrieved every Phase 2 collar and its GPS data, including B13's malfunctioning collar that we retrieved by re-trapping him. Other non-target carnivore species captured in Phase 2 included a mountain lion (see mountain lion results), gray foxes, and a striped skunk. We considered the mountain lion a non-target species because it was very unusual to capture a mountain lion in a cage trap suited for the size and strength of a bobcat. Additionally, we captured a rabbit (*Sylvilagus audubonii*) and a hawk (*Buteo* spp.) during the B13 capture effort. With the exception of the mountain lion, all non-targets were released without immobilization or handling.

We did not obtain photographs of any bobcats tagged during Phase 2 on the remotely-triggered cameras because cameras were removed from the field in December 2003 due to budget limits, about two months after we began the Phase 2 trapping. Additionally, Phase 2 bobcat traps were not in the same vicinity as the camera stations, except for Camera #2037 (lost November 2003), #2038, and #2041 meaning there was little opportunity to detect bobcats collared in Phase 2 at camera stations.

Telemetry – We monitored Phase 1 radio-collared bobcats from December 2002 through July 2003. All of these bobcats (*n* = 10) were monitored for some duration during the wet season with seven monitored in the dry season. We monitored bobcats radio-collared in Phase 2 from October 2003 through May 2004. Similar to the Phase 1 bobcats, all of the Phase 2 bobcats (*n* = 6) were monitored during the wet season with four monitored during the dry season (Figure 10). For both phases, the collars recorded GPS locations of bobcat movements for 84 bobcat months (bobcat month equals one bobcat monitored during any portion of a calendar month) (Figure 10). In addition, during both phases, we monitored bobcats 5.5 times longer during breeding/gestation seasons than young rearing/dispersal seasons (Figure 10).

The number of GPS locations obtained for each of the 16 radio-collared bobcats ranged from 181-359 ($\overline{X}$ = 279 ± 13 SE) (Table 13, Figure 11). The mean percent of GPS locations by fix type was 1% for 1D, 29% for 2D, 29% for 3D, and 41% for 3D+ fixes. Based on area-observation (AO) curves (Figures 12, 13 & 14), 11 bobcats had home ranges that were adequately sampled to describe their home range sizes accurately within the programmed schedules. B6 and B13 occupied larger home ranges than the other bobcats, so we represented their AO curves in a separate figure at a different scale to prevent a visual "swamping out" of the remaining bobcat's AO curve analyses (Figure 13).

Using the GPS locations, we estimated home ranges for all 16 radio-collared bobcats (Table 13; Figures 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, & 30). Since B6 exhibited erratic space use patterns, we excluded his movement patterns when determining home range and core-use areas. Overall, the 100% MCP and 95% FK home range sizes for bobcats (*n*

= 15) ranged from 1.54 to 9.42 km^2 ($\bar{X}$ = 3.62 ± 0.56 SE) and from 1.34 to 13.39 km^2 ($\bar{X}$ = 3.72 ± 0.35 SE), respectively. Core-use areas of bobcats (*n* = 15) ranged from 0.20 to 2.92 km^2 ($\bar{X}$ = 0.67 ± 0.18 SE).

Male bobcats (*n* = 7) had 100% MCP home range sizes from 2.07 to 9.42 km^2 ($\bar{X}$ = 4.76 ± 1.02 SE), and 95% FK home range from 2.06 to 13.39 km^2 ($\bar{X}$ = 5.18 ± 1.46 SE). Core-use areas for males (*n* = 7) ranged from 0.29 to 2.92 km^2 ($\bar{X}$ = 0.96 ± 0.35 SE) (Figure 31). Female bobcats (*n* = 8) had 100% MCP home ranges from 1.54 to 4.56 km^2 ($\bar{X}$ = 2.62 ± 0.33 SE), and 95% FK home ranges from 1.34 to 4.59 km^2 ($\bar{X}$ = 2.43 ± 0.36 SE). Core-use areas for females (*n* = 8) ranged from 0.20 to 1.17 km^2 ($\bar{X}$ = 0.41 ± 0.11 SE) (Figure 32). Although there was no statistically significant difference between male and female 100% MCP (t = 2.114, p = 0.054) and 95% FK (t = 1.951, p= 0.073) home ranges, male 100% MCP home ranges were about two times bigger than females. There was also no statistically significant difference between male and female 50% FK core-use areas (t = 1.597, p = 0.134) (Table 13).

Existing Roads – Eight bobcats occupied home ranges west of CA-241and seven occupied home ranges east of CA-241. One male bobcat (B6) had a home range that spanned CA-241; however, 75% (259 of 344) of his GPS locations and his core-use areas were east of CA-241 (Figures 18 & 31). In addition to B6, two other males (B7, B12) and one female (B19) had home ranges that slightly overlapped the toll road, but only B19 had locations to both sides of CA-241 (Figures 19, 24, 29, 31 & 32). However, B19's seven locations east of CA-241 (Figure 29) were 2D fix types that have error margins of hundreds of meters. Thus, only B6, and B10 whose home range did not overlap CA-241, potentially made documented movements successfully to both sides of CA-241 (Figures 18, 22, & 31). B6 crossed the road on 12 separate occasions (Table 14). From north to south, his crossing events appeared to happen either at-grade (over CA-241) or by using unnamed water culverts (*n* = 9), the Windy Ridge Wildlife Corridor (*n* = 1), and the SCE Wildlife Corridor (*n* = 2). B10 successfully crossed the toll road twice and another developed roadway, Santiago Canyon Road (SCR) 16 times (Table 15). After ground truthing most of B10's road crossings, it appears he probably used water culverts greater than one meter high to avoid at-grade crossings. Another bobcat, B13, potentially moved across SCR 11 times successfully (Table 16). To cross SCR, from west to east, his travels were associated with the UC4 (*n* = 1), UC6 (*n* = 2), and Santiago Creek Bridge 2 (*n* = 6) undercrossings, while the rest of his crossing events (*n* = 2) were not associated with a particular undercrossing. Although we can infer from the movement paths that the bobcats probably crossed roads and used certain undercrossings, we cannot be certain the bobcats did not traverse the roads via the surface.

Mountain Lions: Capture, Radio Telemetry, and Road Crossings

Capture – We captured three adult female mountain lions (P1, P2, P3) with one animal (P1) captured three times (*n* = 5) (Table 17). Initially, P1 was an incidental capture in a bobcat cage trap. However, her two subsequent captures during 2004 occurred on March 24 at S8 and June 28 at S17 in foot snares that we set specifically to target mountain lions. In addition, P1 had a collar replaced during her June 2004 recapture after her first collar malfunctioned in April 2004. Mule deer were the only non-target species captured in foot snares. However, there was physical evidence (hair, tracks, feces, etc.) of other species (bobcat, coyote, and human) at sprung snares throughout the course of the study. We successfully retrieved P1 and P2's collars and downloaded the stored GPS location data that were missed during the scheduled or remotely controlled data downloads. At time of report, we were unable to recover P3's collar due to an equipment malfunction. For this reason, we used the data from the data downloads for analyses instead of the stored GPS location data from the collar.

Telemetry – We documented radio-collared mountain lion movements from October 2003 through May 2005 (Figure 10). We tracked P1 and P3 during both the wet and dry seasons, with 10 of 16 mountain lion months (one mountain lion month equals one mountain lion monitored during any portion of a calendar month) taking place in the wet season. We monitored P2 for 4 months, all during a dry season. In all, the collars recorded GPS locations of mountain lion movements for 20 mountain lion months. In addition, we monitored mountain lions by month almost equally between their breeding/gestation seasons (n = 9) and young rearing/dispersal seasons (n = 11).

The number of GPS locations obtained for all three radio-collared mountain lions ranged from 371 to 1637 ($\bar{X}$ = 1039) (Table 18). Overall, the mean percent of GPS locations by fix type was 54% for 2D fixes and 46% for 3D fixes. The two radio collars worn by P1 collected locations over 215 of the 240 days that the collars were operational (Table 17), and we obtained approximately 50% of the expected locations (1,110 of 2,202). Based on our criteria for area-observation (AO) curves, P1 had a home range that appeared adequately sampled (Figure 33). We obtained locations for P2 over 75 of the 95 days that the collar was operational (Table 17), and we received 40% of the expected locations (371 of 919). Although the AO curve for P2 appeared to level out with increasing numbers of locations, by our criteria it did not technically reach an asymptote (Figure 33). This trend suggests that the observed movements for P2 during this study are a conservative estimate and not a complete representation of her entire home range. For P3, we obtained approximately 60% of the expected locations (1637 of 2792). The collar collected these locations during the entire 132 days that it was operational (Table 17). Based on our criteria for AO curves, P3 had a home range that appeared adequately sampled (Figure 33).

Using the GPS locations, we estimated the home ranges for the three radio-collared mountain lions (Table 18). Overall, the 100% MCP and 95% FK home ranges for the three female mountain lions ranged from 97.00 to 181.26 km^2 ($\bar{X}$ = 132.19 km^2) and 82.67 to 125.40 km^2 ($\bar{X}$ = 105.37 km^2), respectively (Figure 34). Their core-use areas ranged from 6.10 to 20.39 km^2 ($\bar{X}$ = 13.51 km^2) (Figure 34). We found that P1 used the northern end of the NIR, a small portion of the Cleveland National Forest, and some unprotected natural area directly west of the City of Corona. Her home range extended north to CA-91, south just beyond Santiago Canyon Road, and was within and between Weir Canyon to the west and Black Star Canyon to the east. The core-use areas for P1 included Gypsum Canyon, Coal Canyon, Sierra Peak, and Lower Fremont Canyon (Figure 35).

For P2, we found that she used the western side of the NIR from Gypsum Canyon in the north to Bee Canyon in the south. Her home range extended from Irvine Regional Park and the Cemetery of the Holy Sepulcher in the west to the eastern boundary of Irvine Lake (Santiago Reservoir). The core-use areas for P2 were lower Weir Canyon and the Irvine Regional Park impoundment (Figure 36). P2 also spent some time near fruit orchards and landfills (Bowerman Landfill and the now closed Santiago Canyon Landfill), probably using these areas due to the presence of mule deer, as they are often observed nearby (personal comm. Trish Smith).

P3 used an area stretching from CA-241 in the west to Crow Canyon (Starr Ranch Sanctuary) in the east. Lower Fremont Canyon of the NIR and Casper's Wilderness Park provided the north-south boundaries of her home range, respectively. Besides the boundary areas, P3's home range also encompassed portions of the Cleveland National Forest and open space near the Ramakrishna Monastery. From north to south, the core-use areas for P3 were Lomas Ridge near Hicks Canyon Haul Road, Limestone Canyon, Whiting Ranch Wilderness Park, and O'Neill Regional Park (Figure 37).

Existing Roads – P1 possibly made 26 successful road crossings of paved roads during this study (Table 19). She crossed CA-241 14 times. The greatest amount of use occurred at the Windy Ridge and SCE Wildlife Corridors, the two northernmost undercrossings along CA-241 (Figure 35). P1 also possibly crossed CA-91 six times. However, the GPS locations recorded north of CA-91 during each of these crossing events were 2D fixes. These fixes have error margins of hundreds of meters, and P1's most northern GPS location was approximately 340 meters north of CA-91. Additionally, P1 crossed Santiago Canyon Road (SCR) five times between the Limestone Creek Bridge and UC6 undercrossings.

We documented P2 apparently crossing paved roads 36 times successfully. She crossed CA-241 at least 30 times (Table 20). Most of P2's road activity was concentrated at the Oak Canyon Wildlife Corridor and Santiago Creek Bridge 1 undercrossings, the third and fourth crossings located from north to south along CA-241, respectively. She also crossed CA-241 several times at a location about five miles southeast of the CA-241/CA-261 connector. CA-241 is probably permeable in that location because Hicks Canyon Haul Road travels beneath CA-241, so a sizeable undercrossing is present there (Figure 36). In addition, P2 crossed SCR 6 times either using the Presida Canyon undercrossing or a nearby location. Along the northern part of CA-241 (north of the CA-241/CA-261 interchange), it appeared that P1 and P2 spatially separated the location of their road crossings since P1 primarily used the two northernmost undercrossings while P2 usually used the two southern undercrossings.

P3 appeared to make 22 successful road crossings of paved roads during this study (Table 21). She crossed SCR at least 17 times and traversed Live Oak Canyon Road (LOC) on five separate occasions. Seven SCR crossings occurred between the Limestone Creek Bridge and UC6 undercrossings. All other SCR crossings occurred east of UC6 and appeared to be either at-grade road or unknown (not surveyed) undercrossings. We did not survey LOC for undercrossings. We did not document P3 making any movements across CA-241 despite numerous GPS locations near the eastern edge of the toll road (Figure 37) and potential undercrossing locations along this portion of the road.

Although we can infer from the movement paths that the mountain lions probably crossed roads and used certain undercrossings, we cannot be certain the mountain lions did not traverse the roads via the surface. In fact, on two occasions we are sure that P1 and P2 did attempt at-grade road crossings (see below).

Mortality – Vehicles struck and killed two of the three radio-collared mountain lions (P1, P2). Despite the available and probably often used CA-241 undercrossings, P1 attempted an east to west at-grade road crossing on August 18, 2004; a truck traveling southbound struck and killed her (Appendix 3). The incident occurred at approximately 6 am one-half mile south of the Windy Ridge Toll Plaza. The reporting California Highway Patrol officer estimated P1's mortality location, which placed her directly on top of the SCE Wildlife Corridor undercrossing (Figure 35). In October 2004, we lost P2's VHF radio signal. In early November, we detected a mortality signal in Gypsum Canyon and recovered just the GPS radio box and battery which had detached from the entire radio collar assembly belonging to P2 (Appendix 3). On April 13, 2005, we recovered P2's carcass after she was killed along Santiago Canyon Road. P2 had been traveling north to south at-grade across Santiago Canyon Road in between the Shoestring Canyon undercrossing and Hicks Canyon Haul Road (Figure 36). The collar belting was still present on P2, but it was unclear what caused the radio box and battery to detach earlier. At the time of this report, P3 was still alive and we have continued VHF radio tracking waiting for her collar to possibly drop off in November 2005.

Road Encounter Densities for Proposed Jamboree Road Extension

We estimated road encounter densities along the possible Jamboree Road extension for bobcats (Figure 38), mountain lions (Figure 39), and for both species combined (Figure 40). Seven out of nine (78%) collared bobcats in the Jamboree portion of the study area had home ranges that spanned the footprint of the possible Jamboree Road extension (B2, B5, B6, B7, B10, B11, and B19). Movement paths for six bobcats (B2, B5, B6, B7, B10, and B19) intersected the extension, yielding 32 total road encounters. Road encounter densities for bobcats appeared particularly concentrated near the southern and northern ends of the possible road extension (Figure 38), a pattern also evident when combining bobcat with mountain lion road encounters (Figure 40). However, it should be emphasized that this pattern likely reflects the locations of home ranges of bobcats trapped and collared in this study, and not necessarily the overall distribution of all bobcats in the study area. The lack of documented road encounters in the middle section of the extension does not necessarily imply that bobcats are absent along that section and that they do not cross the footprint of the possible extension. Indeed, track and camera surveys, and anecdotal observation of bobcat sign in the area, suggest that bobcats occur along much of the proposed road extension. Home ranges and movement paths for all three GPS-collared mountain lions intersected the proposed Jamboree Road extension. The 24 total road encounters were distributed along the length of the extension (Figure 39). Overall, movement paths for both bobcats and mountain lions intersected the possible Jamboree Road extension in multiple locations throughout the study area (Figure 40).

Discussion

Large mammals represent excellent focal species as targets for conservation in that they are particularly sensitive to human disturbances such as habitat fragmentation (Crooks, 2002) and can play pivotal roles in ecological communities (Crooks & Soulé, 1999; Henke & Bryant, 1999; Estes et al., 2001). As a group, carnivores (Order Carnivora) are collectively listed by the State of California as species of special concern, and top predators (mountain lions, coyotes, and bobcats) have been the focus of special monitoring efforts within the East Orange/Central Irvine Ranch (Haas et al., 2002) and the Nature Reserve of Orange County (NROC) (Crooks & Jones, 1998; George & Crooks, 2001).

The information presented in this report provides baseline data on the distribution, relative abundance, and movement patterns of large mammals within The Irvine Company's North Ranch Land Reserve, including the proposed Jamboree Road extension and North Lake

Road construction. Data collected from track, camera, capture, and GPS telemetry surveys indicate that the NIR, including the Jamboree and North Lake study areas, supports resident populations of a variety of large mammals, including mountain lions, bobcats, and coyotes. Near the proposed Jamboree Road extension, nearly all track transects and camera stations detected bobcats and coyotes. Mountain lions were also detected at two of the four track transects and six of the seven camera stations. Radio-collared bobcats and mountain lions roamed throughout the Jamboree study area, frequently traveling in and around Weir Canyon and intersecting a possible footprint of a Jamboree Road extension in multiple locations. Likewise, bobcats and coyotes were detected at both track transects and five of the seven camera stations near North Lake Road. Mountain lions were detected at one of the two track transects and five out of the seven camera stations near North Lake Road. Radio-collared bobcats and mountain lions also traveled throughout the North Lake study area. To allow for greater interpretation of bobcat and mountain lion movement through this landscape, future analyses will investigate the ecological correlates of their movement patterns, including the effects of topography, habitat, roadways, and season. These results will be published in papers in scientific journals and will be provided to the sponsors.

It is evident from the GPS data that mountain lions, and to a lesser extent bobcats, range widely. Radio-collared bobcats and mountain lions occupied MCP home ranges up to 25.05 and 181.26 km^2, respectively, and moved up to 1.13 and 6.04 km in 15 minutes and an hour, respectively. The mean home range estimate (132.19 km^2) for female adult mountain lions on the NIR property is not particularly large or unusual. In fact, three mountain lion radio telemetry studies from southern California provide comparison. From 1986-1992, Beier and Barrett (1993) reported MCP home ranges averaging 113 km^2 for 12 adult females over a 6-month period. The NIR was a portion of their overall study area. Specifically, they had 10 mountain lions (two male and three female adults, and four male and one female subadults) move through the property during that time. In recent research, Riley et al. (2004) reported a home range of 100 km^2 for a single adult female using the Santa Monica Mountains that feature vegetation and topography very similar to the NIR. Lastly, Cuyamaca Rancho and Anza-Borrego Desert State Park yielded 100% MCP home ranges for four adult females ranging from 78 to 864 km^2. These animals were monitored from 6.7 to 12.8 months during 2002 and 2003 (Sweanor et al., 2004).

Landscape-level connectivity is a key to the persistence of wide-ranging large carnivores in coastal southern California (Hunter et al., 2003). Indeed, in carnivore surveys conducted throughout the region, Crooks (2002) found mountain lions able to persist in only the largest core wildlands with functional connections between habitat blocks. Similarly, a population viability analysis (Beier, 1993) indicated that persistence of mountain lion populations within the Santa Ana Mountains was dependent on dispersal among habitat patches, and that an estimated 1000-2000 km^2 of suitable habitat would be necessary to maintain a lion population with a 98% probability of persistence for 100 years. At ca. 45 km^2 (11,000 acres), the NIR, taken in isolation, is likely too small to permanently support resident populations of large carnivores with long-term viability. When viewed in a regional perspective, the NIR lies at the northern end of what has been identified as a critical connectivity zone (the El Toro linkage) between the Laguna Coast Wilderness and the Santa Ana Mountains that includes the Cleveland National Forest (Penrod et al., 2001). Core habitat blocks within the NIR therefore appear to serve as critical components of a network of wildlands in the region. Core habitat areas in the NIR include 1) Weir Canyon, bounded by CA-241 on the east and urban edges on the west, 2) Lomas/Limestone Canyon/Whiting Ranch, bounded by Santiago Canyon Road on the north and CA-241 on the south, and 3) North Irvine Ranch core habitat, east of the northern portion of CA-241 and north of Santiago Canyon Road.

Fragmented habitat and restricted ranges in urban regions also may lead to greater contact rates within and between large carnivore species, potentially prompting intra- and inter-species disease transmission. For example, 10 of 17 (59%) bobcats captured in this study tested positive for feline immunodeficiency virus (FIVfca), a type of lentivirus typically found in domestic cats (Sam Franklin and Sue Vandewoude, unpubl. data). Interestingly, phylogenetic analysis of DNA from the bobcat viruses revealed that FIVfca viral strains infecting bobcats in Orange County were closely related to puma lentivirus (FIVpco) isolated from a puma captured in Orange County in the late 1980s. Further, genetic distances between the Orange County puma and bobcat viruses were closer than the distances between the Orange County puma sequence and those sequences from pumas in non-overlapping geographic locations (Sam Franklin and Sue Vandewoude, unpubl.). This suggests that interspecies transmission of this virus may have occurred in Orange County.

With continued urban development and road construction, and associated human disturbances (e.g., road kill, direct persecution), the long-term persistence of large carnivores in many areas of the NIR, particularly smaller and more isolated fragments, is precarious. During our study, vehicles killed two of three radio-collared mountain lions. In addition, since October 2003 (when mountain lion P1 was first radio-collared) from the NIR study area to Highway 74, which bisects the Santa Ana Mountains, several other mountain lions (n = 6) have been lost to road kill, public safety incidents, or depredation permits. Vehicles were responsible for killing two uncollared adult female mountain lions on Santiago Canyon Road in November 2003 and January 2004. Another adult female was killed in January 2004 near Trabuco Canyon after a depredation permit was issued due to predation on goats. Also in January 2004, an adult male mountain lion was killed as a public safety measure because it almost certainly attacked and killed an adult male bicyclist and then attacked an adult female bicyclist the same day. Finally, near the southern boundary of P3's home range, a subadult male was killed in October 2003 in another public safety incident and a vehicle on Highway 74 killed a female mountain lion in June 2004.

Although sample sizes are low, if these occurrences are indicative of survival rates of mountain lions in the region, it is unclear if mountain lions can persist long-term without efforts to mitigate such mortality. Roadway underpasses and fencing may be necessary to alleviate road mortality. To minimize mountain lions killed due to depredation, one obvious proactive strategy is to reduce human-lion conflicts in the first place. Human-mountain lion interactions are very rare relative to the numbers of humans using open space in Orange County and living in the surrounding areas, but these interactions can end in death of both mountain lions and people. To minimize possible human-mountain lion encounters, we recommend continued and expanded education and outreach efforts, in conjunction with evaluating the perceptions and attitudes of local residents and recreationists and the effectiveness of education campaigns. In addition, given that our remotely-triggered cameras and track stations have documented possible human trespassing on NIR property throughout the study, we recommend strengthening efforts to reduce trespassing into core areas. More fences and posted signs, in conjunction with periodic enforcement and ticketing, should be considered to reduce trespassing.

Below we provide evaluations and recommendations of various methodologies for long-term monitoring of carnivores in the area. Note that this discussion is intended as a general review of issues concerning carnivore monitoring, and not a specific, detailed carnivore monitoring plan for the NIR. If desired, development of a detailed, long-term monitoring plan would entail formulation of clear questions to be addressed by monitoring (e.g., movement patterns, responses to roadways, human-wildlife interactions, and/or population trends) and then selection of the appropriate methodologies to address these questions. Development of such a monitoring plan would require a coordinated team effort with local resource managers and agency biologists working with experts skilled in carnivore ecology, experimental design, statistics, database management, and adaptive management.

Considerations for Long-term Monitoring: Methods

1. Track and Camera Surveys

Camera and track surveys can be useful tools to assess the distribution, activity, and movement patterns of wildlife. Our combination of track and camera surveys detected a wide variety of native and non-native wildlife, including 337 visits to track stations and 761 photographs by remotely-triggered cameras. In addition to detecting our large carnivore target species, camera and track surveys were also effective at detecting other wildlife, including deer and smaller carnivores (e.g., spotted skunks, long-tailed weasels, foxes). Further, camera and track surveys can also be useful in assessing levels of human activity (George & Crooks, 2006a); our camera surveys recorded 499 photographs of humans (including vehicles and bikes) on trails and roads in the NIR.

Prior experience (e.g., George & Crooks, 2001) suggests that the effectiveness of track and camera surveys appears to vary among species. For example, cameras stationed at track stations occassionally detect animals passing by without visiting track stations: this seems to be more the case for mountain lions, and to a lesser extent bobcats, than for coyotes, which are highly attracted by the scent lures placed on track stations. Other species, such as striped skunks, raccoons, opossums, and domestic dogs, are detected by track stations in some sites and remotely-triggered cameras in others.

Compared to camera surveys, track transects are relatively inexpensive to operate, only requiring tracking medium (e.g., gypsum powder) and scent lure. However, to read prints, track stations need to be checked frequently (usually daily), so they are typically checked continuously only for a relatively short duration (i.e., days or weeks) and are not run for extended periods (i.e., months or years). For large-ranging animals, such as large carnivores, the short duration of track transects reduces the probability of detection, particularly where there are a wide variety of travel routes. Furthermore, track surveys require training and expertise in track identification, and even personnel skilled in tracking at times cannot identify tracks due to unclear or indistinguishable prints on stations.

In comparison to track surveys, camera stations require considerably less time to maintain and less user skill for definitive species identification. Camera stations can be operated daily over much longer time frames, thus increasing the likelihood of detecting the presence of rare or wide-ranging species. The expense of camera units, film, and batteries is therefore somewhat offset by their lower labor costs to maintain. Indeed, remote photography is an increasingly popular tool to survey wildlife populations and is often less time consuming, costly, and invasive than traditional research methods such as capture or telemetry (Cutler & Swann, 1999), particularly for animals such as carnivores that are difficult to trap, handle, and directly observe (Bull et al., 1992; Mace et al., 1994; Karanth, 1995; Hernandez et al., 1997; Foresman & Pearson, 1998; Karanth & Nichols, 1998). Photographs provide unambiguous evidence of species occurrences that are easily identifiable, less subject to observer bias, and permanently available for resource managers and conservationists to use in public relations and educational efforts (Cutler & Swann, 1999). Furthermore, several companies are currently marketing digital remotely-triggered cameras, which, if employed in future surveys, will further reduce costs by limiting the relatively large expense of purchasing and developing film.

Unfortunately, remotely-triggered cameras are subject to theft in areas visited by humans, such as the NIR. Because remotely-triggered cameras are relatively expensive (ca. $500 each) and the data they contain are quite valuable, camera safety is a major factor in determining which areas can be monitored. This concern can eliminate certain crucial areas from being monitored through camera surveys. To help reduce camera theft and damage, we have constructed several types of strong boxes that house the camera units. These boxes are secured by attaching them to the walls of roadway underpasses or other structures, or by affixing them to stakes or posts that can be dislodged and removed only with great effort. In sites with soft soil, securing the post with concrete may be necessary. We recommend that future camera monitoring use such camera strong boxes. This not only minimizes camera theft, but the camera boxes also provide clear, permanent stations that could be repeatedly sampled for long-term monitoring programs. Indeed, repeated sampling at the same station is essential – prior experience suggests that the exact location of a camera station can influence the relative camera indices among species. It is therefore important to choose sampling stations that adequately monitor animal movement in an area, and then repeatedly sample at that point.

Overall, when developing long-term monitoring programs for wildlife in the NIR, we suggest that camera surveys will prove more useful than track surveys. Track surveys, however, could be employed in a targeted fashion, for instance when information on animal movement is desired at a specific location such as a connectivity choke-point, movement linkage, or roadway underpass.

Finally, although camera surveys may prove useful to document wildlife presence and activity in an area, we again wish to issue a cautionary note regarding the interpretation of such indices and their use in population monitoring. Typically, inferences from data on camera and track visits like those recorded from our surveys are limited by the inability to distinguish multiple visits by a single individual from many single visits from multiple individuals (Karanth & Nichols, 1998). While some studies have shown that indirect surveys for carnivores are proportional to actual abundance (e.g., Stander, 1998; Carbone et al., 2001), most studies, like ours, have only reported visitation data as indices of distribution or relative abundance or activity. Such indices cannot yield actual estimates of population densities and have been criticized on these grounds (Anderson, 2001). Changes in track or camera indices across time or space therefore do not necessarily reflect actual changes in population densities of target species, a serious limitation if such surveys are to be used for long-term population monitoring. It should be noted, however, that if individual identification of animals in photographs is possible, then it becomes feasible to actually estimate densities through mark-resight models (e.g., Karanth &

Nichols, 1998). For example, in conjunction with ongoing radio-telemetry or marking studies, camera surveys can be used to resight marked individuals to yield better population estimates of target species. In addition, a recent study (Heilbrun et al., 2003) has suggested that bobcats may be individually identifiable in photographs by their body characteristics and natural markings, therefore providing an alternative to physical capture for mark-recapture population estimates. We intend to explore if this technique will allow individual identification of bobcats photographed in the NIR as well as in an ongoing camera study in the San Joaquin Hills.

2. Radio-telemetry

Track and camera indices are relatively inexpensive and effective methods to evaluate the distribution and relative activity of large mammal populations. These techniques, however, do not lend much insight into individual behavior and movement patterns in an area. The GPS data we collected on mountain lions and bobcats provided unprecedented high-resolution data on the continuous movements of animals through the NIR, and are yielding valuable information on the responses of individuals to habitat types, urban edges, roadways, and landscape linkages. Such data are being incorporated into computer simulation models to predict carnivore movements and to assess landscape-level connectivity throughout coastal southern California (Tracey 2006) and other regions (e.g., Kramer-Schadt et al., 2005).

If the Jamboree Road extension or North Lake Road construction occurs, particularly after individuals in our study have died and the population has turned over (i.e., over 5 years from now), we recommend that further radio-telemetry projects be conducted in the immediate vicinity of the road construction (see below). If animals in the area were radio-collared before, during, and after road construction, this would allow direct assessment of the effects of the construction process and the new roadway on wildlife movement and activity patterns. These data could then be compared to the baseline movement data we collected during this study. Furthermore, capturing and individually marking animals would possibly allow estimation of population sizes through mark-resight (with remotely-triggered cameras) or mark-recapture (with traps) methodologies.

3. Non-invasive DNA Sampling

Indirect surveys such as track and camera surveys have limited applicability for population monitoring, while conventional survey techniques, such as live-trapping, mark-recapture, and radio-telemetry, can be logistically difficult and expensive for carnivores. In contrast, non-invasive sampling of hair or feces (scat) and subsequent genetic analyses can be used to determine important population parameters and behavior patterns of carnivores, including population sizes, dispersal rates, genetic structure, and relatedness within and between populations (Snow & Parker, 1998; Taberlet et al., 1999; Taberlet et al., 2001). Many such parameters are difficult or impossible to determine using conventional methods. In addition, non-invasive genetic sampling allows large numbers of individuals and multiple populations to be studied over a relatively short period of time (Taberlet et al., 1999). Non-invasive hair collection methods and devices have been developed for various carnivore species including black and brown bears, American marten, and lynx (Foran et al., 1997a, 1997b; Woods et al., 1999; McDaniel et al., 2000;). In addition, non-invasive sampling of scat has been used successfully to study mountain lions, coyotes, wolves, bears, and other species (Kohn et al., 1995; Foran et al., 1997a, 1997b; Kohn et al., 1999; Ernest et al., 2000; Creel et al., 2003).

Emily Ruell (a M.S. student with Kevin Crooks at CSU) is currently using hair snare and scat surveys to non-invasively sample bobcat, coyote, and mountain lion DNA in Orange County, including sites within the NIR and the NROC. The objectives of her study are to use non-invasive genetic sampling of carnivore hair and scat samples to examine the effects of habitat fragmentation and connectivity on 1) dispersal, 2) population size, 3) inbreeding and relatedness between individuals, and 4) genetic diversity of carnivore populations in this fragmented landscape. Hair snares consist of 61 cm by 15 cm pine boards with 2-3 white chicken feathers attached as an initial visual attractant. Nailed on the top surface of the boards are 10 cm by 10 cm natural fiber carpet squares baited with carnivore scent lures, which incite carnivores to rub against leaving behind hair. This hair snare sampling has proven very effective: 91% of hair snare stations and 50% of snare sessions in the 2003 field season collected hair samples (Ruell and Crooks, in prep). DNA is then extracted from collected hair and scat, and samples are identified to species using mitochondrial DNA (Mills et al., 2000). DNA extraction success of hair samples, resulting in amplifiable mitochondrial DNA and species identification, was approximately 81% of the 348 hair samples collected in Orange County. Of the 283 hair samples that amplified DNA, approximately 16% were bobcat, 2% were mountain lion, 45% were coyote, 26% were gray fox, and 4% were domestic dog (Figure 41 for bobcat and mountain lion results). Currently, NIR samples are being identified to individuals using multiple microsatellite loci that have been developed and successfully used in noninvasive studies of bobcat, mountain lions, lynx (Menotti-Raymond & O'Brien, 1995; Menotti-Raymond et al., 1999; Ernest et al., 2000; Schwartz et al., 2002), and coyotes (Kohn et al., 1999). Thus far, we have successfully genotyped 94% (17 of 18) of the bobcats we collected tissue samples from and respectively matched at least two non-invasively sampled scat and hair samples to B2 (adult female) and B10 (adult male).

Results to date suggest that scat samples have higher success rates for individual genotyping than hair samples. Further, unlike hair snares, where animals have to be actively attracted to snares, scat surveys allow for passive sampling of carnivores. That is, scats can be systematically searched for and collected along existing roads and trails without modifying the behavior of the animals. For common species such as coyote, bobcat, and gray fox, which defecate frequently enough on roads and trails to obtain a sufficient sample size, scat surveys may work best to collect DNA non-invasively. Encountering mountain lion scats opportunistically is relatively uncommon in this study area, likely reducing the effectiveness of passive scat sampling.

If non-invasive genetic sampling proves effective, we suggest that this survey technique would enhance the effectiveness of a monitoring program for population estimates for large mammals within the NIR. Non-invasive DNA sampling using scat, and perhaps hair snares, at regular intervals (e.g., every 5-10 years) may allow long-term monitoring of population sizes and genetic diversity of target species within the study area.

Considerations for Long-term Monitoring: Other Factors

4. Road-Kill

Distribution of vehicle-killed animals along roadways can provide valuable data for evaluating the impact of roads and effectiveness of underpasses. Throughout Orange County, employees of Caltrans, the Transportation Corridor Authority, and local animal control officers opportunistically pick up or record wild animals that are killed on roadways. We suggest establishing a synthetic, systematic inventory, mapping, and analysis of available road kill data in the area. This cooperative effort would require only minimal additional effort by County animal control officers because they already frequently record road-kills in logbooks. Similarly, acquiring and compiling road kill data that is collected by the Transportation Corridor Authority and Caltrans would also be important. We recommend that The Irvine Company or The Nature Conservancy construct and distribute a simple data sheet on which key personnel could fill in the "date", "location", and "species identification" of road kills encountered. These sheets could be periodically routed to a single collection site for database entry and analysis.

Road-kill data could be used to identify the species most susceptible to road-caused mortality and to map road-kill "hot-spots" to assess locations of barriers to natural dispersal and movement routes (Swift et al., 1993). If Jamboree Road extension or North Lake Road construction were to occur in the future, comparisons of locations and frequencies of road kill before and after construction would greatly strengthen inferences about the impacts of roads and the effectiveness of mitigation structures such as underpasses and fencing (see below).

5. Mule Deer

Although our research efforts have focused on large mammalian carnivores, we recommend the inclusion of mule deer in future NIR planning and monitoring efforts. As dominant herbivores, mule deer represent a critical component to a functioning ecosystem, comprise the majority of mountain lion diet (Beier & Barrett, 1993; Beier, 1996), and may be sensitive to habitat fragmentation. Deer often adapt well along the urban fringe and can become a nuisance due to, for example, browsing ornamental vegetation (Noss & Cooperrider, 1994). However, in highly fragmented areas deer are progressively restricted to smaller, more isolated populations. Because deer are large-bodied and require relatively large ranges, the long-term persistence of deer populations may ultimately depend on their ability to move successfully among fragmented patches of habitat. For example, field observations and communication with longtime residents suggest that mule deer may have declined, and in some situations disappeared, from small habitat fragments within urbanized areas of the NROC (George & Crooks, 2001).

Remotely-triggered cameras appear to be an effective method to document the distribution and relative activity of deer. Deer were the most frequently detected wildlife species at camera stations, recorded at all seven camera stations in the Jamboree study area (159 total detections) and six out of the seven camera stations along North Lake Road (169 total detections). In addition, a host of other methods is available to survey deer populations. These include aerial or ground distance transect surveys (Buckland et al., 2001), radio-telemetry (including GPS telemetry) (Sweanor et al., 2004), and pellet counts (Neff, 1968; Fuller, 1991), potentially in combination with molecular genetic techniques. We recommend that these options be explored, possibly working with the California Department of Fish and Game, to develop an effective monitoring program for deer within the NIR.

6. Human Activity

The long-term persistence of large carnivores in many areas of the NIR is uncertain, and human disturbances pose a threat to carnivore populations. Furthermore, if it is important to understand potential wildlife-human conflicts (e.g., mountain lion-human interactions), it will be important to not only understand the behavior and activity of wildlife, but also the behavior and activity of humans using the reserve.

We therefore recommend monitoring human recreational activity within the reserve. Remotely-triggered cameras may be an effective way to document use by different user groups (e.g., hikers, bikers, equestrians, vehicles). In addition, we recommend expanded education and outreach efforts to facilitate the co-existence of humans and wildlife. We also recommend concurrently evaluating the effectiveness of education campaigns, perhaps by evaluating the perceptions and attitudes of local residents towards wildlife (George & Crooks, 2006b). Finally, we recommend extending efforts to reduce trespassing into core areas, given that our remotely-triggered cameras and track stations have documented possible trespassing on NIR property throughout the study.

Summary of Monitoring Recommendations

1) Both track and camera indices allow evaluation of carnivore distribution and relative activity and site-specific evaluations, but do not typically yield actual estimates of absolute population densities. As such, they have limited utility for long-term monitoring.

2) Camera surveys are more useful for long-term monitoring of carnivore distribution, diversity, and relative activity than track surveys due to the ability of cameras to provide unambiguous evidence of wildlife activity for extended periods. Further, if individual identification of animals in photographs is possible (e.g., in conjunction with ongoing trapping and collaring efforts or by natural markings), then it becomes feasible to actually estimate densities through mark-resight models.

3) If necessary, track surveys could be employed in a targeted fashion at specific sites of conservation concern (e.g., movement linkages or roadway underpasses).

4) If the Jamboree Road extension or North Lake Road construction occurs, we recommend that further radio-telemetry projects be pursued in the immediate vicinity of the road pre- and post-construction, thus allowing for stronger inferences on the impacts of roadways and mitigation measures, and for comparison to the baseline data collected in this study.

5) Non-invasive DNA sampling at regular intervals (e.g., every 5-10 years) may allow for effective long-term monitoring of population sizes and genetic diversity of target species within the study area.

6) Develop and implement a systematic, comprehensive effort to collect, synthesize, and analyze road kill data throughout the NIR and surrounding region.

7) Evaluate and implement a possible monitoring program for mule deer in the NIR.

8) Monitor human recreational activity, perception and attitudes, and effectiveness of educational and outreach campaigns. Reinforce efforts to minimize trespassing on private lands.

Roadway Mitigation

With continued urban development and road construction, it is critical to maintain and restore connectivity among core habitat blocks within and outside of the NIR. We recorded bobcats and mountain lions using existing underpasses under CA-241 and Santiago Canyon Road. Previous studies also have documented underpass use by wildlife in the NROC (Crooks & Jones, 1998) and The Irvine Company's East Orange/Central Irvine Ranch (Haas et al., 2002). Radio-collared mountain lions in the region also used underpasses in a prior study (Beier, 1993; Beier & Barrett, 1993). Such results clearly indicate that roadway undercrossings are helping facilitate wildlife movement in and around the NIR if properly situated and designed.

Although animals do use underpasses, telemetry data also suggest frequent surface crossings of roadways by mountain lions and bobcats. Indeed, in this study, vehicles killed two radio-collared mountain lions attempting to cross CA-241 and Santiago Canyon Road**.** Road kill mortality has also been identified as the principle mortality source for carnivores in other studies in the region (Beier, 1993; Lyren, 2001). Although traffic densities in this area are relatively low to moderate for urban coastal southern California (the AADT volume for CA-241 is 43,000, CA-261 is 13,900, CA-133 is 15,000, and Santiago Canyon Road is 11,500, CDOT, 2005; OCTA, 2005), recent studies have documented high rates of road kill along roadways with intermediate levels of traffic (Lyren, 2001; Ng et al., 2004). Very low traffic volumes do not represent major mortality threats, whereas extremely high traffic volume can act as an impenetrable barrier with few attempted road crossings or mortality. With future increases in road width and traffic volume, including the proposed Jamboree Road extension and North Lake Road construction, suitable crossing structures will need to be designed, situated, and monitored to maintain wildlife travel routes. Furthermore, adequate wildlife fencing should be considered to reduce vehicle-related mortality and enhance existing crossing structures (Haas, 2000; Lyren, 2001). Below we provide recommendations to assess and mitigate the impacts of current and future roadways in the NIR.

1. Underpass Location and Function

Many factors can influence level of wildlife use of a particular underpass, and some underpasses will be used more than others (Reed et al., 1975; Reed, 1981; Foster & Humphrey, 1995; Yanes et al., 1995;; Rodriguez et al., 1997; Clevenger & Waltho, 1999; Clevenger & Waltho, 2000; Haas, 2000; Clevenger & Waltho, 2005). The landscape context of the underpass has been identified as a critical factor in determining if an underpass will be used by a particular species (Crooks & Jones, 1998; Haas, 2000; Clevenger & Waltho, 2005). Landscape characteristics that have a negative impact on underpass use include a) for bobcats: high levels of residential/urban landscapes, narrow corridors, high road densities, and high levels of habitat fragmentation, b) for coyotes: high levels of residential/urban landscapes, narrow corridors, and high levels of habitat fragmentation, and c) for mule deer: high levels of residential/urban landscapes and high road densities (Crooks & Jones, 1998; Haas, 2000).

Habitat characteristics in the immediate vicinity of the underpass are also important in predicting the use of underpasses by wildlife. For bobcats and mule deer, native vegetation surrounding the underpass entrance increases the probability of underpasses use, whereas using non-native, ornamental landscaping decreases the probability of underpass use for bobcats (Crooks & Jones, 1998; Haas, 2000). The function of the underpass is also important for bobcats, as they are less likely to use underpasses that have a road/trail/paved bike path going through them (Crooks & Jones, 1998). Indeed, there has been increasing evidence that human traffic either directly (animal alters activity when a human is present) or indirectly (animal alters activity after a human has vacated the area) may cause animals to alter their activity patterns or avoid areas altogether (Griffiths & Van Schaik, 1993; Clevenger & Waltho, 2000; Clevenger & Waltho, 2005; George & Crooks, 2006a).

In general, to optimize the probability of underpass use by the target species, we recommend that underpasses be situated along primary wildlife travel routes, away from areas containing noise and light pollution, and serve only wildlife needs. Additionally, native vegetation should surround all underpass entrances and replace any proposed rock fill slope protection. Concrete v-ditches and rip-rap should be avoided to allow natural stream flows, which provide the elements critical for the movement of sensitive reptile and amphibian species, and ungulates are reluctant to walk on rip-rap and some other unnatural substrates (Irwin et al., 2003). Sound walls might also be considered along key portions of the roadways to mitigate the effects of traffic noise on wildlife.

2. Underpass Dimensions

Underpass dimensions are also important in determining if a species will use an underpass as well as frequency of use (Haas, 2000; Clevenger & Waltho, 2005). Haas (2000) found that mule deer never used underpasses less than 4.5 m in height and coyotes never used underpasses less than one meter in height. Furthermore, Crooks and Jones (1998) found that mule deer used open span bridges more frequently than box or pipe culverts. Thus, an important variable is the openness of the underpass, which takes into consideration the height, width, and length of the underpass ($O = H \times W / L$). An openness value greater than 0.6 has been recommended for mule deer (Reed, 1981). In fact, Haas (2000) reported that bobcat, coyote, and mule deer frequency of underpass use increased as underpass height, width, and/or openness increased. Although the smaller drainage culverts may receive use by smaller vertebrates (rodents, herpetofauna, and mesopredators), large mammal activity through underpasses less than one meter in height is highly unlikely. Specific underpass dimensions (particularly large underpasses to facilitate mule deer movement), however, may be difficult to achieve due to road profile limitations.

3. Wildlife Fencing Design

To prevent attempted at-grade crossings by target species, it is critical that fencing be installed to “funnel” animals towards each underpass. We recommend that fencing occur along the entire roadway/wildland interface (Jaeger & Fahrig, 2004), particularly along those stretches of roads that experience pronounced wildlife activity. Wildlife will often make end runs around wing fences adjacent to crossing structures, traveling along a wing fence until it ends and attempting to cross the roadway at that location (Thompson, 1978; Roof & Wooding, 1996; Lyren, 2001). Such end runs may decrease underpass use and expose animals to animal-vehicle collisions. If lengthy stretches of road cannot be fenced, we recommend that monitoring take place to 1) identify high activity zones where wildlife mortality is occurring and 2) compare how those activity zones shift in relation to wildlife fencing position. If lengthy portions of the road are fenced, it is critical that multiple underpasses of adequate size be provided so that the fencing does not create a barrier in itself.

We recommend that the fencing be a neutral color (e.g., brown or green) to complement the natural landscape, instead of the shiny silver that is standard. This would allow fencing to be installed along lengthy stretches of the roadways, but minimize the interruption of the scenery and maximize both functionality for wildlife and public enjoyment of the landscape. Additionally, native vegetation that does not hang over fencing could be strategically placed along fencing to minimize its intrusiveness. This may be an added benefit because additional vegetation could buffer noise and/or light accompanying traffic volume, which appears to suppress frequency of underpass use for coyotes (Lyren, 2001). Fencing should have mesh that is less than 10 cm x 15 cm (4 in x 6 in) (Thompson, 1978) and be seated at least 45 cm (18 in), preferably 60 cm (24 in), into the ground to prevent medium to large-sized animals from exploiting any weaknesses. Fencing should not span v-ditches or other types of manufactured channels used to direct water, and when used as part of a gate, the gate bottom must be flush to the ground (Appendix 4). Taking both these necessary precautions will help prevent animals from accessing the road and becoming trapped. The height of the fencing should be 3 m (10 ft) minimum, except in areas down slope from road cuts where it should be 3.5 m (12 ft) high to prevent mule deer from going over the top (Evink, 2000). Finally, fencing should be closely inspected and repaired twice per year to ensure it retains it integrity against natural and anthropogenic disturbances.

4. Pre and Post-Construction Monitoring

As discussed above, if the Jamboree Road extension or North Lake Road construction occurs in the future, we recommend further surveys in the immediate vicinity before, during, and after construction. Efforts could include targeted track and camera, radio-telemetry, and road kill surveys. These would allow direct assessment of the effects of the construction process and the new roadway on wildlife movement and activity patterns. These data could also be compared to the baseline movement data we collected during this study. Ideally, sections of these roadways (or similar roads in the area) that will not experience construction would be monitored as well during this time to provide a before-after-control-impact experimental (BACI) design. Such an approach would allow for the most complete evaluation of the impacts of roadway construction and success of mitigation measures.

Post-construction monitoring should occur for a minimum of one year after the roadway widening has occurred; however, it should be noted that even two-year studies might not be adequate to fully determine long-term movement patterns of larger predators. Additionally, mule deer may exhibit reluctance to use underpasses for at least eight months after installation (Reed, 1981; Ward, 1982; Haas, 2000;).

Summary of Roadway Mitigation Recommendations

To summarize, we provide a list of recommendations to facilitate connectivity relative to proposed road construction projects:

1) Drainages used by large mammals should contain underpasses large enough to facilitate their movement where feasible.

2) Fencing should be constructed along portions of the roadways experiencing animal surface crossings and underpass use.

3) To enhance the areas surrounding each underpass, we recommend planting native vegetation to provide continuous cover for animals as they use these structures. Additional cover may also help reduce light and/or noise pollution.

4) If the Jamboree Road extension or North Lake Road construction occurs in the future, we recommend further surveys in the immediate vicinity of the road pre- and post-construction, thus allowing for stronger inference on the impacts of roadways and mitigation measures, and for comparison to the baseline data collected in this study.

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Table 1. GPS coordinates of undercrossing locations in the proximity of the North/Central Irvine Ranch, Orange County, CA. Undercrossings are listed as they are encountered along CA-241 from north to south and along Santiago Canyon Road from west to east.

General Site	Undercrossing Name[a]	Degrees N	Degrees W
CA-241	Windy Ridge Wildlife Corridor	33.83410	-117.71825
CA-241	SCE Wildlife Corridor	33.81792	-117.71825
CA-241	Oak Canyon Wildlife Corridor	33.80772	-117.72408
CA-241	Santiago Creek Bridge 1	33.79639	-117.72998
Santiago Canyon Road	Presida Canyon Road (Cam 19)	33.76749	-117.72686
Santiago Canyon Road	Shoestring Road (Cam 18)	33.76354	-117.71267
Santiago Canyon Road	Limestone Creek Bridge (Cam 17)	33.76002	-117.70340
Santiago Canyon Road	UC4 (Cam 25)	33.75259	-117.69027
Santiago Canyon Road	UC5 (Cam 24)	33.75271	-117.68815
Santiago Canyon Road	UC6 (Cam 20)	33.75278	-117.68509
Santiago Canyon Road	Santiago Creek Bridge 2 (Cam 16)	33.74770	-117.67557
Santiago Canyon Road	UC8 (Cam 21)	33.73626	-117.65731
Santiago Canyon Road	UC9 (Cam 22)	33.73404	-117.65328

[a] Comments within parentheses refer to the camera numbers/names used to monitor that same undercrossing in the East Orange/Central Irvine Ranch Mammal Movement Study (Figure 3, Haas et al. 2002). Also see Figure 1b this report.

Table 2. GPS coordinates of baited scent and camera stations for mammal sampling at the North/Central Irvine Ranch, Orange County, CA from August 2002 to December 2003. Study area subsections are shown in bold and correspond to potential road projects within the NIR.

Track Transect		Degrees N	Degrees W	Camera	Degrees N	Degrees W
Jamboree Road						
Blind Canyon	1	33.82056	-117.72597	#2001	33.83958	-117.72229
	2	33.82101	-117.72868	#2002	33.82098	-117.73096
	3	33.82087	-117.73077	#2003	33.83808	-117.73384
	4	33.82087	-117.73301	#2030	33.81445	-117.74949
	5	33.82197	-117.73540	#2031	33.83052	-117.73959
				#2039	33.80431	-117.74956
MWD Road	1	33.81339	-117.74478	#2040	33.80858	-117.74568
	2	33.81071	-117.74632			
	3	33.80867	-117.74672			
	4	33.80678	-117.74906			
	5	33.80443	-117.74922			
Weir Canyon	1	33.83660	-117.73421			
	2	33.83348	-117.73455			
	3	33.83211	-117.73621			
	4	33.83026	-117.73824			
	5	33.82858	-117.74042			
Windy Ridge	1	33.83183	-117.72038			
	2	33.83118	-117.72221			
	3	33.83255	-117.72353			
	4	33.83393	-117.72547			
	5	33.83438	-117.72819			
North Lake Road						
Fremont Canyon	1	33.79392	-117.72791	#2032	33.79843	-117.73636
	2	33.79131	-117.72539	#2033	33.78873	-117.72001
	3	33.78986	-117.72486	#2034	33.79159	-117.71987
	4	33.78919	-117.72093	#2035	33.78586	-117.72143
	5	33.78779	-117.71862	#2037	33.77743	-117.69485
				#2038	33.77607	-117.68605
North Lake Road	1	33.77601	-117.69341	#2041	33.77884	-117.70384
	2	33.77547	-117.69048			
	3	33.77534	-117.68803			
	4	33.77522	-117.68586			
	5	33.77441	-117.68309			

Table 3. Programming schedule for GPS-Posrec™ 120 radio-collars fitted to bobcats in the North/Central Irvine Ranch, Orange County, CA, December 2002 to May 2004. All schedules are shown in Pacific Standard Time (PST).

	Collar Type / Total Duration			
Starting Day	**10 Week[a]**	**18 Week[b]**	**19 Week[a]**	**25 Week[a]**
Sunday	11:00 PM - 12:45 AM	X	11:00 PM - 12:45 AM	10:00 PM - 12:45 AM
Monday	X	12:00 AM - 3:30 AM	X	X
Tuesday	11:00 PM - 12:45 AM	X	X	X
Wednesday	X	X	X	X
Thursday	11:00 PM - 12:45 AM	X	11:00 PM - 12:45 AM	X
Friday	X	12:00 AM - 3:30 AM	X	X
Saturday	11:00 PM - 12:45 AM	X	X	X
Maximum number GPS locations projected by manufacturer[e]	324	284	306	295
Ideal candidate for collar type	Adult male	None specified[c]	Adult female	Juvenile (male or female)

[a] 10, 19, and 25-week collars (four of each type) obtained GPS positions every 15 minutes during the scheduled daily time periods during Phase 1. For example, the 11:00pm-12:45am schedule would result in location attempts at 11:00, 11:15, 11:30, 11:45, 12:00, 12:15, 12:30, and 12:45 ideally resulting in 8 locations/sampling session. However, 25-week collars began sampling at 10:00, thus ideally resulting in 12 locations/sampling session.

[b] During Phase 2, 18-week collars (four total) obtained GPS positions every 30 minutes during the scheduled daily time periods resulting in location attempts at 12:00, 12:30, 1:00, 1:30, 2:00, 2:30, 3:00, and 3:30 ideally resulting in 8 locations/sampling session. For more details on this collar schedule see section Bobcats: Phase 2, GPS Collar Programming.

[c] This schedule was added in Phase 2 after initial analysis of Phase 1 data indicated we needed some longer time intervals between GPS locations that should have subsequently provided longer movement distances (see Bobcats: Phase 2, GPS Collar Programming).

Table 4. Phase 1 GPS coordinates of bobcat trapping locations established at the North/Central Irvine Ranch, Orange County, CA from November 2002 to February 2003. Study site refers to subsections within the study area corresponding to the potential road projects within the NIR. Habitat codes are CSS = Coastal Sage Scrub, MCH = Mixed Chaparral, and RIP = Riparian.

Study Site	Trap Name	Trap Habitat	Degrees N	Degrees W
Jamboree	T1A	CSS	33.81674	-117.74320
Jamboree	T2A	RIP	33.83675	-117.72846
Jamboree	T3A	CSS	33.80425	-117.74978
Jamboree	T4A	CSS	33.80842	-117.74618
Jamboree	T5A	RIP	33.83696	-117.73449
Jamboree	T6A	CSS	33.81364	-117.74486
Jamboree	T7A	CSS	33.82229	-117.73196
Jamboree	T8A	CSS	33.82488	-117.74137
Jamboree	T9A	CSS	33.83245	-117.72300
Jamboree	T10A	CSS	33.80240	-117.74452
Jamboree	T17A	CSS	33.81640	-117.74444
Jamboree	T18A	CSS	33.81994	-117.74437
Jamboree	T19A	CSS	33.82996	-117.73978
North Lake	T11A	CSS	33.79784	-117.73400
North Lake	T12A	RIP	33.79510	-117.73003
North Lake	T13A	CSS	33.78227	-117.71327
North Lake	T14A	CSS	33.78834	-117.71919
North Lake	T15A	CSS	33.79139	-117.72476
North Lake	T16A	CSS	33.79705	-117.73841
North Lake	T20A	RIP	33.77713	-117.69490
North Lake	T21A	RIP	33.78102	-117.70048
North Lake	T22A	RIP	33.78385	-117.71766
North Lake	T23A	RIP	33.77536	-117.68657
North Lake	T24A	CSS	33.77797	-117.70090
North Lake	T25A	MCH	33.78224	-117.70385
North Lake	T26A	CSS	33.78556	-117.72137
North Lake	T27A	MCH	33.78360	-117.70727
North Lake	T28A	CSS	33.77621	-117.69343
North Lake	T29A	RIP	33.79139	-117.71955
North Lake	T30A	CSS	33.79446	-117.73671
North Lake	T31A	CSS	33.78110	-117.71630
North Lake	T32A	CSS	33.77901	-117.70384

Table 5. Phase 2 GPS coordinates of bobcat trapping locations established at the North/Central Irvine Ranch (NIR), Orange County, CA from October 2003 to November 2004. Study site refers to subsections within the study area corresponding to the potential road projects within the NIR. Habitat codes are CSS = Coastal Sage Scrub, COW = Coastal Oak Woodland, GRS = Grassland, MCH = Mixed Chaparral, and RIP = Riparian.

Study Site	Trap Name	Trap Habitat	Degrees N	Degrees W
Jamboree	T7A	CSS	33.82229	-117.73196
Jamboree	2T45A	CSS	33.83266	-117.73477
Jamboree	2T46A	COW	33.83471	-117.73037
Jamboree	2T47A	CSS	33.83664	-117.72422
Jamboree	2T48A	COW	33.83587	-117.72854
Jamboree	2T49A	CSS	33.83648	-117.72890
Jamboree	2T50A	CSS	33.83317	-117.72466
Jamboree	2T51A	CSS	33.83210	-117.72254
Jamboree	2T52A	CSS	33.83600	-117.73429
Jamboree	2T53A	CSS	33.83009	-117.73964
Jamboree	2T54A	CSS	33.83622	-117.72337
Jamboree	2T55A	CSS / COW	33.83001	-117.73820
Jamboree	2T56A	COW	33.83333	-117.73340
Jamboree	2T57A	CSS	33.82463	-117.74114
Jamboree	2T58A	CSS	33.82799	-117.74161
Jamboree	2T59A	CSS / COW	33.82345	-117.73758
Jamboree	2T60A	COW	33.82203	-117.74564
North Lake	T21A	RIP	33.78102	-117.70048
North Lake	T23A	RIP	33.77536	-117.68657
North Lake	T24A	CSS	33.77797	-117.70090
North Lake	T25A	MCH	33.78224	-117.70385
North Lake	T27A	MCH	33.78360	-117.70727
North Lake	T32A	CSS	33.77901	-117.70384
North Lake	2T33A	RIP	33.77742	-117.69493
North Lake	2T34A	CSS	33.77464	-117.68313
North Lake	2T35A	MCH	33.79052	-117.69211
North Lake	2T36A	COW	33.79243	-117.68818
North Lake	2T37A	MCH	33.79311	-117.68615
North Lake	2T38A	CSS	33.76172	-117.68114
North Lake	2T39A	CSS	33.76184	-117.68209
North Lake	2T40A	CSS	33.76838	-117.68224
North Lake	2T41A	COW	33.77293	-117.68766
North Lake	2T42A	COW	33.77080	-117.69100
North Lake	2T43A	MCH	33.79116	-117.68077
North Lake	2T44A	GRS	33.79000	-117.70101
North Lake	2T61A	RIP	33.75144	-117.69328
North Lake	2T62A	COW	33.77283	-117.68887
North Lake	2T63A	RIP	33.75454	-117.67920
North Lake	2T64A	RIP	33.75892	-117.67923
North Lake	2T65A	RIP	33.75118	-117.69073

Table 6. GPS coordinates of mountain lion cage trap and snare locations established at the North/Central Irvine Ranch, Orange County, CA from March 2004 to December 2004. Habitat codes are CSS = Coastal Sage Scrub, COW = Coastal Oak Woodland, GRS = Grassland, MCH = Mixed Chaparral, and RIP = Riparian.

Study Site	Snare Name	Snare Habitat	Degrees N	Degrees W
NIR	Cage Trap	COW	33.79185	-117.72171
NIR	S1	COW	33.83539	-117.73467
NIR	S2	COW	33.83409	-117.73484
NIR	S3	COW	33.82414	-117.74155
NIR	S4	COW	33.82525	-117.73665
NIR	S5	RIP	33.82532	-117.74358
NIR	S6	COW	33.82106	-117.74765
NIR	S7	RIP	33.81595	-117.72320
NIR	S8	COW	33.80829	-117.74675
NIR	S9	COW	33.80776	-117.74723
NIR	S10	COW	33.81632	-117.75049
NIR	S11	MCH	33.81216	-117.72757
NIR	S12	COW	33.81664	-117.72521
NIR	S13	COW	33.79175	-117.72080
NIR	S14	COW	33.79182	-117.72118
NIR	S15	RIP / CSS	33.77689	-117.69498
NIR	S16	RIP / CSS	33.77559	-117.68633
NIR	S17	COW	33.83127	-117.67311
NIR	S18	COW / RIP	33.83103	-117.67172
NIR	S19	COW	33.81609	-117.70656
NIR	S20	COW / RIP	33.82468	-117.68266
NIR	S21	COW	33.81595	-117.67074
NIR	S22	COW	33.81635	-117.66976
NIR	S23	COW	33.79159	-117.71985
NIR	S24	COW	33.73409	-117.68605
NIR	S25	COW	33.76031	-117.71770
NIR	S26	COW	33.76047	-117.71763
NIR	S27	COW	33.75444	-117.70380
NIR	S28	COW	33.75468	-117.70487

Table 7. Total sampling effort for track transects and camera stations at the North/Central Irvine Ranch from August 2002 to December 2003. Track transects along Jamboree were surveyed Aug 6-10 and Oct 15-19, 2002, and Aug 19-23 and Nov 22-26, 2003. Track transects along North Lake were surveyed Aug 19-23 and Nov 22-26, 2003. Cameras #2001, 2002, 2003, and 2039 were established August 2002. Jamboree cameras #2030, 2031, and 2040, and North Lake cameras #2032, 2033, 2034, 2035, and 2041 were established in January 2003. Cameras #2037 and 2038 were established in June 2003. CSE refers to the number of days the camera was active. $TSE_j = (s_j n_j) - o_j$, where, s_j = number of stations in transect j, n_j = number of nights station was active in transect j, o_j = number of station nights omitted in transect j due to complications.

Track Transect	Track Sampling Effort (TSE_j)	Camera ID	Camera Sampling Effort (CSE)
Jamboree Road Extension			
Blind Canyon	98	#2001	458
MWD Road	98	#2002	495
Weir Canyon	94	#2003	185
Windy Ridge	100	#2039	473
		#2030	299
		#2031	255
		#2040	281
North Lake Road			
Fremont Canyon	48	#2032	327
North Lake Road	49	#2033	326
		#2034	321
		#2035	278
		#2037	83
		#2038	196
		#2041	324

Table 8. Mammal species detected at track transects at the North/Central Irvine Ranch from August 2002 to November 2003. Jamboree Road Extension and North Lake Road refer to subsections within the study area corresponding to potential road projects within the NIR. Values for each species or track transect indicate number of detections by named species followed by the associated track index within parentheses (if applicable). Track index is $I_j = \{v_j/(s_j n_j)\text{-}o_j\}$, where I_j = index of activity at transect j, v_j = number of stations that detected a species in transect j, s_j = number of stations at transect j, n_j = number of nights that stations were active in transect j, and o_j = number of omits in transect j.

	Transect Name							
	Jamboree Road Extension				North Lake Road			
Species Detected	**Blind Cyn**	**MWD Rd**	**Weir Cyn**	**Windy Rdg**	**Fremont Cyn**	**No. Lake Rd**	**Total # Detections by Species**	**# of Transects Detecting Species**
<u>Target Species</u>								
Puma concolor (Mountain lion)	0	0	2 (0.021)	3 (0.030)	2 (0.042)	0	**7**	**3**
Canis latrans (Coyote)	7 (0.071)	10 (0.102)	41 (0.436)	13 (0.130)	4 (0.083)	14 (0.286)	**89**	**6**
Lynx rufus (Bobcat)	8 (0.082)	6 (0.061)	4 (0.043)	0	3 (0.063)	1 (0.020)	**22**	**5**
<u>Non-Target Species</u>								
Odocoileus hemionus (Mule deer)	1 (0.010)	0	0	1 (0.010)	1 (0.021)	1 (0.020)	**4**	**4**
Urocyon cinereoargenteus (Gray fox)	49 (0.500)	40 (0.408)	19 (0.202)	22 (0.220)	6 (0.125)	18 (0.367)	**154**	**6**
Procyon lotor (Raccoon)	0	1 (0.010)	0	0	0	0	**1**	**1**
Mephitis mephitis (Striped skunk)	2 (0.020)	12 (0.122)	9 (0.096)	10 (0.100)	2 (0.042)	2 (0.041)	**37**	**6**
Spilogale gracilis (Spotted skunk)	0	1 (0.010)	3 (0.032)	0	0	0	**4**	**2**
Didelphis virginiana (Opossum)	1 (0.010)	0	2 (0.021)	0	0	1 (0.020)	**4**	**3**
<u>Human Associated Species</u>								
Homo sapien (Human)	0	1 (0.010)	0	0	0	0	**1**	**1**
Canis familiaris (Domestic dog)	0	3 (0.031)	11 (0.117)	1 (0.010)	0	0	**15**	**3**
Total # Detections by Transect	**68**	**74**	**91**	**50**	**18**	**37**	**338**	
# of Species Detected at Transect	**6**	**8**	**8**	**6**	**6**	**6**		

Table 9. Mammal species detected at camera stations along the proposed Jamboree extension from August 2002 to December 2003. Cameras #2001, 2002, 2003, and 2039 were established August 2002. Cameras #2030, 2031, and 2040 were established January 2003. Values for each species or camera indicate number of detections for each named species followed by associated camera index within parentheses (if applicable). Camera index is calculated as $I_j = \{v_j/n_j\}$, where I_j = index of activity at camera j, v_j = number of detections of species at camera j, n_j = number of nights that camera j was active.

	Camera Number								
Species Detected	**2001**	**2002**	**2003**	**2030**	**2031**	**2039**	**2040**	**Total # Detections by Species**	**# of Cameras Detecting Species**
Target Species									
Puma concolor (Mountain lion)	0	4 (0.008)	1 (0.005)	1 (0.003)	1 (0.004)	1 (0.002)	2 (0.007)	**10**	**6**
Canis latrans (Coyote)	1 (0.002)	1 (0.002)	40 (0.216)	1 (0.003)	1 (0.004)	5 (0.011)	0	**49**	**6**
Lynx rufus (Bobcat)	9 (0.020)	1 (0.002)	27 (0.146)	4 (0.013)	6 (0.024)	20 (0.042)	10 (0.036)	**77**	**7**
Non-Target Species									
Odocoileus hemionus (Mule deer)	28 (0.061)	20 (0.040)	5 (0.027)	88 (0.294)	1 (0.004)	13 (0.027)	4 (0.014)	**159**	**7**
Urocyon cinereoargenteus (Gray fox)	0	60 (0.121)	1 (0.005)	23 (0.077)	3 (0.012)	4 (0.008)	3 (0.011)	**94**	**6**
Procyon lotor (Raccoon)	0	0	4 (0.022)	0	0	0	0	**4**	**1**
Mephitis mephitis (Striped skunk)	0	4 (0.008)	0	4 (0.013)	19 (0.075)	0	0	**27**	**3**
Spilogale gracilis (Spotted skunk)	0	0	0	1 (0.003)	0	0	0	**1**	**1**
Didelphis virginiana (Opossum)	0	0	0	0	1 (0.004)	0	0	**1**	**1**
Human Associated Species									
Homo sapien (Human)									
USGS/CSU Personnel	18 (0.039)	18 (0.036)	22 (0.119)	7 (0.023)	8 (0.031)	21 (0.044)	29 (0.103)	**123**	**7**
Unknown humans	29 (0.063)	0	87 (0.470)	1 (0.003)	0	59 (0.125)	3 (0.011)	**179**	**5**
Canis familiaris (Domestic dog)	2 (0.004)	0	15 (0.081)	0	0	3 (0.006)	0	**20**	**3**
Equus caballus (Domestic horse)	0	1 (0.002)	2 (0.011)	0	0	5 (0.011)	1 (0.004)	**9**	**4**
Vehicle	1 (0.002)	1 (0.002)	0	0	0	119 (0.252)	0	**121**	**3**
Bicycle	0	2 (0.004)	0	0	0	5 (0.011)	0	**7**	**2**
Total # Detections by Camera	**88**	**112**	**204**	**130**	**40**	**255**	**52**	**881**	
# of Species Detected at Camera	**7**	**10**	**10**	**9**	**8**	**11**	**7**		

Table 10. Mammal species detected at camera stations along North Lake Road from January 2003 to December 2003. All cameras were established in January 2003 except #2037 and 2038 that were established in June 2003. Values for each species or camera indicate number of detections for each named species followed by associated camera index within parentheses (if applicable). Camera index is calculated as $I_j = \{v_j/n_j\}$, where I_j = index of activity at camera j, v_j = number of detections of species at camera j, n_j = number of nights that camera j was active.

Species Detected	Camera Number 2032	2033	2034	2035	2037	2038	2041	Total # Detections by Species	# of Cameras Detecting Species
Target Species									
Puma concolor (Mountain lion)	1 (0.003)	0	5 (0.016)	0	1 (0.012)	2 (0.010)	6 (0.019)	**15**	**5**
Canis latrans (Coyote)	5 (0.015)	0	1 (0.003)	1 (0.004)	0	0	3 (0.009)	**10**	**4**
Lynx rufus (Bobcat)	23 (0.070)	1 (0.003)	17 (0.053)	1 (0.004)	0	0	0	**42**	**4**
Non-Target Species									
Odocoileus hemionus (Mule deer)	13 (0.040)	4 (0.012)	25 (0.078)	2 (0.007)	0	22 (0.112)	103 (0.318)	**169**	**6**
Urocyon cinereoargenteus (Gray fox)	54 (0.165)	0	3 (0.009)	0	0	30 (0.153)	6 (0.019)	**93**	**4**
Procyon lotor (Raccoon)	0	0	0	0	0	0	0	**0**	**0**
Mephitis mephitis (Striped skunk)	5 (0.015)	0	0	0	0	4 (0.020)	0	**9**	**2**
Spilogale gracilis (Spotted skunk)	0	0	0	0	0	0	0	**0**	**0**
Didelphis virginiana (Opossum)	0	0	1 (0.003)	0	0	0	0	**1**	**1**
Human Associated Species									
Homo sapien (Human)									
USGS/CSU Personnel	6 (0.018)	7 (0.021)	12 (0.037)	5 (0.018)	3 (0.036)	10 (0.051)	4 (0.012)	**47**	**7**
Unknown humans	1 (0.003)	0	17 (0.053)	1 (0.004)	0	0	3 (0.009)	**22**	**4**
Canis familiaris (Domestic dog)	0	1 (0.003)	0	0	0	0	0	**1**	**1**
Equus caballus (Domestic horse)	0	0	0	0	0	0	0	**0**	**0**
Vehicle	0	0	0	0	0	0	0	**0**	**0**
Bicycle	0	0	0	0	0	0	0	**0**	**0**
Total # Detections by Camera	**108**	**13**	**81**	**10**	**4**	**68**	**125**	**409**	
# of Species Detected at Camera	**8**	**4**	**8**	**5**	**2**	**5**	**6**		

Table 11. Phase 1 capture and monitoring data for 12 bobcats captured in the North/Central Irvine Ranch, Orange County, CA from December 2002 to July 2003. B1 and B3 were not radio-collared. Sex refers to M = male, F = female, and U = unknown. Age refers to K = kitten (0-12 months), Y = yearling (13-24 months), and A = adult (> 24 months). Capture dates are initial capture dates (see text for recapture information). Last monitored date is the day a location was last recorded by the GPS collar, except for B1 and B3 where this date is their capture date.

Collar Schedule / Animal ID #	Sex	Age	Right Ear Tag Color/Shape	Capture Date	Capture Location	# of Camera Captures	Cameras Detected At	Last Monitored
None								
B1	F	K	white circle	12/12/2002	T9A	0		12/12/2003
B3	U	U	none	12/12/2002	T14A	0		12/13/2003
10 Week								
B6	M	A	red bar	1/5/2003	T7A	0		3/30/2003
B7	M	A	blue circle	1/7/2003	T4A	0		3/31/2003
B12	M	A	red circle	1/16/2003	T26A	1	2034	4/9/2003
19 Week								
B2	F	A	yellow bar	12/12/2002	T10A	3	2032, 2039	5/5/2003
B4	F	A	white triangle	1/3/2003	T15A	1	2034	5/26/2003
B5	F	Y	yellow circle	1/5/2003	T16A	7	2039	5/26/2003
B11	M	A	white circle	1/13/2003	T8A	0		6/2/2003
25 Week								
B8	M	A	orange circle	1/9/2003	T6A	0		7/7/2003
B9	F	A	orange triangle	1/11/2003	T14A	8	2033, 2034	7/7/2003
B10	M	A	green bar	1/12/2003	T3A	4	2032, 2040	7/14/2003

Table 12. Phase 2 capture and monitoring data for 8 bobcats captured in the North/Central Irvine Ranch, Orange County, CA from October 2003 to May 2004. B14 and B15 were not radio-collared since they were too small to collar. Sex refers to M = male, F = female, and U = unknown. Age refers to K = kitten (0-12 months), Y = yearling (13-24 months), and A = adult (> 24 months). Capture dates are initial capture dates (see text for recapture information). Last monitored date is the day a location was last recorded by the GPS collar, except for B13, B14, and B15 where this date is their capture or recapture date.

Collar Schedule / Animal ID #	Sex	Age	Right Ear Tag Color/Shape	Capture Date	Capture Location	Last Monitored
None						
B14	F	A	none	10/9/2003	2T40A	10/9/2003
B15	M	K	none	10/9/2003	2T39A	11/18/2004
10 Week						
B16	F	A	blue cross	10/10/2003	2T37A	12/31/2003
18 Week						
B17	F	A	red triangle	11/18/2003	2T36A	3/29/2004
B18	M	A	white & black bar	11/23/2003	2T37A	4/2/2004
B19	F	A	yellow circle w/black stripes	1/10/2004	2T47A	5/21/2004
B20	F	A	green circle	1/15/2004	2T56A	5/24/2004
25 Week						
B13	M	Y	white circle w/black stripes	10/8/2003	2T38A	11/20/2004

Table 13. GPS location data and subsequent 100% Minimum Convex Polygon (MCP) and 95% Fixed Kernel (FK) home range and 50% FK core-use area estimates (km^2) for 16 bobcats radio-tracked in the North/Central Irvine Ranch, Orange County, CA, December 2002 to May 2004. Bobcats are grouped by collar type and associated maximum number of GPS locations projected by manufacturer. Sex refers to M = male and F = female. Age refers to Y = yearling (12-24 months) and A = adult (> 24 months). Each animal had 5 or fewer "1D" locations (*n* = 21), and thus, is not presented here.

Animal ID # and Sex and Age	GPS Locs	3D+		3D		2D		Home Range Estimate (km^2)		
		#	% GPS Locs	#	% GPS Locs	#	% GPS Locs	MCP 100%	FK 95%	FK 50%
10 Week (324)										
B6 - M/A	344	132	0.38	92	0.27	120	0.35	25.05	24.19	1.75
B7 - M/A	325	121	0.37	96	0.30	104	0.32	6.49	5.45	1.14
B12 - M/A	359	138	0.38	112	0.31	104	0.29	3.00	3.73	0.60
B16 - F/A	350	227	0.65	70	0.20	52	0.15	4.56	4.59	1.17
18 Week (284)										
B17 - F/A	227	56	0.25	75	0.33	94	0.41	3.01	2.92	0.43
B18 - M/A	263	121	0.46	65	0.25	77	0.29	5.87	5.42	0.96
B19 - F/A	247	85	0.34	79	0.32	83	0.34	1.54	1.34	0.31
B20 - F/A	194	41	0.21	61	0.31	89	0.46	2.05	1.68	0.37
19 Week (306)										
B2 - F/A	317	142	0.45	115	0.36	60	0.19	1.88	1.75	0.25
B4 - F/A	309	124	0.40	96	0.31	86	0.28	2.49	2.46	0.20
B5 - F/Y	275	75	0.27	99	0.36	101	0.37	2.71	2.16	0.24
B11 - M/A	288	140	0.49	62	0.22	85	0.30	2.09	2.26	0.53
25 Week (295)										
B8 - M/A	256	103	0.40	64	0.25	88	0.34	2.07	2.06	0.29
B9 - F/A	249	120	0.48	80	0.32	49	0.20	2.73	2.55	0.31
B10 - M/A	285	147	0.52	74	0.26	63	0.22	4.36	3.97	0.29
B13 - M/Y	181	70	0.39	53	0.29	58	0.32	9.42	13.39	2.92
Totals and Mean Percent GPS Locs	**4469**	**1842**	**0.41**	**1293**	**0.29**	**1313**	**0.29**	**N/A**	**N/A**	**N/A**

Table 14. Road crossing data for bobcat B6 monitored in the North/Central Irvine Ranch, Orange County, CA from January to March 2003. GPS locations were recorded 8 times per sampling session (see Table 3). Number of missed locations was calculated using the 10-Week collar schedule. Terrain, vegetation, and clouds could prevent acquisition of scheduled GPS locations.

Road Crossing ID	Location 1			Location 2			Roadway Crossed	# Missed Locations between Loc1 & Loc2	Distance between Crossing Points (meters)	Time elapsed between Loc1 & Loc2
	Date & Time	Day of Week	Fix	Date & Time	Day of Week	Fix				
1	1/10/03 0:45	F	2D	1/11/03 23:07	S	3D+	CA-241	0	1893	46 h 22 m
2	1/12/03 23:15	SU	3D	1/12/03 23:30	SU	3D	CA-241	0	161	15 m
3	1/14/03 23:45	T	2D	1/15/03 0:00	W	2D	CA-241	0	242	15 m
4	1/17/03 0:30	F	2D	1/18/03 23:08	S	3D+	CA-241	1	3818	46 h 38 m
5	1/19/03 0:45	SU	2D	1/19/03 23:01	SU	2D	CA-241	0	401	22 h 16 m
6	2/2/03 0:45	SU	3D+	2/2/03 23:04	SU	2D	CA-241	0	3730	22 h 19 m
7	2/3/03 0:15	M	2D	2/3/03 0:30	M	2D	CA-241	0	148	15 m
8	2/3/03 0:30	M	2D	2/3/03 0:45	M	3D	CA-241	0	350	15 m
9	2/5/03 0:00	W	2D	2/5/03 0:15	W	2D	CA-241	0	52	15 m
10	3/4/03 23:46	T	2D	3/6/03 23:11	TH	3D+	CA-241	4	6540	47 h 25 m
11	3/10/03 0:45	M	3D+	3/11/03 23:08	T	3D	CA-241	0	4411	46 h 23 m
12	3/26/03 0:45	W	3D	3/27/03 23:09	TH	3D+	CA-241	0	6582	46 h 24 m
AVERAGE:									**2361**	

Table 15. Road crossing data for bobcat B10 monitored in the North/Central Irvine Ranch, Orange County, CA from January to July 2003. GPS locations were recorded 12 times per sampling session (see Table 3). Number of missed locations was calculated using the 25-Week collar schedule. Terrain, vegetation, and clouds could prevent acquisition of scheduled GPS locations.

Road Crossing ID	Location 1			Location 2			Roadway Crossed	# Missed Locations between Loc1 & Loc2	Distance between Crossing Points (meters)	Time elapsed between Loc1 & Loc2
	Date & Time	Day of Week	Fix	Date & Time	Day of Week	Fix				
1	1/13/03 0:45	M	2D	1/19/03 22:25	SU	3D+	Santiago Cyn Rd	1	675	165 h 40 m
2	1/20/03 0:30	M	2D	1/26/03 22:16	SU	3D+	Santiago Cyn Rd	2	687	165 h 46 m
3	1/26/03 23:00	SU	3D+	1/26/03 23:15	SU	3D+	Santiago Cyn Rd	0	131	15 m
4	1/27/03 0:45	M	3D+	2/2/03 22:21	SU	2D	Santiago Cyn Rd	1	1612	165 h 36 m
5	4/21/03 0:00	M	3D+	4/21/03 0:15	M	3D	Santiago Cyn Rd	0	66	15 m
6	4/21/03 1:45	M	3D+	4/27/03 23:24	SU	3D+	Santiago Cyn Rd	1	828	164 h 39 m
7	4/28/03 1:46	M	2D	5/4/03 23:28	SU	3D+	Santiago Cyn Rd	1	992	165 h 42 m
8	5/5/03 0:45	M	3D+	5/5/03 1:00	M	3D+	Santiago Cyn Rd	0	191	15 m
9	5/12/03 1:45	M	2D	5/18/03 23:31	SU	3D+	Santiago Cyn Rd	2	2552	165 h 46 m
10	5/19/03 0:00	M	3D+	5/19/03 0:15	M	3D+	Santiago Cyn Rd	0	324	15 m
11	5/26/03 1:45	M	2D	6/1/03 23:21	SU	3D+	Santiago Cyn Rd	1	147	165 h 36 m
12	6/1/03 23:30	SU	3D+	6/1/03 23:45	SU	3D+	Santiago Cyn Rd	0	157	15 m
13	6/23/03 0:45	M	3D+	6/23/03 1:00	M	2D	CA-241	0	154	15 m
14	6/23/03 1:45	M	3D+	6/29/03 23:21	SU	3D	CA-241	1	1121	165 h 36 m
15	6/29/03 23:21	SU	3D	6/29/03 23:30	SU	3D	Santiago Cyn Rd	0	183	9 m
16	6/30/03 1:45	M	3D+	7/6/03 23:18	SU	3D+	Santiago Cyn Rd	1	1508	165 h 33 m
17	7/7/03 1:30	M	3D	7/7/03 1:45	M	3D+	Santiago Cyn Rd	0	169	15 m
18	7/7/03 1:45	M	3D+	7/13/03 23:20	SU	1D	Santiago Cyn Rd	1	1527	165 h 35 m
AVERAGE:									**724**	

Table 16. Road crossing data for bobcat B13 monitored in the North/Central Irvine Ranch, Orange County, CA from October 2003 to March 2004. GPS locations were recorded 12 times per sampling session (see Table 3). Number of missed locations was calculated using the 25-Week collar schedule. Terrain, vegetation, and clouds could prevent acquisition of scheduled GPS locations.

Road Crossing ID[a]	Location 1			Location 2			Roadway Crossed	# Missed Locations between Loc1 & Loc2	Distance between Crossing Points (m)	Time elapsed between Loc1 & Loc2
	Date & Time	Day of Week	Fix	Date & Time	Day of Week	Fix				
1	10/13/03 1:45	M	2D	10/19/03 23:30	SU	3D+	Santiago Cyn Rd	2	2535	165 h 45 m
2	10/27/03 0:45	M	3D	11/2/03 22:24	SU	3D+	Santiago Cyn Rd	1	2883	165 h 39 m
3	11/3/03 0:45	M	2D	11/9/03 22:34	SU	3D+	Santiago Cyn Rd	2	1582	165 h 49 m
4	11/23/03 23:00	SU	3D+	11/23/03 23:15	SU	3D+	Santiago Cyn Rd	0	395	15 m
5	12/1/03 0:30	M	3D+	12/1/03 0:45	M	3D+	Santiago Cyn Rd	0	146	15 m
6	12/22/03 0:30	M	3D+	12/22/03 0:45	M	3D	Santiago Cyn Rd	0	191	15 m
7	12/29/03 0:45	M	2D	1/4/04 23:02	SU	2D	Santiago Cyn Rd	4	1036	166 h 17 m
8	1/5/04 0:15	M	3D+	1/5/04 0:30	M	3D+	Santiago Cyn Rd	0	182	15 m
9	1/5/04 0:45	M	3D	1/11/04 22:37	SU	3D+	Santiago Cyn Rd	2	1739	165 h 52 m
10	1/12/04 0:45	M	2D	1/18/04 22:35	SU	3D+	Santiago Cyn Rd	2	3066	165 h 50 m
11	1/26/04 0:45	M	3D+	2/1/04 23:53	SU	2D	Santiago Cyn Rd	7	2969	167 h 08 m
AVERAGE:									**1520**	

[a] B13 had two additional road crossing events associated with his captures. He crossed Santiago Canyon Road after his capture (captured north of the road and the first location was south of the road) and before his recapture (recaptured north of the road and the last location was south of the road).

Table 17. Capture and monitoring data for three mountain lions captured in the North/Central Irvine Ranch, Orange County, CA from October 2003 to May 2005. Last monitored date is the day a location was last recorded by the GPS collar (P1, P2) or last location downloaded from GPS collar (P3).

Animal ID	Sex	Age	Ear Tag Color/Shape	Initial Capture Date	Capture Location	Last Monitored	# Days of GPS Data Collection
Schedule A							
P1	F	Adult	green circle	10/4/2003	T21A	8/18/2004	215
P2	F	Adult	blue circle	7/2/2004	S4	10/5/2004	75
Schedule B							
P3	F	Adult	red circle	12/1/2004	S13	5/17/2005	132[a]

[a] Number of days for downloaded data only, since collar was not recovered at time of this report. Data were not obtained from Dec 24, 2004 to Jan 18, 2005 and from Mar 2 to Apr 2, 2005.

Table 18. GPS location data and 100% Minimum Convex Polygon (MCP) and 95% Fixed Kernel (FK) home range and 50% FK core-use areas for three mountain lions radio-tracked in the North/Central Irvine Ranch, Orange County, CA from October 2003 to May 2005.

Animal ID	#GPS Locs	3D		2D		Home Range Estimate (km^2)		
		#	% GPS Locs	#	% GPS Locs	MCP 100%	FK 95%	FK 50%
Schedule A								
P1	1110	524	0.47	586	0.53	118.31	108.03	14.03
P2	371	159	0.43	212	0.57	97.00	82.67	6.10
Schedule B								
P3	1637	761	0.46	876	0.54	181.26	125.40	20.39
Totals and Mean Percent GPS Locs	**3118**	**1444**	**0.46**	**1674**	**0.54**	**N/A**	**N/A**	**N/A**

Table 19. Road crossing data for mountain lion P1 monitored in the North/Central Irvine Ranch, Orange County, CA from October 2003 to August 2004. There were six records of P1 potentially crossing CA-91. However, most of P1's crossings of CA-91 were poor resolution 2D fixes for which the GPS error may be hundreds of meters; P1's most northern location was only 340 meters north of CA-91. GPS locations were recorded every hour on Wed and Sat, but only four times per day (1:15, 5:15, 12:15, 17:15) on other days. Number of missed locations was calculated using collar Schedule A (see Figure 9).

	Location 1			Location 2						
Road Crossing ID	**Date & Time**	**Day of Week**	**Fix**	**Date & Time**	**Day of Week**	**Fix**	**Roadway Crossed**	**# Missed Locations between Loc 1 & Loc 2**	**Distance between Crossing Points (meters)**	**# Hours elapsed between Loc1 & Loc2**
1	12/24/2003 12:15	W	3D	12/27/2003 0:16	S	2D	CA-91	19	5905	60
2	12/27/2003 10:15	S	2D	12/27/2003 12:16	S	2D	CA-91	1	201	2
3	12/27/2003 12:16	S	2D	12/27/2003 15:15	S	2D	CA-91	2	315	3
4	12/27/2003 15:15	S	2D	12/27/2003 17:16	S	3D	CA-91	1	261	2
5	12/27/2003 22:15	S	3D	12/29/2003 5:15	M	2D	CA-91	6	4013	31
6	12/29/2003 5:15	M	2D	12/29/2003 17:16	M	3D	CA-91	1	376	12
7	2/24/04 17:15	T	2D	2/25/04 0:15	W	2D	Santiago Cyn Rd	0	4062	7
8	2/25/04 3:15	W	2D	2/25/04 4:15	W	2D	Santiago Cyn Rd	0	1365	1
9	3/3/2004 0:16	W	2D	3/3/2004 1:15	W	2D	CA-241	0	1330	1
10	3/4/2004 17:16	TH	2D	3/5/2004 12:16	F	3D	CA-241	8	5431	19
11	3/6/2004 21:15	S	2D	3/6/2004 22:15	S	3D	Santiago Cyn Rd	0	969	1
12	3/7/2004 1:16	SU	3D	3/7/2004 5:15	SU	3D	Santiago Cyn Rd	0	3810	4
13	3/8/2004 17:16	M	3D	3/9/2004 1:16	T	3D	CA-241	0	4409	8
14	3/11/2004 1:15	TH	3D	3/11/2004 5:16	TH	3D	CA-241	0	2425	4
15	3/11/2004 17:15	TH	2D	3/12/2004 5:16	F	3D	Santiago Cyn Rd	1	4982	12
16	3/13/2004 2:15	S	3D	3/13/2004 3:15	S	3D	Santiago Cyn Rd	0	1937	1
17	3/16/2004 17:16	T	2D	3/17/2004 0:15	W	3D	CA-241	0	2942	7
18	3/18/2004 5:15	TH	3D	3/19/2004 5:16	F	2D	CA-241	3	6666	24
19	3/21/2004 1:16	SU	2D	3/22/2004 1:15	M	3D	CA-241	3	6726	24
20	3/30/2004 1:15	T	3D	3/30/2004 12:16	T	2D	CA-241	1	4285	11
21	7/5/2004 5:16	M	2D	7/7/2004 1:17	W	2D	CA-241	6	5812	44
22	7/7/2004 1:17	W	2D	7/7/2004 2:16	W	3D	CA-241	0	1108	1
23	7/11/2004 1:15	SU	2D	7/11/2004 5:15	SU	3D	CA-241	0	1481	4
24	7/16/2004 1:16	F	3D	7/16/2004 5:16	F	3D	CA-241	0	1939	4
25	7/27/2004 1:15	T	2D	7/28/2004 2:16	W	2D	CA-241	4	6040	25
26	7/28/2004 21:15	W	2D	7/28/2004 22:15	W	3D	CA-241	0	975	1
AVERAGE:								**2**	**3068**	**12**
AVERAGE (WITH CA-91 CROSSINGS REMOVED):								**1**	**3435**	**10**

Table 20. Road crossing data for mountain lion P2 monitored in the North/Central Irvine Ranch, Orange County, CA from July to October 2004. GPS locations were recorded every hour on Wed and Sat, but only four times per day (1:15, 5:15, 12:15, 17:15) on other days. Number of missed locations was calculated using collar Schedule A (see Figure 9).

Road Crossing ID	Location 1			Location 2			Roadway Crossed	# Missed Locations between Loc1 & Loc2	Distance between Crossing Points (meters)	# Hours elapsed between Loc1 & Loc2
	Date & Time	Day of Week	Fix	Date & Time	Day of Week	Fix				
1	7/10/04 22:16	S	2D	7/10/04 23:15	S	3D	CA-241	0	1316	1
2	7/11/04 17:16	SU	2D	7/12/04 1:15	M	2D	CA-241	0	3590	8
3	7/14/04 20:15	W	3D	7/14/04 21:15	W	3D	CA-241	0	1969	1
4	7/16/04 1:16	F	3D	7/16/04 5:16	F	2D	CA-241	0	1871	4
5	7/16/04 5:16	F	2D	7/17/04 3:16	S	3D	CA-241	4	1172	22
6	7/20/04 5:16	T	2D	7/21/04 2:16	W	3D	CA-241	3	2034	21
7	7/21/04 19:15	W	3D	7/21/04 22:15	W	3D	CA-241	2	1072	3
8	7/26/04 1:15	M	2D	7/26/04 5:15	M	2D	CA-241	0	914	4
9	7/31/04 8:15	S	2D	7/31/04 15:16	S	2D	CA-241	6	1668	7
10	8/1/04 1:15	SU	2D	8/1/04 5:16	SU	3D	CA-241[a]	0	2220	4
11	8/1/04 1:15	SU	2D	8/1/04 5:16	SU	3D	Santiago Cyn Rd[a]	0	2220	4
12	8/1/04 5:16	SU	3D	8/1/04 17:15	SU	2D	CA-241	1	2831	12
13	8/1/04 17:15	SU	2D	8/2/04 1:15	M	3D	Santiago Cyn Rd	0	1232	8
14	8/2/04 1:15	M	3D	8/2/04 5:16	M	2D	Santiago Cyn Rd	0	1206	4
15	8/2/04 5:16	M	2D	8/4/04 2:16	W	3D	CA-241	7	3972	45
16	8/11/04 6:15	W	2D	8/11/04 18:16	W	3D	CA-241	11	2096	12
17	8/11/04 22:16	W	2D	8/11/04 23:15	W	3D	CA-241	0	439	1
18	8/12/04 5:15	TH	2D	8/13/04 17:16	F	3D	CA-241	5	1069	36
19	8/13/04 17:16	F	3D	8/14/04 1:16	S	3D	CA-241	7	1337	8
20	8/14/04 2:15	S	3D	8/14/04 4:16	S	2D	CA-241	1	990	2
21	8/14/04 20:16	S	2D	8/14/04 21:16	S	3D	CA-241	0	807	1
22	8/14/04 21:16	S	3D	8/17/04 1:16	T	3D	CA-241	11	1931	52
23	8/17/04 1:16	T	3D	8/17/04 17:16	T	2D	Santiago Cyn Rd	2	3596	16
24	8/20/04 5:16	F	3D	8/21/04 1:16	S	2D	CA-241	2	5214	20
25	8/29/04 17:16	SU	3D	8/30/04 1:15	M	2D	CA-241	0	904	8
26	8/30/04 17:16	M	2D	8/31/04 1:15	T	3D	CA-241	0	1397	8
27	9/12/2004 5:15	SU	3D	9/13/2004 1:15	M	3D	CA-241	2	3455	20
28	9/13/2004 17:16	M	3D	9/15/2004 1:16	W	2D	CA-241	4	5521	32
29	9/19/2004 1:15	SU	2D	9/19/2004 5:15	SU	2D	CA-241	0	1175	4
30	9/19/2004 12:16	SU	2D	9/19/2004 17:16	SU	2D	CA-241	0	582	5
31	9/19/2004 17:16	SU	2D	9/20/2004 1:15	M	2D	CA-241	0	5717	8
32	9/23/2004 0:15	W	2D	9/24/2004 1:16	F	2D	Santiago Cyn Rd	4	1096	25
33	9/24/2004 1:16	F	2D	9/24/2004 5:16	F	2D	CA-241	0	2710	4
34	9/25/2004 18:15	S	2D	9/25/2004 19:16	S	3D	CA-241	0	691	1
35	9/25/2004 22:15	S	3D	9/25/2004 23:15	S	2D	Santiago Cyn Rd	0	705	1
36	9/30/2004 1:15	TH	3D	9/30/2004 5:15	TH	2D	CA-241	0	1310	4
AVERAGE								**2**	**2001**	**12**

[a] P2 crossed both CA-241 and Santiago Canyon Road in a single crossing event on 8/1/04. The two roads run parallel to each other for a short ways just west of Irvine Lake.

Table 21. Road crossing data for mountain lion P3 monitored in the North/Central Irvine Ranch, Orange County, CA from December 2004 to May 2005. GPS locations were recorded every hour on Wed and Sat, but as many as 20 times per day on Sun, Mon, Tues, Thurs, and Fri. Number of missed locations was calculated using collar Schedule B (see Figure 9).

Road Crossing ID	Location 1			Location 2			Roadway Crossed	# Missed Locations between Loc 1 & Loc 2	Distance between Crossing Points (meters)	# Hours elapsed between Loc1 & Loc2
	Date & Time	Day of Week	Fix	Date & Time	Day of Week	Fix				
1	12/8/04 20:16	W	2D	12/8/04 21:16	W	2D	Santiago Canyon Rd	0	681	1
2	12/14/04 22:15	T	3D	12/14/04 23:15	T	3D	Santiago Canyon Rd	0	717	1
3	12/17/04 5:15	F	2D	12/17/04 6:15	F	2D	Live Oak Canyon Rd	0	1491	1
4	12/19/04 4:15	SU	3D	12/19/04 5:15	SU	2D	Santiago Canyon Rd	0	684	1
5	1/24/05 21:15	M	3D	1/24/05 22:16	M	3D	Santiago Canyon Rd	0	949	1
6	1/24/05 22:16	M	3D	1/24/05 23:16	M	3D	Live Oak Canyon Rd	0	740	1
7	1/26/05 17:16	W	2D	1/26/05 18:15	W	3D	Live Oak Canyon Rd	0	1394	1
8	2/3/05 2:15	TH	3D	2/3/05 4:15	TH	3D	Santiago Canyon Rd	1	3066	2
9	2/4/05 19:15	F	3D	2/4/05 20:15	F	3D	Santiago Canyon Rd	0	971	1
10	2/4/05 20:15	F	3D	2/4/05 21:16	F	3D	Santiago Canyon Rd	0	934	1
11	2/14/05 5:15	M	3D	2/14/05 7:15	M	2D	Santiago Canyon Rd	1	2216	2
12	2/16/05 21:15	W	3D	2/17/05 0:15	TH	3D	Santiago Canyon Rd	2	1550	3
13	2/19/05 23:15	S	3D	2/20/05 0:15	SU	2D	Santiago Canyon Rd	0	1038	1
14	2/20/05 8:15	SU	3D	2/20/05 9:15	SU	3D	Santiago Canyon Rd	0	1042	1
15	4/4/05 16:15	M	3D	4/4/05 20:16	M	2D	Santiago Canyon Rd	2	3673	4
16	4/5/05 19:16	T	2D	4/5/05 20:16	T	2D	Santiago Canyon Rd	0	973	1
17	4/11/05 0:15	M	2D	4/11/05 1:16	M	2D	Santiago Canyon Rd	0	1815	1
18	4/12/05 20:16	T	2D	4/12/05 21:15	T	3D	Santiago Canyon Rd	0	1309	1
19	5/1/05 3:15	SU	2D	5/1/05 6:15	SU	2D	Santiago Canyon Rd	2	834	3
20	5/9/05 10:15	M	2D	5/9/05 12:15	M	3D	Live Oak Canyon Rd	0	797	2
21	5/12/05 18:15	TH	2D	5/12/05 19:16	TH	2D	Live Oak Canyon Rd	0	955	1
22	5/13/05 22:15	F	3D	5/13/05 23:16	F	3D	Santiago Canyon Rd	0	847	1
AVERAGE:								**0**	**1303**	**1**

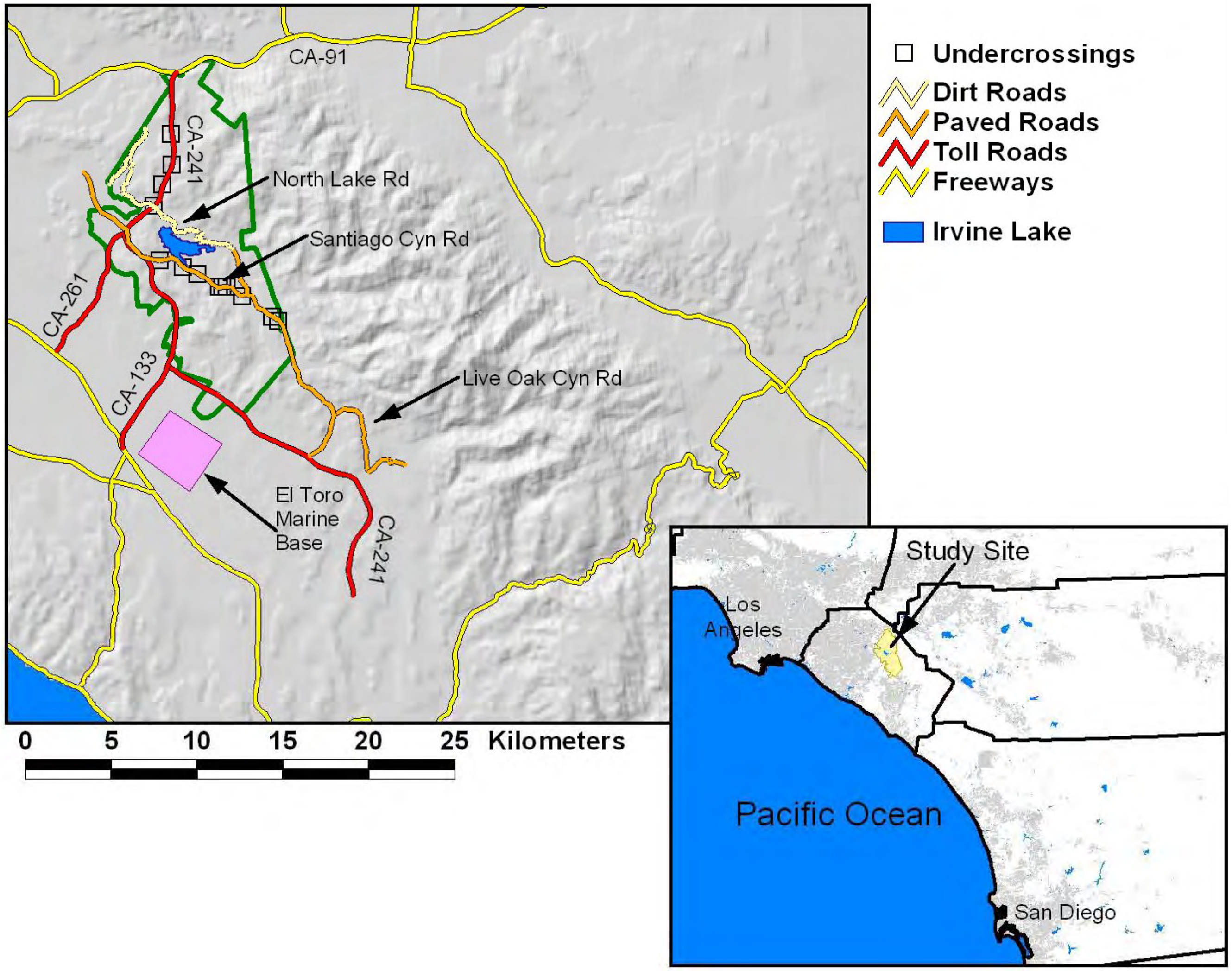

Figure 1a. Location of the study area, North/Central Irvine Ranch (NIR), Orange County, CA (green boundary line). Primary map includes the Santa Ana Mountains terrain. Inset map depicts rural residential and urban development in gray and water bodies in blue.

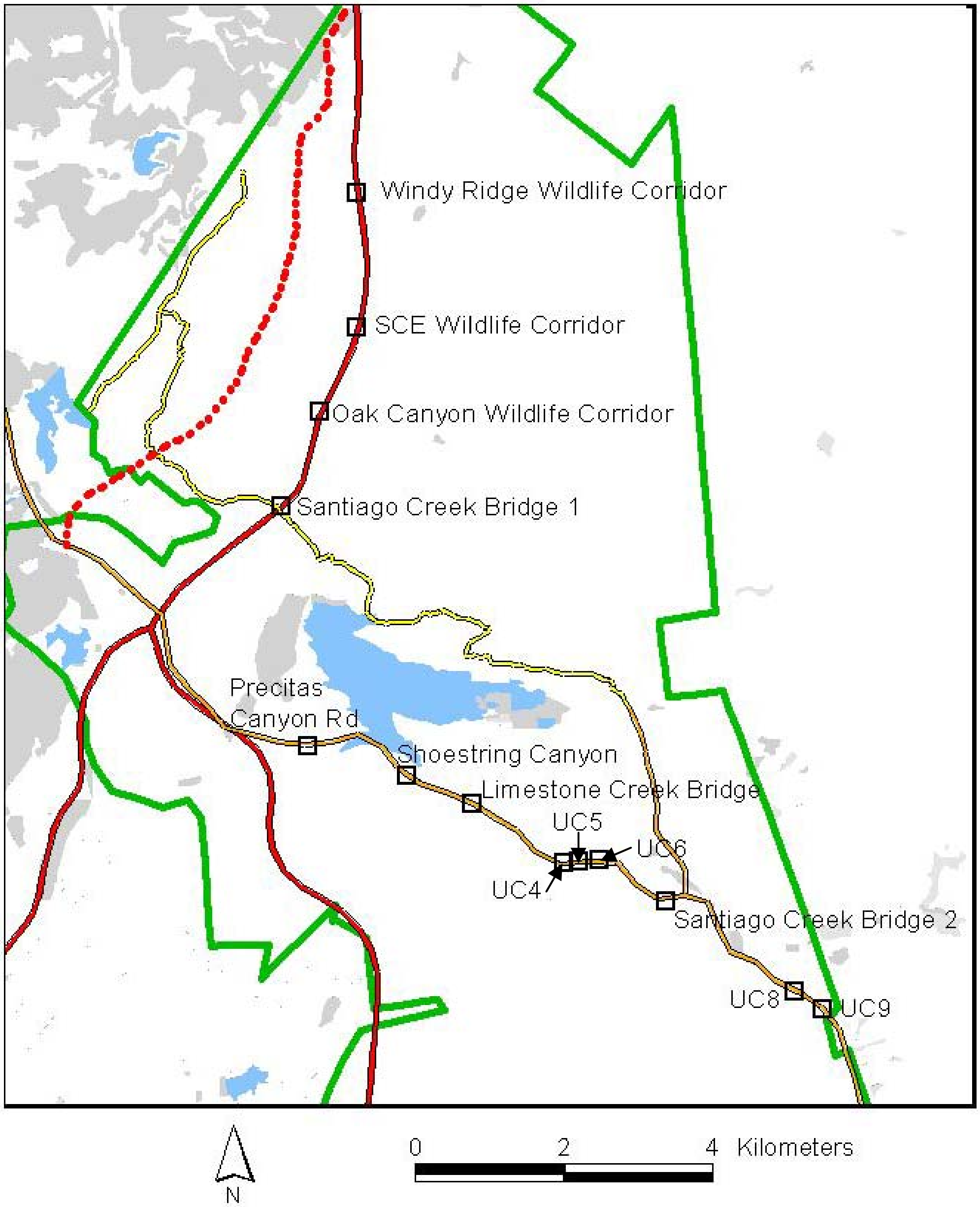

Figure 1b. Locations of undercrossings along northern section of CA-241 (solid red) and Santiago Canyon Road (solid orange), and a proposed extension of Jamboree Road (dashed red line) in the study area, North/Central Irvine Ranch (NIR), Orange County, CA. Additional undercrossing information in Table 1.

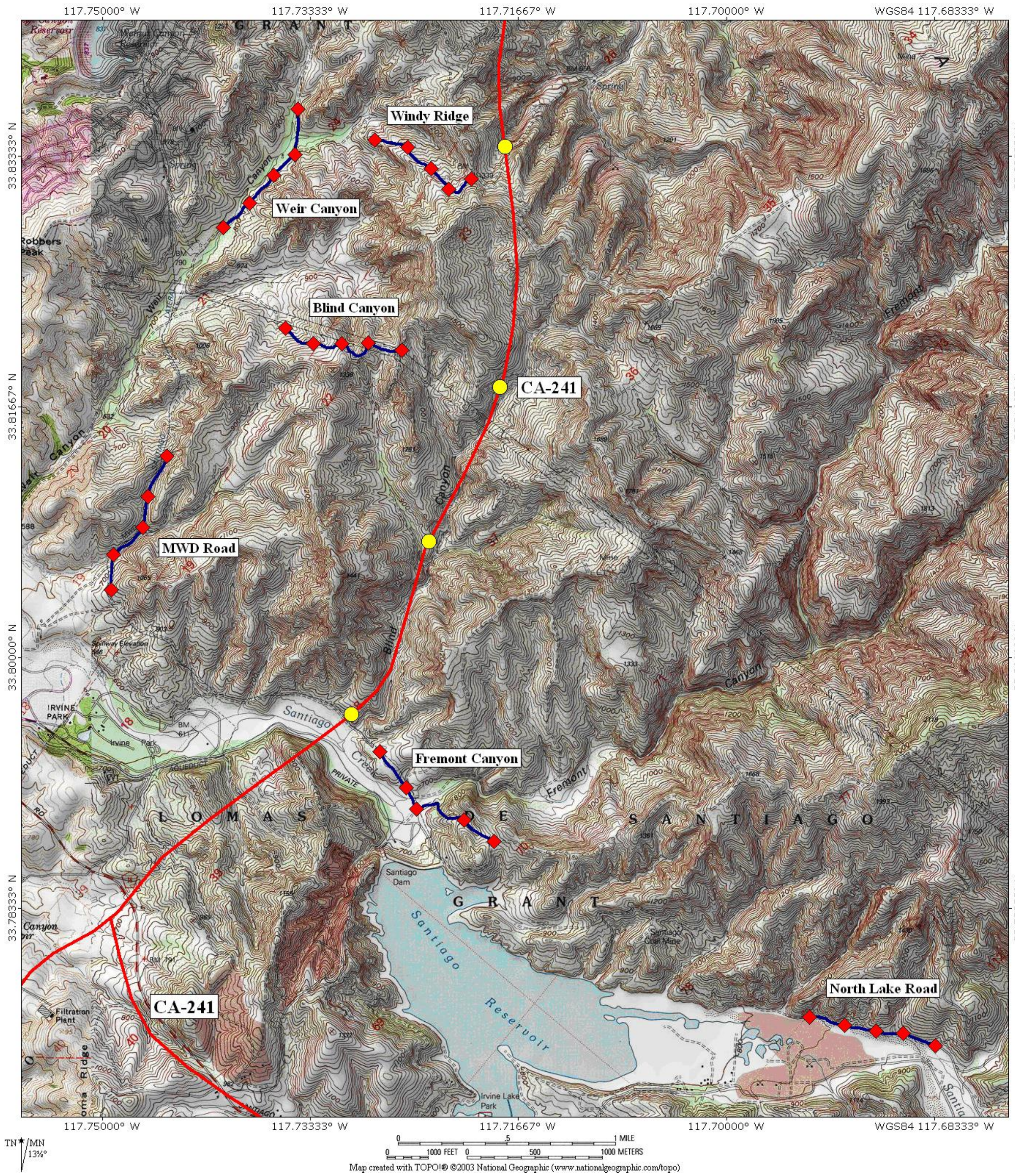

Figure 2. Location of track transects (blue lines) with baited scent stations (red diamonds) with CA-241 (red line) and underpass locations (yellow circles) for reference. All track transects contained five scent stations and were located along existing roads. To preserve clarity, North Lake Road is not denoted on the current map. See Figure 1 for North Lake Road.

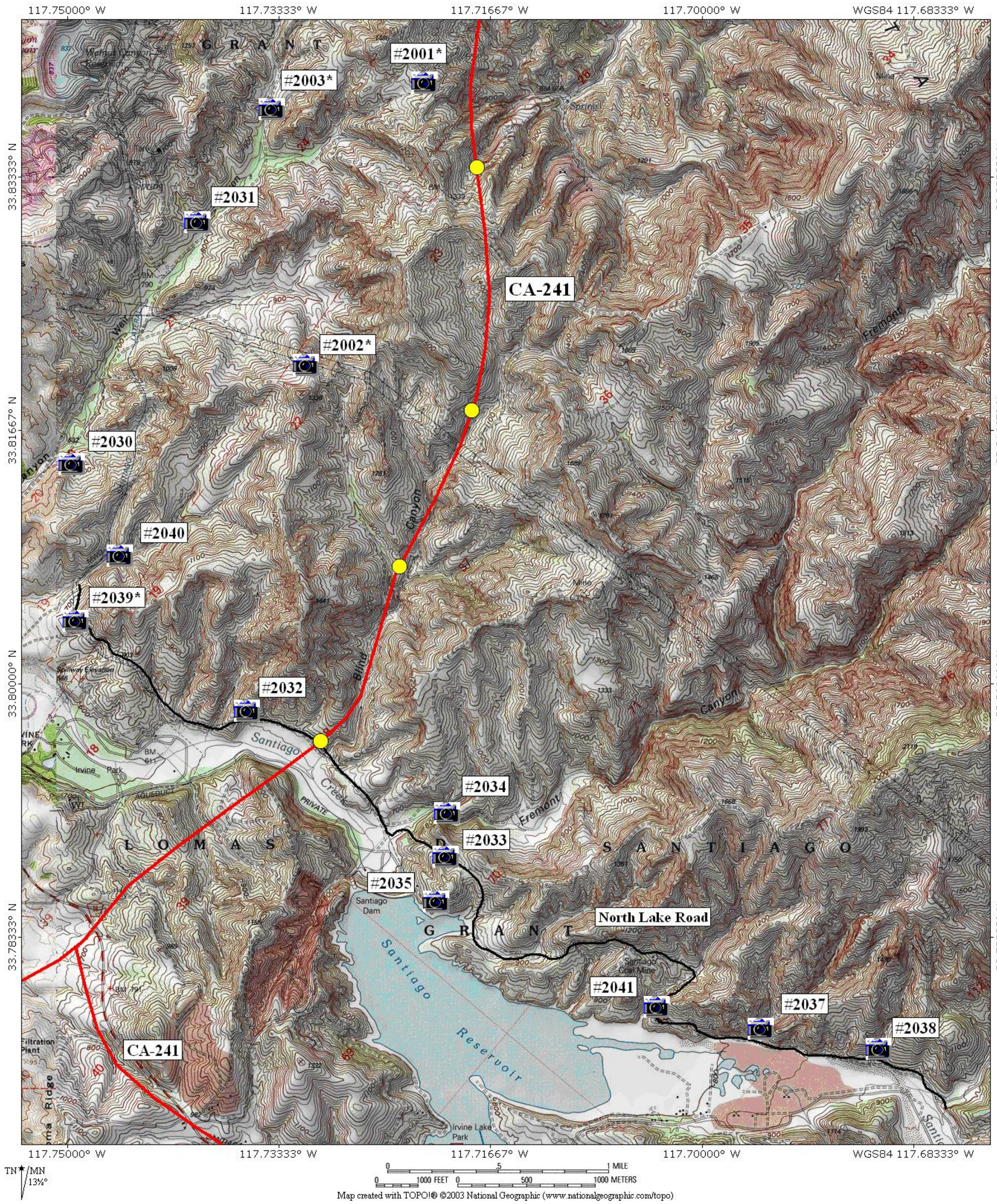

Figure 3. Locations of camera stations (camera icon), CA-241 (red line), underpasses (yellow circles) and North Lake Road (black line) for reference. (*) indicates cameras that were established in August 2002. All other cameras were established in January 2003.

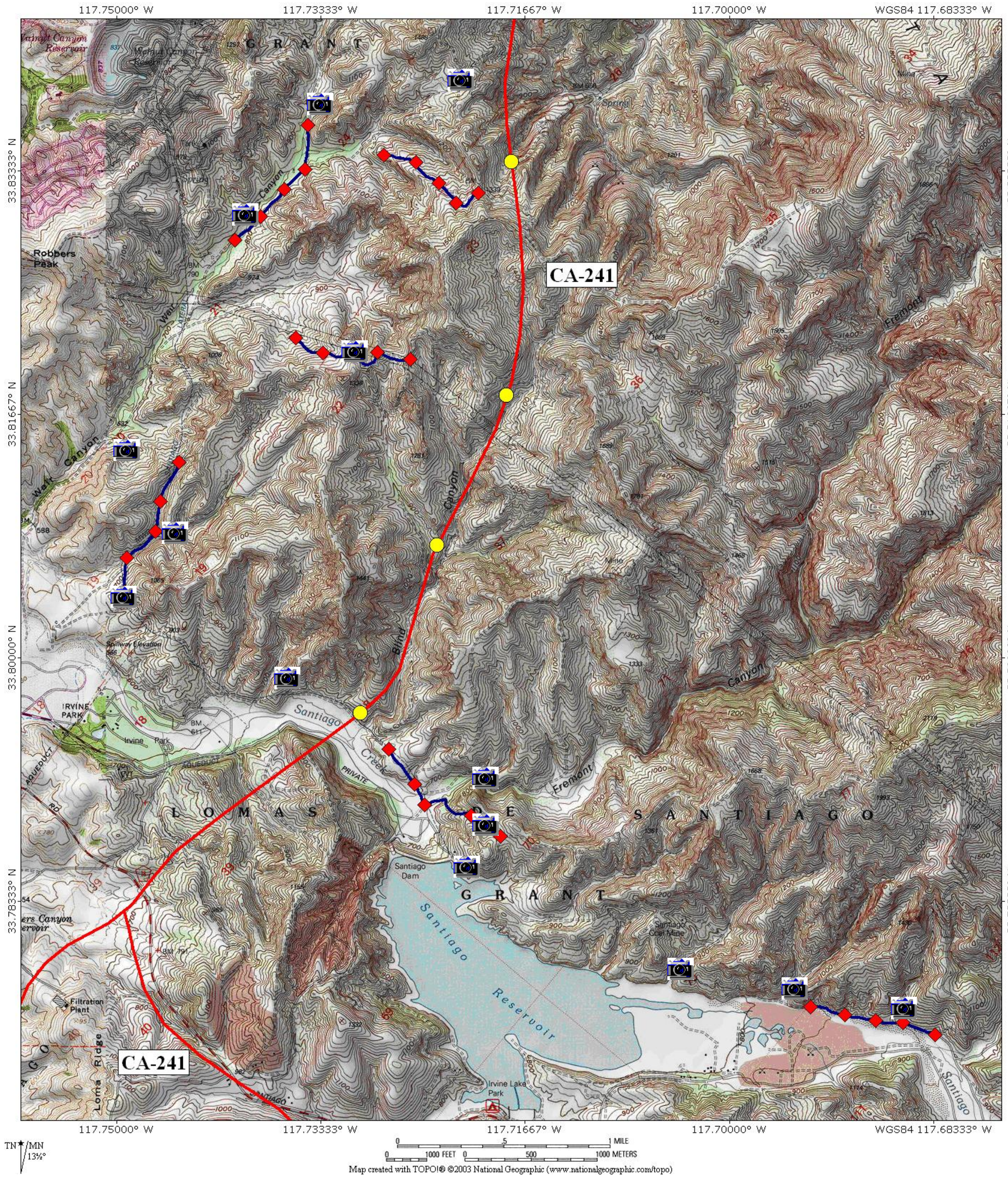

Figure 4. Track transects (blue line) with baited scent stations (red diamonds) and camera stations (camera icons) in the North Irvine Ranch, Orange County, CA. The red line represents CA-241 and underpasses are represented with yellow circles. To preserve clarity, North Lake Road is not denoted on the current map.

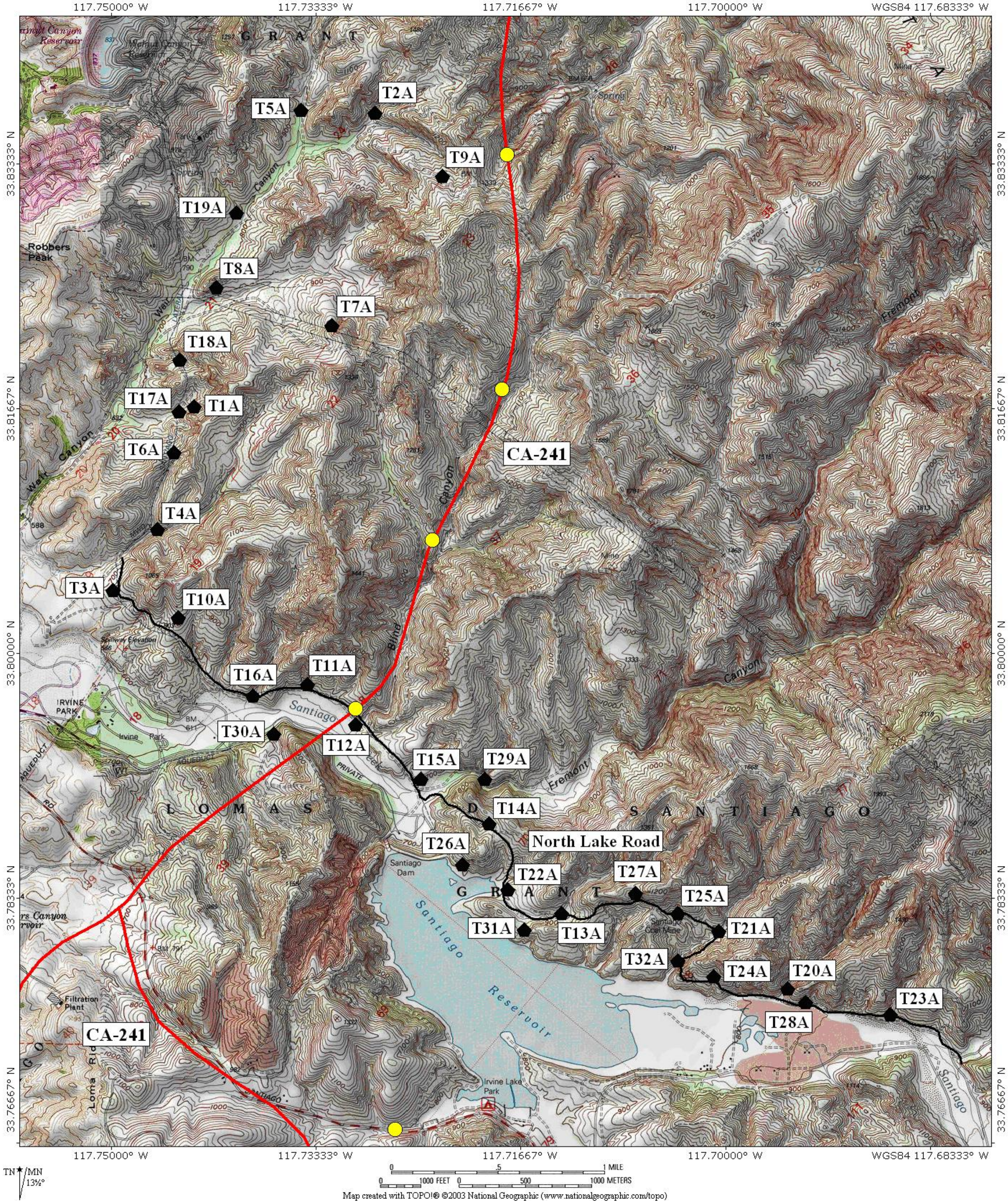

Figure 5. Phase 1 bobcat trap locations (black pentagons) in the North Irvine Ranch, Orange County, CA. The red line represents CA-241 while current North Lake Road is represented by a black line. Underpass locations are represented by yellow circles.

Figure 6. Phase 2 bobcat trap locations (black pentagons) in the North/Central Irvine Ranch, Orange County, CA. The red line represents CA-241 while current North Lake Road is represented by a black line. Underpass locations are represented by yellow circles.

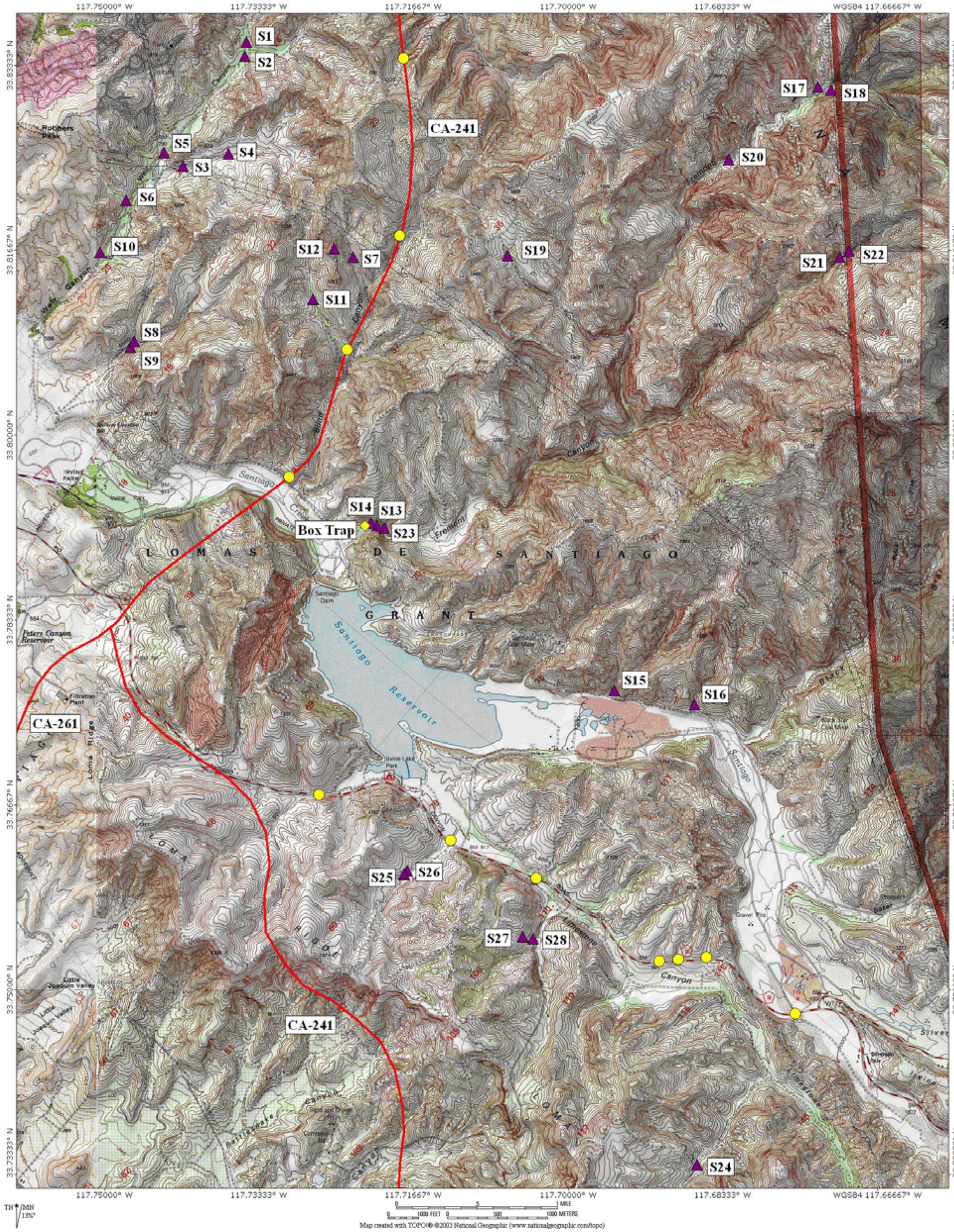

Figure 7. Mountain lion snare (purple triangles) and cage trap locations (yellow diamond) in the North/Central Irvine Ranch, Orange County, CA. The red line represents CA-241 and CA-261, and underpass locations are represented by yellow circles.

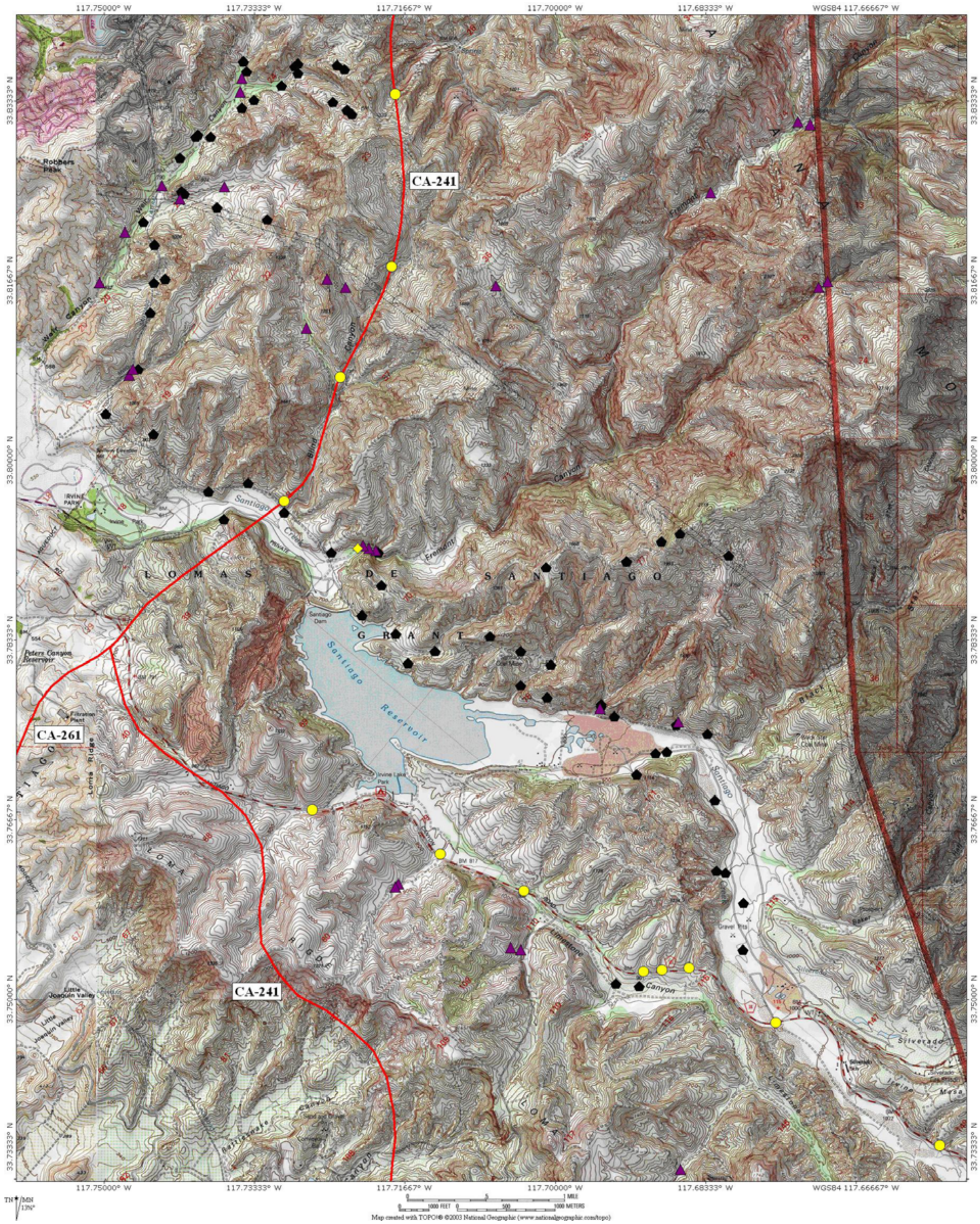

Figure 8. All Phase 1 and Phase 2 bobcat trap (black pentagons), mountain lion snare (purple triangles) and box trap locations (yellow diamond) in the North/Central Irvine Ranch, Orange County, CA. The red line represents CA-241 and CA-261, and underpass locations are represented by yellow circles.

Schedule A

	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Sun																								
Mon																								
Tues																								
Wed																								
Thur																								
Fri																								
Sat																								

Expected Duration: 46 weeks
Expected maximum number GPS locations: about 3200

Schedule B

	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Sun																								
Mon																								
Tues																								
Wed																								
Thur																								
Fri																								
Sat																								

Expected Duration: 25 weeks
Expected maximum number GPS locations: about 3700

Figure 9. Hourly programming schedules for GPS-Simplex™ radio collars fitted to mountain lions in the North/Central Irvine Ranch, Orange County, CA from October 2003 to June 2005. Schedule A was used for mountain lions P1 and P2. Schedule B was used for mountain lion P3. Radio collars obtained GPS locations at shaded dates and times. GPS locations were recorded at 15 minutes past the indicated hour, and only one location per hour was recorded.

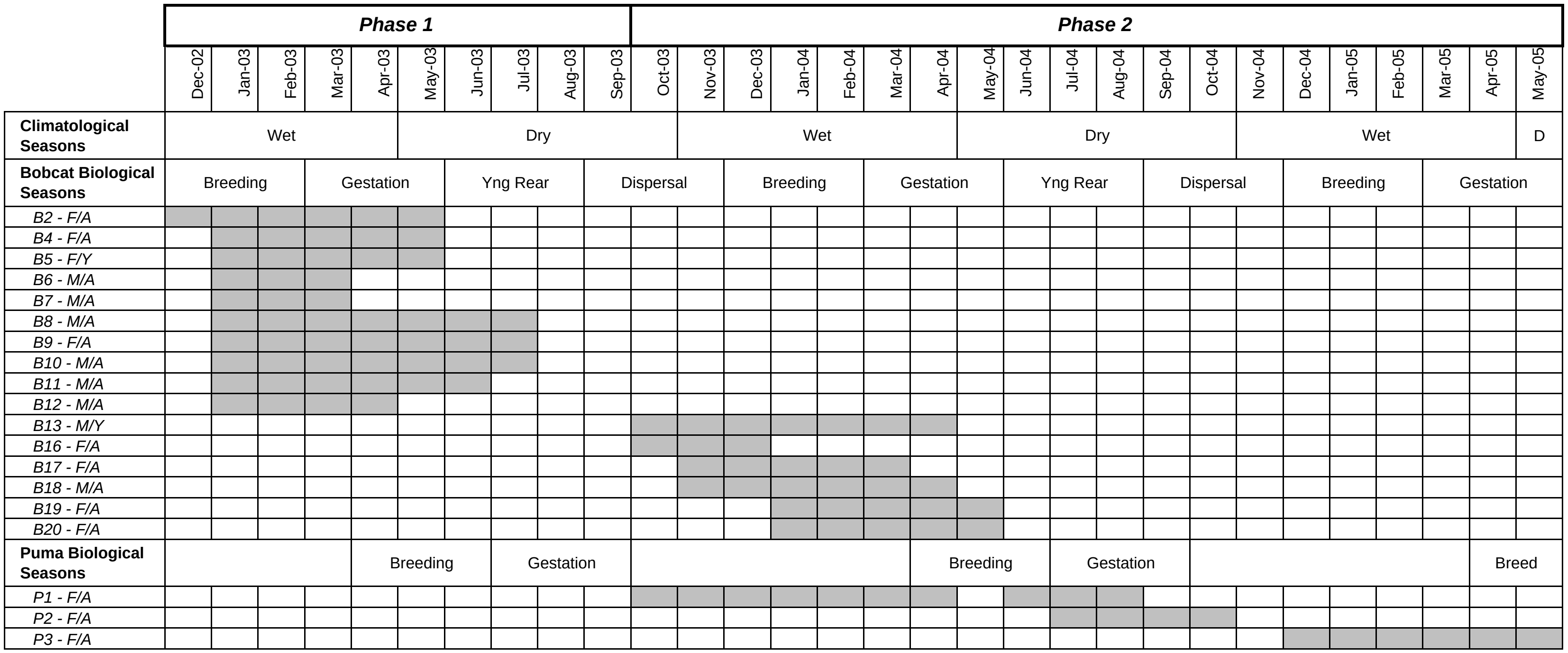

Figure 10. Seasonal monitoring schedule by month for bobcats and mountain lions at the North/Central Irvine Ranch, Orange County, CA from December 2002 to May 2005. See Lyren 2001, and Logan and Sweanor 2001 for explanation of bobcat and puma biological seasons. Animal identification numbers include sex and age class as M = male, F = Female; age Y = yearling (12-24 months) and A = adult (> 24 months).

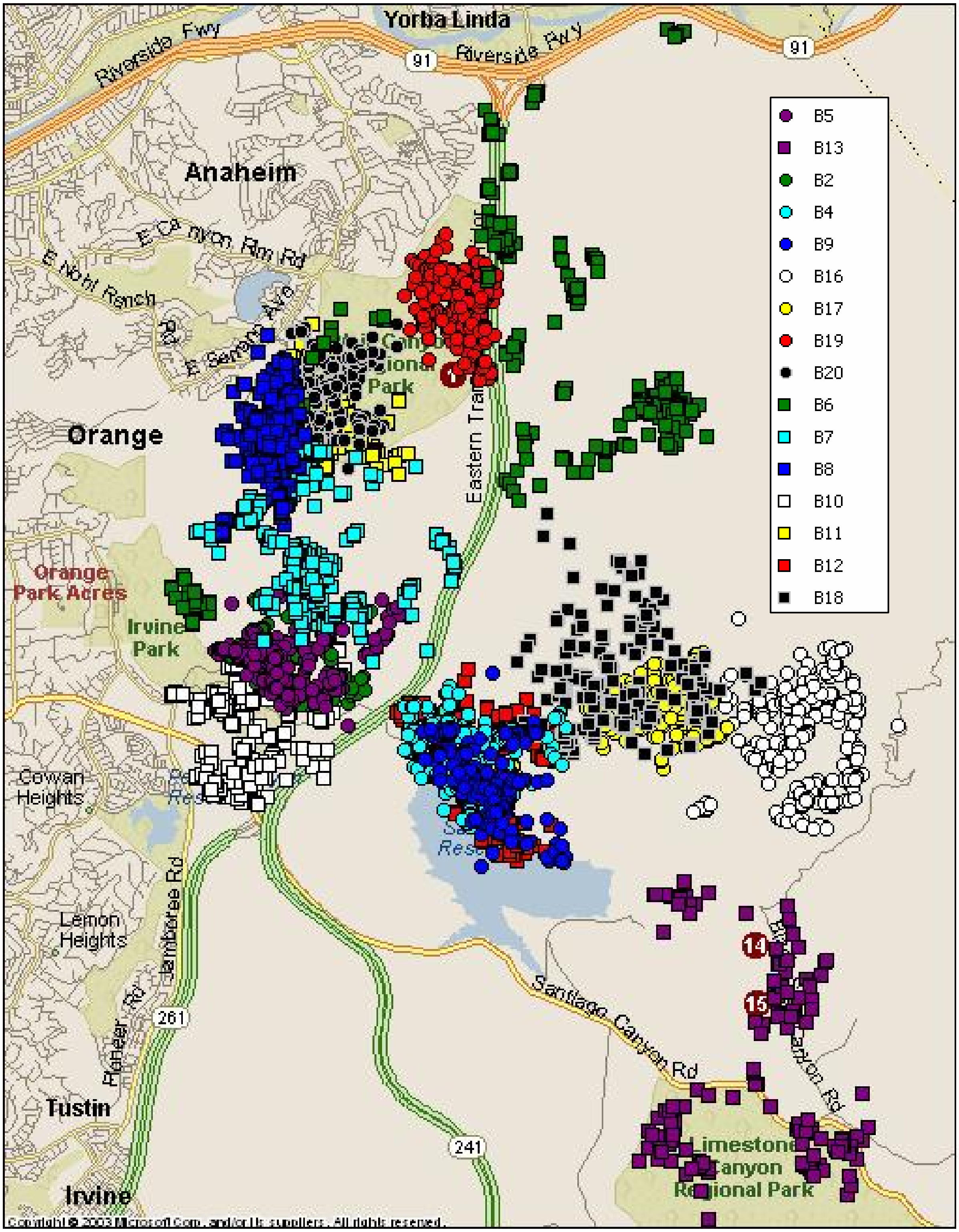

Figure 11. All Phase 1 and Phase 2 GPS locations for 16 radio-collared bobcats in the North /Central Irvine Ranch from December 2002 to July 2004. Juveniles are in purple. Circles represent females and squares represent males. Brown circles with numbers (1, 14, 15) represent capture locations for bobcats that were not radio-collared (B1, B14, and B15; B3 not visible underneath B4, B9, and B12 GPS locations).

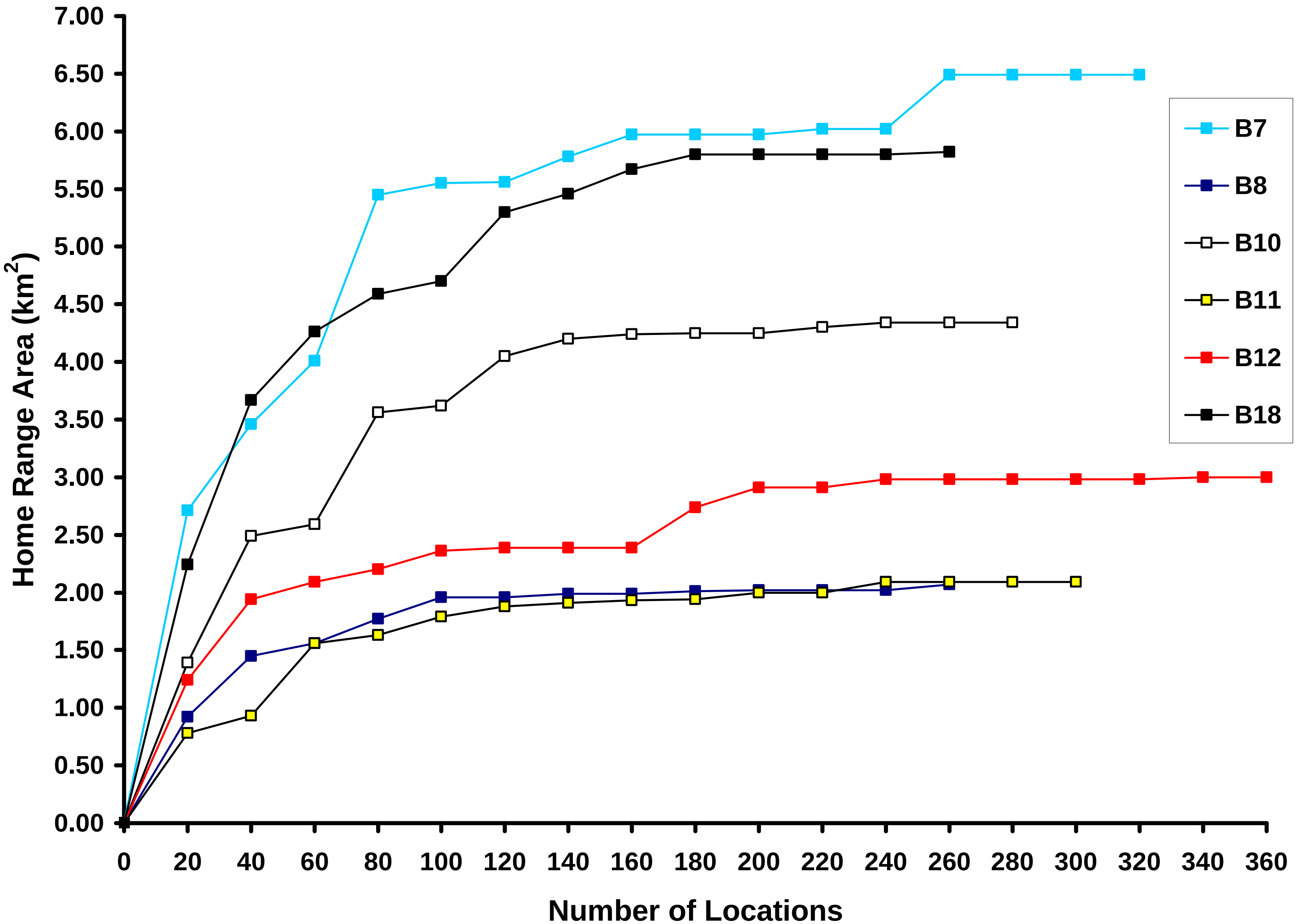

Figure 12. Area-observation curves for all male bobcats, except B6 and B13, radio-collared in the North/Central Irvine Ranch, CA, during Phase 1 and Phase 2 using the 100% minimum convex polygon method. Asymptotes were not reached for B7 or B11 (see results).

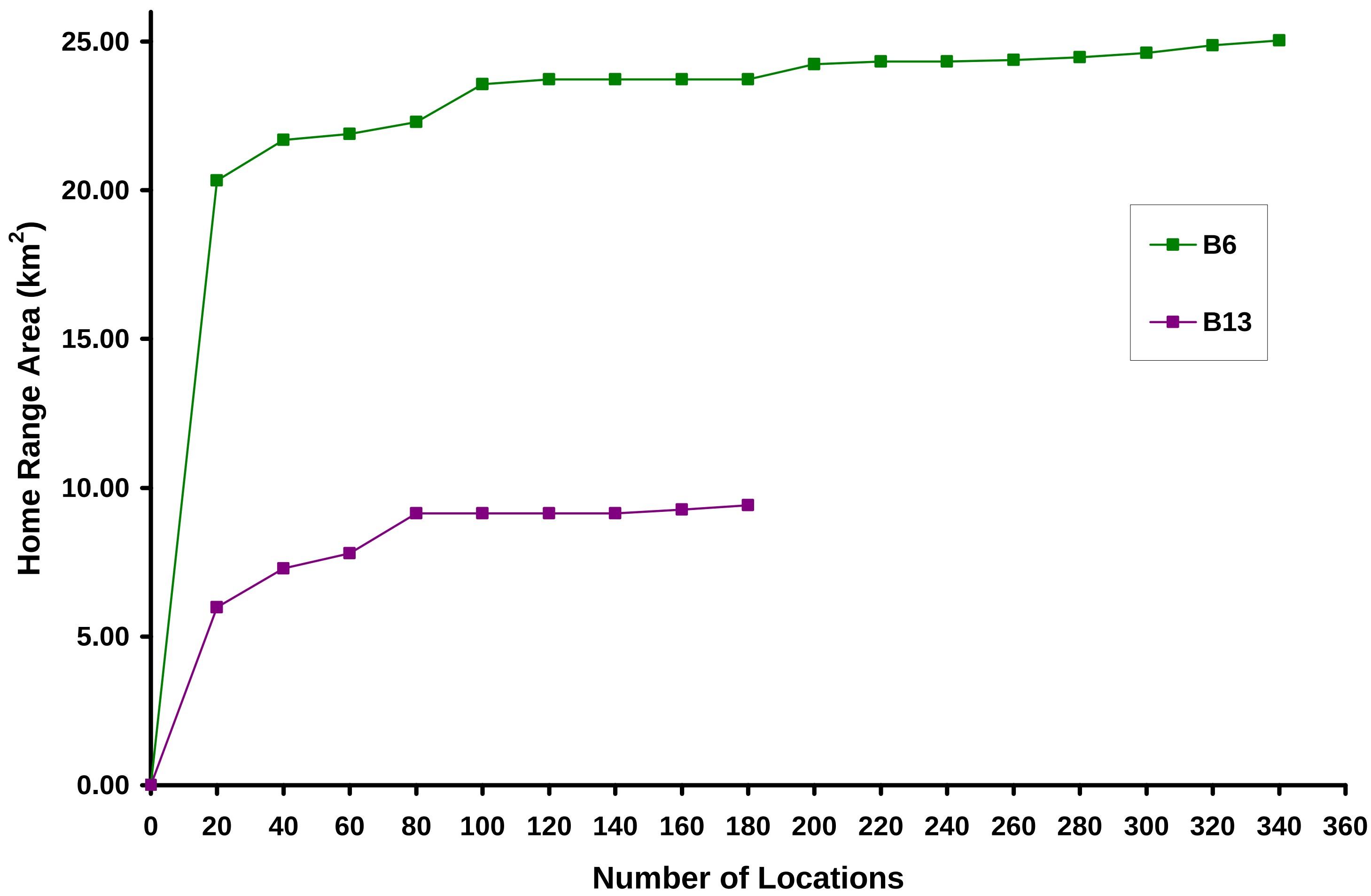

Figure 13. Area-observation curves for male bobcats B6 and B13 radio-collared in the North/Central Irvine Ranch, CA, during Phase 1 and Phase 2 using the 100% minimum convex polygon method.

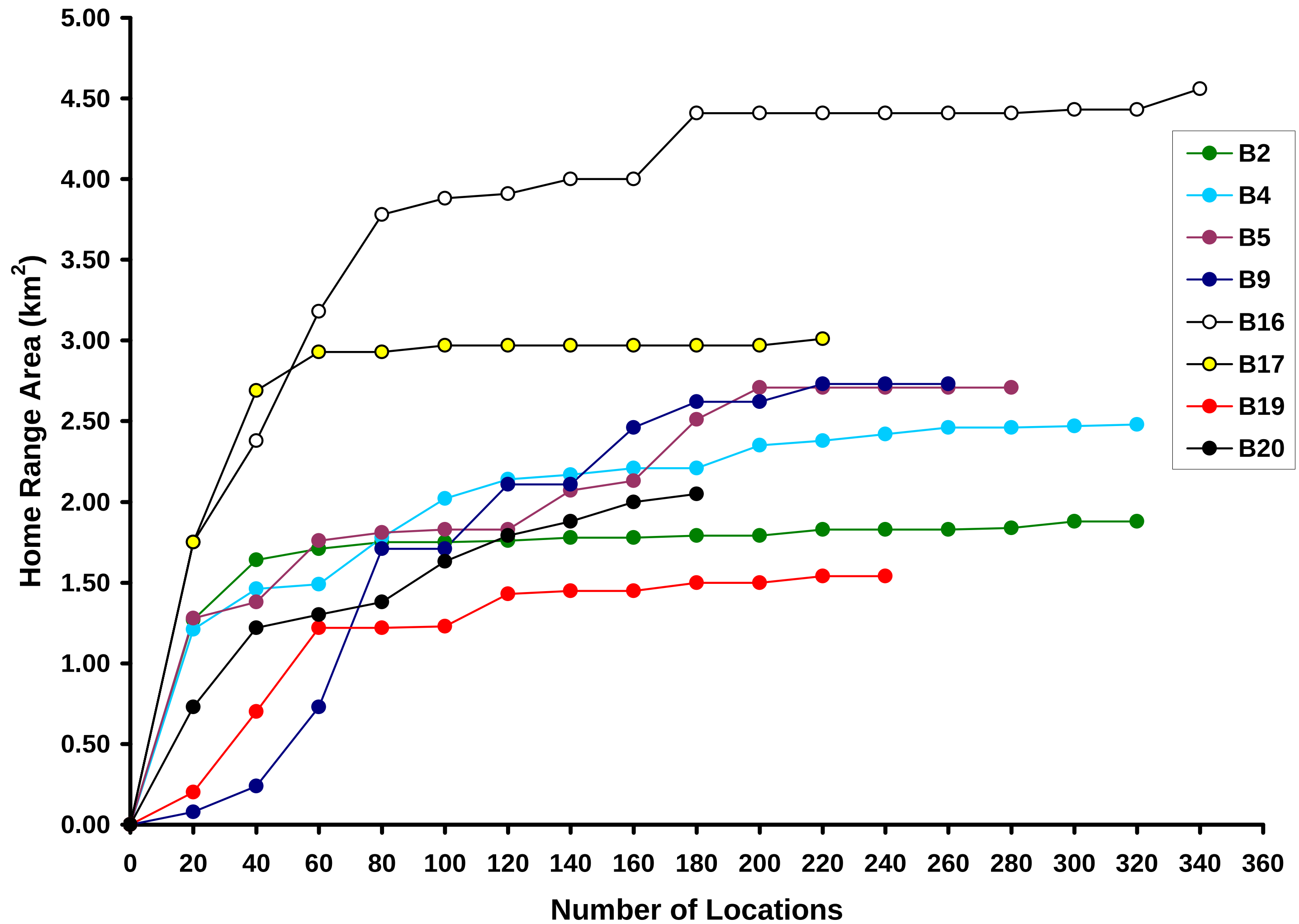

Figure 14. Area-observation curves for female bobcats radio-collared in the North/Central Irvine Ranch, CA, during Phase 1 and Phase 2 using the 100% minimum convex polygon method. Asymptotes were not reached for B5, B9, or B20 (see results).

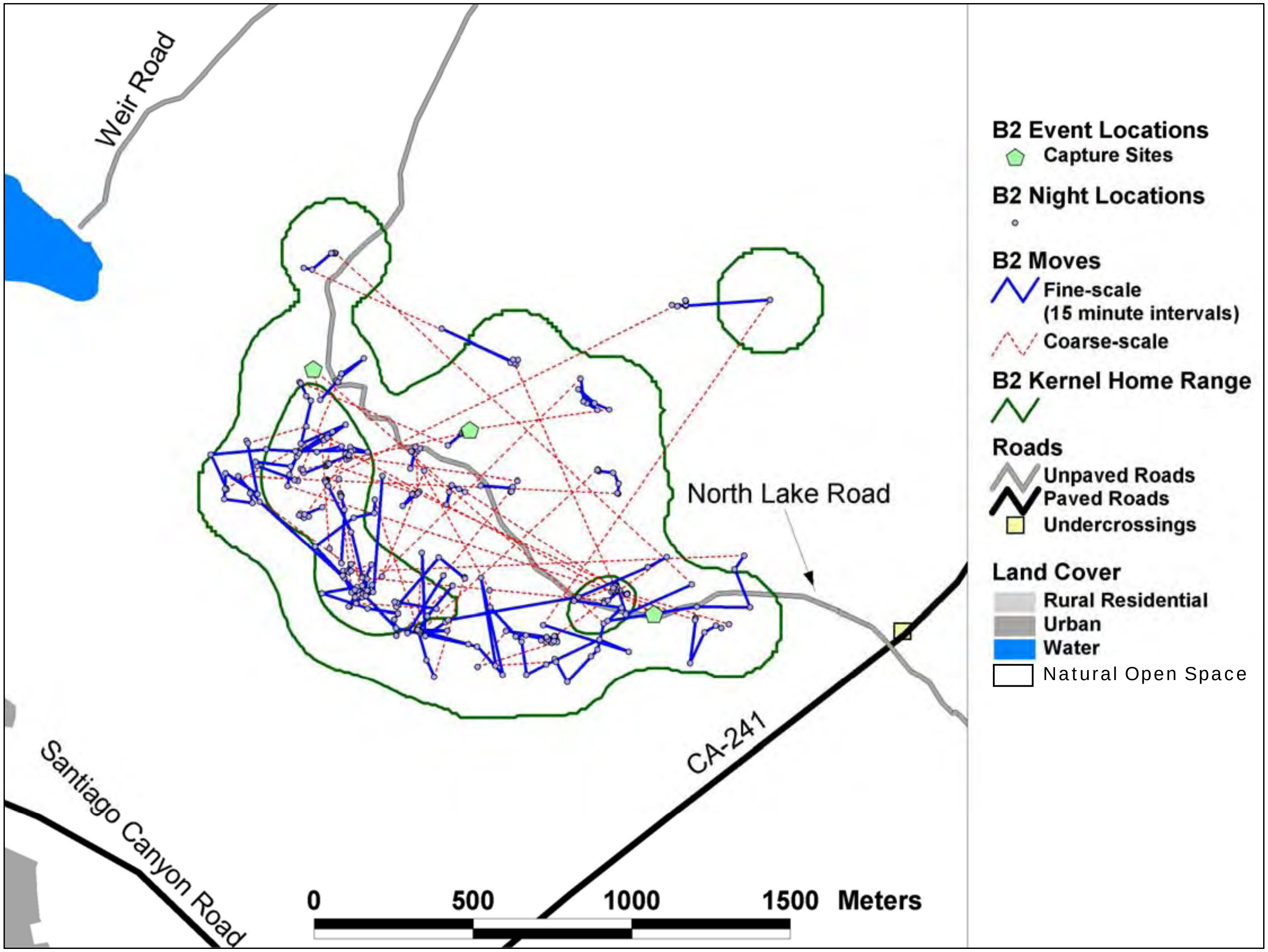

Figure 15. B2's (female, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from December 2002 to May 2003 in the North Irvine Ranch, Orange County, CA.

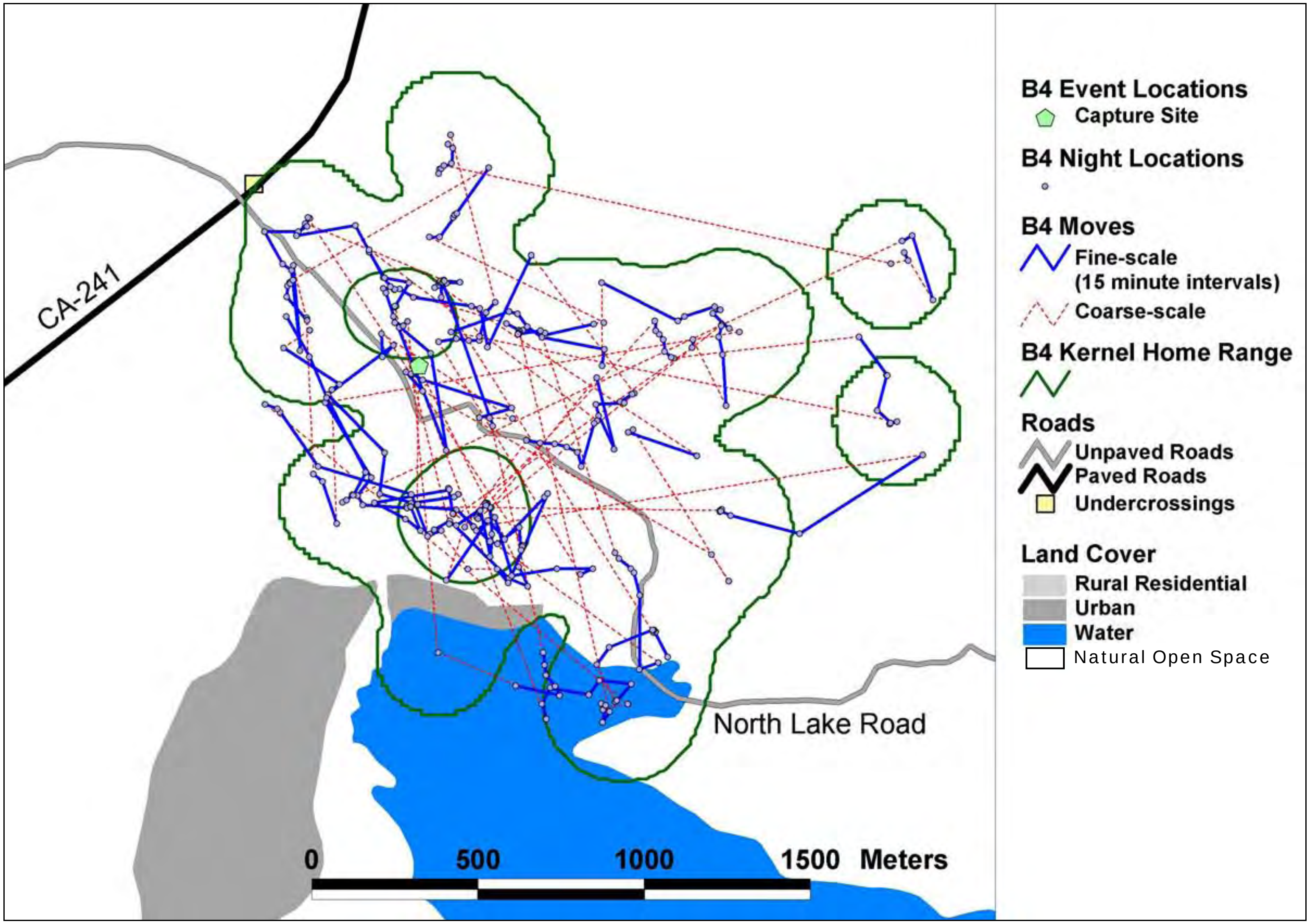

Figure 16. B4's (female, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from January to May 2003 in the North Irvine Ranch, Orange County, CA.

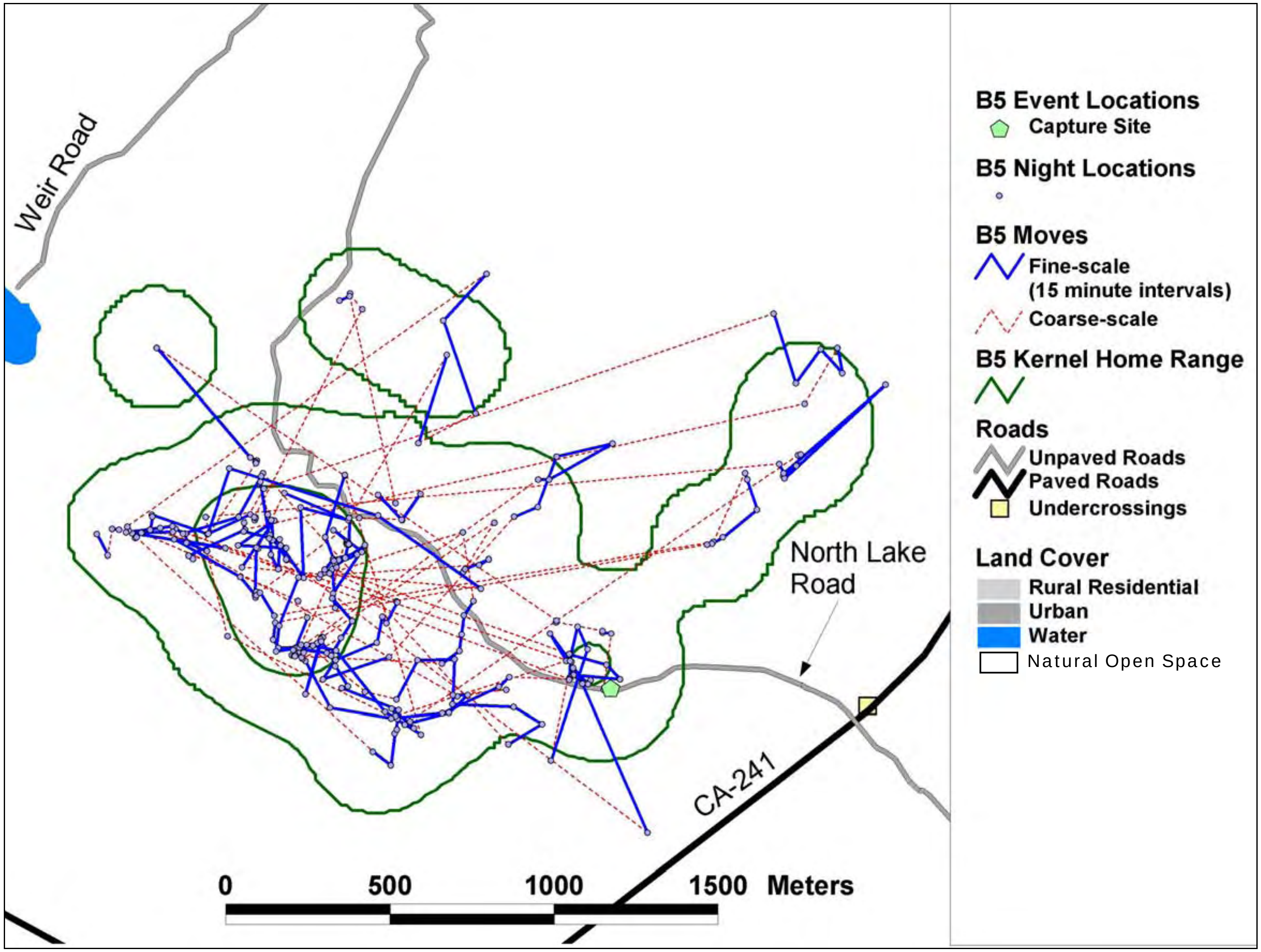

Figure 17. B5's (female, yearling) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from January to May 2003 in the North Irvine Ranch, Orange County, CA.

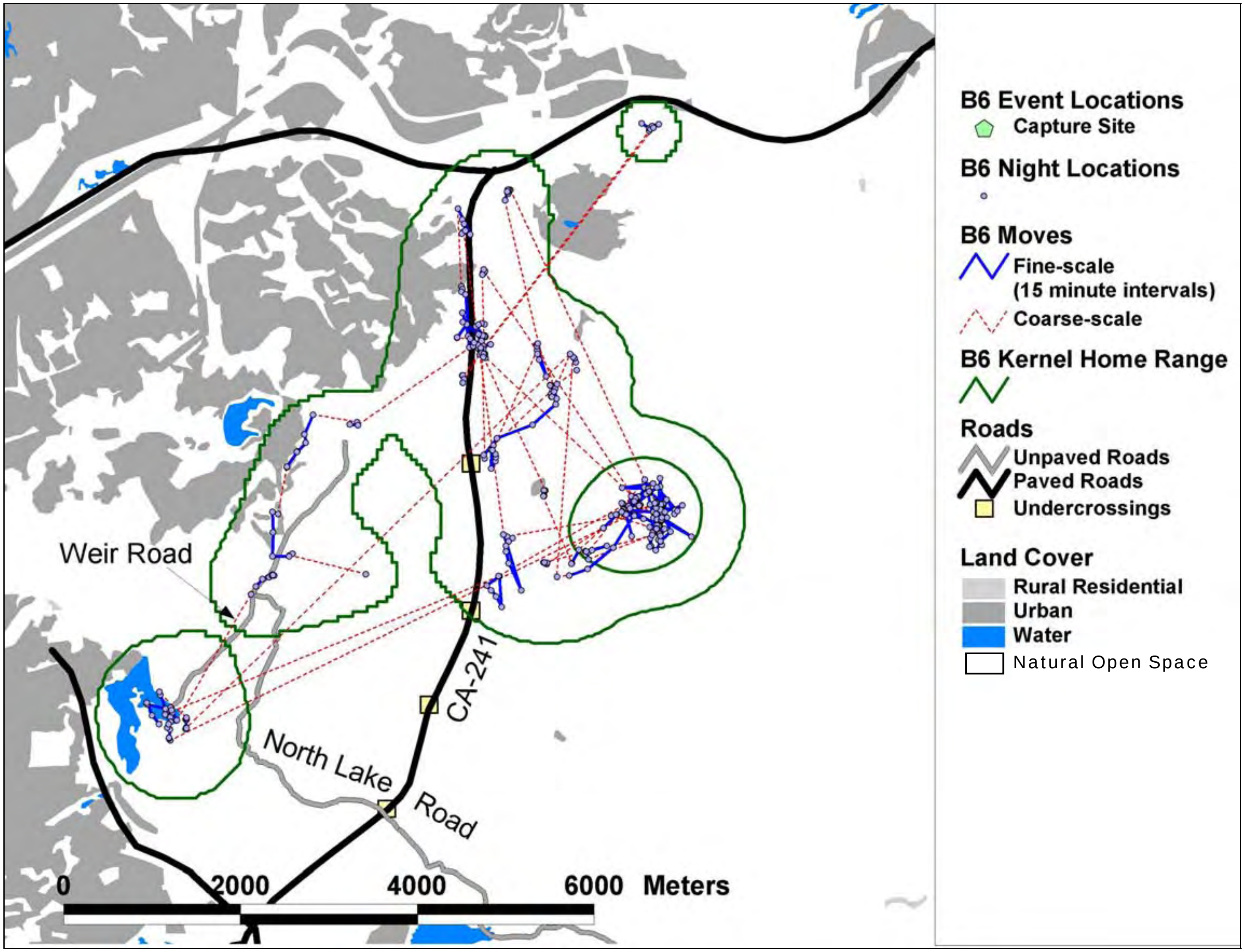

Figure 18. B6's (male, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from January to March 2003 in the North Irvine Ranch, Orange County, CA.

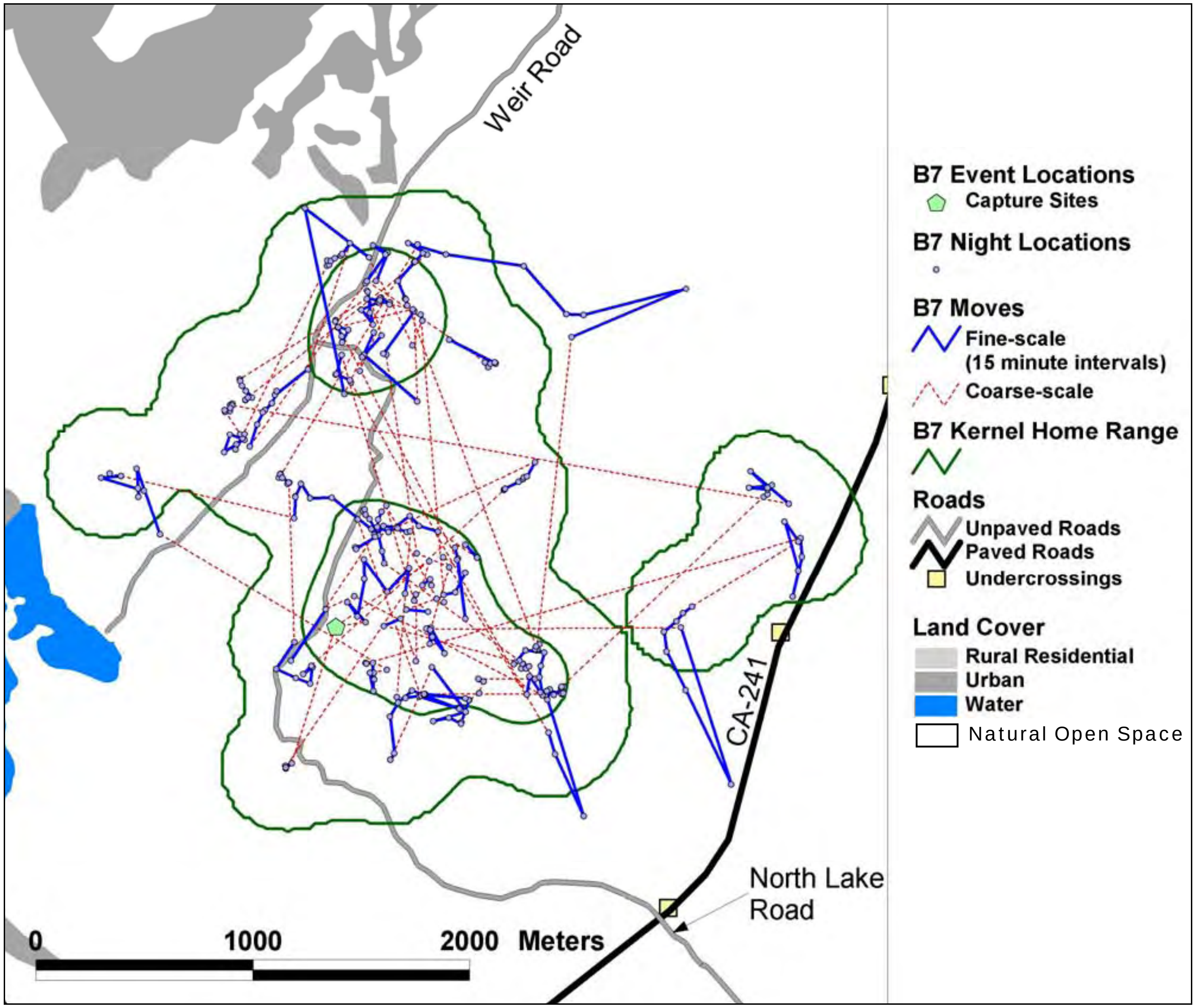

Figure 19. B7's (male, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from January to March 2003 in the North Irvine Ranch, Orange County, CA.

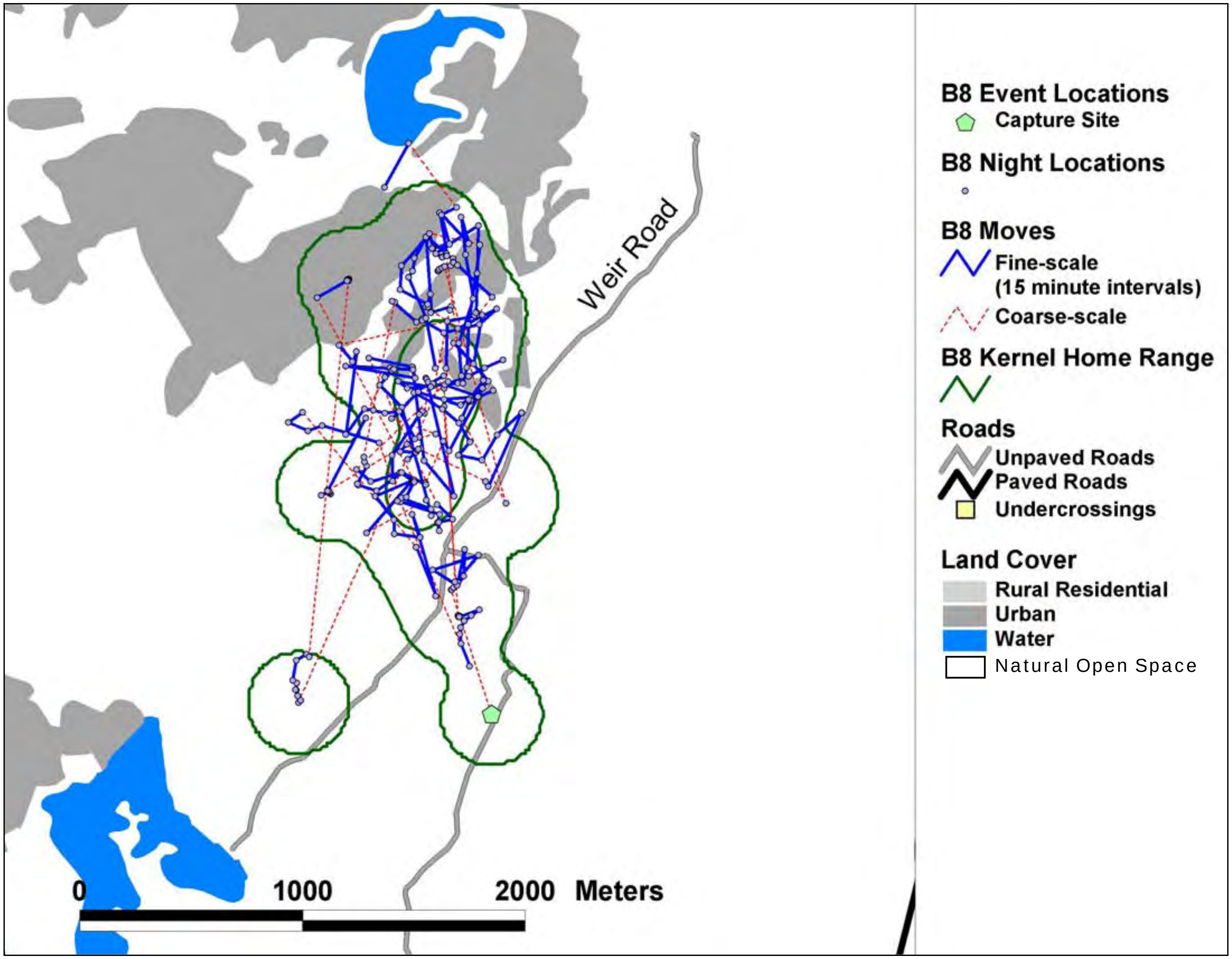

Figure 20. B8's (male, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from January to July 2003 in the North Irvine Ranch, Orange County, CA.

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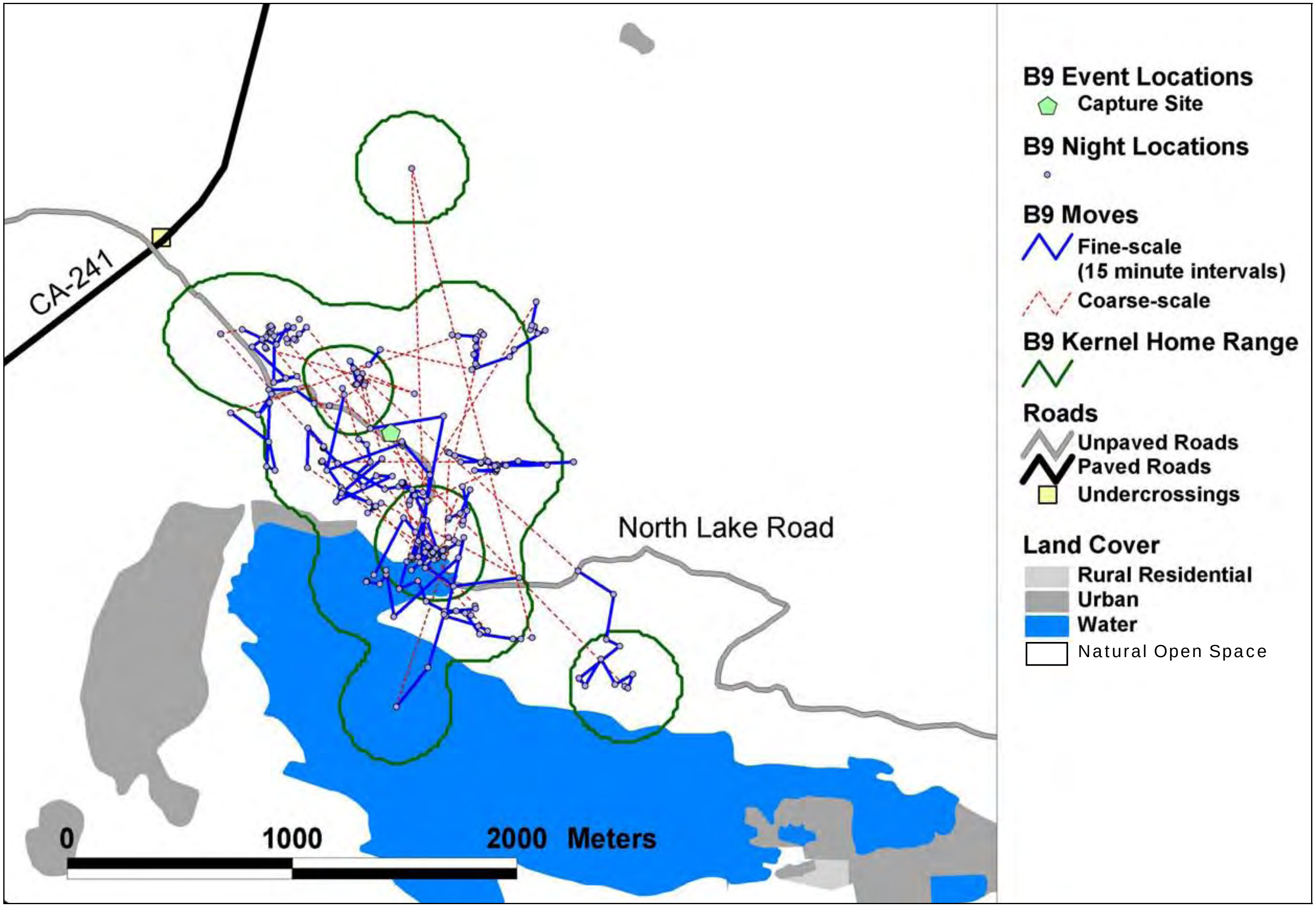

Figure 21. B9's (female, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from January to July 2003 in the North Irvine Ranch, Orange County, CA.

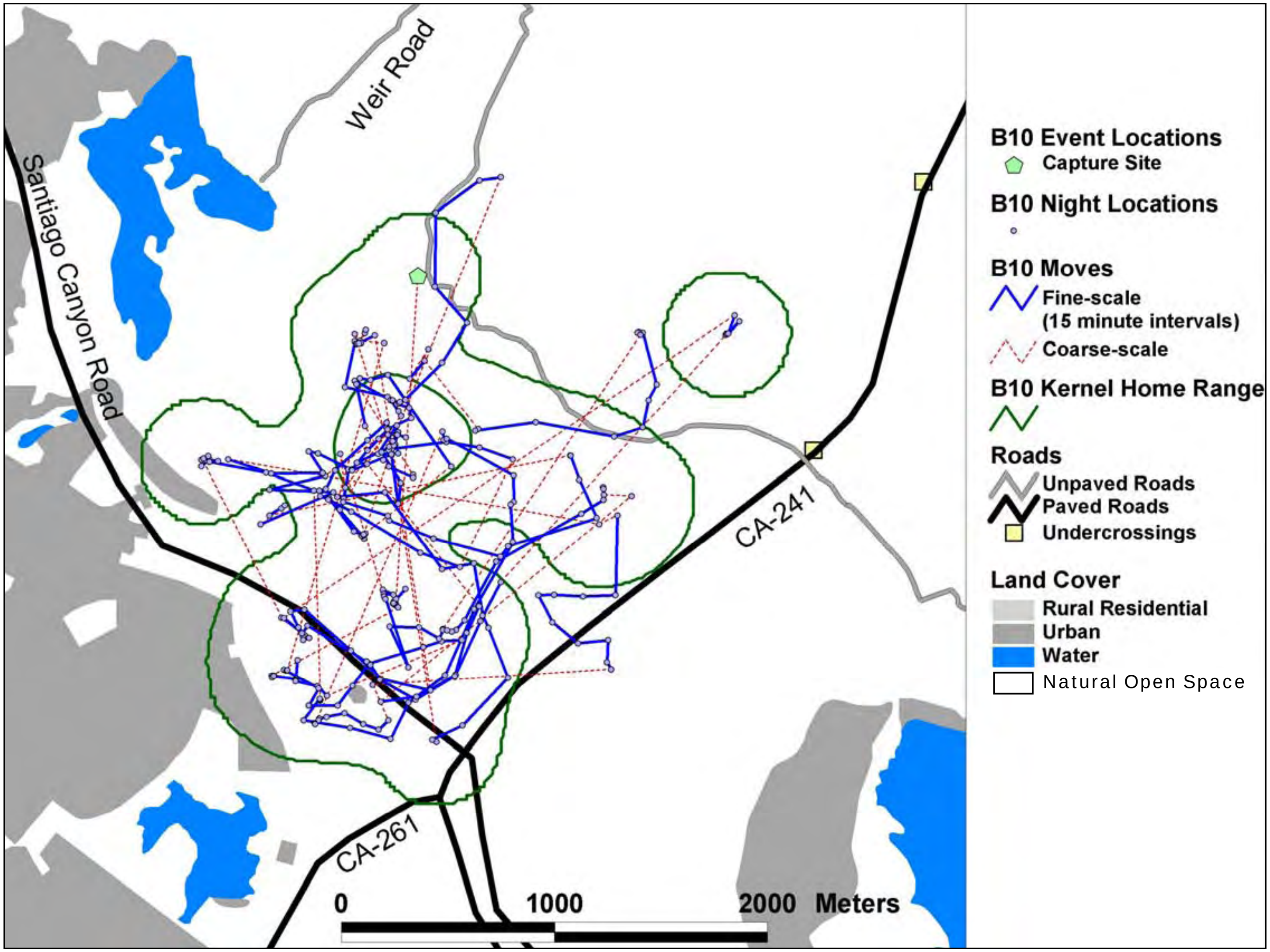

Figure 22. B10's (male, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from January to July 2003 in the North Irvine Ranch, Orange County, CA.

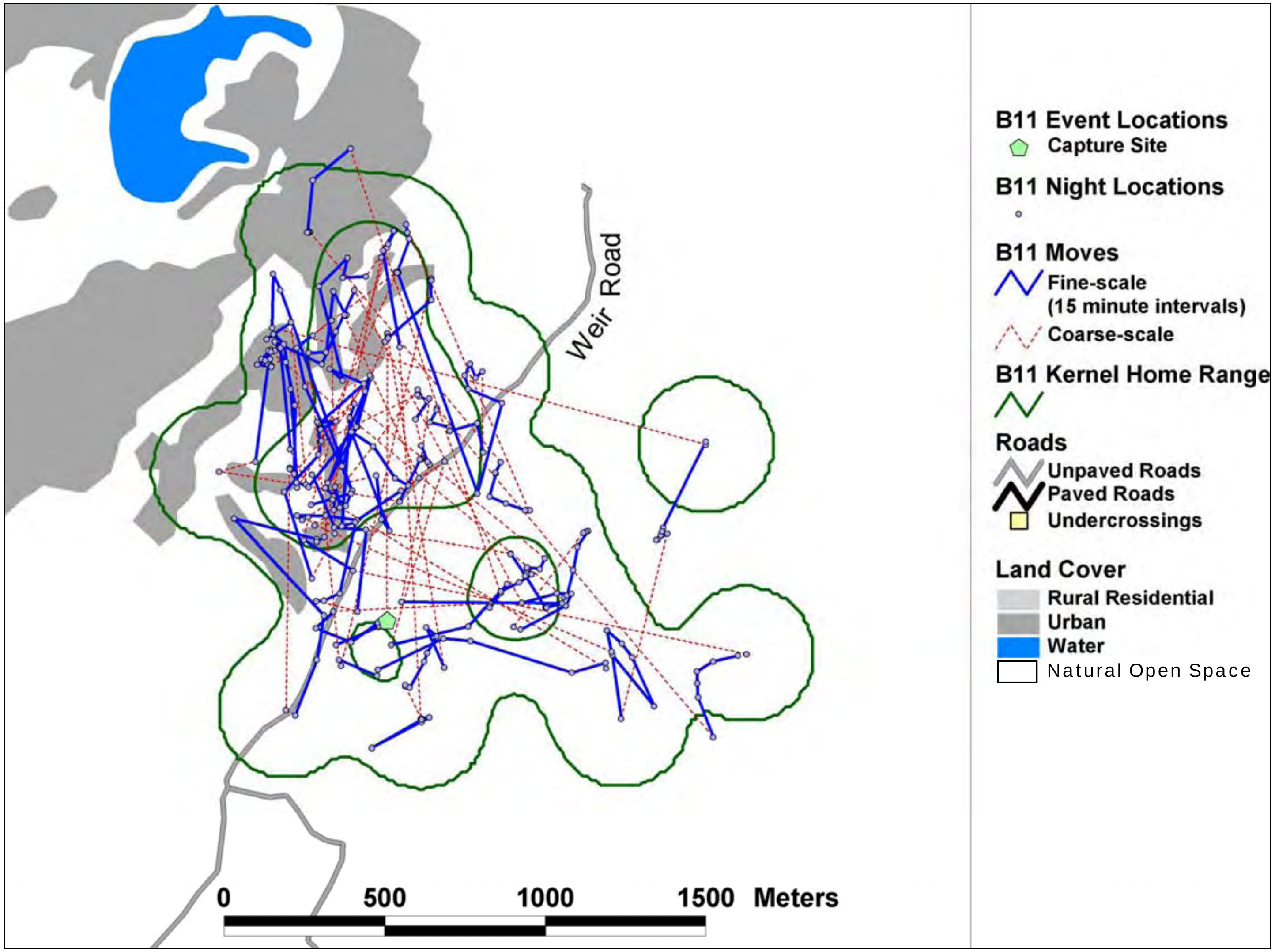

Figure 23. B11's (male, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from January to June 2003 in the North Irvine Ranch, Orange County, CA.

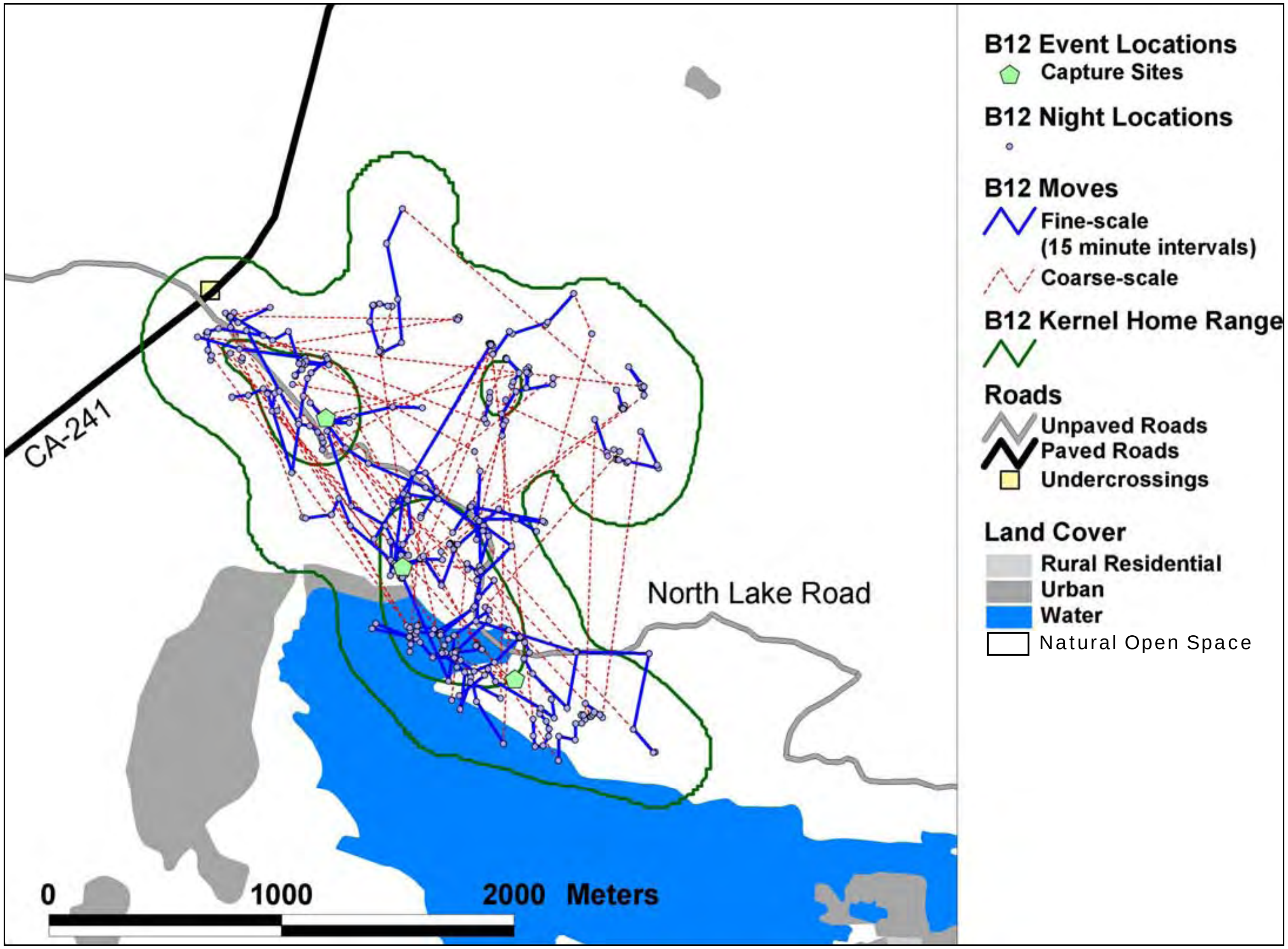

Figure 24. B12's (male, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from January to April 2003 in the North Irvine Ranch, Orange County, CA.

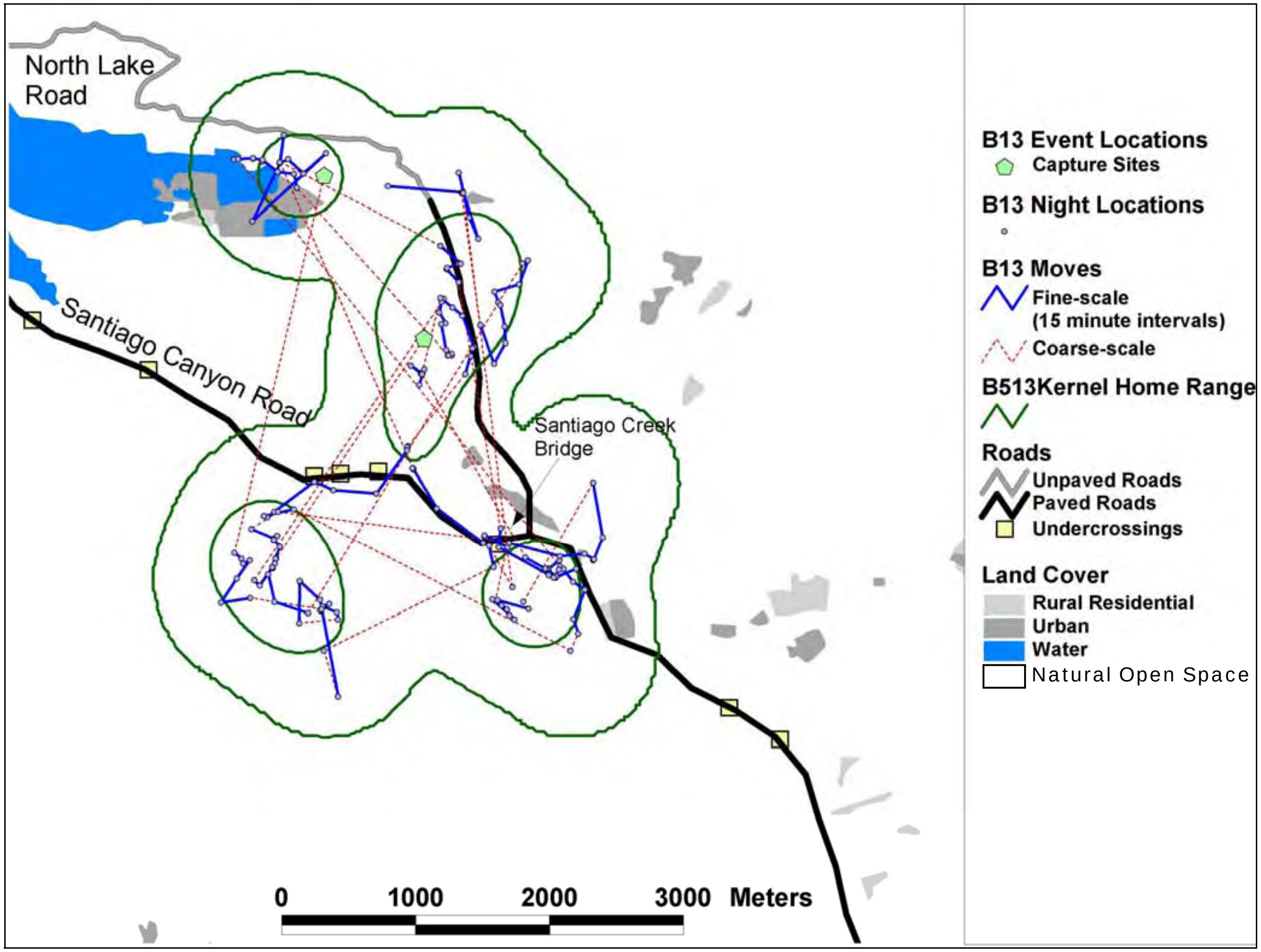

Figure 25. B13's (male, yearling) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from October 2003 to November 2004 in the North/Central Irvine Ranch, Orange County, CA. B13's collared failed prematurely in March 2004; he was recaptured November 2004.

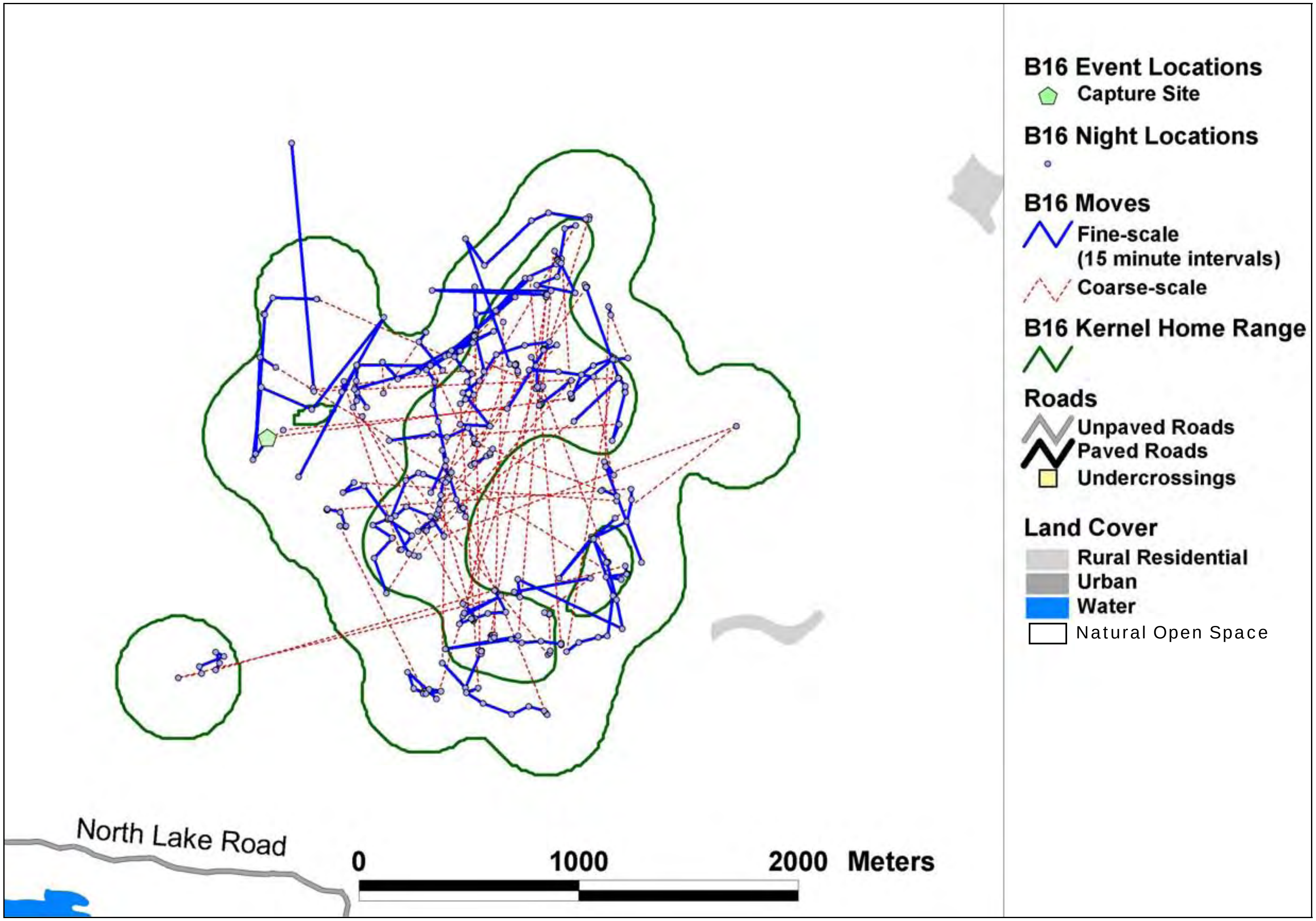

Figure 26. B16's (female, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from October to December 2003 in the North Irvine Ranch, Orange County, CA.

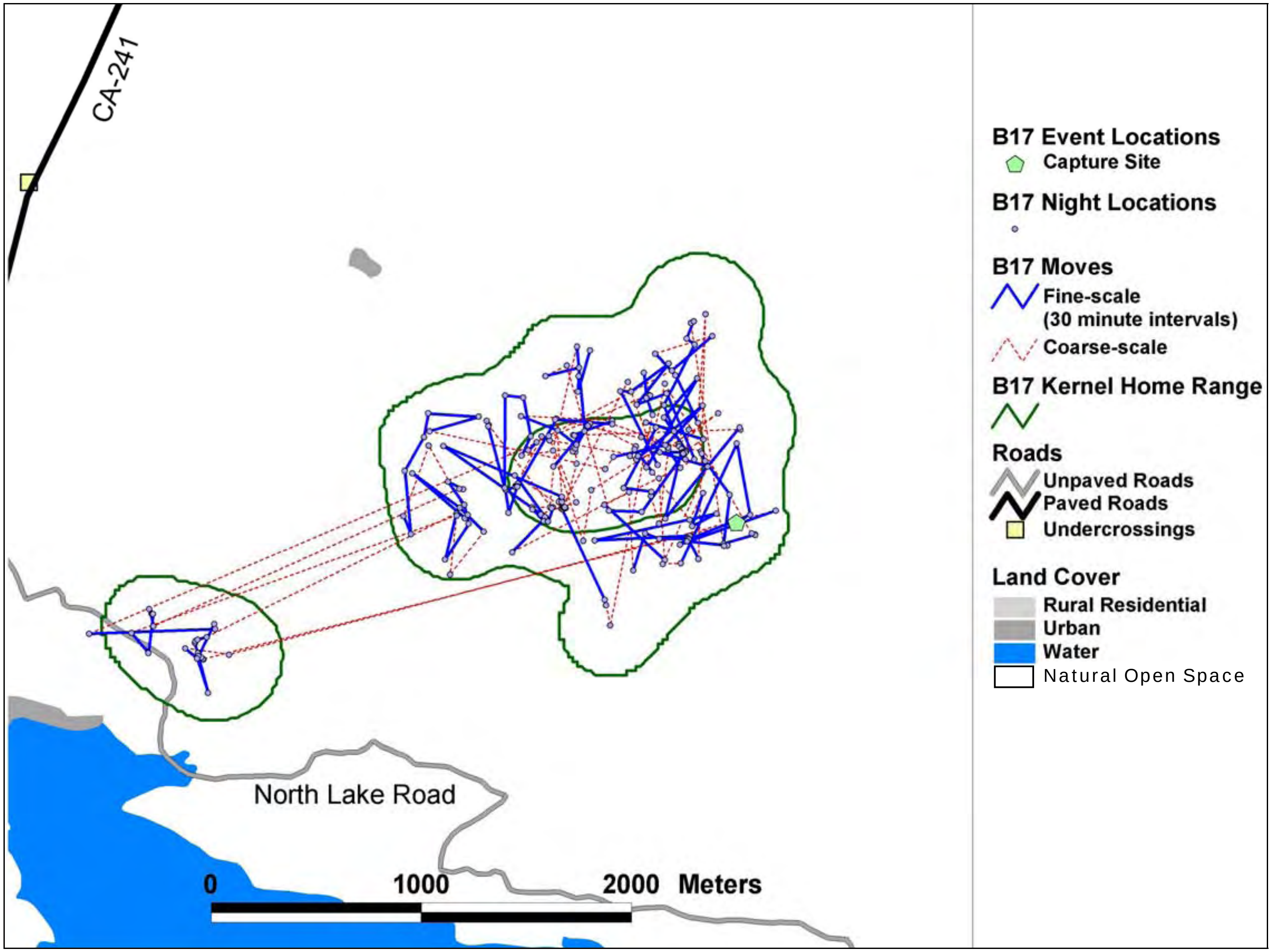

Figure 27. B17's (female, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from November 2003 to March 2004 in the North Irvine Ranch, Orange County, CA.

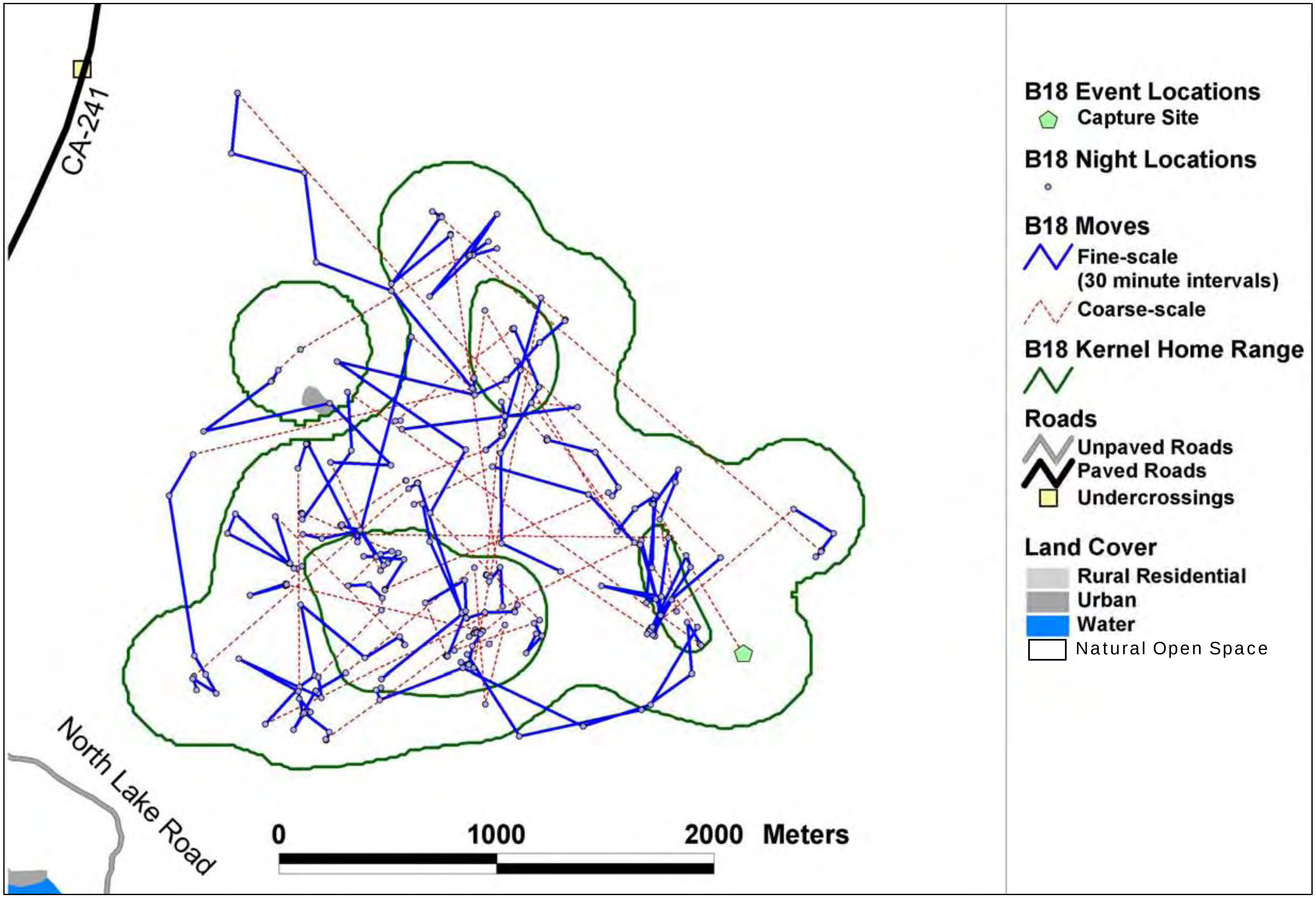

Figure 28. B18's (male, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from November 2003 to April 2004 in the North Irvine Ranch, Orange County, CA.

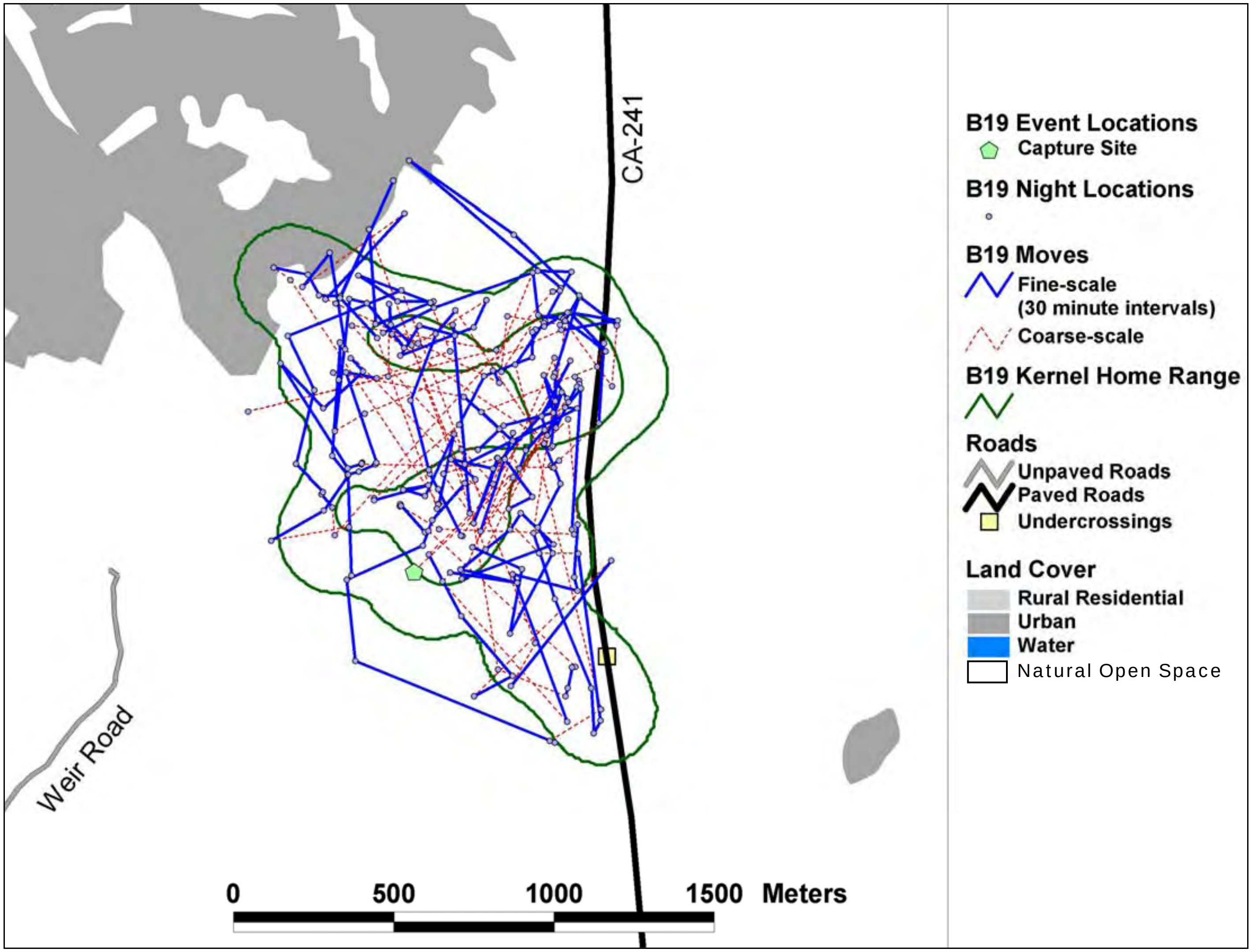

Figure 29. B19's (female, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from January to May 2004 in the North Irvine Ranch, Orange County, CA.

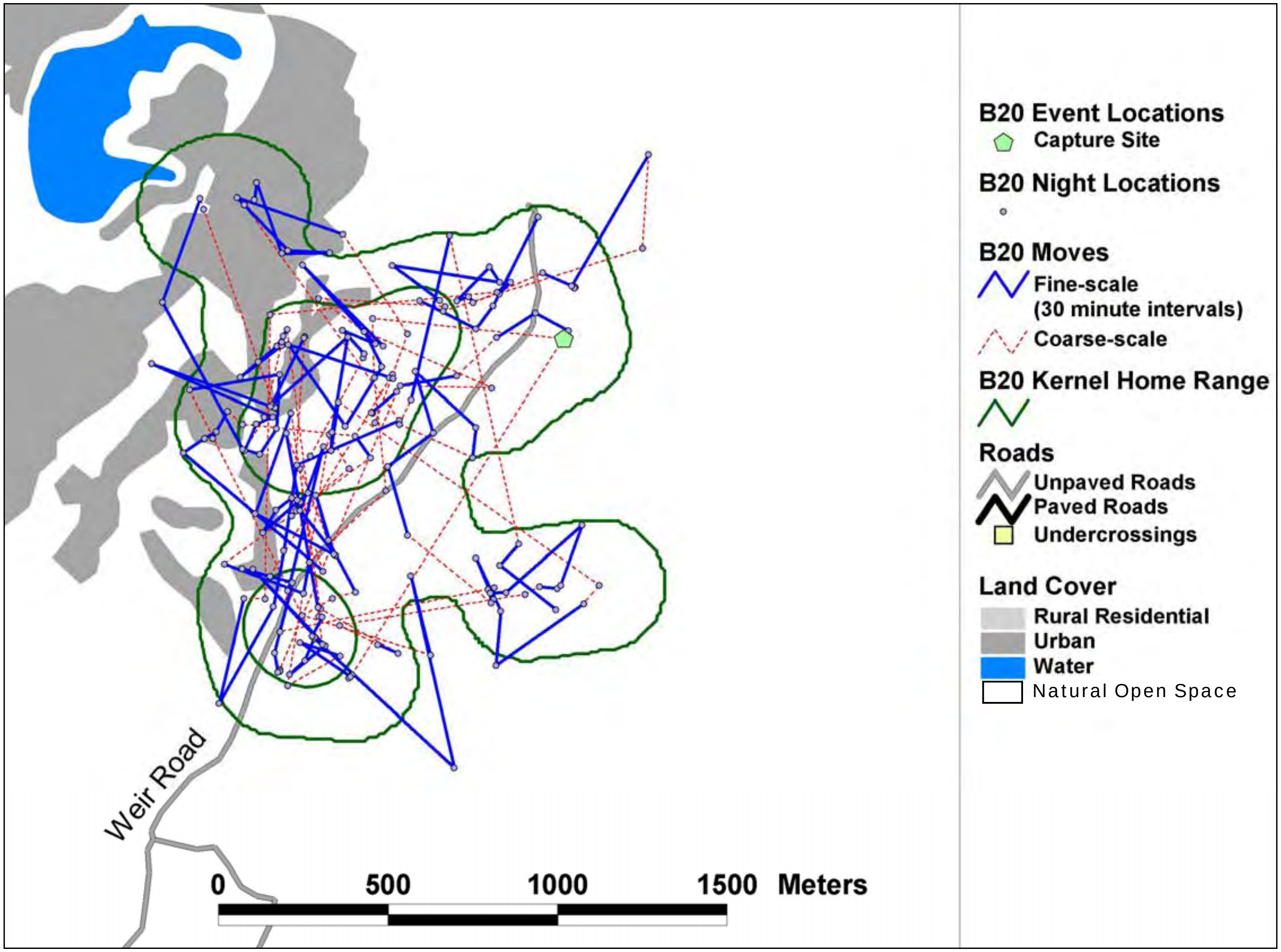

Figure 30. B20's (female, adult) GPS locations, movement path, and home range (95%) and core-use (50%) polygons from January to May 2004 in the North Irvine Ranch, Orange County, CA.

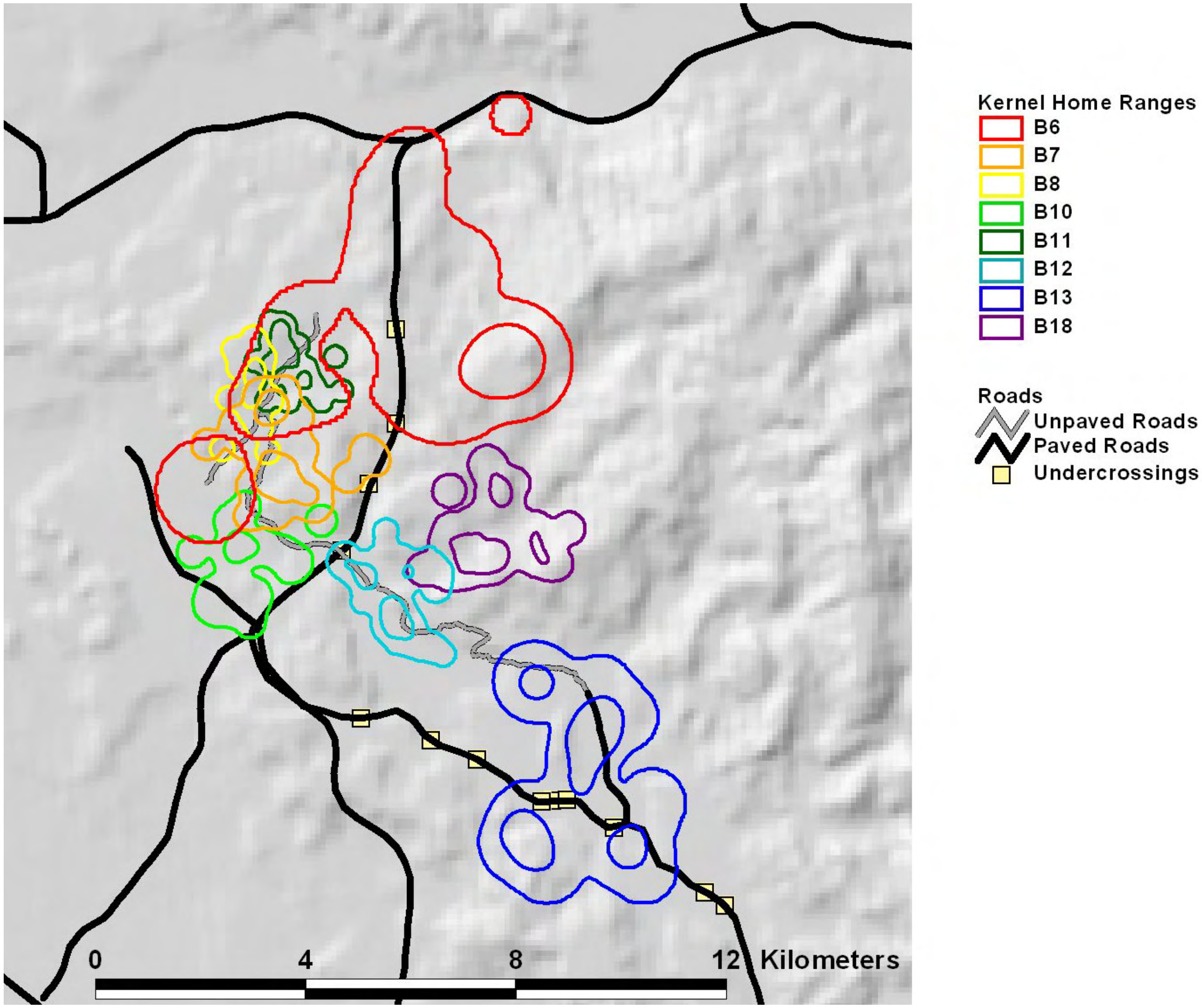

Figure 31. Fixed kernel home range (95%) polygons for male bobcats captured in the North/Central Irvine Ranch during Phases 1 and 2. Phase 1 bobcats are B6, B7, B8, B10, B11, and B12. Phase 2 bobcats are B13 and B18. Background layer is terrain with elevations ranging from 120 to 1220 meters.

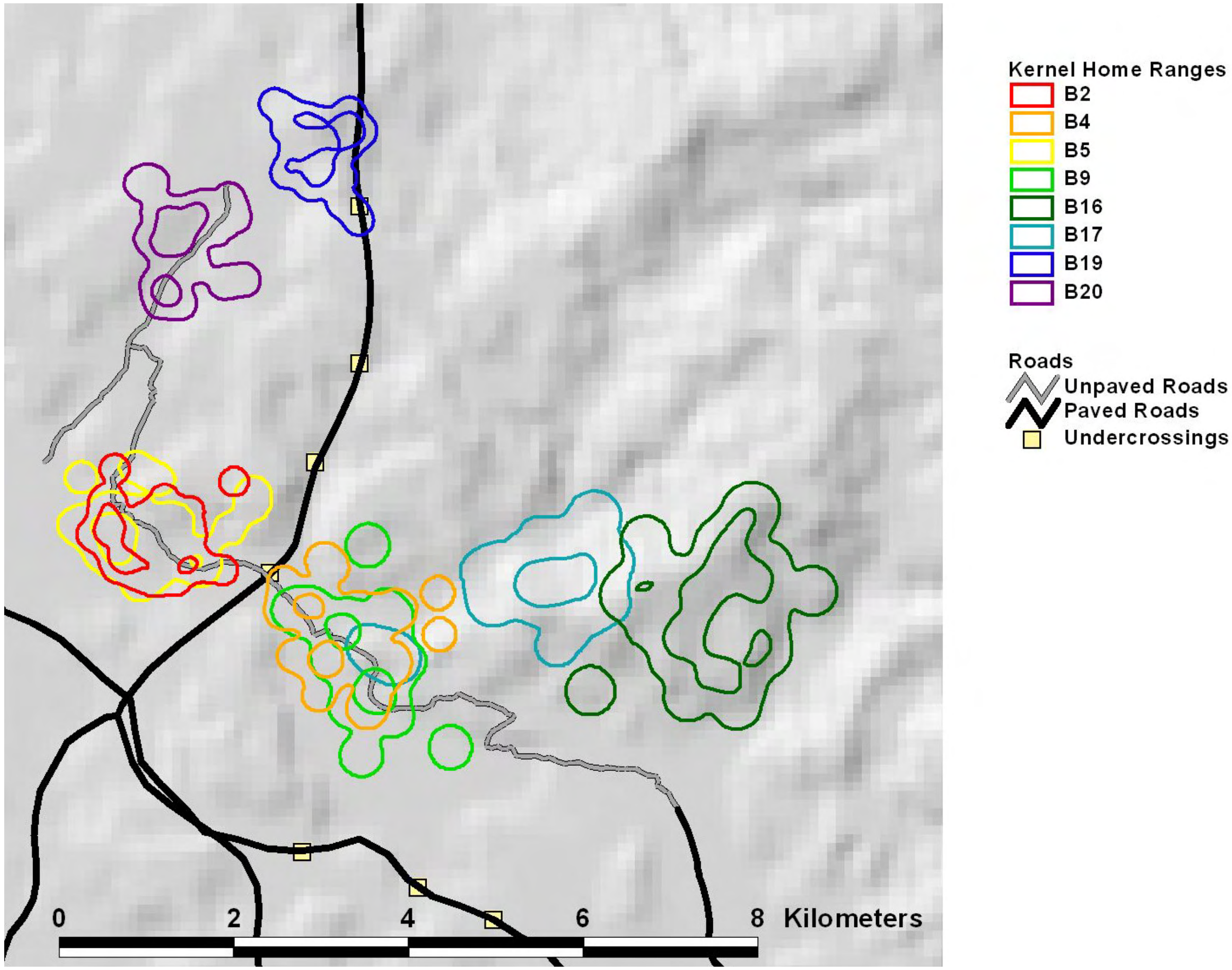

Figure 32. Fixed kernel home range (95%) polygons for female bobcats captured in the North Irvine Ranch during Phases 1 and 2. Phase 1 bobcats are B2, B4, B5, and B9. Phase 2 bobcats are B16, B17, B19, and B20. Background layer is terrain with elevations ranging from 120 to 1220 meters.

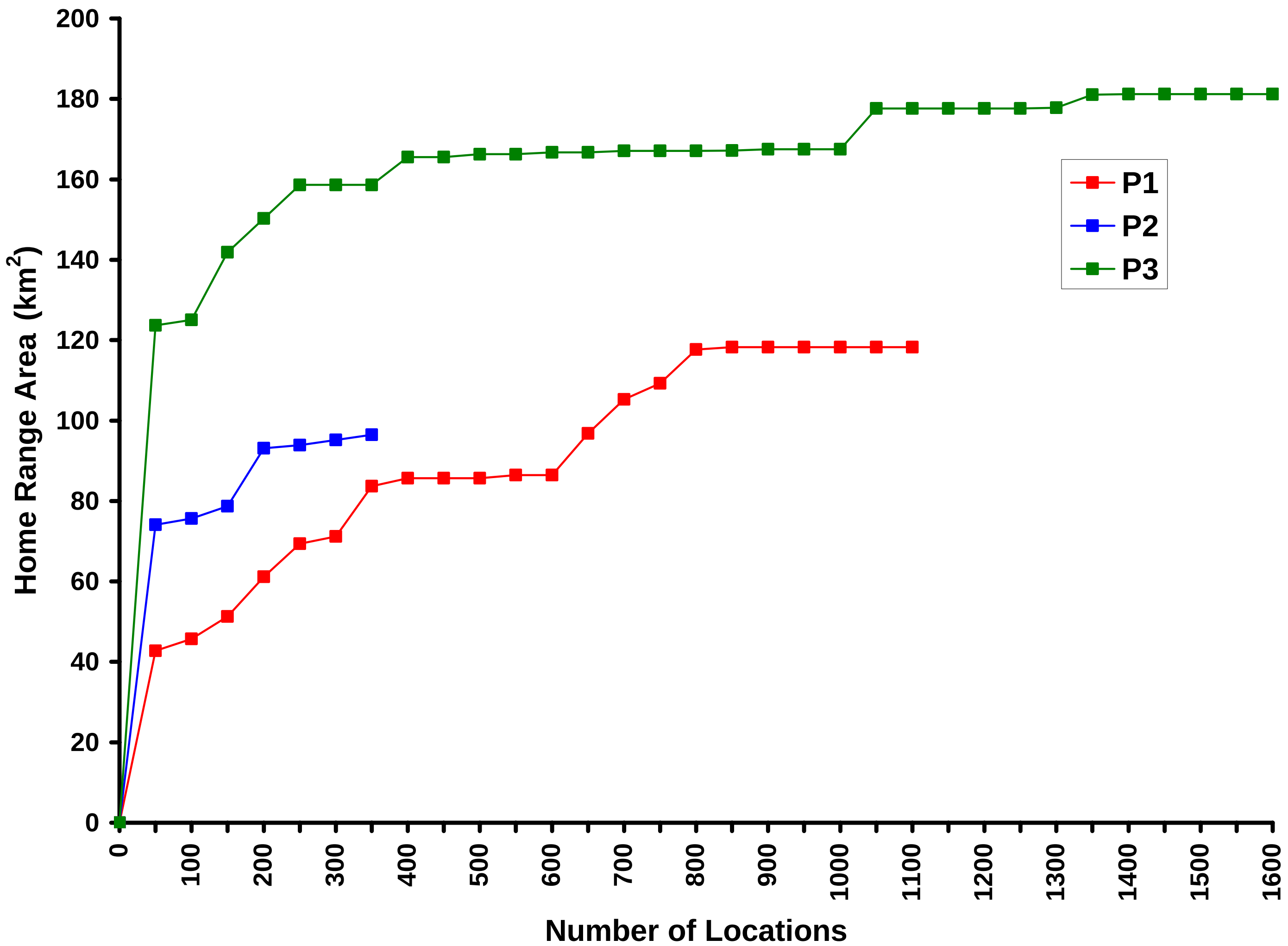

Figure 33. Area-observation curves for three female mountain lions radio-collared in the North/Central Irvine Ranch, Orange County, CA from October 2003 to May 2005 using the 100% MCP method. An asymptote was not reached for P2.

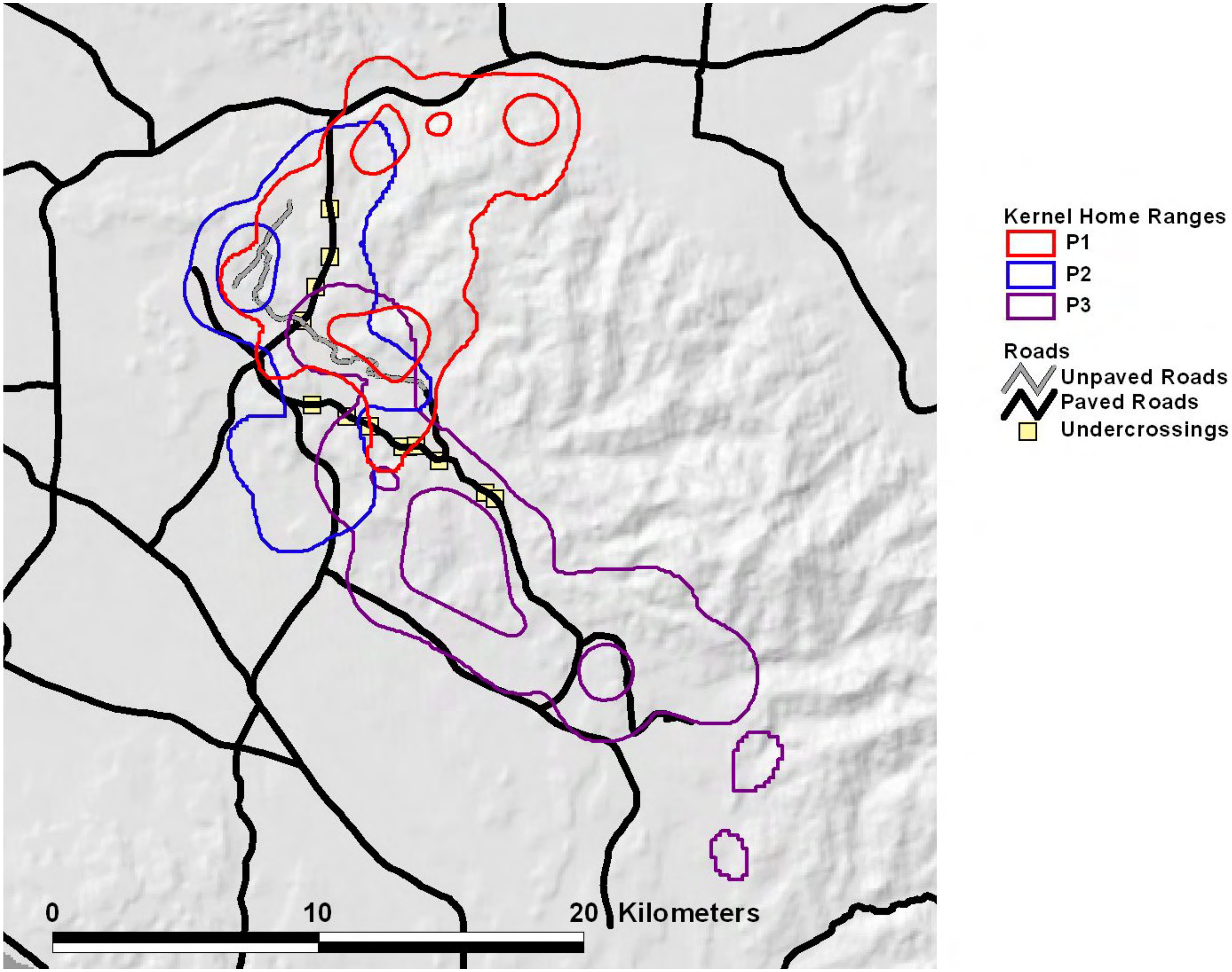

Figure 34. Fixed kernel home range (95%) and core-use (50%) polygons for female mountain lions captured in the North/Central Irvine Ranch from October 2003 to May 2005. Background layer is terrain with elevations ranging from 120 to 1740 meters.

This figure has been removed at the request of the client due to the sensitivity of the data.

Figure 35. P1's (female, adult) GPS locations and movement path from October 2003 to August 2004 in the North/Central Irvine Ranch, Orange County, CA. P1's mortality occurred August 18, 2004.

This figure has been removed at the request of the client due to the sensitivity of the data.

Figure 36. P2's (female, adult) GPS locations and movement path from July to October 2004 in the North/Central Irvine Ranch, Orange County, CA. P2's mortality occurred April 13, 2005, six months after her radio collar failed.

This figure has been removed at the request of the client due to the sensitivity of the data.

Figure 37. P3's (female, adult) GPS locations and movement path from December 2004 to May 2005 in the North/Central Irvine Ranch, Orange County, CA.

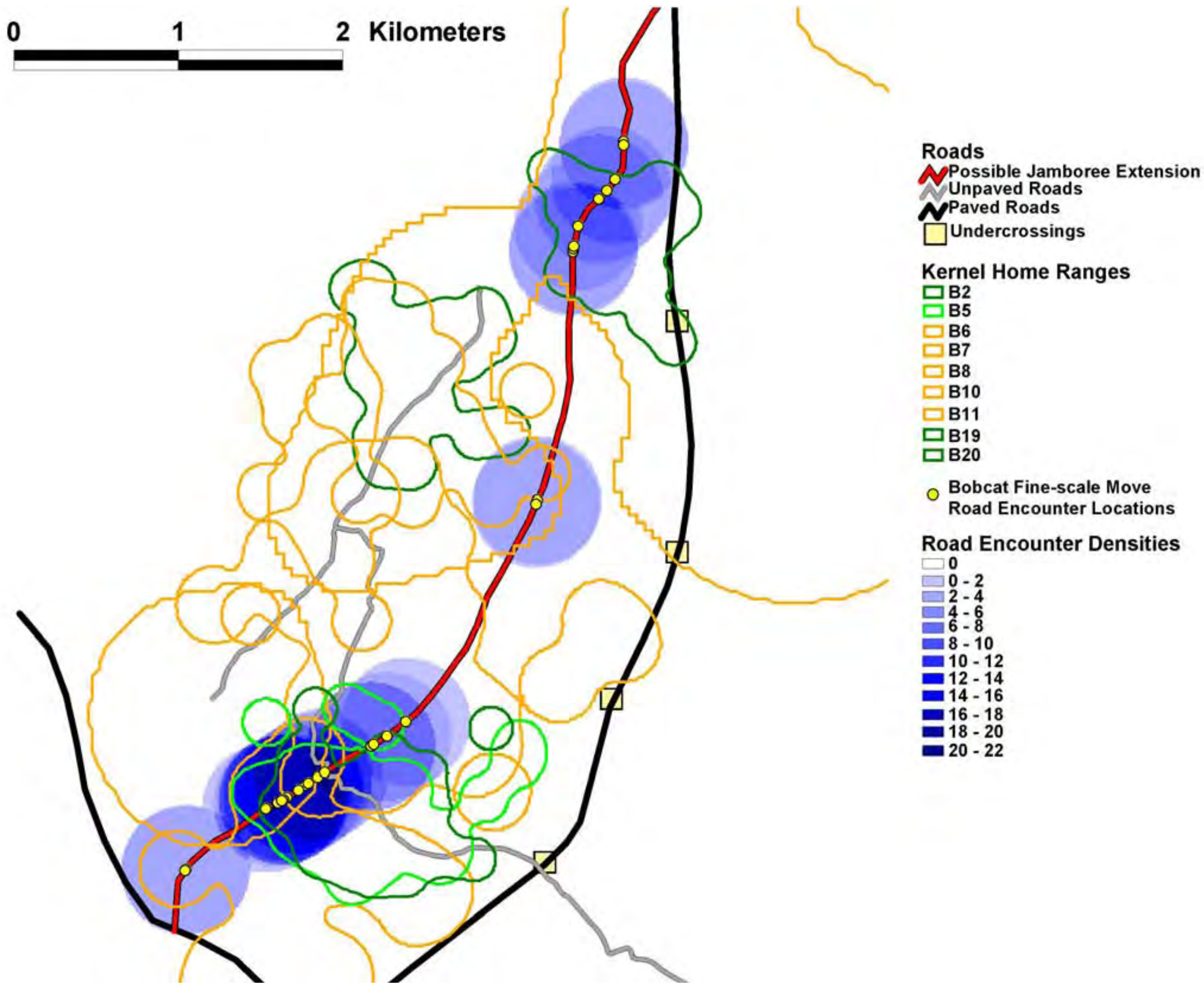

Figure 38. Bobcat road encounter densities along a possible Jamboree Road extension in the North/Central Irvine Ranch, Orange County, CA. Dark green polygons are adult females, light green polygons are yearling females, and orange polygons are adult males. Densities are the number of movement paths that intersect the road within a circle with a 500-meter radius.

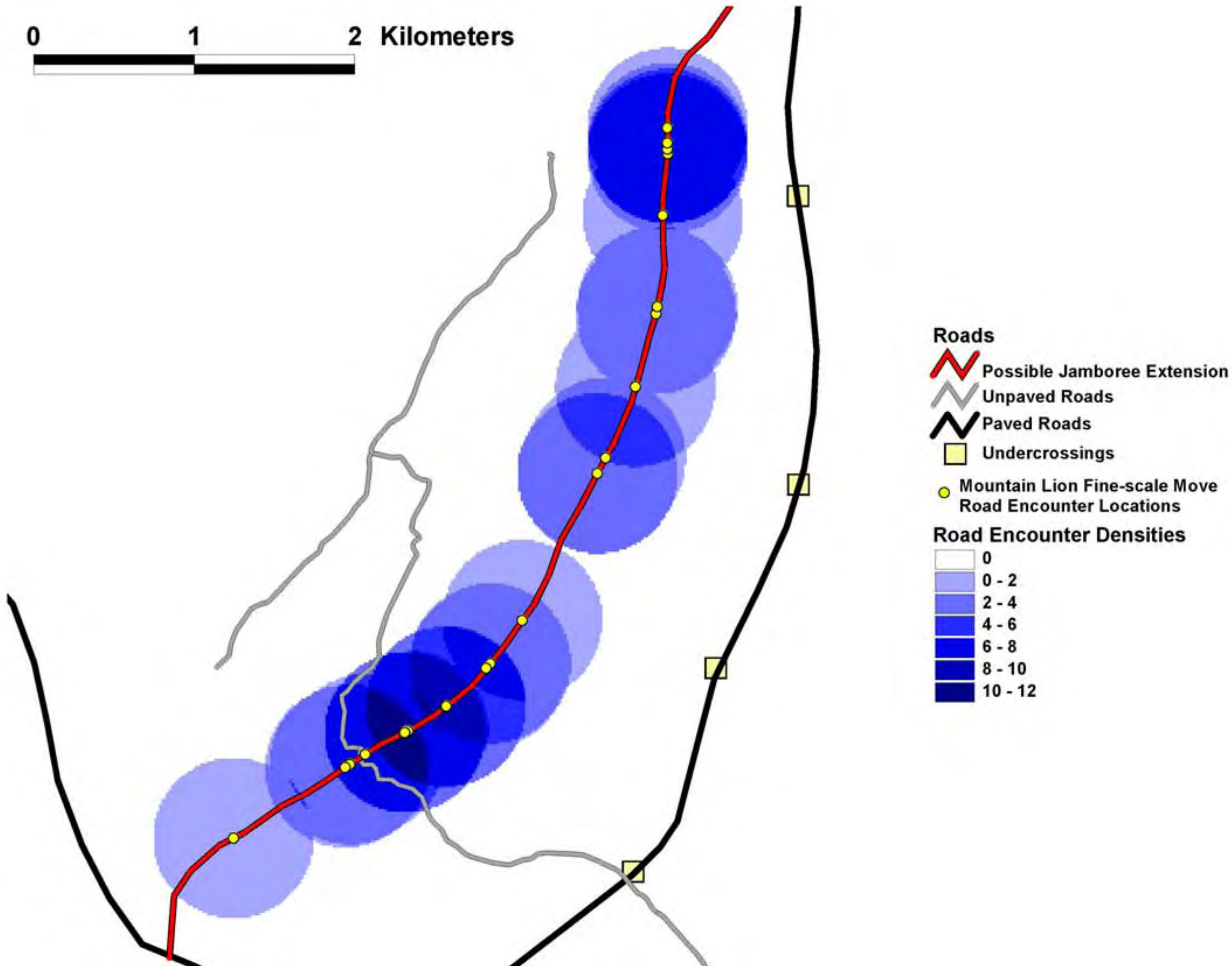

Figure 39. Mountain lion road encounter densities along a possible Jamboree Road extension in the North/Central Irvine Ranch, Orange County, CA. All three mountain lion movement paths intersected the possible roadway. Densities are the number of movement paths that intersect the road within a circle with a 500-meter radius.

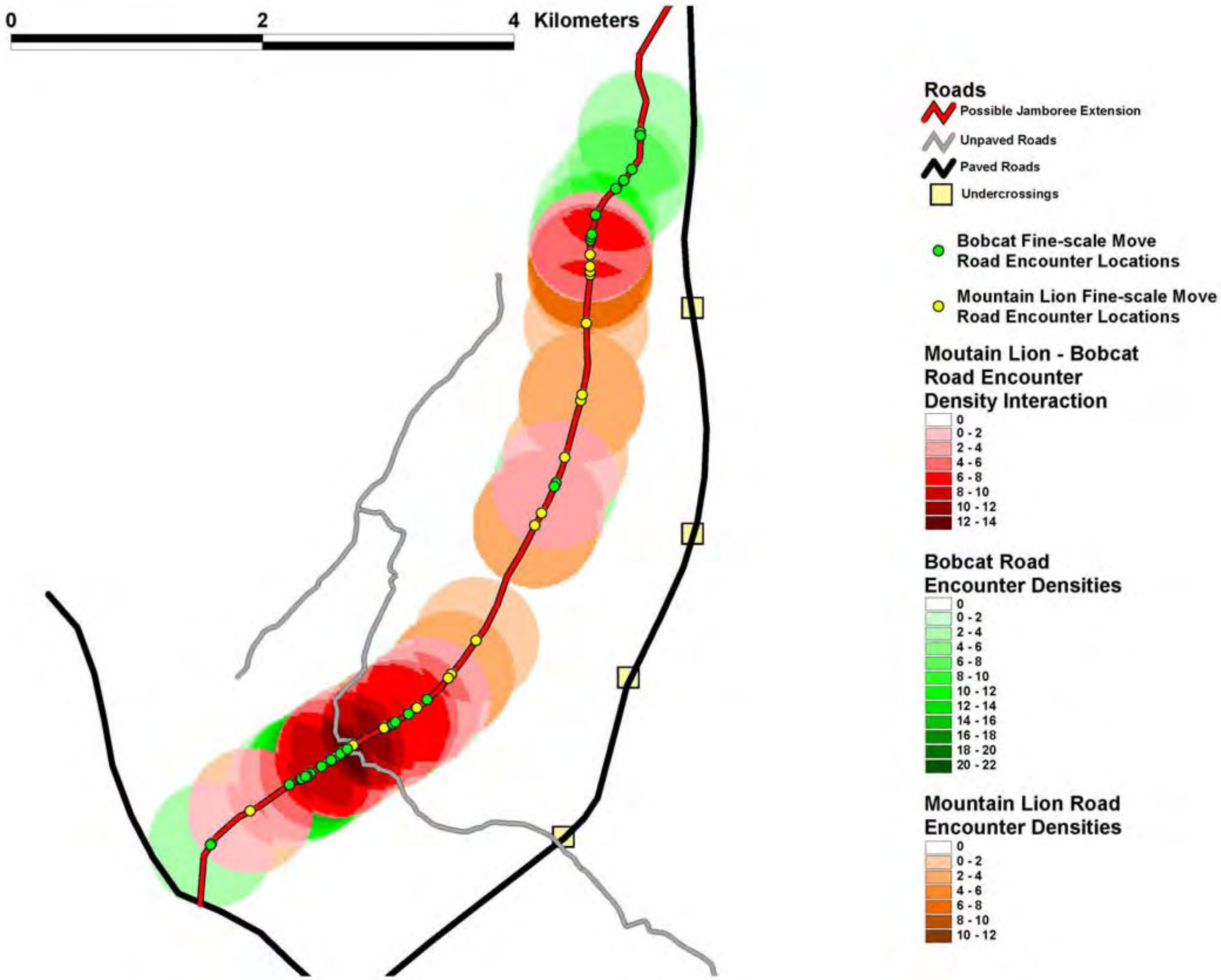

Figure 40. Combined road encounter densities for bobcats and mountain lions along a possible Jamboree Road extension in the North/Central Irvine Ranch, Orange County, CA. Densities are the number of movement paths that intersect the road within a circle with a 500-meter radius.

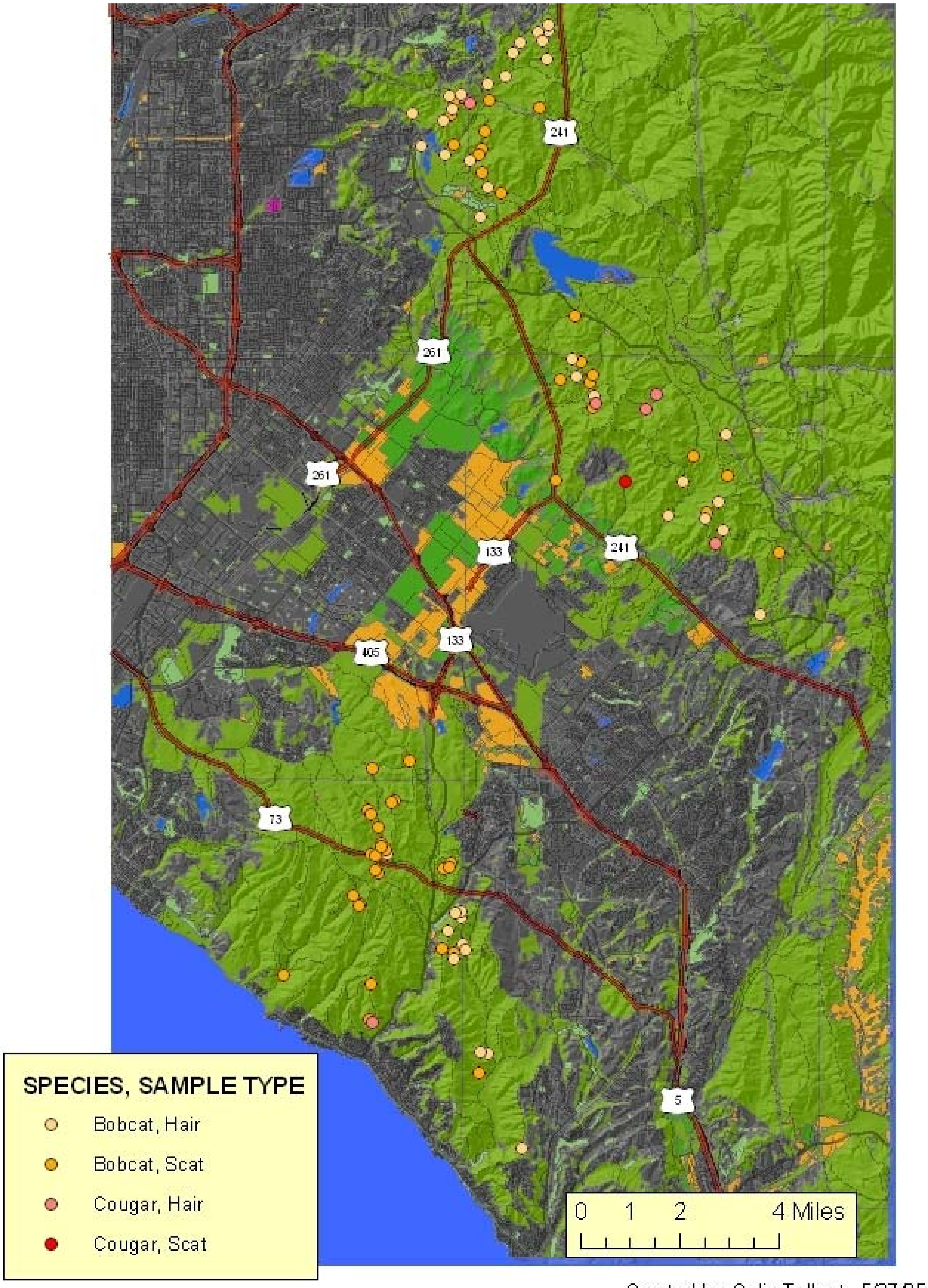

Figure 41. Locations of bobcat and mountain lion (cougar) hair and scat samples documented by non-invasive DNA sampling for April and May 2003 and July 2004 in the North/Central Irvine Ranch and Nature Reserve of Orange County, CA (Ruell and Crooks in prep).

Appendix 1. Northern CA-241 and Santiago Canyon Road (SCR) undercrossings.

Appendix 1a. Windy Ridge Wildlife Corridor from the west side of CA-241.

Appendix 1b. SCE Wildlife Corridor from the west side of CA-241.

Appendix 1c. Oak Canyon Wildlife Corridor from the east side of CA-241.

Appendix 1d. Santiago Creek Bridge 1 from the west side of CA-241.

Appendix 1 (Continued). Northern CA-241 and Santiago Canyon Road (SCR) undercrossings.

Appendix 1e. Presida Canyon Road under SCR.

Appendix 1f. Shoestring Road under SCR.

Appendix 1 (Continued). Northern CA-241 and Santiago Canyon Road (SCR) undercrossings.

Appendix 1g. Limestone Creek Bridge under SCR.

Appendix 1h. UC4 from the north side of SCR.

Appendix 1 (Continued). Northern CA-241 and Santiago Canyon Road undercrossings.

Appendix 1i. UC5 from the north side of SCR.

Appendix 1j. UC6 under SCR.

Appendix 1k. Santiago Creek Bridge 2 under SCR.

Appendix 1l. UC8 under SCR.

Appendix 1m. UC9 under SCR.

Appendix 2. Representative photos of marked bobcats taken at camera stations.

Camera 2039: Bobcat B2

Camera 2039: Bobcat B5

Camera 2040: Bobcat B10

Camera 2039: Marked bobcat; unable to identify

Appendix 3. P1 and P2 mortality and collar recovery photos.

Appendix 3a. P1 was stuck and killed by a vehicle traveling southbound on CA-241 August 18, 2004. Photo courtesy of California Highway Patrol.

Appendix 3b. P2's radio box and battery recovered in October 2004 in northern Gypsum Canyon.

Appendix 3 (Continued). P1 and P2 mortality collar recovery photos.

Appendix 3c. P2's collar belting removed from her body in April 2005. Radio box and battery should have been attached between the two metal brackets in the foreground.

Appendix 3d. P2 was stuck and killed by a vehicle on Santiago Canyon Road April 13, 2005. She was traveling from north to south (left to right) across the roadway in the general vicinity shown in this photograph.

Appendix 4. Improper fencing examples along CA-241.

Appendix 4a. Fencing that improperly spans a large manufactured channel (v-ditch) used to direct water away from residential development located uphill to the west (right) allowing carnivores easy access to CA-241.

Appendix 4b. Fencing that was used as a part of a gate along CA-241. Note that the gate is not flush to the ground and wildlife have created a trail (separation in dark herbaceous vegetation) leading to CA-241.