Evaluation of Functional Connectivity for Bobcats and Coyotes across the Former El Toro Marine Base, Orange County, California

By Lisa M. Lyren, Robert S. Alonso, Kevin R. Crooks, and Erin E. Boydston

Former El Toro Marine Base looking southeast post grubbing (April 2007).

Administrative Report

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Abstract

We evaluated functional connectivity for bobcats and coyotes within and around the former El Toro Marine Base. We sought to identify potential wildlife corridors, as well as barriers to animal movement across the former base that was situated between the Central and Coastal reserves of the Nature Reserve of Orange County. Methods included the use of remotely-triggered camera surveys to detect the presence of bobcats and coyotes and their use of undercrossings beneath roads, high-resolution Global Positioning System (GPS) telemetry to document their fine-scale movements, recording the locations where they were found dead, and opportunistic surveys to locate their tracks and scats. These field activities were focused in five planning and design sections that spanned from the north of Irvine Blvd, through the center of the former base, and to the south of the I-5/I-405 interchange where a proposed wildlife corridor would potentially connect to the Coastal Reserve in the San Joaquin Hills. We also developed computer models of bobcat movement to predict corridors. Finally, we drew from existing literature and technical expertise to evaluate the permeability of specific sites in the study area to bobcat and coyote movements.

Remotely-triggered cameras detected coyotes across almost all the camera stations, including those in the center of the former Marine base. In contrast to coyotes, cameras detected bobcats only to north of Irvine Blvd and south of I-5 but not in the middle of the former base between these roads. Several other species of carnivores were detected, with the greatest diversity of species occurring in the northern part in Section 1 that was the area between Irvine Blvd and CA-241. Species detected only in this section of the study area included mountain lion, gray fox, and spotted skunk.

Using GPS tracking collars, we recorded hundreds of GPS locations for four bobcats and two coyotes that were captured north of Irvine Blvd and two bobcats captured south of I-5. These GPS-collared bobcats and coyotes occupied home ranges up to 13 km^2 and 8 km^2, respectively, and at times moved large distances, frequently encountering existing and proposed roadways and undercrossings. We marked additional captured animals to be individually identifiable if recaptured, photographed at remotely-triggered camera stations, seen by observers, or found dead. GPS data indicated that two collared coyotes traveled south of Irvine Blvd; one marked coyote was also captured south of the road. No collared bobcats were found south of Irvine Blvd or north of the I-5/I-405 interchange during this study.

Within and near the former El Toro Marine Base, we documented six coyotes and three bobcats that were killed on roads by vehicles. Two other bobcats were found dead, one that had a severe mange infestation and the other died from injuries received in the October 2007 Santiago wildfire.

In general, coyotes and bobcats ranged widely in the Marine base vicinity, but we found almost no evidence of bobcats occurring in the center of the former base between Irvine Blvd and I-5/I-405 during the study. It is possible bobcats went undetected in the central sections, but construction-related activities on the former base during our field work, including vegetation removal along riparian areas and other likely movement routes, may have excluded bobcats from areas they traveled through prior to the construction preparations.

Computer simulation models identified two potential corridor routes between the inland Santa Ana Mountains (Central Reserve) and the coastal San Joaquin Hills. One route approximated the proposed wildlife corridor across the former El Toro Marine base, whereas another route approximated a southern linkage via Arroyo Trabuco Creek and Salt Creek. The model also identified a major constriction in the El Toro route at the I-5/I-405 interchange that could prevent such a corridor from being functional for wildlife. Site-specific evaluations from ground surveys identified barriers, both major and minor, to wildlife traveling this route.

For functional connectivity to exist between the Santa Ana Mountains and the San Joaquin Hills, each section of the proposed corridor must offer safe passage to carnivores, and the transitions between these need also to be passable. Unless these constrictions are ameliorated, a wildlife corridor through El Toro may not provide adequate connectivity between coastal and inland habitat but instead create a cul-de-sac that diverts animal movement into a dead end. Thus, a functional linkage across the former El Toro Marine Base would necessitate mitigation and restoration along the entire route. Therefore, in conclusion, we provide recommendations by planning section to maintain and (or) facilitate bobcat and coyote movement through the proposed wildlife corridor from CA-241 to south of the I-5/I-405 interchange.

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 the primary cause of species endangerment (Czech et al. 2000; Soulé 1991). Such is the case in the coastal southern California region, which currently is 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. Six counties of coastal southern California encompass about 25% of California's land area, but as of 2000 about 60% (nearly 20 million people) 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 Los Angeles County by 7-8% (U. S. Census Bureau 2000). As might be expected, the dramatic growth of human populations and the resulting sprawl has 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 that occur in southern California and nowhere else in the world (Myers 1990; Wilson 1992). This rich biodiversity, coupled with the massive human population growth and associated environmental impacts, has helped create an epicenter of endangerment and extinction in the region (Dobson et al. 1997; Myers 1990; Wilson 1992).

Preserving natural levels of landscape connectivity strengthens efforts to protect wildlife and their habitats in developing landscapes (Crooks & Sanjayan 2006). Connectivity, the degree of movement of organisms or processes among habitat patches (Taylor et al. 1993), is essential for the natural ranging behavior of animals between foraging or breeding sites and for the dispersal of wildlife from their natal ranges. Such movements may be critical to facilitate the exchange of genetic material among otherwise isolated populations. Further, at large spatial and temporal scales, maintaining natural levels of 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 the continuity of large-scale ecological processes and the flow of material, energy, or nutrients.

Because of the threat that habitat fragmentation poses to natural environments, connectivity conservation is often incorporated into land-management plans worldwide.

One of the most practical and effective measures to maintain wildlife in urban settings is establishing linkages that permit dispersal across barriers, such as roadways and developments (Crooks & Sanjayan 2006; Noss 1983; Noss et al. 1996). For some species, such "conservation corridors" do not have to be huge, elaborate structures (although usually larger is better). Research has shown that 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. Bridges or underpasses, however, are often required to accommodate the movement of larger species, such as deer and mountain lions, through the urban environment (Haas 2000; Land & Lotz 1996; Lyren 2001; Ng et al. 2004; Tigas et al. 2002). Where functional movement corridors are not retained across the urban landscape, many wildlife species, 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; Soule & Terborgh 1999). Focal species are chosen to symbolize ecological conditions that are critical to healthy, functioning ecosystems (Lambeck 1997). Use of mammalian carnivores as focal species can be effective for evaluating the degree of landscape-level connectivity, or fragmentation, in a region. Large carnivores are particularly vulnerable to extinction in fragmented habitat because of wide range and resource requirements, low densities, slow population growth rates, and direct persecution by humans (Crooks 2000; Crooks 2002; Noss et al. 1996; Woodroffe & Ginsberg 1998). Consequently, top predators may not persist in landscapes that are not connected by functional movement corridors.

Carnivores, therefore, are ecologically pivotal organisms whose status can indicate the 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 having less demanding needs (Carroll et al. 1999; Lambeck 1997; Miller et al. 1998). In southern California, bobcats (*Lynx rufus*) are excellent focal species for the evaluation of connectivity (Crooks 2000, 2002). Bobcats are less sensitive to fragmentation than mountain lions and are therefore valuable indicators of connectivity at smaller spatial scales and intermediate levels of fragmentation and urbanization. They have relatively large home ranges (ca. 50 km^2) and can disperse long distances (Lawhead 1984, Litvaitis et al. 1986, Lovallo and Anderson 1996; Sauvajot et al. 2000; Tigas et al. 2002; Riley et al. 2003, 2006). Although coyotes are widespread and relatively abundant throughout the region and are less sensitive to fragmentation than bobcats, certain populations are vulnerable to localized extinction in habitat fragments that are too small, disturbed, or isolated (Crooks 2002; Crooks & Soule 1999). 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 and gray foxes, and thus increase predation pressure on a variety of small prey species, including scrub-breeding birds (Crooks & Soule 1999).

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 in Orange County, California within the East Orange/Central Irvine Ranch (Haas et al. 2002), the North/Central Irvine Ranch (Lyren et al. 2006), the Nature Reserve of Orange County (Crooks & Jones 1998; George & Crooks 2001; George & Crooks 2006), and the San Joaquin Hills (Lyren et al. 2008). A primary question of these Orange County carnivore studies has been to evaluate the degree of connectivity within and between the Coastal and Central Subareas of the Nature Reserve of Orange County (NROC). The Central Subarea (including the North/Central Irvine Ranch), located in the county's foothills and extending north of Irvine to the Santa Ana River, consists of large natural areas that are adjacent to still larger blocks of protected lands. The Coastal Subarea (including the San Joaquin Hills), a few miles to the southwest, is surrounded by either ocean or urbanization with several smaller parks and reserves in low lying, more heavily developed areas.

Unlike mountain lions that require larger intact blocks of habitat, bobcats and coyotes still maintain resident populations within NROC's Coastal Subarea. As such, their persistence might serve as important indicators of the degree of connectivity between the coastal and inland reserves. Our prior studies suggest that such connections are limited (Crooks & Jones 1998; George & Crooks 2001), and that a potentially critical linkage is the former El Toro Marine Base, currently being planned as a 1,347 acre metropolitan park similar to New York City's Central Park and developed through the Orange County Great Park Corporation. If designed and implemented properly, the former El Toro Marine Base may serve as a vital linkage for wildlife connectivity between coastal and inland habitat.

Objectives

Our primary research goal was to identify wildlife movement routes, and potential barriers to movement, within and around the former El Toro Marine Base, as it might serve as a critical linkage between the Central and Coastal Subareas of the Nature Reserve of Orange County. Large carnivores, specifically bobcats and coyotes, were the focal species for the study because they were identified as focal species in the Irvine Wildlife Corridor Plan (Cotton/Bridges/Associates May 2004).

We employed a suite of approaches to accomplish our objectives of evaluating connectivity through the El Toro study area. Methods included the use of high-resolution GPS (Global Positioning System) telemetry to document fine-scale movement of bobcats and coyotes in and around the proposed wildlife corridor. We also used non-invasive techniques, including remotely-triggered cameras, opportunistic surveys for animal sign, and mortality surveys to evaluate activity of large carnivores and other wildlife in the area, and to identify movement through potential constrictions (e.g. roadway crossings) along the linkage. Further, we developed and implemented computer models of animal movement to predict likely move paths, and hence connectivity, through the study area. Finally, we drew from existing literature and technical expertise to evaluate specific sites, such as existing undercrossings, within the study area to determine the potential for carnivore movement through these sites. In all, these approaches can help identify potential wildlife corridors through El Toro, as well as connectivity "hot-spots" where movement between the central and coastal reserves appears to be restricted. In the final section of the report, we review actions to facilitate connectivity through the proposed wildlife corridor, as well as provide suggestions of various methodologies for long-term monitoring and management of carnivores and connectivity in the area.

Methods

Study Area

The primary study area was the former El Toro Marine Base (33°40'N; 117°43'W) and the City of Irvine property directly south (planning area 34) that linked the base to the Central and Coastal Subareas of the Nature Reserve of Orange County, and included the proposed Irvine Wildlife Corridor (herein referred to as the proposed corridor) and five planning and design sections previously described by Cotton/Bridges/Associates (May 2004). The Central Reserve consisted of the northwest foothills of the Santa Ana Mountains while the Coastal Reserve consisted primarily of the San Joaquin Hills (fig. 1). The sections were ordered from north to south. Section 1 was a largely undeveloped area with several free-flowing seasonal creek beds. It encompassed the proposed El Toro National Wildlife Refuge (about 1,000 acres) bordered to the north by CA-241, a principal 6-lane toll road supporting an average annual daily traffic volume (AADT) of 50,000 vehicles during 2007 (California Department of Transportation 2007), and bordered to the south by Irvine Boulevard, a 4-lane secondary (collector) road. Along both CA-241 and Irvine Boulevard were several undercrossing (i.e., bridge, culvert) structures (fig. 2). In Section 2, which extended from Irvine Boulevard to the southern end of the Marine base's aircraft runway and the proposed alignment of Marine Way road, the free-flowing creeks became channelized as they continued across the main station of the base. Sections 3 and 4 consisted of only the Serrano creek bed in the middle of several agricultural fields that were bisected by a railroad track and two secondary roads. Section 3 was between the runway and the intersection of Alton and Barranca Parkways. Alton Parkway was a 6-lane secondary road and Barranca Parkway was a 4-lane secondary road. Section 4 extended from that intersection south to the Interstate 5 and 405 interchange (aka "El Toro Y") of which both were principal roads. The El Toro Y was 26 traffic lanes wide with an AADT volume of 410,500 vehicles in 2007 (California Department of Transportation 2007). Section 5 was the gateway into the San Joaquin Hills. It consisted of the area south of the interchange and between Laguna Canyon Road/CA-133 and Veeh Creek, and terminating about half way between I-405 and CA-73. Commercial development was situated at the northern half while the southern half consisted of open space. Areas outside these sections that could potentially allow for carnivore movement within the rest of the Orange County Great Park or nearby were considered as and named peripheral areas. Section 5 was also the same area termed Laguna Laurel in our San Joaquin Hills (SJH) bobcat research (Lyren et al. 2008), and some data from that project have been included in this final report where the two study sites overlapped. We refer to all portions of the study area here collectively as El Toro throughout the rest of this report.

The wildlife corridor was proposed to span about six miles across El Toro with an average width of 1,000 feet and to encompass approximately 750 acres (Cotton/Bridges/Associates May 2004). In Section 1, design and construction of the wildlife corridor was the joint responsibility of federal, regional, and local agencies, and The Irvine Company. Sections 2, 3, and 4 were incorporated into the

Orange County Great Park and its corporation was responsible for design and construction of those sections. The Irvine Company was responsible for Section 5 (Cotton/Bridges/Associates May 2004). In addition to the wildlife corridor, there were also a few roads proposed to intersect Sections 1 and 5. Alton Parkway was proposed to be extended from Irvine Boulevard to CA-241 in the north while Bake Parkway and Lake Forest Drive were proposed to be joined and extended to Laguna Canyon Road/CA-133 in the south. From 2003 through most of 2006, Laguna Canyon Road was also under construction between I-405 and CA-73. Construction included widening from a 2-lane secondary road to a principal 4-lane divided expressway and realigning the footprint eastward to avoid splitting the Laguna Lakes. Construction was completed in winter 2006 and the AADT volume for 2007 was 35,000 vehicles (California Department of Transportation 2007). Across the five sections, several undercrossings (e.g., culverts and bridges) were located where roadways and railways intersected creek beds potentially acting as constriction sites for carnivore movements. There were also openings created when sections of creeks were channelized underground. We termed these openings, along with creek crossings by roads and other structures, as "undercrossings," and included them in the proposed wildlife corridor that would be created as a result of potential new construction (fig. 2).

The study area had a warm, dry Mediterranean climate with a mean annual precipitation of 33.3 cm, primarily occurring during the wet season (Nov-Apr) (Municipal Water District of Orange County 2005). During this study, annual precipitation (July through June of following year) for 2006/07 and 2007/08 fell below average at 7.2 and 24.2 cm, respectively (Watershed and Coastal Resources Division 2007). Temperature data loggers, which we installed in canyon bottoms and on ridge tops, recorded temperatures ranging from a low of -7.8 °C in January 2007 to a high of 45.3 °C in May 2007. Both temperatures were detected by the canyon-bottom data logger placed in Section 1. Riparian, coastal sage scrub, annual grassland communities, and a golf course primarily dominated the study area.

Portions of the study area burned in the Santiago Fire that started on October 21, 2007 along Santiago Canyon Road adjacent to Limestone Canyon Regional Park. On October 22, it swept south of CA-241 into the El Toro study area, burning most of the natural habitat in Section 1 and stopping at Irvine Boulevard. After October 22, the Santiago Fire continued to burn areas north of CA-241, moving from this toll road east to Modjeska Peak until it was fully contained on November 9, 2007.

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 or memory cards and batteries. Motion, such as an animal walking in front of the camera trap, triggers a camera to take a photograph and to be automatically stamped with the date and time of the triggering event. We used film (Camtrakker; CamTrak South Inc., Watkinsville, GA) and digital (Cuddeback Expert; NonTypical Inc., Park Falls, WI) camera traps with digital cameras set at a 1-minute delay between photographs and film cameras at a 3-minute delay.

We conducted camera surveys from December 2006 through August 2007, placing cameras at 20 priority sites across El Toro for evaluation of carnivore movements. Camera station sites included locations where roads, railroads, and fences crossed drainages in the study area. When possible, we positioned cameras to monitor openings of undercrossings through which carnivores might travel. Other cameras monitored locations near where proposed changes might result in the construction of a new road with an undercrossing or a new undercrossing on an existing road. At some locations, we had to adjust the camera position during the study for logistical reasons, e. g., moving the camera when sunlight regularly interfered with the resulting images, or we had to add a second camera to monitor extremely wide undercrossing areas where it was not possible for a single camera to “see” the entire underpass opening and thus whether animals were exiting or entering from it. One camera (LL_A) was part of the SJH bobcat study, and thus began operating in July 2007.

In addition to these surveys, we used five "scouting cameras," camera traps that monitored for specific study animals for potential recapture when their GPS collars failed to drop off automatically. Scouting cameras were located at camera survey sites in Section 1 (n = 1), Section 5 (n = 2), and we installed cameras at two new locations in Section 1. These scouting cameras operated from April 2007 to June 2008 (table 1).

We calculated an index for each camera station to represent relative activity levels of each species based on the sampling effort at that station. The camera index was the number of detections of a species (digital photographs) divided by the number of nights the camera station was active (the sampling effort), and 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 across camera locations and for different carnivore species.

Trapping and Capture Effort

We targeted coyotes and bobcats for capture using different methods for each species. For coyotes, we used a combination of foot and neck snares. Foot snares were Fremont foot snares (Fremont Humane Traps, Beaumont, Alberta) modified with stop-locks, breakaway locks, swivels, and shock springs to reduce non-target (not coyote) captures and minimize potential for injury. We used two types of neck snares: standard and Collarum (Green Mountain Inc.; Lander, WY) snares. The standard neck snare was a passive method requiring individuals simply to walk through them in order to be captured, while the Collarum was an active method needing individuals to bite and pull a scented tab to trigger the mechanism. All neck snares had stop-locks, swivels, and shock springs. We placed snares along existing wildlife trails or at locations where an obvious hole or trail under chain-link fencing indicated that coyotes had been crossing under the fence.

To target bobcats for capture, we used wire cage traps (24” x 17” x 43”). We chose trap site locations based upon bobcat sign (e.g., tracks, scat) in an area. We placed cages along washes, wildlife trails, and dirt roadways, and situated them under shrubs, tree canopy, and other shaded areas. Most traps were modified to hold a live white dove as a lure animal in a separate enclosure (12” x 8” x 17”) built inside the upper back portion of the trap and inaccessible to bobcats. In addition to doves, we used other visual and odor attractants singly or in combinations, which included rabbit and bird decoys, feathers, artificial nests, carcass portions, and carnivore scent lures.

Handling of Captured Animals

We initially restrained captured bobcats using a push board to restrict the animal at the back of the cage trap, allowing for an intramuscular hand injection of chemical anesthesia drugs consisting of a combination of ketamine (10 mg/kg) and xylazine HCL (1 mg/kg). Once the bobcat was completely anesthetized, we removed it from the cage, placed the animal on a blanket, applied ophthalmic ointment, blindfolded it to reduce stimulation, and monitored temperature, heart rate, and respiration at five to 10 minute intervals. Each bobcat was marked with an ear tag, fitted with a GPS collar if it was above the minimum weight limit, sexed, aged, and weighed. We aged bobcats by body mass and/or tooth eruption patterns, and classified them as juveniles (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 antagonized the xylazine by administering an injection of yohimbine HCL (0.125 mg/kg) either intravenously or intramuscularly 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.

Coyotes were physically restrained and handled without the use of chemical anesthetics. Captured individuals were marked with an ear tag, fitted with a GPS collar if it was above the minimum weight limit, sexed, aged, and weighed. We recorded standard body measurements, collected blood, hair, and parasite samples, and released coyotes immediately upon completion of handling.

U.S. Geological Survey (USGS) and Colorado State University-Fort Collins (CSU) Animal Care and Use Committees approved capture and animal handling procedures.

GPS and VHF Radio Collars

We conducted GPS telemetry to document movement patterns of individual bobcats and coyotes using two different GPS collar models: Televilt Tellus Basic and HABIT Research. GPS collars were programmed to collect GPS locations at 15-minute intervals over 3-hour time blocks around the hours of dawn, dusk, noon, and midnight, and emitted a VHF radio-signal. Televilt collars stored GPS data on-board, and retrieval of GPS data required retrieving the actual collar. GPS data could be remotely downloaded about every 2 weeks from HABIT Research collars via a special receiver. Tellus Basic collars weighed 270 g each and were fitted to bobcats and coyotes. HABIT collars weighed 175 g each and were fitted only to bobcats. Televilt collars were equipped with automatic drop-off mechanisms, while HABIT collars had a strip of fabric in the belting so that the collars would fall off when the fabric tore completely. We did not recover all Tellus Basic GPS collars due to failed drop-off mechanisms, and some HABIT collars failed to collect GPS data. Both Tellus Basic and HABIT research GPS collars were new models that had not been previously tested on carnivores here and we experienced major problems with both models in retrieving collars and data. At the time of this report, the Tellus Basic GPS collar was still in production but HABIT Research stopped all GPS collar production. Following GPS-collaring, we re-collared one bobcat (HOM) and two coyotes (ANG, MLX) with Telonics VHF-only collars, and we collared one additional coyote (CLB) with a VHF-only collar. We customized these collars by adding fabric to the belting to ensure the collars later dropped off the animals.

In addition to date, time, and geographic coordinates, Tellus Basic 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). A 3D fix was a location acquired with four or more satellites with an error margin of less than ±100-200 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. We omitted all 1D locations from all analyses. Data from the HABIT collar did not directly include information on spatial quality or “fix type” but we were able to exclude erroneous points as ones that also had incomplete time-stamp information, and after discussions with the manufacturers and close inspection of the data, we included all remaining points.

VHF tracking was conducted regularly to monitor locations of GPS-collared animals and determine if the signal indicated the collar was about to or had dropped off, and to obtain locations of animals with VHF-only collars through triangulation. To triangulate a location based on the VHF signal, field technicians used a portable receiver and hand-held Yagi antenna (Telemetry Solutions). 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^{o} and 120^{o} (Gese et al. 1988), was recorded in less than 30 minutes. Technicians attempted to gain radiolocations from radio-collared animals two to six times per week. Using LOCATE II (Pacer 2000), we used each set of bearings for an animal to generate their VHF radiolocation estimates. In addition, technicians gained extra locations for an animal by opportunistic visual identification of tagged animals (Hein & Andelt 1995) but this rarely occurred.

Space Utilization Patterns and Movements

All GIS mapping and analyses were conducted using ArcGIS 9.2 (ESRI, Redlands, CA) with Hawth's Tools Extension (Beyer 2004) or ArcView 3.3 (ESRI, Redlands, CA) with the Animal Movement Extension (Hooge & Eichenlaub 1997). We calculated two area estimates of home range size for GPS-collared animals: minimum convex polygon (MCP) and 95% Fixed Kernel (FK) utilization distributions using least square cross validation. We also calculated 50% FKs as estimates of "core-use areas" (Powell 2000; Worton 1989). For both 50% and 95% FKs, we used a subset of GPS data that included only locations separated in time by at least 4 hours to ensure independence among locations (Swihart & Slade 1988).

For animals collared with VHF-only collars, we used telemetry data in combination with sightings, capture locations, and remote camera detections to determine if any of these animals moved across major roads or near the proposed corridor. We present map figures depicting the location data for all GPS and VHF collared bobcats and coyotes, including their GPS or VHF locations, capture locations, visual observations, and camera detections.

Using ArcGIS, GPS locations for bobcats and coyotes were associated with one of three landuse categories that were derived from 2005 vector data with detailed landuse categories from Southern California Association of Governments (following Riley et al. 2003): 1) natural habitat-- undeveloped areas and protected open space areas with contiguous vegetation 2) altered areas-- golf courses, landscaped parks and lawns, graded areas, and small strips or patches of natural vegetation within high-density office or residential developments, 3) urban areas-- developed areas of housing, offices, commercial developments and roads. The percentage of locations in each landuse category was calculated as the number of locations per category divided by the individual's total number of GPS locations.

We present map figures depicting each GPS-collared animal's space utilization patterns relative to landuse by overlaying utilization distribution contours, GPS locations and locations from other events such as capture, VHF tracking, and visual observation onto a 2005 aerial photograph on which natural habitat and altered areas were highlighted.

To depict movements of GPS-collared carnivores, we used GIS software to draw straight lines between each individual's GPS locations in chronological order. We termed these lines connecting pairs of consecutive GPS locations movement or travel "paths." Because GPS collars collected most of their data at 15-minute intervals but locations could be separated by almost a week, we divided paths into two groups according to the length of time between the pairs of points: 1) "fine scale" movement paths-- those paths that connected GPS locations separated by less than 45 minutes, and 2) "coarse scale" paths-- those paths that connected locations separated by 45 minutes or more. We evaluated movement paths with respect to roads, and we calculated the number of times that fine scale paths intersected highways, secondary roads, and proposed roads by intersecting GIS layers representing travel paths with roads in ArcView. We visually inspected movement paths to evaluate bobcat and coyote behavior with respect to constriction sites and to estimate possible use or avoidance of undercrossings within their home ranges.

Mortality

We examined carcasses of coyotes and bobcats found dead in the study area and surrounding environs. To help find carcasses, we relied on a network of local animal control officers, natural resource agency personnel, and residents who promptly notified us when a coyote or bobcat was found dead. We recorded the date, location, and, if known at the time, the animal's sex and age. We generated a GPS location representing the specific mortality site by either visiting the site ourselves or by soliciting more information from the reporting party to plot it using Google Earth. All retrieved carcasses were kept at our facilities until we could necropsy them. During necropsy, we confirmed sex and age, and weighed each animal. We also recorded the type and location of all trauma, general body and reproductive condition, stomach contents, and collected blood and other tissue (for genotyping), hair, and parasite samples.

Landscape-level Connectivity Analysis

Bobcats were selected as the focal species for the connectivity modeling because they were identified as one of the target carnivores species for the proposed corridor and because of the availability of fine-scale movement data for bobcats acquired via GPS telemetry from this and prior studies in the region (Lyren et al. 2008; Lyren et al. 2006). Our analysis focused on functional connectivity for bobcats between the Santa Ana Mountains and the San Joaquin Hills. Functional connectivity refers to the ability of animals to move through the landscape (Crooks and Sanjayan 2006). We conducted the analysis by (a) deriving a land cover layer for the study area, (b) creating a layer of core habitat areas for the Santa Ana Mountains and San Joaquin Hills, and (c) applying two different methods plus a combined result to assess functional connectivity between the Santa Ana Mountains and the San Joaquin Hills. As a result, our analysis was based on the permeability of the land cover between the core areas. The first method uses computer simulations of individual movement to assess connectivity between the core habitat patches. The second uses a cost surface created from the land cover layer and then calculates cost-weighted distances from the core habitat patches to each location in the landscape. The combined result uses the output from the two previous methods to produce a map that highlights areas that both methods predict are important for functional connectivity. Below we provide a summary of each stage in the analysis.

Landscape Layers

We created a land-cover raster layer by combining Southern California Association of Government (SCAG) landuse data and USDA LandFire land cover data to have full landuse coverage over a larger region. This derived layer had twelve land cover types that we reduced to four categories for this analysis: water, urban, habitat, and altered/disturbed land cover types. We created core habitat patches by applying a smoothing filter to the cells classified as habitat in the land cover layer and eliminating patches for areas other than the Santa Ana Mountains and the San Joaquin Hills. We then assessed connectivity between the Santa Ana Mountains and the San Joaquin Hills core habitat patches.

Move Simulation Approach

We placed simulated bobcats at random locations in the core habitat patches and then simulated movement behavior on the land cover layer. We used movement models that combined (a) the tendency of the bobcats we studied in North Irvine Ranch to move with directional persistence (i.e., a correlated random walk) and (b) preference for the different land cover types. Our modeling imposed the rules that water is completely avoided, urban areas have a very low preference, disturbed areas have a low preference, and habitat areas have a high preference. We ran 500 simulations of 292 individual animals that represented dispersing bobcats. The simulated individuals were allowed to make 11,538 movements (each move represented approximately 7.5 minutes of simulated time, and the total simulation time represented 60 days of continuous movement). After simulating the movements, we extracted the move paths that went from one core habitat patch to another (i.e. from Santa Ana Mountains to the San Joaquin Hills, or vice versa). These paths were then converted to a raster layer in which the cell values represented average use by movement paths between the core habitat patches. This layer was then displayed to show movement routes predicted by the simulations.

Cost-weighted Distance Approach

A cost value raster was created by assigning a cost to each land cover type. Habitat was given the lowest cost, followed by disturbed areas, urban areas, and water. Next, a cost-weighted distance layer was created by first assigning each cell in a core habitat patch a cost of zero, and then propagating the cost-weighted distance values outward from those cells through the cost value raster. The resulting cost-weighted distance layer was displayed to show connectivity between the core habitat patches predicted by the analysis.

Combined layer

A combined layer was created by rescaling the output layers from the movement simulation approach and the cost-weighted distance approach between zero and one, and then taking the geometric mean (the square root of the products of the values in each cell) to produce a combined result layer. The combined result layer had a high connectivity value in areas that both of the previous analyses had high connectivity values, and low connectivity values in areas where either method produced low values. The purpose of combining the results was to emphasize areas that both methods predicted were important for functional connectivity. Studies in other fields indicate that using predictions from multiple models generally result in more reliable predictions (Sivillo et al. 1997).

Local-scale Constriction and Connectivity Evaluation

We examined data from all of the above methods to evaluate specific sites on the El Toro landscape where carnivore movement might be inhibited, or constricted to a narrow area, such as at a road, culvert, or other type of undercrossing that could potentially facilitate animal movement. We provided a holistic assessment of these locations based on results found here and technical expertise.

Results

Camera Surveys

Camera trap station LL_A sampled for a total of 358 days, which was longer than other camera stations included here. This station was deployed prior to the start of this project as part of the SJH bobcat study (Lyren et. al. 2008). The sampling effort for all other camera stations included here ranged from 67 to 211 days across all sections. The sampling effort for scouting cameras ranged from 27 to 415 days (table 1). Native carnivore species that camera traps detected were bobcat, coyote, mountain lion (*Puma concolor*), gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and spotted skunk (*Spilogale gracilis*). Cameras also recorded opossum (*Didelphis virginiana*), mule deer (*Odocoileus hemionus*), domestic dog (*Canis familiaris*), and humans. 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 (tables 4, 5, 6, 7, 8, 9, 10).

None of the camera stations detected every native species. Camera ET241C in Section 1 monitored the large Agua Chinon Wash undercrossing along CA-241 and detected the greatest number of species (n = 9), which included mountain lion and gray fox detected nowhere else across El Toro. Camera ET241D, which also monitored an undercrossing along CA-241, detected mule deer twice, but they appeared to be browsing next to the underpass instead of using it to cross underneath the road. Also in Section 1, camera ETMLX_DO, located next to a paved road near the western border of the proposed national wildlife reserve, detected a single spotted skunk on October 30, 2007 (post Santiago Fire; see below). Coyotes were detected by all camera stations including those monitoring the peripheral areas, except for camera ETI5SE that monitored the north side of the El Toro Y undercrossing (Fig. 3). However, camera ETI5SE was installed after grubbing had been completed and was stolen after only 67 days. Bobcats were detected by all cameras in Section 1 and four of five cameras in Section 5. No cameras in the middle sections or in the peripheral areas detected bobcats (Fig. 4).

Cameras detected coyotes about 9 times as often as bobcats (tables 4–10). Coyote activity was highest at Section 1 camera ET241C and equally lowest at Section 1 camera ETBOWR and Section 4 camera ETABSE. Upon visual inspection of the two coyote photos from camera ETABSE, however, it appears that the coyotes might have been moving across the wash rather than through the underpass. Bobcat activity was highest at Section 1 camera ET241C, followed by camera ETBOWR, and lowest at Section 1 camera ET241B that monitored the smaller undercrossing in the Agua Chinon Wash (fig. 4).

Camera traps also photographed the Santiago Fire as it swept across Section 1 on October 22, 2007 (app. 3) (Marris 2007). Two to seven cameras monitored Section 1 at any one time for a period of 1 - 7 months, depending on the camera station, prior to the fire. By August 2007, we had removed all cameras except two scouting cameras (ETBOWR, ETMLX_DO) (app. 3) that remained in place until about 6 – 8 months after the fire (table 1). Prior to the fire, camera ETBOWR had the lowest index of coyote activity and the second highest bobcat activity index of all camera stations and scouting cameras. The last pictures of bobcats before the fire were taken August 14 at ETBOWR and October 17 at ETMLX_DO. Neither camera detected bobcats during the 6 – 8 months after the fire through the end of the study. In contrast, both cameras detected coyotes the next day on October 23 with camera ETMLX_DO confirming coyote presence as soon as 18 hours after the fire passed. Camera trap images indicated a lack of vegetation and available prey after the fire, which may have been responsible for the absence of bobcats in Section 1. Indeed, at camera ETMLX_DO, rabbits were detected 185 times and ground squirrels 29 times before the fire, but only a single rabbit was detected post-fire.

Trapping and Capture

Overall, we placed coyote and bobcat traps at 224 locations throughout the study area, with one trap per location. We set coyote traps at 171 locations with 131 traps in Section 1, 10 in Section 2, 16 in Section 3, 4 in Section 4, and 10 in Section 5 (table 2). We set bobcat traps at 53 locations with 19 in Section 1, 8 in Section 2, 3 in Section 3, and 23 in Section 5 (table 3). The available bobcat habitat in Section 4 was limited to the riparian area within Serrano Wash, an incised wash with very little cover leaving no trap sites that were safe and secured from water and human disturbance. In March 2007, the riparian areas in sections 2, 3, and 4 were grubbed of all vegetation prior to the breeding bird season, thereby removing all potential bobcat-trapping locations.

We conducted trapping for both species from November 2006 through May 2007, excluding April. Coyote trapping was conducted from November 15-17 in Section 1, and from December 4-8, 2006 in the remaining sections, for a total of 311 trap nights (one trap set for one night equals one trap night). Bobcat trapping was conducted January 29-31; February 1-2, 5-9, 12-16, 20-23, 26-28; March 1-2, 4-7; and May 9-11, 4-18, 2007, and began in Section 5 and moved north towards Section 1 producing 575 trap nights. We accumulated 886 trap nights for bobcats and coyotes combined.

We conducted additional trapping for previously collared bobcat and coyotes to manually remove GPS collars that became inoperable soon after deployment or failed to drop off automatically. Failure occurred on collars fitted to three bobcats [APO (inoperable collar); HOM, OSC (failed drop-off)] and five coyotes [PEA (inoperable collar); AND, EIN, MLX, SCH (failed drop-off); (see capture results)]. We used camera trap data and direct observations of collared animals to identify potential trapping sites. Our recapture efforts in Section 1 occurred on May 7-8, and June 1-7, 21-22, and 25-29, 2007. This resulted in an additional 61 and about 567 trap nights respectively for bobcats and coyotes to try to remove failed collars.

We captured one female and six male bobcats (table 11, fig. 5). One male was a yearling (13-24 months) and all other animals were adults (> 24 months). Upon their first captures, the female and five of the males were GPS-collared and released within a few hours. The sixth male was removed by Orange County animal control officers from the grounds of the O.C. Sheriff Department's James Musick facility adjacent to Section 1 on December 4, 2007 after he was reported to have been eating chickens from the facility's coop. This animal was taken to Serrano Animal and Bird Hospital where veterinarian's examination revealed he was suffering from fire related injuries and was under weight. He was treated for burned ears and feet and remained at the hospital until January 7, 2008 when he was released back into Section 1. Prior to his release, we fitted him with a GPS collar and assigned him the identification code of ZIP.

Three of the bobcats were recaptured during the study. Male HOM was captured three times. His second capture was on February 15, 2007 at T134, about 2 weeks after being GPS-collared, when he was simply released without subsequent handling. We intentionally captured him 5 months later to remove his GPS collar that had a failed drop-off mechanism. At this third capture, we removed his GPS collar and fitted him with a VHF-only collar. Other bobcats that were captured more than once included 1) bobcat SLO captured February 7, 14 and 16, 2007 at T111, T118, and T134 respectively; she was immediately released without additional handling at the later captures, and 2) bobcat OSC captured

March 7 and again May 8, 2007 at T137 to replace his malfunctioning GPS collar with another GPS collar. Excluding bobcat ZIP, one bobcat was captured every 52.3 trap nights by cage trap.

We successfully retrieved collars and their GPS data from bobcats HOM, ORI, and OSC via recapture (HOM, OSC) or recovering the carcass (ORI). We also retrieved HOM's VHF-only collar when the fabric in the belting tore sooner than expected. GPS data from collars on bobcats DTE, SLO, and ZIP were remotely downloaded before their collars failed prematurely (DTE, ZIP) or battery life expired (SLO). Attempted remote data downloads indicated that bobcat APO's collar failed hours after we released him from the cage trap, and we were unable to recapture him during this research to replace his collar.

Among captured coyotes, the ratio of males to females was 10 males, 7 females and 1 undetermined (HOU) that escaped before handling could occur (table 12, fig. 5); resulting in one coyote captured every 15.5 trap nights. Of the 17 coyotes that we handled, there were eight adults (> 24 months), eight yearlings (13-24 months), and one juvenile (0-12 months). We placed GPS collars on three adult males, one adult female, and two yearling males. One adult male (CLB) was fitted with a VHF-only collar. We successfully retrieved GPS collars and their data from only the yearling male coyotes (ANG, MLX). These males were captured in Section 1 and recaptured about 7 months later, at which time they were considered adult age class and fitted with VHF-only collars. We were unable to recapture coyote SCH in this same area to retrieve his collar that failed to drop-off automatically. The fate of the female (PEA) who was captured in Section 2 was unknown. She might have dispersed from the study area, her collar might have failed, or both. We could not detect her VHF signal six weeks post-capture despite numerous attempts to track her from several ground and an aerial telemetry survey. Furthermore, we did not obtain any camera trap photos of her. GPS collars on coyotes in Section 5

(AND, EIN) appeared functional for a few months, but failed to drop off, and logistical and budget constraints prevented recapture efforts. Thus, we did not obtain GPS data from four collared coyotes.

We also captured non-target (not coyote or bobcat) native carnivore species including raccoons and striped skunks. Additionally, we captured one opossum, one rabbit, California ground squirrels (*Spermophilus beecheyi*), eight or nine Cooper's Hawks, two Red-tailed Hawks, Turkey Vultures, and a Barn Owl. All hawks were banded as part of Peter Bloom's (Western Foundation of Vertebrate Zoology) raptor research program.

Space Utilization Patterns and Movements

From six GPS-collared bobcats, we obtained 14,881 GPS locations of 2D or better "fix type" quality. We obtained only two weeks of GPS data from one of these bobcats before the collar stopped functioning. The other five animals were GPS-tracked for 12 to 22 weeks each (table 13). Among bobcats collared for at least 12 weeks, Minimum Convex Polygon (MCP) estimates of space use ranged from 7.95 to 12.93 km^2 (fig. 6, 7a-f). The collar that functioned for only two weeks was on male bobcat DTE, yielded 158 GPS locations, and the MCP estimate for this short tracking period was 1.97 km^2. For four bobcats, home range size estimates based on 95% Fixed Kernel (FK) utilization distributions were about half the size of the MCP estimate. For all bobcats, 50% FK "core areas" were less than 1 km^2 (table 13), suggesting that collared animals spent much of their time in only a small portion of their home ranges.

Four bobcats had home ranges north of Irvine Boulevard in Section 1 and two had home ranges to the south of I-405 and I-5 in Section 5. No GPS locations for bobcats were recorded in Sections 2, 3, or 4. The percentage of each bobcat's GPS locations in one of three general landuse categories (natural, altered, urban) was highest for natural areas; 48% to 89% of each bobcat's GPS locations were in areas classified as natural (table 13). The landuse category with the next highest percentage of locations varied between urban and altered (table 13).

We obtained 5,768 GPS locations of 3D or better quality for coyote ANG and 5,102 locations for coyote MLX (table 13). Although their home ranges covered largely the same area (Fig. 8a, 8b), the two coyotes had different home range size estimates. The MCP estimate was 8.06 km^2 for ANG and 4.77 km^2 for MLX, and their 95% FK estimates were 1.82 km^2 and 2.17 km^2, respectively. MLX had a few GPS points to the southeast of his 95% FK outline that contributed to his much larger MCP, but otherwise both coyotes had very similar space utilization patterns. They were usually north of Irvine Boulevard in Section 1 but had several GPS locations in Section 2 to the south of Irvine Boulevard. They also had similar patterns of landuse association (table 13) with 67% (ANG) and 61% (MLX) of their GPS locations estimated to be in areas classified as natural. Most of the GPS locations that were associated with urban landuse were in an area of former military housing that had been empty for several years and that was torn down during this study.

Connecting each individual bobcat's consecutive GPS locations with straight lines yielded a total of 2,101 coarse-scale movement paths (45 minutes or more between locations) and 12,772 fine-scale movement paths (less than 45 min between locations). For the two coyotes, we obtained 9,793 coarse-scale and 1,076 fine-scale movement paths. Fine scale paths indicated where collared bobcats and coyotes encountered existing and proposed roads (table 14), and where they encountered some of the undercrossings and potential constriction sites in the study area (fig. 9a-f).

Of the four GPS-collared bobcats with home ranges north of Irvine Boulevard, three (ORI, OSC, ZIP) had GPS locations on either side of CA-241 with fine scale paths near existing undercrossings along this highway (fig. 9a-c). ORI and OSC also crossed Portola Parkway and ORI crossed CA-241 to the northwest of Portola, but we did not map culverts or other structures along these roadways. ORI and OSC had several paths intersecting with the location of the undercrossing BOWR. BOWR was a short box culvert in Borrego Canyon Wash where the landscape did not restrict animals to moving only through the culvert, and GPS data were not precise enough to determine if bobcats tended to travel around, over, or through this short culvert (camera ETBOWR did not confirm this either). As they moved through a narrow length of habitat intersected by Bake Parkway, OSC and ZIP crossed Bake Parkway at different locations. ORI, OSC, and ZIP frequently traveled along the creek bed of Borrego Canyon Wash and a tributary that followed a path perpendicular to the proposed Alton Parkway extension. OSC's movement paths showed that he traveled south in the wash to the point where it met Irvine Boulevard and was channelized (undercrossing site IBBW) but that OSC did not cross to the south of Irvine Boulevard.

Coyote ANG also approached site IBBW, the channelized portion of Borrego at Irvine Boulevard but did not cross here during GPS-tracking (fig. 10a). However, ANG crossed Irvine Boulevard elsewhere to the north of Alton Parkway on multiple occasions. GPS data show he crossed at or near undercrossing sites IBAC and IBMG as several movement paths intersected near these sites. Movement paths intersecting Irvine Boulevard at other locations likely indicate at least some surface crossings, but they may also indicate that the coyote was moving too fast for the frequency of the GPS data collection to capture the precise location where he encountered the road. Three paths intersected Irvine Boulevard at site IBEH that had a barrier at its undercrossing, so he may have crossed over the street. Coyote MLX had a similar pattern of fine scale paths across Irvine Boulevard with respect to IBAC and IBEH (fig. 10b). MLX had many fewer paths intersecting Irvine Boulevard elsewhere than did ANG, but there was a point about 0.5 km northwest of IBAC where both coyotes apparently crossed several times.

To the south of Sections 2-4, GPS data showed that female bobcat SLO regularly moved across I-405. Male bobcat HOM had a single GPS location across I-405 (fig. 7f), but this was likely an erroneous point, because the lengths of the fine scale paths leading to it and away from it were much longer than the vast majority of HOM's paths and because it was the only point out of 5,595 GPS locations on the north side of I-405. Most movement paths for both HOM and SLO followed San Diego Creek, which included a series of undercrossings in the creek bed where Irvine Center Drive intersects San Diego Creek, but GPS data alone did not indicate whether they went through or around the undercrossings. HOM's GPS data also indicated that he approached undercrossing DIV8 at Bake Parkway, which would lead directly toward the southern end of the proposed wildlife corridor, but would have required crossing underneath I-5 through a culvert much longer than any of the ones surveyed here (fig. 11).

Among tagged animals for which we did not obtain GPS data, most had VHF or other location data suggesting they crossed primary or secondary roads (fig. 12a-h). The one exception was a male coyote found only in Section 1 (fig. 12a). A coyote captured at the southern end of the study area was tracked on one occasion north of I-405 while all other location data were to the south (fig. 12f). The longest movement of any animal in the study was a female coyote (CHL) who was too small to collar at the time of her capture on June 4, 2007. We obtained no other data for her until she was found dead from a vehicle impact 5.5 km from her capture site (fig. 12e). Female PEA was originally captured in Section 2 and tracked once to the north of Irvine Boulevard before she disappeared or her collar failed (fig. 12d). Male coyote CLB was detected at a camera station in Section 2 just south of PEA's capture site. This was the furthest south in Section 2 that any tagged individual was detected (fig. 12c). However, unmarked coyotes were detected elsewhere in Section 2 (fig. 3).

Mortality

Six coyotes and five bobcats were reported dead over a period of 17 months (table 15). We retrieved eight carcasses for necropsy, as three coyotes (C11, C13, CHL) were either too decomposed to necropsy or had been inadvertently disposed of before we could retrieve them. Nine animals (6 coyotes, 3 bobcats) were struck and died from vehicular trauma, one bobcat died from mange infestation, and one bobcat died from injuries sustained in the Santiago Fire 2.5 weeks after the fire began (fig. 13). Of the 11 mortalities, two had been previously captured and marked, including one coyote (CHL; yearling female) killed by a vehicle and one bobcat (ORI; adult male) that died from mange. Coyote CHL's carcass was recovered by animal control officers about 5.5 km east of Section 1, four months after her capture there and only two days after the Santiago Fire swept across Section 1. Of the four coyotes for which we could determine sex and age, all were females with two adults and two yearlings. The bobcats included two adult males, one yearling male, and one female adult and yearling each. Of eight animals struck by vehicles, four were killed on primary roads and four were killed on secondary roads.

Landscape-level Connectivity Analysis

Landscape-level modeling suggested that there were two main corridors between the Santa Ana Mountains and the San Joaquin Hills. One passed though the El Toro study area and the other in southern Orange County at Arroyo Trabuco and Salt creeks (fig. 14a–c). Our results further suggested that there was a major constriction zone in the proposed corridor around the junction of the I-5 and I-405 freeways. The move simulation approach indicated a large gap southwest of the freeway junction where areas of high connectivity were patchy creating a gap in the corridor (fig. 15a). The cost-weighted approach also indicated that connectivity values were lower adjacent to the freeways but here the values were lower on the northeast side than the southwest (fig. 15b). In the combined approach, the gap in connectivity that formed the constriction point was most apparent along the freeways and to the southwest (fig. 15c).

Local-scale Constriction and Connectivity Evaluation

A local-scale examination of the configuration of crossing sites in the study area and data associated with each site showed variation in potential permeability to carnivores. We present these results by section from north to south, evaluating roads and other potential barriers a bobcat or coyote would encounter moving between the Santa Ana Mountains and the San Joaquin Hills (table 16).

Along the northern border of Section 1, we detected carnivores at most of the undercrossings that we evaluated along CA-241. We detected carnivores via camera traps positioned at undercrossing sites AC241, 241D, and 241H, obtaining photographs of mountain lion, coyote, bobcat, gray fox, raccoon, and striped skunk across these sites (fig. 16a). During our initial field visit to undercrossing site AC241, we observed evidence of an additional carnivore species in the area; ringtail tracks were found on the southwest side of CA-241. Also in Section 1, but not at the undercrossings on CA-241, we obtained our only detection of a spotted skunk via a camera capture on October 30, 2007, 8 days after the area burned in the Santiago Fire.

While camera traps recorded animals near three of these undercrossing sites, GPS telemetry showed that the collared bobcats generally moved throughout Section 1 and were sometimes in proximity to undercrossings along CA-241 (fig. 17a). Indeed, GPS telemetry provided strong evidence that bobcat ORI moved through undercrossing AC241 (fig. 9b) and that bobcat OSC used either the underpass at 241G or 241H (fig. 9c) to cross CA-241. In addition, post-fire GPS telemetry revealed that bobcat ZIP used undercrossings at sites 241G and 241H (fig. 9A). GPS-telemetry data for two collared coyotes did not show them at the undercrossing sites along CA-241 (fig. 17b). Although we did not have camera traps near undercrossing sites 241E and 241F, track surveys revealed both coyote and bobcat tracks on the northeast side of CA-241 at both places. However, at site 241F the carnivore tracks were adjacent to the road shoulder in the v-ditch drainage, but not at or inside the underpass. Although we detected seven different carnivore species in the riparian areas just southwest of CA-241, we detected only coyote, bobcat, and striped skunk at undercrossing site BOWR in the center of Section 1.

We detected fewer carnivore species in Section 2 than in Section 1. In Section 2, we detected only coyote, bobcat, and striped skunk, the same three species detected at undercrossing site BOWR in Section 1 (fig. 16a-b). Although coyotes were detected at every undercrossing site in Section 2 by various methods (fig. 17b), the only confirmed bobcat detection was one set of bobcat footprints in Agua Chinon Wash at undercrossing site ACSS during our initial site survey (fig. 17a).

In Section 2, there appeared to be more coyote movement along Agua Chinon Wash than at the other drainages that contained undercrossing sites IBEH and IBMG (fig. 10a-b). In particular, GPS data for coyotes ANG and MLX showed that these animals likely used the underpass at site IBAC to move between Sections 1 and 2 across Irvine Boulevard, but were also probably making surface crossings of the road near sites IBEH and IBMG (fig. 10a-b). The strongest evidence for this behavior was the numerous movement paths over site IBAC that were oriented along the drainage, unlike the fewer and tangential movement paths observed at sites IBEH and IBMG. There were also coyote mortalities on Irvine Boulevard during the study (fig. 13). These unsuccessful surface crossings suggested coyotes did attempt to cross Irvine Boulevard via the road surface. At undercrossing site IBBW, GPS telemetry suggested that both coyotes and bobcats approached from north of Irvine Boulevard, but did not cross the road into Section 2 (fig. 9c, 10a). However, track surveys during our initial site survey indicated coyotes were moving into the dirt lot at the corner of Irvine Boulevard and Alton Parkway, possibly putting them in contact with the road surfaces.

In Section 3, we only detected one native carnivore species, coyotes. We also detected domestic dogs on camera stations, and these detections were more prevalent here than in any other section across the study area. Furthermore, in this section, dogs had a higher camera index of activity than coyotes (tables 4-9). There were no bobcat detections in this section by any method (fig.17a). Camera stations detected coyotes on both side of the railroad tracks, none of which were tagged animals.

In Section 4, we had confirmed detections of raccoons in addition to coyotes and domestic dogs. We also collected two possible bobcat scats (fig. 17a) for which species identification may later be confirmed through genetic analysis. One of these possible bobcat scats was found on the south side of the Alton and Barranca Parkways intersection in Serrano Creek. Also at this intersection, camera stations documented coyotes, but there were only two photographs and those images suggested the animals were moving across the creek bed perpendicular to the proposed corridor rather than entering or exiting the undercrossing. Section 4 terminated at the I-5 and I-405 interchange, where we found the other of the two possible bobcat scats within this section at the south end of Serrano Creek. Inside the underpass tunnel, we observed a few bobcat footprints traveling south where a diversionary culvert joined the main undercrossing (fig. 17a). The footprints ended where there was standing water at this junction. We also had a visual sighting of a coyote here; however, the camera station monitoring this same location was the only camera station across El Toro that did not detect coyotes, suggesting infrequent use of this entrance into the ETY underpass by coyotes.

Section 5 was separated from the proposed corridor by a major freeway interchange. In this section, we had GPS evidence of two bobcats with movement paths and home ranges that essentially traced San Diego Creek. In addition, GPS data for bobcat HOM indicated he moved into Serrano Creek and headed north towards the opening of undercrossing site ETY, but that he did not enter the proposed corridor (fig. 11, 16b). Although the other bobcat (SLO) moved across I-405 several times at one location, this location was not connected to the proposed corridor (fig. 9e). The camera station at undercrossing site ETY did not detect bobcats, but it did document coyotes moving into this undercrossing (table 8). Further south at Research Drive, a camera station at undercrossing site RDUC detected both coyotes and bobcats using the underpass to move between the diversionary channel and San Diego Creek. In addition, telemetry data revealed the two GPS-collared bobcats crossed Research Drive at site RDTR between the sections of San Diego Creek. Because there was a large grate over the northeast opening of RDTR, the bobcats likely crossed over the road surface instead of through the underpass (fig. 9e-f). We also found coyote tracks indicating road surface crossings at this location. Similarly, GPS data showed that bobcats crossed Irvine Center Drive, and camera data at site ICSC confirmed collared bobcats and coyotes made surface crossings of the road. Overall, we detected four species of native carnivores in Section 5, including coyote, bobcat, raccoon, and striped skunk. We also detected domestic dogs, but only at one camera station.

At sites west of the proposed corridor, we had evidence of coyotes and bobcats along the Bee Canyon Wash that paralleled the other washes through the Marine base. We received a report of a bobcat sighting at the University of California South Coast Research and Extension Center north of Irvine Boulevard. In addition, there were two bobcat mortalities, one at Irvine Boulevard and CA-133 and one at Trabuco Road on the main station (table 15). Along the railroad tracks across the south end of the main station, only coyotes were detected by a camera station at site MWFW, which was at a break in the fencing (table 16). At the CA-133 and I-5 interchange, there was evidence of one coyote mortality on the freeway overpass (fig. 13). Photos from sites RDUC and MWFW suggested coyotes were moving along the railroad tracks crossing Borrego Canyon Wash (app. 2). In combination, the evidence from coyote detections at those three locations suggested movement parallel to the railroad tracks and potentially entering the main station in a direction perpendicular to the proposed corridor path. Another area for potential animal movement into the proposed corridor was near Serrano Creek north of Irvine Boulevard. GPS telemetry and mortality data revealed bobcats moved frequently in and across the Borrego Canyon Wash towards Bake Parkway to access the upper reaches of Serrano Creek (fig. 9a-c, 13).

Discussion

Large mammals are valuable focal species and targets for conservation because they are particularly sensitive to human disturbances such as habitat fragmentation (Crooks 2002; Crooks & Sanjayan 2006) and can play pivotal roles in ecological communities (Crooks & Soule 1999; Estes et al. 2001; Henke & Bryant 1999). In southern California, bobcats and coyotes are an excellent focal species for the evaluation of connectivity (Crooks 2000; Crooks 2002; Hunter et al. 2003; Riley et al. 2007; Riley et al. 2006; Riley et al. 2003; Tigas et al. 2002). From these studies, it is apparent that landscape connectivity appears to be the key to the persistence of bobcats, and to a lesser extent coyotes, in many urban areas.

Connectivity between the Central and Coastal Subareas of the Nature Reserve of Orange County, however, appears tenuous (Crooks & Jones 1998; George & Crooks 2001). Crooks and Jones (1998) used track, scat, and camera surveys to assess the functionality of possible linkages between the central and coastal subregions, including both Arroyo Trabuco and Aliso creeks under Interstate 5. They found minimal connectivity for bobcats between the coast and inland reserves; no bobcats were detected at Aliso Creek, and only one detection was recorded under Arroyo Trabuco Creek under I-5. A recent genetic survey of bobcats in the San Joaquin Hills (Lyren et al. 2008) suggests that only 4 of 42 bobcats sampled in the coastal reserve likely immigrated from elsewhere, that no bobcats sampled from the central reserve likely originated from the San Joaquin Hills, and that the San Joaquin Hills population was genetically distinct from the central reserve population; there was no evidence, however, of inbreeding in either coastal or central bobcat populations. Interestingly, genetic evidence also suggested that although coast-inland movement was limited, individuals that did disperse did so from the central to the coastal reserve, but not from coastal populations inland. Although some individuals within the San Joaquin Hills were likely recent immigrants, we know little about reproductive success or survivorship of such animals. Indeed, reproductive success of new arrivals might be low. A recent study in the Santa Monica Mountains indicated that even though bobcats were able to cross a major freeway (the Ventura Freeway US-101) severing the Santa Monica Mountains, they rarely reproduced, resulting in genetic differentiation of bobcat populations across the roadway (Riley et al. 2006).

Our findings suggest that coastal-inland movement, when it does occur, may be via routes in addition to or other than the proposed corridor. Our models of landscape-level connectivity predicted two major movement corridors that can facilitate functional connectivity for bobcats between the Santa Ana Mountains and the San Joaquin Hills: 1) a northern route, via the El Toro study area, and 2) a southern route, via Arroyo Trabuco Creek to Salt Creek. Protecting and enhancing the functionality of both corridors could increase the viability of the coastal reserve with respect to wildlife, because a redundancy in connectivity would create a more resilient habitat reserve network. The northern route passes through the southeastern portion of the former El Toro Marine Base (similar to the path of the proposed wildlife corridor), but has a major constriction at its southwestern end (fig. 15c). Unless this constriction is ameliorated, a wildlife corridor through El Toro may not provide adequate connectivity between coastal and inland habitat but instead create a cul-de-sac that diverts animal movement into a dead end.

We did not document an individually identified bobcat or coyote moving the length of the proposed corridor during the study, but coyotes and bobcats did range widely in the El Toro vicinity. GPS-collared bobcats and coyotes occupied MCP home ranges up to 13 km^2 and 8 km^2, respectively, and at times moved large distances, frequently encountering existing and proposed roadways and undercrossings. Remotely-triggered cameras detected coyotes across almost all camera stations, including those in the center of El Toro, demonstrating that there were coyotes visiting points along the proposed corridor. In contrast to coyotes, cameras detected bobcats only in the northern and southern sections, but not in the center of the study area. We also did not capture any bobcats or record any GPS telemetry locations for collared bobcats in Section 2, 3, or 4. A set of bobcats tracks was found in Section 2 and two possible bobcat scats were found in Section 4 in the proposed corridor (fig. 17a) during field scouting at the start of the project; however, the only bobcat detection in Sections 2, 3, or 4 later in the study was a fire-injured bobcat found just beyond the northwest edge of the former airfield (fig. 13, 17a). Although we cannot rule out the possibility that bobcats went undetected (and un-captured) in the center of the former Marine base, construction initiated early in our study, including grubbing of vegetative cover in riparian areas and other likely movement routes, may have excluded occasional movements of bobcats within the proposed corridor during our data collection period. Additionally, the availability of suitable habitat for bobcats in Sections 2, 3, and 4 even at the start of the study was extremely limited, and while we documented GPS-collared coyotes crossing Irvine Boulevard, we did not have any evidence of GPS-collared bobcats crossing this road that separated Section 1 from the main station.

Individual animals differed considerably in their response to urbanization; in general, GPS-collared bobcats and coyotes were not frequently located within urban development. On average, 73% of GPS locations of collared bobcats were within natural areas, and only 16% of locations were located within areas classified as urban. In comparison to bobcats, coyotes were more frequently located within urban development, with on average 25% of their locations in areas classified as urban, although much of this area was former military housing in Section 1 now vacant. That the urban matrix is relatively impermeable for bobcats, and to a lesser extent for coyotes, was evident in the home range and move path figures presented in this report, with the urban edge frequently acting as the outer boundary for home ranges. Where bobcats and coyotes do penetrate the urban matrix, they frequently do so by moving through corridors of riparian or other natural habitat, or moving through altered, yet somewhat permeable, landscapes such as golf courses (present study; Lyren et al. 2008). Relatively small patches of habitat can play an important role in carnivore conservation in fragmented landscapes, but they must be adequately connected to other natural areas (Crooks 2002). For example, relatively small habitat patches within the San Joaquin Hills are utilized by bobcats, with resident animals constructing home ranges by incorporating multiple patches (Lyren et al. 2008).

Our results and those of prior studies in coastal southern California (Crooks 2002; Crooks et al. 1998; George & Crooks 2001; George & Crooks 2006; Haas 2000; Haas et al. 2002; Lyren 2001; Lyren et al. 2008; Lyren et al. 2006; Riley et al. 2007; Riley et al. 2006; Riley et al. 2003) suggest that bobcats and coyotes in urban areas are exposed to a variety of threats, including (but not limited to): road kill, habitat loss and fragmentation (due to disturbances such as urban development, roads, or fire), disease (e.g., mange), predation by other carnivores, and, on a longer time scale, low genetic variability and resulting inbreeding depression and reduced evolutionary potential. In particular, roadways clearly serve as a major agent of fragmentation and primary source of mortality for large carnivores (Lyren 2001; Riley et al. 2003). In the 17 months of the El Toro study, all six coyotes and three of five bobcats reported dead were killed by motor vehicles. Similarly, in the San Joaquin Hills, over 32 months, all 26 bobcats reported dead were killed by vehicles (Lyren et al. 2008). Locations of road kills were distributed around the study area, including on a secondary road that bisected the proposed corridor.

Previous studies have documented underpass use by wildlife, including bobcats and coyotes, in the Nature Reserve of Orange County, including the North Irvine Ranch (Lyren et al. 2006), the East

Orange/Central Irvine Ranch (Haas et al. 2002), and the San Joaquin Hills (Lyren et al. 2008). Such results clearly indicate that roadway undercrossings are helping facilitate wildlife movement through roaded areas in Orange County, if properly situated and designed. However, our GPS telemetry and road-kill data demonstrate frequent surface crossings of roadways, both successful and unsuccessful, by bobcats and coyotes. Although many of the recorded crossings were across surface streets and not primary highways, other studies in southern California have documented high rates of road kill along roadways with intermediate levels of traffic such as secondary roads and expressways (Lyren 2001; Ng et al. 2004). With additional roads or future increases in road width and traffic volume, 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).

A functional linkage across the former El Toro Marine Base would necessitate mitigation and restoration along the entire corridor beyond the boundaries of the proposed corridor. For example, implementation of a functional corridor would necessitate restoration of the connection through the Interstate 5 and 405 interchange, including facilitating animal movement along San Diego and Serrano Creeks and restoring existing annual grasslands to native scrub habitat where appropriate in the Laguna Laurel area to provide greater cover for movement. Locations within the proposed corridor that could restrict carnivore movements, and locations that would reduce the probability of carnivores reaching the corridor, would also need to be addressed for the corridor to offer functional connectivity. Just as multiple corridors can offer redundancy in providing connectivity between disconnected areas of intact habitat, multiple entrances to a corridor can offer redundancy within a corridor that would strengthen its chances for success.

Below we discuss specific recommendations for a proposed corridor between the Santa Ana Mountains and the San Joaquin Hills to offer functional connectivity for carnivores ("Recommendations for Functional Connectivity"). We describe our results and observations for each of the sections in the study area with a focus on existing and proposed features that can affect carnivore movements, and we then offer information on options for roadway mitigation. We then provide specific evaluations and suggestions of various methodologies for long-term monitoring and management of bobcats and coyotes, and other wildlife, in and around the El Toro study area ("Recommendations and Methods for Long-term Monitoring and Management"). This discussion is intended as a general review of issues concerning carnivore monitoring and management, and not a specific, detailed monitoring and management plan for the proposed corridor. If desired, development of an adaptive management plan for wildlife with the Orange County Great Park 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 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.

Recommendations for Functional Connectivity

Corridor Recommendations

For functional connectivity to exist between the Santa Ana Mountains and the San Joaquin Hills, each section of the proposed corridor must offer safe passage to carnivores and the transitions between these also needs to be passable. Here we combine technical expertise on carnivore movements, roadways, and undercrossings with the implications of our findings in this project to outline some of the mitigation that would be necessary for functional connectivity between the two areas. Note that our list is far from exhaustive, however, and does not consider the implications of variations on proposed designs either singly or in combination along the corridor. We provide this evaluation to identify some specific locations that pose particular challenges to carnivore movements, and to highlight many aspects of the landscape, wildlife biology, and roadway engineering issues that should be considered when addressing barriers and habitat fragmentation presented by roadways. To ensure functional connectivity throughout the El Toro study area all of these mitigation strategies must be implemented over the entire stretch of the corridor including the peripheral areas. Eliminating even one piece would be much like removing a link from a chain - if one is broken or missing, then the entire chain is not functional.

Section 1

At the time of this study, there were no obvious barriers to north-south movements of animals within this section. However, we found a lower diversity of native carnivore species at the southwestern end of Section 1 than we found in the northeastern area that was bordered by CA-241. The main connectivity challenges for this section with adjacent areas were the major roadways and proposed roadways that border it, and the potential landuse changes within the section. Thus, for functional connectivity for carnivores, the following are important:

- **Maintenance of this section as natural open space, with few human structures or activities -** Maintaining this section in its present form, or preferably with habitat restoration, will be critical to allow bobcats or coyotes to potentially reach the north entrance of the proposed corridor or be able to exit into a safe area of suitable habitat if attempting to disperse to the north.
- **Realignment and repair of wildlife fencing** (see “Wildlife Fencing Design” page 59) **along CA-241, as we observed carnivore tracks leading to and on the road shoulders -** These

adjustments should allow carnivores direct access to the undercrossings and prevent them from moving on to the road surface.

- **Further study to understand patterns of species diversity within Section 1**

Section 2

Along the northern edge of this section, Irvine Boulevard posed challenges to connectivity for carnivores, acting as a 'filter' to movement of animals between Sections 1 and 2 as shown by carnivore mortalities, movement paths ending at the road or resulting in probable surface crossings, and the lower species diversity here than Section 1. Within the section, potential barriers to carnivore movements were few and consisted primarily of cementing and situating drainages underground for long distances, and barriers present at underpass entrances. Section 2 had minimal human activity prior to and at the beginning of the fieldwork. Later, there was some human activity within various parts of Section 2, such as grubbing the riparian areas and removal and rearrangement of trees from and around the golf course, but most of the time large portions remained relatively free of humans and vehicles. Section 2 appeared to offer suitable habitat for coyotes but not for bobcats, likely due to a lack of shrubs or vegetation that offered cover. Thus, we can only partially address how animals might utilize a corridor through this section, given that the configuration would differ very dramatically than the conditions under which we conducted our observations because the Orange County Great Park and wildlife corridor has yet to be constructed. Based on our results and technical expertise, we identified the following actions as important to functional connectivity across Section 2:

- **Enhance the functionality of undercrossing site IBMG for carnivores** (see “Underpass Location and Function” page 57) (Forman et al. 2003; Haas 2000) **–** Improvement of the underpass should include removal of asphalt and agriculture fields on both sides of undercrossing and restoration with natural vegetation, and removal of a tall chain-link gate at the opening. Restricted or eliminating human traffic would also be important.

- **Maintain undercrossing site IBAC as an alternative location for carnivores to cross Irvine Boulevard -** More than one undercrossing from Section 1 to Section 2 would add the redundancy that is an important feature to functional connectivity. Furthermore, the Orange County Great Park has already identified this area as the site of a proposed 115-acre drainage-riparian corridor in the Agua Chinon Wash. Because riparian corridors are natural movement routes for carnivores, we expect carnivores will try to utilize this site to also cross Irvine Boulevard.
- **Repair or install wildlife fencing** (see "Wildlife Fencing Design" page 59) **along both sides of Irvine Boulevard between CA-133 and Alton Parkway, particularly adjacent to existing undercrossings or where natural or landscape vegetation abuts road –** Roadside vegetation provides valuable cover that carnivores can utilize for travel and hunting, though it can also increase the chances of animal-vehicle collisions by concentrating animals along the road. Fencing will allow animals to use the existing cover while funneling them to safe road crossing locations.
- **Utilize permeable, 3-strand nail post fencing along the proposed corridor to allow carnivores access to the adjacent golf course and other vegetated areas –** An additional golf course is proposed west of the proposed wildlife corridor. The golf course might act as a buffer to the wildlife corridor providing additional areas for carnivores, as we have observed golf courses acting as core habitat or areas in which carnivores move between core habitats (Crooks 2002; Lyren et al. 2008). Therefore, permeable fencing would prevent human access into the corridor while allowing carnivores to freely travel between the

corridor and golf course, would help increase the functional width of the corridor, and thus would improve connectivity.

Sections 3 and 4

Two major secondary roads and a railroad track crossed these sections and pose connectivity challenges. Another major challenge is the proposed routing of the corridor, leaving the path of the Borrego Canyon Wash and joining Serrano Creek without the benefits of following a natural creek bed. Section 3 and 4 had low diversity of carnivore species. There was no evidence of bobcats utilizing any of Section 3 during this study, and only two possible detections in Section 4. Below we identify some specific actions to improve connectivity for carnivores:

- **Design proposed undercrossing sites SCRRUC and MARINE following the general recommendations below** (see all sections under "Roadway Mitigation" page 57)**, and of Foreman (2003) to include a dry pathway through the structures** - Underpass design elements should include a structure that is high and wide to provide ample light and a feeling of "openness" with native vegetation leading into and through the underpass to encourage carnivore movement. These characteristics are similar to the structural dimensions and landscape features that were in existence at site RRUC prior to grubbing (see app. 1). Standing water should be minimized as it deters carnivore movement through an underpass.
- **Limit the length of the proposed wildlife ramp attached to undercrossing site ABSE -** Long narrow underpasses have a low probability of use by carnivores (Clevenger & Waltho 1999; Haas 2000), and we did not find clear evidence of carnivores using this underpass.
- **Provide a dry pathway through undercrossing ABSE** - Standing water across the width of the underpass may have been one of the deterrents to carnivores utilizing this underpass.

- **Maintain Serrano Creek without cement-channelized walls, reduce the slope of the walls, and restore native vegetation in the creek bed and on the embankments.**
- **Install wildlife fencing** (see "Wildlife Fencing Design" page 59) **along the proposed corridor to keep carnivores off the road surfaces along Alton and Barranca Parkways.**

Section 5

Our landscape connectivity modeling identified part of Section 5 as the major constriction point between the Santa Ana Mountains and the San Joaquin Hills. In fact, as carnivores move south into this section, approaching the 26-lane I-5/I-405 interchange, they encounter the biggest obstacle to functional connectivity throughout the study area. Here, current undercrossing characteristics are not conducive to wildlife use. The underpass is long and narrow, has a concrete bottom, and abruptly turns at a ninety-degree angle at the main and diversionary culvert. If coyotes and bobcats do successfully move through the underpass system at the El Toro Y, they still face a series of additional obstacles. Given current conditions, a carnivore traveling across Section 5 towards the coastal reserve would need to navigate narrow riparian drainages surrounded by commercial development, cross several roads in a short distance, locate suitable crossing locations, and circumvent barriers such as grates over underpass entrances and standing water. However, we did obtain evidence of GPS-collared bobcats making multiple movements back and forth through the narrow riparian areas just south of the El Toro Y underpass entrance. For functional connectivity through Section 5 for carnivores, the following are important:

- **Inspection of the inside of the undercrossing at site RDTR to assess its compatibility with carnivore use, and removal or modification of the grate on the northeast entrance**
  – Obstructions inside, such as silting, or an underpass that changes direction inside will prevent or inhibit carnivore use.

- **Modification of environmental conditions at 1) lower Serrano Creek to prevent standing water inside the cement channelized portion from Irvine Center Drive north through undercrossing site ETY, and 2) site RDTR on the southwest side of Research Drive to prevent standing water at the outside of the underpass entrance -** Standing water can prevent carnivores from using undercrossings, causing them to turn around or seek other routes, such as a road surface.
- **Provide a dry pathway at undercrossing site ICSC under Irvine Center Drive –** We observed standing water inside the reinforced box culvert connecting San Diego Creek to Serrano Creek. Installation of an additional box culvert under Irvine Center Drive that directly connects the two halves of San Diego Creek might be necessary to provide a dry pathway alternative.
- **Installation of wildlife fencing** (see "Wildlife Fencing Design" page 59) **along both sides of Research and Irvine Center Drives where natural or landscape vegetation abuts roads -** Roadside vegetation provides cover that carnivores can utilize and may increase chances of an animal-vehicle collision, if adequate fencing that could prevent carnivores from moving onto surfaces of roadways is missing. Fencing should direct carnivores to the underpass entrances and keep them from moving towards the road surfaces ensuring both animal and driver safety.
- **A design for the proposed Lake Forest Drive and Bake Parkway extensions that include additional undercrossings that facilitate carnivore movement through San Diego Creek -** More than one undercrossing site would add the redundancy that is an important feature to functional connectivity, allowing alternative pathways when changes in ecological or environmental conditions limit the utility of some undercrossings.

- **Installation of wildlife fencing** (see “Wildlife Fencing Design” page 59) **along the entire stretch and on both sides of Lake Forest Drive and Bake Parkway extensions where natural or landscape vegetation abuts roads -** Wildlife fencing is critical along these road extensions. The proposed Lake Forest Drive extension would be positioned perpendicularly to a few small north-to-south side drainages that are natural carnivore movement paths across an open landscape. The proposed Bake Parkway extension would parallel riparian vegetation that is high quality bobcat habitat. Both instances either lead carnivores to a road surface or concentrate them alongside a road significantly increasing their chances of being struck and killed by vehicles. Wildlife fencing would prevent animals from moving on to the road surfaces and direct animals to proposed bridge or culvert undercrossings.

Peripheral Areas

Peripheral areas that were outside the proposed corridor might offer additional habitat or dispersal routes for animals leaving or entering the proposed corridor at points other than its terminal ends. One such peripheral area was Bee Canyon Wash west of the proposed corridor where we monitored three sites. The other area was the upper reaches of Serrano Creek north of Irvine Boulevard. Provisions for carnivore movements to and from these areas include some of the following issues:

- **Modification of undercrossing site IBLM to provide a location for carnivores to cross Irvine Boulevard west of the proposed corridor –** The Orange County Great Park has already identified this area as the site of a proposed 114-acre drainage-riparian corridor along Bee Canyon Wash. Because riparian corridors are natural movement routes for carnivores, we expect carnivores will try to utilize this undercrossing to also cross Irvine Boulevard. Mortality, sighting, and track data suggests that carnivores are in fact already trying to cross Irvine Boulevard at this location. Further, more than one undercrossing site from Section 1 to Section 2 would add the redundancy that is an important feature to functional connectivity.

- **Evaluate wildlife movement along the railroad tracks to determine the feasibility of connecting the proposed drainage-riparian corridor along Bee Canyon Wash to the altered areas west of the CA-133 and I-5.**
- **Installation of multiple undercrossings large enough to facilitate carnivore movement and wildlife fencing** (see “Wildlife Fencing Design” page 59) **along the length of the proposed Alton Parkway extension -** Bobcats frequently moved along the Borrego Canyon Wash, indicating this area was important for them and that it allowed for connectivity to areas southeast of Section 1. Allowing carnivores to move towards the upper reaches of Serrano Creek through this connection appeared to be particularly important during and after the Santiago Fire. Mitigation would be necessary to facilitate bobcat and coyote movement and to reduce chances of animal-vehicle collisions on the road extension.

Roadway Mitigation

Underpass Location and Function

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

Habitat characteristics in the immediate vicinity of an underpass also influence use of underpasses by wildlife. For bobcats, native vegetation surrounding underpass entrances increases the probability of underpass use, whereas using non-native, ornamental landscaping decreases the probability of underpass use by bobcats (Crooks & Jones 1998; Haas 2000). The function of the underpass is also important for bobcats, as bobcats 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 or indirectly may cause animals to alter their activity patterns or avoid areas altogether (Clevenger & Waltho 2000, 2005; Griffiths & Van Schaik 1993). In the Nature Reserve of Orange County, bobcats shifted their activity around trails to become more nocturnal on trails with higher levels of human recreation (George & Crooks 2006).

In general, to optimize underpass use by target species, underpasses should 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 underpass entrances and replace proposed rock fill slope protection. Concrete v-ditches and rip-rap should also be avoided; more natural stream flows and riparian banks better facilitate animal movement. Sound walls might also be considered along key portions of the roadways to mitigate the effects of traffic noise on wildlife (Forman et al. 2003).

Underpass Dimensions

Underpass dimensions are an important determinant of underpass use by wildlife (Clevenger & Waltho 2005; Haas 2000). A variable of particular importance is the openness of the underpass, which takes into consideration the height, width, and length of the underpass (O = H x W / L); for example, an openness value greater than 0.6 m has been recommended for mule deer (Reed 1981). Along CA-71 through the Chino Hills, Haas (2000) reported that bobcat, coyote, and mule deer frequency of underpass use increased as underpass height, width, and/or openness increased. Although 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.

Wildlife Fencing Design

To prevent attempted at-grade crossings by target species, proper fencing should be installed to "funnel" animals towards each underpass. To be most effective, fencing should 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 (Lyren 2001; Roof & Wooding 1996; Thompson 1978). Such end runs may decrease underpass use and expose animals to animal-vehicle collisions. If lengthy stretches of road cannot be fenced, we suggest 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 where the limited wildlife fencing or other mitigation measures were positioned (e.g., animal detection/wildlife warning systems, vegetation treatments, or rip rap as fence end treatments). If lengthy portions of the road are fenced, it is critical that multiple underpasses of adequate size should be provided so that the fencing does not create a barrier in itself.

Installment of fencing that is a neutral color (e.g., brown or green), instead of the shiny silver that is standard, would complement the natural landscape and minimize visual interruption of the scenery. Additionally, native vegetation could be strategically placed along fencing to minimize its aesthetic intrusiveness, as long as the vegetation does not hang over the fencing and provide a means for animals to climb over. Additional vegetation might also help buffer noise and/or light accompanying traffic volume, which appears to suppress frequency of underpass use by coyotes (Lyren 2001). Fencing should have mesh with openings less than 10 cm x 15 cm (4 in x 6 in) (Thompson 1978) and should be seated at least 45 cm (18 in), preferably 60 cm (24 in), into the ground to prevent medium to large-sized animals from crawling through or digging underneath. 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. Adopting both of these necessary precautions will help prevent animals from accessing the road and becoming trapped. The height of wildlife 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). In conjunction with fencing, escape or "jump-out" ramps could also be used to help those animals that might have become entrapped on a road to safely exit (although careful attention to design would be needed to prevent access to the road via these structures). Finally, the condition of fencing should be closely inspected and repaired twice per year to ensure it retains its integrity against natural and anthropogenic disturbances; situating fencing close to the road improves access for fence maintenance activities.

Recommendations and Methods for Long-term Monitoring and Management

Camera Surveys

Camera surveys can be useful tools to assess the distribution, activity, and movement patterns of wildlife and have been used to assess the impact of human recreational activity on wildlife activity in Orange County, including the San Joaquin Hills (George & Crooks 2006). In the El Toro study area, camera stations recorded a variety of wildlife species, including bobcat, coyote, mountain lion, gray fox, raccoon, striped skunk, spotted skunk, mule deer, and opossum. Further, camera surveys detected a range of human activities, including pedestrians, dog-walkers, bicyclists, and motorized vehicles.

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; Foresman & Pearson 1998; Hernandez et al. 1997; Karanth 1995; Karanth & Nichols 1998; Mace et al. 1994). In comparison to other non-invasive field surveys for carnivore detection, such as 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 periods than track surveys, thus increasing the likelihood of detecting the presence of rare or wide-ranging species. Images from camera stations 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).

Remotely-triggered cameras are particularly effective in monitoring bobcat populations due to the potential for individual identification of bobcats by their spotting patterns (Heilbrun et al. 2003; Heilbrun et al. 2006; Larrucea et al. 2007). Typically, inferences from camera data are limited by the researchers inability to distinguish multiple visits by a single individual animal 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 (Carbone et al. 2001; Stander 1998), most studies, including many of our prior camera surveys in the region (George & Crooks 2001; George & Crooks 2006; Haas et al. 2002; Lyren et al. 2006), have reported camera visitation data only 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 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. However, because individual identification of bobcats in photographs is possible, then it becomes feasible to actually estimate population sizes and trends through mark-resight models (Heilbrun et al. 2003; Heilbrun et al. 2006; Larrucea et al. 2007).

Unfortunately, remotely-triggered cameras are subject to theft in areas visited by humans, such as around the El Toro study area. 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.

GPS Telemetry

Remote cameras are a relatively inexpensive and effective method to evaluate the distribution, activity, and abundance of carnivores and other wildlife. Camera surveys, however, do not lend much insight into individual behavior and movement patterns of animals in an area, including their responses to urban development or corridors. GPS telemetry on bobcats and coyotes in and around the El Toro study area provided high-resolution data on the continuous movements of animals, and yielded valuable information on the responses of individuals to habitat types, urban edges, roadways, and landscape linkages. GPS data are being incorporated into computer simulation models to predict carnivore movements and to assess landscape-level connectivity throughout coastal southern California (Tracey 2006). Furthermore, capturing and individually marking animals allows estimation of population sizes through mark-resight (with remotely-triggered cameras) methodologies. In the future, we therefore suggest targeted GPS telemetry studies to assess the impacts of development, construction, or mitigation efforts on bobcat and coyote movement, and hence functional connectivity, within and around the proposed corridor. This would be particularly important after construction of the Orange County Great Park, to evaluate the functionality of the designed wildlife corridors.

Mortality Surveys

Distribution of vehicle-killed animals along roadways can provide valuable data for mapping road-kill hot-spots and locations of barriers to natural dispersal and movement routes. Working with a network of animal control officers, natural resource agency personnel, and local residents, we were able to collect road kill data throughout our study area. Continued collection of such data will be critical in further assessments of functional connectivity for wildlife through the proposed corridor. As such, we suggest establishment of a cooperative effort to continue collection and synthesis of road kill data into the future. To be successful, participation is critical by agencies currently removing or recording road kill animals in the region, including animal control agencies, local resource agencies, the California Department of Transportation, and the Transportation Corridor Authority.

Landscape-level Connectivity Models

An expansion of the functional connectivity analysis presented here could aid in further diagnosing the requirements for successful corridors. Our connectivity modeling can be extended in several directions to assist planning and decision-making. The movement models and cost surfaces can be parameterized by more rigorous and detailed means, including parameterization from data collected in the field. The approach can also be applied to other species and extended to include other landscape features such as roads or terrain. We can also study the implications of existing and future connectivity and habitat availability on the persistence of focal species. Finally, rather than conducting the analysis on models of the current landscape, we can use models of landscapes based on potential park designs to predict connectivity after park completion.

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References Cited

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin **29**:1294-1297.

Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. Available at *http://www.spatialecology.com/htools*

Bull, E. L., R. S. Holthausen, and L. R. Bright. 1992. Comparison of three techniques to monitor marten. Wildlife Society Bulletin **20**:406-410.

California Department of Transportation. 2007. Traffic Volumes (Annual Average Daily Traffic (AADT)) for all vehicles on California State Hwys.

Carbone, C., S. Christie, K. Conforti, T. Coulson, N. Franklin, J. R. Ginsberg, M. Griffiths, J. Holden, K. Kawanishi, M. Kinnaird, R. Laidlaw, A. Lynam, D. W. Macdonald, D. Martyr, C. McDougal, L. Nath, T. O'brien, J. Seidensticker, D. J. L. Smith, M. Sunquist, R. Tilson, and W. N. Wan Shahruddin. 2001. The use of photographic rates to estimate densities of tigers and other cryptic mammals. Animal Conservation **4**:75-79.

Carroll, C., W. J. Zielinski, and R. F. Noss. 1999. Using presence-absence data to build and test spatial habitat models for the fisher in the Klamath Region, U.S.A. Conservation Biology **13**:1344-1359.

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

Clevenger, A. P., and N. Waltho. 2005. Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation **121**:453-464.

Clevenger, T., and N. Waltho. 1999. Dry drainage culvert use and design considerations for small- and medium sized mammal movement across a major transportation corridor. Page 263–277 *in* G. L. Evink, P. Garrett, and D. Zeigler, editors. Proceedings of the third international conference on wildlife ecology and transportation. Florida Department of Transportation, Tallahassee, Florida, USA.

Conley, R. H. 1966. An investigation of some techniques for determining age of bobcats (*Lynx rufus*) in the southeast. University of Georgia, Athens, Georgia. 44 pp.

Cotton/Bridges/Associates. May 2004. Irvine Wildlife Corridor Plan. Page 111.

Crooks, K., and D. Jones. 1998. Monitoring Program for Carnivore Corridor Use in the Nature Reserve of Orange County. Annual Report to Nature Reserve of Orange County, Santa Ana, CA.pp.

Crooks, K. R. 2000. Mammalian carnivores as target species for conservation in southern California. Pages 105-112 *in* J. F. Keeley, M. Baer-Keeley, and C. J. Fotheringham, editors. Second interface between ecology and land development in California. U. S. Geological Survey.

Crooks, K. R. 2002. Relative sensitivities of mammalian carnivores to habitat fragmentation. Conservation Biology **16**:488-502.

Crooks, K. R., and M. A. Sanjayan 2006. Connectivity Conservation. Cambridge University Press, Cambridge, UK.

Crooks, K. R., M. A. Sanjayan, and D. F. Doak. 1998. New insights into conservation through demographic modeling. Conservation Biology **12**:889-895.

Crooks, K. R., and M. Soule. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature **400**:563-566.

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

Cutler, T. L., and D. E. Swann. 1999. Using remote photography in wildlife ecology: a review. Wildlife Society Bulletin **27**:571-581.

Czech, B., P. R. Krausman, and P. K. Devers. 2000. Economic associations among causes of species endangerment in the United States. Bioscience **50**:593-601.

Dobson, F. S., R. K. Chesser, J. L. Hoogland, D. W. Sugg, and D. W. Foltz. 1997. Do black-tailed prairie dogs minimize inbreeding? Evolution **51**:970-978.

Estes, J., K. Crooks, and R. Holt. 2001. Ecological role of predators. Pages 857-878 *in* S. Levin, editor. Encyclopedia of Biodiversity. Academic Press, San Diego, California.

Evink, G. L. 2000. Florida Department of Transportation initiatives related to wildlife mortality. Florida Department of Transportation Environmental Management Office. 9 pp.

Foresman, K. R., and D. E. Pearson. 1998. Comparison of proposed survey techniques for detection of forest carnivores. Journal of Wildlife Management **62**:1217-1226.

Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter 2003. Road Ecology: Science and Solutions. Island Press.

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

George, S., and K. Crooks. 2001. Monitoring Program for Mammalian Carnivores in The Nature Reserve of Orange County. Nature Reserve of Orange Countypp.

George, S. L., and K. R. Crooks. 2006. Recreation and large mammal activity in an urban nature reserve. Biological Conservation **133**:107-117.

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

Griffiths, M., and C. P. Van Schaik. 1993. The impact of human traffic on the abundance and activity periods of Sumatran rain forest wildlife. Conservation Biology **7**:623-626.

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

Haas, C. D., K. L. Raymond, L. M. Lyren, R. N. Fisher, and K. R. Crooks. 2002. East Orange/Central Irvine Ranch mammal movement study. U.S. Geological Survey Technical Report. 39 pp.

Heilbrun, R. D., D. J. Silvy, M. E. Tewes, and M. J. Peterson. 2003. Using automatically triggered cameras to individually identify bobcats. Wildlife Society Bulletin **31**:748-755.

Heilbrun, R. D., N. J. Silvy, M. J. Peterson, and M. E. Tewes. 2006. Estimating bobcat abundance using automatically triggered cameras. Wildlife Society Bulletin **34**:69-73.

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

Henke, S. E., and F. C. Bryant. 1999. Effects of coyote removal on the faunal community in western Texas. Journal of Wildlife Management **63**:1066-1081.

Hernandez, F., D. Rollins, and R. Cantu. 1997. An evaluation of Trailmaster camera systems for identifying ground-nest predators. Wildlife Society Bulletin **25**:848-853.

Hooge, P. N., and B. Eichenlaub. 1997. Animal movement extension to ArcView. ver. 1.1. U.S. Geological Survey.

Hunter, R., R. Fisher, and K. R. Crooks. 2003. Landscape-level connectivity in coastal southern California as assessed by carnivore habitat suitability. Natural Areas Journal **23**:302-314.

Jackson, D. L., E. A. Gluesing, and H. A. Jacobson. 1988. Dental eruption in bobcats. Journal of Wildlife Management **52**:515-517.

Jacobson, H. A., J. C. Kroll, R. W. Browning, B. H. Koerth, and M. H. Conway. 1997. Infrared-triggered cameras for censusing white-tailed deer. Wildlife Society Bulletin **25**:547-556.

Jaeger, J. A. G., and L. Fahrig. 2004. Effects of road fencing on population persistence. Conservation Biology **18**:1651-1657.

Karanth, K. U. 1995. Estimating tiger *Panthera tigris* populations from camera-trap data using capture-recapture models. Biological Conservation **71**:333-338.

Karanth, K. U., and J. D. Nichols. 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology **79**:2852-2862.

Lambeck, R. J. 1997. Focal species: A multi-species umbrella for nature conservation. Conservation Biology **11**:849-856.

Land, D., and M. Lotz. 1996. Wildlife crossing designs and use by Florida panthers and other wildlife in southwest Florida *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in addressing transportation related wildlife mortality. State of Florida Department of Transportation, Tallahassee, Florida.

Larrucea, E. S., G. Serra, M. M. Jaeger, and R. H. Barrett. 2007. Censusing bobcats using remote cameras. Western North American Naturalist **67**:538-548.

Lyren, L. M. 2001. Movement patterns of coyotes and bobcats relative to roads and underpasses in the Chino Hills area of southern California. California State Polytechnic University, Pomona, California. 127 pp.

Lyren, L. M., R. A. Alonso, K. R. Crooks, and E. E. Boydston. 2008. GPS Telemetry, Camera Trap, and Mortality Surveys of Bobcats in the San Joaquin Hills, Orange County, California. U.S. Geological Survey Administrative Report. 132 pp.

Lyren, L. M., G. M. Turschak, E. S. Ambat, C. D. Haas, J. A. Tracey, E. E. Boydston, S. A. Hathaway, R. N. Fisher, and K. R. Crooks. 2006. Carnivore activity and movement in a southern California protected area, the North/Central Irvine Ranch. U.S. Geological Survey Technical Report. 115 pp.

Mace, R. D., S. C. Minta, T. L. Manley, and K. E. Aune. 1994. Estimating grizzly bear population size using camera sightings. Wildlife Society Bulletin **22**:74-83.

Marris, E. 2007. 2007 Gallery: images of the year. Nature **450**:1144-1149.

McCaull, J. 1994. The Natural Community Conservation Planning Program and the coastal sage scrub ecosystem of southern California. Pages 281-292 *in* R. E. Grumbine, editor. Environmental Policy and Biodiversity. Island Press, Washington D.C.

Miller, B., R. Reading, J. Strittholt, C. Carroll, R. Noss, M. Soulé, O. Sanchez, J. Terborgh, D. Brightsmith, T. Cheeseman, and D. Foreman. 1998. Using focal species in the design of nature reserve networks. Wild Earth **8**:81-92.

Municipal Water District of Orange County. 2005. O. C. Annual Rainfall. MWDOC. Available at *http://www.mwdoc.com/reports.htm*

Myers, N. 1990. The biodiversity challenge: expanded hot-spots analysis. The Environmentalist **10**:243-256.

Ng, S. J., J. W. Dole, R. M. Sauvajot, S. P. D. Riley, and T. J. Valone. 2004. Use of highway undercrossings by wildlife in southern California. Biological Conservation **115**:499-507.

Noss, R. F. 1983. A regional landscape approach to maintain diversity. Bioscience **33**:700-706.

Noss, R. F., H. B. Quigley, M. G. Hornocker, T. Merrill, and P. C. Paquet. 1996. Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology **10**:949-963.

Pacer. 2000. Locate II. Available at *http://www.nsac.ns.ca/envisci/staff/vnams/locate.htm*.

Powell, R. A. 2000. Animal home ranges and territories and home range estimators. Pages 65-110 *in* L. Boitani, and T. K. Fuller, editors. Research techniques in animal ecology: controversies and consequences. Columbia University Press, New York.

Reed, D. F. 1981. Mule deer behavior at a highway underpass exit. Journal of Wildlife Management **45**:542-543.

Reed, D. F., T. N. Woddard, and T. M. Pojar. 1975. Behavior response of mule deer to a highway underpass. Journal of Wildlife Management **39**:361-367.

Riley, S. P. D., C. Bromley, R. H. Poppenga, F. A. Uzal, L. Whited, and R. M. Sauvajot. 2007. Anticoagulant exposure and notoedric mange in bobcats and mountain lions in urban southern California. Journal of Wildlife Management **71**:1874-1884.

Riley, S. P. D., J. P. Pollinger, R. M. Sauvajot, E. C. York, C. Bromley, T. K. Fuller, and R. K. Wayne. 2006. A southern California freeway is a physical and social barrier to gene flow in carnivores. Molecular Ecology **10**:1-9.

Riley, S. P. D., R. M. Sauvajot, T. K. Fuller, E. C. York, D. A. Kamradt, C. Bromley, and R. K. Wayne. 2003. Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California. Conservation Biology **17**:566-576.

Rodriguez, A., G. Crema, and M. Delibes. 1997. Factors affecting crossing of red foxes and wildcats through non-wildlife passages across a high-speed railway. Ecography **20**:287-294.

Roof, J., and J. Wooding. 1996. Evaluation of the S. R. 46 wildlife crossing in Lake County, Florida *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in Addressing Transportation Related Wildlife Mortality: Proceedings of the Transportation Related Wildlife Mortality Seminar, Tallahassee, Florida.

Sivillo, J. K., J. E. Ahlquist, and Z. Toth. 1997. An ensemble forecasting primer. Weather and Forecasting **12**:809-818.

Soulé, M. E. 1991. Land use planning and wildlife maintenance: guidelines for conserving wildlife in an urban landscape. Journal of the American Planning Association **57**:313-323.

Soule, M. E., and J. Terborgh 1999. Continental Conservation: Scientific Foundations of Regional Reserve Networks. Island Press, Washington, D.C.

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

Stander, P. E. 1998. Spoor counts as indices of large carnivore populations: the relationship between spoor frequency, sampling effort and true density. Journal of Applied Ecology **35**:378-385.

Swihart, R. K., and N. A. Slade. 1988. Relating body size to the rate of home range use in mammals. Ecology **69**:393-399.

Taylor, P. D., L. Fahrig, K. Henein, and G. Merriam. 1993. Connectivity is a vital element of landscape structure. Oikos **68**:571-573.

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

Tigas, L. A., D. H. Van Vuren, and R. M. Sauavajot. 2002. Behavioral responses of bobcats and coyotes to habitat fragmentation and corridors in an urban environment. Biological Conservation **108**:299-306.

Tracey, J. A. 2006. Individual-based modeling as a tool for conserving connectivity. Pages 343-368 *in* K. R. Crooks and M. Sanjayan, editor. Connectivity Conservation. Cambridge University Press, Cambridge, UK.

U. S. Census Bureau. 2000. Census 2000: Data for the State of California: Population Data by County. Available at *http://www.census.gov/census2000/states/ca.html*

Watershed and Coastal Resources Division. 2007. OC Watersheds Program - Rainfall data: past rainfall data: Costa Mesa. Orange County Public Works. Available at *http://www.ocwatersheds.com/rainfall/default.aspx?ID=1000369*

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

Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. BioScience **48**:607-615.

Wilson, E. O. 1992. The diversity of life. W. W. Norton & Company, New York.

Woodroffe, R., and J. R. Ginsberg. 1998. Edge effects and the extinction of populations inside protected areas. Science **280**:2126-2128.

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

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

Table 1. GPS coordinates and sampling effort of 22 camera stations for carnivore monitoring throughout the El Toro study area, Orange County, CA from December 2006[1] through June 2008.

Camera	Location	Degrees N	Degrees W	Camera start date	Camera end date	Total days active
Section 1						
ET241B	1	33.69288	-117.69029	01/25/07	08/17/07	205
ET241C	1	33.69275	-117.68992	01/19/07	08/17/07	211
ET241D	1	33.69021	-117.68413	01/19/07	08/17/07	144
ET241H	1	33.68625	-117.67836	03/06/07	08/17/07	97
ETBOWR	1	33.67746	-117.69544	03/16/07	08/17/07	154
Section 2						
ETIBAC	1	33.67679	-117.71490	03/20/07	08/17/07	151
ETIBMG	1	33.66816	-117.70659	12/21/06	08/17/07	141
ETGCNO	1	33.66564	-117.71409			
ETGCNO	2	33.66295	-117.71130	03/16/07	08/17/07	139
ETACSS	1	33.66939	-117.72098	12/04/06	08/17/07	191
Section 3						
ETGCSO	1	33.65511	-117.72564	03/16/07	08/17/07	155
ETRRUC	1	33.65514	-117.73041	01/18/07	08/17/07	189
Section 4						
ETABSE	1	33.64751	-117.72551			
ETABSE	2	33.64846	-117.72474	03/19/07	08/17/07	152
ETI5SE	1	33.64139	-117.73115	03/19/07	05/24/07	67
Section 5						
ETDIV8	1	33.63864	-117.73327	12/05/06	08/16/07	204
ETRDUC	1	33.63557	-117.73382	01/18/07	08/17/07	211
ETISDN	1	33.63556	-117.73659	12/05/06	08/17/07	168
ETISDS	1	33.63526	-117.73734			
ETISDS	2	33.63518	-117.73734	12/05/06	08/16/07	195
LL_A	1	33.62785	-117.74459	07/05/06	08/16/07	358
Corridor Periphery						
ETBEAQ	1	33.68158	-117.73108	03/16/07	08/17/07	155
ETMWFW	1	33.67041	-117.75136	01/18/07	08/17/07	212
Scouting Cameras						
ETBOWR	1	33.67746	-117.69544	08/18/07	04/15/08	241
ETMLX_DO	1	33.67748	-117.70471	04/25/07	06/20/08	415
ETMLX_UP	1	33.67904	-117.70088	04/24/07	05/20/07	27
ETRDUC	1	33.63557	-117.73382	08/18/07	04/26/08	254
ETISDN	1	33.63556	-117.73659	08/18/07	04/23/08	113

[1] Camera LL_A was installed as part of the San Joaquin Hills bobcat study (Lyren et al. 2008).

Table 2. GPS coordinates for 171 coyote snare locations in the El Toro study area, Orange County, CA from November 2006 through June 2007. [Trap locations are ordered by section then trap name. The letter following the trap number indicates which type of snare was used at that location. C = Collarum™, L = foot, S = standard neck]

Section	Trap name	Degrees N	Degrees W
Section 1	100S	33.68048	-117.69493
Section 1	101S	33.68056	-117.69506
Section 1	102S	33.68194	-117.69554
Section 1	103S	33.67656	-117.69543
Section 1	104S	33.67578	-117.69768
Section 1	105S	33.67556	-117.69784
Section 1	106S	33.67614	-117.69872
Section 1	107S	33.67618	-117.69887
Section 1	108S	33.67620	-117.69906
Section 1	109S	33.67620	-117.69906
Section 1	110S	33.67663	-117.70014
Section 1	111S	33.67664	-117.70070
Section 1	112S	33.67665	-117.70118
Section 1	113S	33.67661	-117.70065
Section 1	114S	33.67646	-117.69937
Section 1	115S	33.67564	-117.69769
Section 1	116S	33.67522	-117.69791
Section 1	117S	33.67653	-117.69971
Section 1	118S	33.67722	-117.69713
Section 1	119S	33.67952	-117.69624
Section 1	120S	33.68008	-117.69633
Section 1	121S	33.68046	-117.69635
Section 1	122S	33.67939	-117.69488
Section 1	123S	33.68018	-117.69475
Section 1	124S	33.68142	-117.69618
Section 1	125S	33.68151	-117.69619
Section 1	126S	33.67976	-117.70034
Section 1	127S	33.67995	-117.70262
Section 1	128S	33.67602	-117.70661
Section 1	129S	33.67610	-117.70655
Section 1	130S	33.67517	-117.70620
Section 1	131S	33.67680	-117.70610
Section 1	132S	33.68301	-117.69043
Section 1	133S	33.68326	-117.69011
Section 1	134S	33.68320	-117.69019
Section 1	135S	33.68190	-117.68973
Section 1	136S	33.68191	-117.68966
Section 1	137S	33.68196	-117.68950
Section 1	138S	33.68159	-117.68948
Section 1	139S	33.68091	-117.68921
Section 1	140S	33.67860	-117.69269
Section 1	141S	33.67841	-117.69666
Section 1	142S	33.67438	-117.70456
Section 1	143S	33.68230	-117.69637

Table 2. Continued

Section	Trap name	Degrees N	Degrees W
Section 1	144S	33.67619	-117.69576
Section 1	1C	33.68063	-117.69475
Section 1	2C	33.68177	-117.69413
Section 1	3C	33.68098	-117.69083
Section 1	4C	33.68043	-117.70211
Section 1	5C	33.67661	-117.69984
Section 1	301S	33.66922	-117.70163
Section 1	302S	33.66866	-117.70132
Section 1	303S	33.66878	-117.70220
Section 1	304S	33.66912	-117.70241
Section 1	305S	33.67037	-117.70438
Section 1	306S	33.67339	-117.70871
Section 1	307S	33.67377	-117.70870
Section 1	308S	33.67570	-117.70651
Section 1	309S	33.67407	-117.70553
Section 1	310S	33.67405	-117.70561
Section 1	311S	33.67420	-117.70480
Section 1	312S	33.67438	-117.70453
Section 1	313S	33.67515	-117.70617
Section 1	314S	33.67659	-117.70492
Section 1	315S	33.67602	-117.70653
Section 1	316S	33.67687	-117.70650
Section 1	317S	33.67646	-117.69758
Section 1	318S	33.67623	-117.69784
Section 1	319S	33.67579	-117.69771
Section 1	320S	33.67532	-117.69790
Section 1	321S	33.67595	-117.69807
Section 1	322S	33.67624	-117.69883
Section 1	323S	33.67629	-117.69896
Section 1	324S	33.67682	-117.70002
Section 1	325S	33.67662	-117.70055
Section 1	326S	33.67669	-117.70114
Section 1	327S	33.67515	-117.70607
Section 1	328S	33.67530	-117.70593
Section 1	329L	33.67731	-117.70811
Section 1	330S	33.67693	-117.70723
Section 1	331C	33.67783	-117.70449
Section 1	332S	33.68048	-117.70216
Section 1	333S	33.67822	-117.70172
Section 1	334S	33.67234	-117.70026
Section 1	335S	33.67830	-117.70764
Section 1	336S	33.67789	-117.70798
Section 1	337S	33.67821	-117.70765
Section 1	338S	33.68292	-117.70197
Section 1	339S	33.68411	-117.70467
Section 1	340S	33.68085	-117.69721
Section 1	341S	33.67363	-117.70885
Section 1	342S	33.68191	-117.68969
Section 1	343S	33.68190	-117.68966

Table 2. Continued

Section	Trap name	Degrees N	Degrees W
Section 1	344S	33.68192	-117.68971
Section 1	345S	33.68194	-117.68975
Section 1	346S	33.68218	-117.71455
Section 1	347S	33.68729	-117.70868
Section 1	348S	33.68720	-117.70869
Section 1	349C	33.68290	-117.70440
Section 1	350C	33.68299	-117.70433
Section 1	351C	33.67853	-117.71017
Section 1	352S	33.68043	-117.69650
Section 1	353S	33.67789	-117.70325
Section 1	354S	33.67789	-117.70325
Section 1	355S	33.67365	-117.70886
Section 1	356C	33.67546	-117.70639
Section 1	357S	33.67511	-117.70630
Section 1	358S	33.67357	-117.70883
Section 1	359C	33.67485	-117.70124
Section 1	360C	33.67490	-117.70119
Section 1	361S	33.68358	-117.70391
Section 1	362C	33.68388	-117.70402
Section 1	363C	33.67976	-117.70271
Section 1	364L	33.67976	-117.70269
Section 1	365C	33.67996	-117.70436
Section 1	366S	33.67812	-117.70311
Section 1	367S	33.67815	-117.70302
Section 1	368S	33.68265	-117.70108
Section 1	369S	33.68455	-117.69087
Section 1	370S	33.67515	-117.70634
Section 1	371S	33.67641	-117.69555
Section 1	372S	33.67963	-117.69647
Section 1	373L	33.68247	-117.70140
Section 1	374C	33.67730	-117.70814
Section 1	375L	33.67565	-117.70641
Section 1	376S	33.67660	-117.70508
Section 1	377S	33.67464	-117.70419
Section 1	378S	33.67487	-117.70396
Section 1	379S	33.67603	-117.70275
Section 1	380S	33.68526	-117.69081
Section 1	381S	33.68326	-117.69011
Section 2	6C	33.66869	-117.72166
Section 2	201S	33.66864	-117.72176
Section 2	202S	33.66818	-117.72222
Section 2	229S	33.66786	-117.72265
Section 2	230S	33.66940	-117.72099
Section 2	236S	33.67025	-117.71130
Section 2	237S	33.66895	-117.70948
Section 2	238S	33.66499	-117.70913
Section 2	240S	33.67467	-117.71579
Section 2	241S	33.67467	-117.71579
Section 3	203S	33.65557	-117.72971

Table 2. Continued

Section	Trap name	Degrees N	Degrees W
Section 3	204S	33.65560	-117.72980
Section 3	205S	33.65475	-117.72822
Section 3	206S	33.65498	-117.72860
Section 3	207S	33.65509	-117.72913
Section 3	208S	33.65523	-117.72945
Section 3	209S	33.65452	-117.72766
Section 3	210S	33.65560	-117.72480
Section 3	224S	33.65457	-117.73201
Section 3	225S	33.65508	-117.72874
Section 3	226S	33.65500	-117.72862
Section 3	227S	33.65616	-117.73092
Section 3	228S	33.65561	-117.72990
Section 3	231S	33.65527	-117.72949
Section 3	234S	33.65525	-117.72953
Section 3	235S	33.65643	-117.73140
Section 4	211S	33.64165	-117.73079
Section 4	212S	33.64206	-117.73039
Section 4	213S	33.64143	-117.73123
Section 4	220S	33.64656	-117.72636
Section 5	214S	33.63729	-117.73338
Section 5	215S	33.63663	-117.73355
Section 5	216S	33.63560	-117.73373
Section 5	217S	33.63556	-117.73427
Section 5	218S	33.63557	-117.73542
Section 5	219S	33.63871	-117.73335
Section 5	221S	33.63239	-117.74561
Section 5	222S	33.63179	-117.74481
Section 5	223S	33.63178	-117.74495
Section 5	239S	33.63324	-117.74631

Table 3. GPS coordinates for 53 bobcat cage-trap locations in the El Toro study area, Orange County, CA from January through June 2007.
[Trap locations are ordered by section then trap name]

Section	Trap name	Degrees N	Degrees W
Section 1	T135	33.66675	-117.69486
Section 1	T136	33.67504	-117.69320
Section 1	T137	33.67755	-117.69551
Section 1	T138	33.68119	-117.69008
Section 1	T139	33.67299	-117.69763
Section 1	T141	33.68577	-117.69652
Section 1	T142	33.68385	-117.69779
Section 1	T143	33.67751	-117.70312
Section 1	T144	33.67776	-117.70144
Section 1	T145	33.68337	-117.69984
Section 1	T146	33.68293	-117.70092
Section 1	T147	33.67361	-117.70314
Section 1	T148	33.67871	-117.69596
Section 1	T149	33.67505	-117.70103
Section 1	T150	33.67584	-117.70000
Section 1	T151	33.67173	-117.70113
Section 1	T152	33.67741	-117.70477
Section 1	T153	33.67917	-117.70057
Section 1	T154	33.67763	-117.69535
Section 2	T119	33.66227	-117.71355
Section 2	T120	33.66290	-117.71380
Section 2	T121	33.66323	-117.71473
Section 2	T124	33.65781	-117.72513
Section 2	T125	33.65790	-117.72493
Section 2	T126	33.66492	-117.71353
Section 2	T129	33.65801	-117.72480
Section 2	T132	33.66882	-117.72159
Section 3	T122	33.65542	-117.72973
Section 3	T123	33.65491	-117.73130
Section 3	T140	33.65502	-117.73099
Section 5	T106	33.63866	-117.73329
Section 5	T107	33.63635	-117.73358
Section 5	T108	33.63552	-117.73429
Section 5	T109	33.63553	-117.73636
Section 5	T110	33.63504	-117.73741
Section 5	T111	33.63440	-117.73841
Section 5	T112	33.63434	-117.74374
Section 5	T113	33.63460	-117.74366
Section 5	T114	33.63337	-117.74570
Section 5	T115	33.62966	-117.74403
Section 5	T116	33.62997	-117.74248
Section 5	T117	33.62705	-117.73470
Section 5	T118	33.62764	-117.73891
Section 5	T127	33.63188	-117.74456
Section 5	T128	33.63070	-117.74456

Table 3. Continued

Section	Trap name	Degrees N	Degrees W
Section 5	T130	33.63587	-117.74856
Section 5	T131	33.63417	-117.74645
Section 5	T133	33.64617	-117.75360
Section 5	T134	33.63894	-117.74995
Section 5	T161	33.63391	-117.74628
Section 5	T162	33.63424	-117.74370
Section 5	T163	33.63416	-117.74434
Section 5	T164	33.63135	-117.74451

Table 4. Mammal species detected at camera stations in Section 1 of the El Toro study area, Orange County, CA from January to August 2007.

[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 name										Total no. detections	Total no. cameras
	ET241B		ET241C		ET241D		ET241H		ETBOWR			
Bobcat	1	*(0.005)*	46	*(0.218)*	8	*(0.056)*	5	*(0.052)*	32	*(0.203)*	**92**	**5**
Coyote	12	*(0.059)*	488	*(2.313)*	2	*(0.014)*	2	*(0.021)*	2	*(0.013)*	**506**	**5**
Mountain lion	0		2	*(0.009)*	0		0		0		**2**	**1**
Gray Fox	0		25	*(0.118)*	0		0		0		**25**	**1**
Raccoon	0		1	*(0.005)*	0		0		0		**1**	**1**
Spotted skunk	0		0		0		0		0		**0**	**0**
Striped skunk	2	*(0.010)*	20	*(0.095)*	62	*(0.431)*	0		1	*(0.006)*	**85**	**4**
Opossum	0		4	*(0.019)*	0		0		0		**4**	**1**
Mule deer	0		0		2	*(0.014)*	0		0		**2**	**1**
Domestic dog	0		1	*(0.005)*	0		0		0		**1**	**1**
Human[1]	39	*(0.190)*	84	*(0.398)*	53	*(0.368)*	2	*(0.021)*	7	*(0.044)*	**185**	**5**
USGS/CSU Personnel	29	*(0.141)*	55	*(0.261)*	9	*(0.063)*	2	*(0.021)*	6	*(0.038)*	**101**	**5**
Unknown humans	10	*(0.049)*	29	*(0.137)*	44	*(0.306)*	0		1	*(0.006)*	**84**	**4**
Vehicle	0		0		0		0		0		**0**	**0**
Bicycle	0		0		0		0		0		**0**	**0**
Total no. detected	**54**		**671**		**127**		**9**		**42**		**903**	
Total no. of species detected[2]	**4**		**9**		**5**		**3**		**4**			

[1]The Human category included only people on foot.

[2]For the Total # Species Detected, Human, Vehicle, and Bike photos were all considered one species (Human).

Table 5. Mammal species detected at camera stations in Section 2 of the El Toro study area, Orange County, CA from December 2006 to August 2007.

[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 name								Total no. detections	Total no. cameras
	ETIBAC		ETIBMG		ETACSS		ETGCNO			
Bobcat	0		0		0		0		**0**	**0**
Coyote	6	*(0.040)*	3	*(0.021)*	76	*(0.398)*	24	*(0.173)*	**103**	**4**
Mountain lion	0		0		0		0		**0**	**0**
Gray fox	0		0		0		0		**0**	**0**
Raccoon	0		0		0		0		**0**	**0**
Spotted skunk	0		0		0		0		**0**	**0**
Striped skunk	0		0		2	*(0.010)*	0		**2**	**1**
Opossum	0		0		0		0		**0**	**0**
Mule deer	0		0		0		0		**0**	**0**
Domestic dog	0		0		0		0		**0**	**0**
Human[1]	12	*(0.079)*	18	*(0.128)*	17	*(0.089)*	18	*(0.129)*	**53**	**4**
USGS/CSU Personnel	12	*(0.079)*	9	*(0.064)*	7	*(0.037)*	5	*(0.036)*	**21**	**4**
Unknown humans	0		9	*(0.064)*	10	*(0.052)*	13	*(0.094)*	**32**	**3**
Vehicle	0		108	*(0.766)*	0		44	*(0.317)*	**152**	**2**
Bicycle	0		0		0		0		**0**	**0**
Total no. detected	**18**		**129**		**95**		**86**		**310**	
Total no. of species detected[2]	**2**		**2**		**3**		**2**			

[1] The Human category included only people on foot.

[2] For the Total # Species Detected, Human, Vehicle, and Bike photos were all considered one species (Human).

Table 6. Mammal species detected at camera stations in Section 3 of the El Toro study area, Orange County, CA from January to August 2007.

[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 name: ETRRUC		Camera name: ETGCSO		Total no. detections	Total no. cameras
Bobcat	0		0		**0**	**0**
Coyote	37	*(0.196)*	6	*(0.039)*	**43**	**1**
Mountain lion	0		0		**0**	**0**
Gray fox	0		0		**0**	**0**
Raccoon	0		0		**0**	**0**
Spotted skunk	0		0		**0**	**0**
Striped skunk	0		0		**0**	**0**
Opossum	0		0		**0**	**0**
Mule deer	0		0		**0**	**0**
Domestic dog	63	*(0.333)*	0		**63**	**0**
Human[1]	535	*(2.831)*	11	*(0.071)*	**546**	**1**
USGS/CSU Personnel	13	*(0.069)*	9	*(0.058)*	**22**	**1**
Unknown humans	522	*(2.762)*	2	*(0.013)*	**524**	**1**
Vehicle	28	*(0.148)*	15	*(0.097)*	**43**	**1**
Bicycle	38	*(0.201)*	0		**38**	**0**
Total no. detected	**701**		**32**		**733**	
Total no. of species detected[2]	**3**		**2**			

[1] The Human category included only people on foot.

[2] For the Total # Species Detected, Human, Vehicle, and Bike photos were all considered one species (Human).

Table 7. Mammal species detected at camera stations in the Section 4 of El Toro study area, Orange County, CA from March to August 2007.

[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 Ij = {vj/nj}, where Ij = index of activity at camera j, vj = number of detections of species at camera j, nj = number of nights that camera j was active.]

Species detected	Camera name				Total no. detections	Total no. cameras
	ETABSE		ETI5SE			
Bobcat	0		0		**0**	**0**
Coyote	2	*(0.013)*	0		**2**	**1**
Mountain lion	0		0		**0**	**0**
Gray fox	0		0		**0**	**0**
Raccoon	0		0		**0**	**0**
Spotted skunk	0		0		**0**	**0**
Striped skunk	0		0		**0**	**0**
Opossum	0		0		**0**	**0**
Mule deer	0		0		**0**	**0**
Domestic dog	0		0		**0**	**0**
Human[1]	15	*(0.099)*	9	*(0.134)*	**24**	**2**
USGS/CSU Personnel	4	*(0.026)*	1	*(0.015)*	**5**	**2**
Unknown humans	11	*(0.072)*	8	*(0.119)*	**19**	**2**
Vehicle	9	*(0.059)*	8	*(0.119)*	**17**	**2**
Bicycle	9	*(0.059)*	0		**9**	**1**
Total no. detected	**35**		**17**		**52**	
Total no. of species detected[2]	**2**		**1**			

[1]The Human category included only people on foot.

[2]For the Total # Species Detected, Human, Vehicle, and Bike photos were all considered one species (Human).

Table 8. Mammal species detected at camera stations in the Section 5 of El Toro study area, Orange County, CA from December 2006 to August 2007.

[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 Ij = {vj/nj}, where Ij = index of activity at camera j, vj = number of detections of species at camera j, nj = number of nights that camera j was active.]

Species detected	Camera name										Total no. detections	Total no. cameras
	ETDIV8		ETRDUC		ETISDN		ETISDS		LL_A			
Bobcat	0		21	*(0.100)*	13	*(0.077)*	3	*(0.015)*	10	*(0.028)*	**47**	**4**
Coyote	5	*(0.025)*	23	*(0.109)*	13	*(0.077)*	16	*(0.082)*	48	*(0.134)*	**105**	**5**
Mountain lion	0		0		0		0		0		**0**	**0**
Gray fox	0		0		0		0		0		**0**	**0**
Raccoon	1	*(0.005)*	23	*(0.109)*	21	*(0.125)*	5	*(0.026)*	1	*(0.003)*	**51**	**5**
Spotted skunk	0		0		0		0		0		**0**	**0**
Striped skunk	0		1	*(0.005)*	0		0		0		**1**	**1**
Opossum	0		1	*(0.005)*	0		0		0		**1**	**1**
Mule deer	0		0		0		0		0		**0**	**0**
Domestic dog	0		0		0		0		37	*(0.103)*	**37**	**1**
Human[2]	144	*(0.706)*	18	*(0.085)*	62	*(0.369)*	67	*(0.344)*	223	*(0.623)*	**514**	**5**
USGS/CSU Personnel	13	*(0.064)*	1	*(0.005)*	9	*(0.054)*	5	*(0.026)*	9	*(0.025)*	**37**	**5**
Unknown humans	131	*(0.642)*	17	*(0.081)*	53	*(0.315)*	62	*(0.318)*	214	*(0.598)*	**477**	**5**
Vehicle	0		0		0		19	*(0.097)*	81	*(0.226)*	**100**	**2**
Bicycle	3	*(0.015)*	0		0		1	*(0.005)*	5	*(0.014)*	**9**	**3**
Total no. detected	**153**		**87**		**109**		**111**		**405**		**865**	
Total no. of species detected[2]	**3**		**6**		**4**		**4**		**5**			

[1] Camera LL_A was installed as part of the San Joaquin Hills bobcat study (Lyren et al. 2008).

[2] The Human category included only people on foot.

[3] For the Total # Species Detected, Human, Vehicle, and Bike photos were all considered one species (Human).

Table 9. Mammal species detected at camera stations in the Peripheral area of the El Toro study area, Orange County, CA from January to August 2007.

[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 name				Total no. detections	Total no. cameras
	ETBEAQ		ETMWFW			
Bobcat	0		0		**0**	**0**
Coyote	5	*(0.032)*	166	*(0.783)*	**177**	**2**
Mountain lion	0		0		**0**	**0**
Gray fox	0		0		**0**	**0**
Raccoon	0		0		**0**	**0**
Spotted skunk	0		0		**0**	**0**
Striped skunk	6	*(0.039)*	0		**6**	**1**
Opossum	0		0		**0**	**0**
Mule deer	0		0		**0**	**0**
Domestic dog	0		0		**0**	**0**
Human[1]	5	*(0.032)*	17	*(0.080)*	**34**	**2**
USGS/CSU Personnel	1	*(0.006)*	5	*(0.024)*	**18**	**2**
Unknown humans	4	*(0.026)*	12	*(0.057)*	**16**	**2**
Vehicle	1	*(0.006)*	29	*(0.137)*	**30**	**2**
Bicycle	0		0		**0**	**0**
Total no. detected	**17**		**212**		**247**	
Total no. of species detected[2]	**3**		**2**			

[1] The Human category included only people on foot.

[2] For the Total # Species Detected, Human, Vehicle, and Bike photos were all considered one species (Human).

Table 10. Mammal species detected at scouting camera stations in the El Toro study area, Orange County, CA from April 2007 to June 2008.

[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 name										Total no. detections	Total no. cameras
	ETBOWR		ETMLX_UP		ETMLX_DO		ETRDUC		ETISDN			
Bobcat	0		2	*(0.074)*	13	*(0.042)*	2	*(0.010)*	1	*(0.016)*	**18**	**4**
Coyote	27	*(0.138)*	2	*(0.074)*	408	*(1.333)*	10	*(0.050)*	1	*(0.016)*	**448**	**4**
Mountain lion	0		0		0		0		0		**0**	**0**
Gray fox	0		0		0		0		0		**0**	**0**
Raccoon	0		0		0		59	*(0.295)*	2	*(0.033)*	**61**	**2**
Spotted skunk	0		0		1	*(0.003)*	0		0		**1**	**1**
Striped skunk	0		0		0		0		0		**0**	**0**
Opossum	0		0		0		0		0		**0**	**0**
Mule deer	0		0		0		0		0		**0**	**0**
Domestic dog	0		0		0		2	*(0.010)*	0		**2**	**1**
Human[1]	5	*(0.026)*	1	*(0.037)*	13	*(0.042)*	11	*(0.055)*	21	*(0.344)*	**51**	**4**
USGS/CSU Personnel	4	*(0.020)*	1	*(0.037)*	8	*(0.026)*	1	*(0.005)*	3	*(0.049)*	**17**	**4**
Unknown humans	1	*(0.005)*	0		5	*(0.016)*	10	*(0.050)*	18	*(0.295)*	**34**	**3**
Vehicle	0		1	*(0.037)*	150	*(0.490)*	0		0		**151**	**2**
Bicycle	0		0		0		0		0		**0**	**0**
Total no. detected	**32**		**6**		**585**		**84**		**25**		**732**	
Total no. of species detected[2]	**2**		**3**		**4**		**5**		**4**			

[1] The Human category included only people on foot.

[2] For the Total # Species Detected, Human, Vehicle, and Bike photos were all considered one species (Human).

Table 11. Capture and monitoring information for 7 individual bobcats in the El Toro study area, Orange County, CA from January 2007 through January 2008.
[Sex refers to M = male and F = female. Age refers to J = juvenile (0-12 months), Y = yearling (13-24 months), and A = adult (> 24 months)]

Collar type / Animal ID	Section	Sex	Age	Ear tag color/shape	Capture date	Capture location	Tracking start date	Tracking end date	Last date detected	Method detected
GPS Tellus Basic										
HOM	Section 5	M	A	Green circle donut	1/31/2007	T131	1/31/2007	6/17/2007	see VHF collar below	
ORI	Section 1	M	A	Blue cross	2/23/2007	T135	2/23/2007	6/5/2007	6/6/2007	Mortality-Mange
GPS HABIT Research										
SLO	Section 5	F	A	White cross stripe	2/7/2007	T111	2/7/2007	4/30/2007	8/13/2007	Camera
APO	Section 1	M	Y	White circle	2/21/2007	T135	2/21/07	3/8/2007	4/3/2007	Camera
OSC	Section 1	M	A	Yellow circle	3/7/2007	T141	3/7/2007	8/8/2007	10/17/2007	Camera
DTE	Section 1	M	A	Red cross stripe	5/10/2007	T141	5/10/2007	5/25/2007	6/19/2007	Camera
ZIP	Section 1	M	A	none	12/4/2007	OCAC[1]	1/7/2008	4/3/2008	4/3/2008	GPS Telemetry
VHF-only										
HOM	Section 5	M	A	none	6/29/2007	T162	7/3/2007	7/27/2007	8/5/2007	Camera

[1] Orange County Animal Control

Table 12. Capture and monitoring information for 18 individual coyotes in the El Toro study area, Orange County, CA from November 2006 through March 2008.
[Sex refers to M = male, F = female, and U = unknown. Age refers to J = juvenile (0-12 months), Y = yearling (13-24 months), and A = adult (> 24 months)]

Collar type / Animal ID	Section	Sex	Age	Ear tag color/shape	Capture date	Capture location	Tracking start date	Tracking end date	Last date detected	Method detected
No Radio Collar										
GGL	Section 1	M	J	Green circle X	11/16/2006	113S	n/a	n/a	11/16/2006	Capture
STN	Section 1	M	A	Red bar	11/17/2006	135S	n/a	n/a	11/17/2006	Capture
WLV	Section 1	M	A	Green bar	11/17/2006	108S	n/a	n/a	11/17/2006	Capture
HOU	Section 3	U	U	n/a	12/5/2006	208S	n/a	n/a	12/5/2006	Capture
BUB	Section 5	F	A	Green bar	12/5/2006	223S	n/a	n/a	5/3/2007	Camera
STR	Section 1	F	Y	Blue circle	6/1/2007	315S	n/a	n/a	10/8/2007	Camera
CHL	Section 1	F	Y	Yellow circle	6/4/2007	360C	n/a	n/a	10/24/2007	Mortality-Road kill
PAR	Section 1	F	Y	White circle/cross	6/5/2007	322S	n/a	n/a	6/5/2007	Capture
NIC	Section 1	F	Y	Green cross	6/5/2007	324S	n/a	n/a	6/5/2007	Capture
RNB	Section 1	F	Y	Red circle	6/6/2007	372S	n/a	n/a	2/29/2008	Camera
GHO	Section 1	M	Y	Yellow circle	6/7/2007	350C	n/a	n/a	11/27/2007	Camera
GPS Tellus Basic										
ANG	Section 1	M	Y	Blue circle X	11/16/2006	107S	11/16/2006	3/29/2007	see VHF collar below	
SCH[1]	Section 1	M	A	none	11/16/2006	117S	collar remains on animal[2]		2/23/2008	Camera
MLX[1]	Section 1	M	Y	Yellow circle X	11/16/2006	126S	11/16/2006	3/14/2007	see VHF collar below	
EIN	Section 5	M	A	White circle X	12/5/2006	219S	collar remains on animal[2]		4/20/2008	Camera
AND	Section 5	M	A	Red circle/red circle X	12/5/2006	222S	collar remains on animal[2]		6/20/2007	VHF Telemetry
PEA	Section 2	F	A	Green circle	12/8/2006	238S	collar remains on animal[2]		1/17/2007	VHF Telemetry
VHF-only										
ANG	Section 1	M	A	Blue circle X	6/2/2007	374C	6/2/2007	1/28/2008	1/28/2008	VHF Telemetry
CLB	Section 1	M	A	Yellow cross	6/3/2007	329L	6/3/2007	1/28/2008	3/22/2008	Camera
MLX	Section 1	M	A	none	6/7/2007	374C	6/7/2007	1/28/2008	3/12/2008	Camera

[1] MLX and SCH no longer have their ear tag.

[2] The automatic drop-off devices failed on these collars; see "Trapping and Capture" in "Results".

Table 13. 100% Minimum Convex Polygon (MCP), 95% and 50% Fixed Kernel (FK) estimates (km^2), and percentage of GPS locations within each landuse category for 6 GPS-collared bobcats and 2 GPS-collared coyotes in El Toro study area, Orange County, CA.

[Table is ordered by the number of weeks each animal was tracked . Sex (M = male, F = female). # Weeks Tracked is the length of time the collar collected GPS data prior to dropping off the animal.]

				Area estimate (km^2)			Percent GPS loctions by landuse		
	Sex	**No. weeks tracked**	**No. GPS locations**	**MCP 100%**	**FK 95%**	**FK 50%**	**Natural**	**Altered**	**Urban**
Bobcats									
OSC	M	22	3,209	12.93	6.58	0.64	71%	20%	9%
HOM	M	20	5,595	7.98	2.56	0.40	80%	3%	17%
ORI	M	15	4,011	7.95	4.93	0.22	80%	14%	5%
ZIP	M	12	1,178	8.02	4.02	0.49	89%	10%	1%
SLO	F	12	730	10.93	10.61	0.89	48%	16%	35%
DTE	M	2	158	1.97	2.17	0.16	68%	6%	27%
Coyotes									
ANG	M	19	5,768	8.06	1.82	0.13	67%	13%	21%
MLX	M	17	5,102	4.77	2.17	0.36	61%	10%	29%

Table 14. Numbers of times that fine-scale movement paths intersected roads for GPS-collared bobcats and coyotes in the El Toro study area, Orange County, CA.

[Total number of fine scale paths for each bobcat is shown in parentheses.]

Bobcats	Feature type	Road name	No. intersections fine scale paths and roads
HOM (4,596)	highway	I-405	2
	secondary road	Irvine Center Dr	28
		Bake Pkwy	2
		Lake Forest Dr	1
		Ridge Route Dr	1
		Santa Maria	1
	proposed road	Bake (proposed)	51
		Lake Forest (proposed)	68
ORI (3,530)	highway	CA-241	10
	secondary road	Portola Pkwy	15
	proposed road	Alton (proposed)	26
OSC (2,797)	highway	CA-241	2
	secondary road	Commercentre Dr	4
		Portola Pkwy	1
	proposed road	Alton (proposed)	59
		Bake (proposed)	6
ZIP (921)	highway	CA-241	2
	secondary road	Bake Pkwy	6
		Commercentre Dr	4
	proposed road	Alton (proposed)	25
SLO (467)	highway	I-405	2
		CA-133	5
	secondary road	Barranca Pkwy	12
		Alton Pkwy	2
		Old Laguna Canyon Rd	1
		Ridge Route Dr	1
	proposed road	Bake (proposed)	3
		Lake Forest (proposed)	2
DTE (101)			0

Coyotes	Feature type	Road name	No. intersections fine scale paths and roads
ANG (5,197)	secondary road	Irvine Blvd	26
	proposed road	Alton (proposed)	5
MLX (4,596)	secondary road	Irvine Blvd	23

Table 15. Mortality data for 6 coyotes and 5 bobcats in the El Toro study area, Orange County, CA from September 2006 through January 2008.

[Animals are grouped by mortality cause and then by road killed. The nearest intersection is listed, and if known, the street the animal was crossing when hit is denoted in bold print. Sex refers to M = male, F = female, and U = Unknown. Age refers to J = juvenile (0-12 months), Y = yearling (13-24 months), and A = adult (> 24 months)]

Animal ID	Cause of mortality	Species	Sex	Age	Mortality date	Nearest geographic area	Road killed / nearest cross street	Estimated degrees N	Estimated degrees W
R25	Road Kill	LYRU	F	Y	09/17/07	Corridor Periphery	**CA-241 /** CA-133	33.71284	-117.72049
C14	Road Kill	CALA	F	Y	07/11/07	Corridor Periphery	**CA-133** / I-5	33.66812	-117.75299
C11	Road Kill	CALA	U	U	12/28/06	Corridor Periphery	**CA-133** / Trabuco Road	33.68199	-117.74810
R18	Road Kill	LYRU	M	Y	07/11/07	Corridor Periphery	**CA-133** / Irvine Blvd	33.69545	-117.73548
C10	Road Kill	CALA	F	A	03/02/07	Corridor Periphery	**Irvine Blvd** / Modjeska	33.68658	-117.72088
C22	Road Kill	CALA	F	A	01/31/08	Section 1	**Irvine Blvd /** Desert Storm Drive	33.67291	-117.70966
C13	Road Kill	CALA	U	U	07/05/07	Corridor Periphery	**El Toro /** Marguerite Pkwy	33.66086	-117.64314
CHL	Road Kill	CALA	F	Y	10/24/07	N/A	Alicia Pkwy / Marguerite Pkwy[1]	33.62782	-117.65125
R22	Road Kill	LYRU	F	A	08/07/07	Corridor Periphery	Bake Pkwy / North Pointe Drive[2]	33.66180	-117.69307
ORI	Mange	LYRU	M	A	06/06/07	Section 1	N/A	33.69166	-117.69544
R29	Fire	LYRU	M	A	11/07/07	Corridor Periphery	N/A	33.68256	-117.74223

[1] Both roads were secondary roads.

[2] Bake Pkwy was a secondary road while North Point Dr was a local or tertiary road.

Table 16. Description of 24 local-scale constriction and connectivity sites across the El Toro study area, Orange County, CA.

[Sites are ordered from north to south. Crossing types: RCP = reinforced concrete pipe, RCB = reinforced concrete box, CMP = corrugated metal pipe. A number before the type indicates how many were present side-by-side. See Appendix 1 for photos of each site including additional camera stations.]

Section	Cotton/Bridges/Associate name for site	Map label	Proposed or existing crossing	Site description
1	Foothill Trans. Corridor / Agua Chinon Wash	**AC241**	existing	● A relatively small RCP and a larger 2-RCB in the Agua Chinon Wash under CA-241. ● North of CA-241, the smaller RCP directed water flow from a tributary of Agua Chinon that joined the wash south of CA-241. ● At the RCP on the northeast side, fencing was in front of the underpass entrance. On the southwest side, extensive rip rap was present. RCP appeared silted in the middle of its length or angled upwards. ● The larger 2-RCB was identified as the "preferred" wildlife crossing for corridor planning (Cotton/Bridges/Associates 2004). ● Ample light was visible through the 2-RCB. ● At the 2-RCB on the northeast side, there was a gap in the fencing near the underpass.
1	Foothill Trans. Corridor West	**241D**	existing	● 2-CMP under CA-241. ● On the northeast side, fencing was in front of the underpass entrance, blocking carnivore access. ● On the southwest side, there was a gap in the fencing.
1	Foothill Trans. Corridor East	**241E**	existing	● 2-CMP under CA-241. ● On the northeast side, fencing was in front of the underpass entrance, blocking carnivore access. ● On the southwest side, water knocked fencing down.
1	none	**241F**	existing	● RCP under CA-241. ● On the northeast side, fencing was in front of the underpass entrance, blocking carnivore access.
1	none	**241G**	existing	● RCP under CA-241. ● On the northeast side, fencing was in front of the underpass entrance, blocking carnivore access.
1	none	**241H**	existing	● RCP under CA-241. ● On the northeast side, fencing was in front of the underpass entrance, blocking carnivore access.
1	none	**BOWR**	existing	● RCB in tributary of Borrego Canyon Wash under unnamed road connecting Magazine Rd to covered concrete pad present in the middle of the section. ● Ample light was visible through the RCB.

Table 16. Continued

Section	Cotton/Bridges/Associate name for site	Map label	Proposed or existing crossing	Site description
2	none	**IBAC**	existing	● RCB in the Agua Chinon Wash under Irvine Blvd. ● On the northeast side, drainage was channelized with natural surface bottom and cement walls for about 350 m north of the road. ● On the southwest side, drainage was channelized with natural surface bottom and walls for about 350 m until it went underground at the aircraft runway. This portion was grubbed in March 2007. ● Ample light was visible through the RCB. ● Site ACSS was downstream of this location.
2	none	**IBEH**	existing	● 1/2-RCP under Irvine Blvd; consisted of a single RCP to the northeast and a double RCP to the southwest of the road. ● There was a large grate over the northeast entrance with vertical bars blocking carnivore access. ● On the southwest side at about the northern edge of the cuvlert, there was a gap in the 6' chain-link fence. This entrance was usually full of water.
2	Magazine Road Undercrossing	**IBMG**	existing	● Span bridge that allowed Magazine Rd to pass underneath Irvine Blvd. ● Magazine Rd was an asphalt track under the bridge. ● On the northeast side, a 6' chain-link fence ran along both sides of Magazine Rd, which was then gated and locked about 100 meters north of Irvine Blvd to prevent vehicles from freely accessing the main station. ● On the northeast side, no native vegetation to within 350 meters of bridge.
2	Irvine Boulevard / Borrego Canyon Wash	**IBBW**	existing	● 2-RCB in the Borrego Canyon Wash where it intersected Irvine Blvd at Alton Pkwy. ● Southwest of Irvine Blvd, wash was a deep channelized cement drainage for about 2.5 km to Barranca Pkwy. ● Site AST was downstream of this location.
2	none	**ACSS**	existing	● 3-RCB in the Agua Chinon Wash at the break between the aircraft runways; downstream of site IBAC. ● Site was grubbed in March 2007.

Table 16. Continued

Section	Cotton/Bridges/Associate name for site	Map label	Proposed or existing crossing	Site description
2	Astor Road / Borrego Canyon Wash	**AST**	existing	● 2-RCB inside the channelized portion of Borrego Canyon Wash where it intersected Astor Rd; downstream of site IBBW. ● Wash was a deep channelized cement drainage with a 6' chain-link fence bordering both sides and no vegetative cover or dry movement path alternative available. ● Camera **ETGCNO** was installed nearby to increase probability of detecting animals in the area.
3	Borrego Canyon Wash / SCRRA Railroad	**RRUC**	existing	● 2-span railroad bridge over Borrego Canyon Wash. ● Site was grubbed in March 2007.
3	SCRRA Railroad Undercrossing	***SCRRUC***	proposed	● Exact location of this proposed railroad bridge undercrossing was unknown. ● Camera **ETGCSO** was installed nearby to increase probability of detecting animals in the area.
4	Alton Parkway / Barranca Avenue Undercrossing	**ABSE**	existing	● 3-RCB inside the channelized portion of Serrano Creek where it intersected the Alton and Barranca Pkwys intersection. ● North of the intersection a wildlife "ramp" was proposed to join the channel to allow animals use of the 3-RCB to navigate under the intersection while remaining in the corridor (Cotton/Bridges/Associate 2004). ● South of the intersection, a cement apron and rip rap abutted the underpass entrance. ● Serrano Creek was grubbed in March 2007 between sites AB and ETY.
4	Lower Marine Way	***MARINE***	proposed	● 2-RCB proposed to be installed in Serrano Creek under Marine Way to facitate animal movement in the corridor (Cotton/Bridges/Associates 2004). ● Exact location of the proposed Marine Way road extension on the ground was unknown.
4	El Toro "Y" Undercrossing	**ETY**	existing	● RCB in Serrano Creek attached to another RCB in a diversionary channel under the I-5 and I-405 interchange. ● Camera stations monitored both entrances. ● Camera **ETI5SE** was in the Serrano Creek north of the freeways. ● Camera **ETDIV8** was in the diversionary channel south of the freeways, as Serrano Creek was channelized with a portion of it underground, from south of the interchange until it joined San Diego Creek south of Irvine Center Dr. ● Standing water was constantly present inside the RCB until just north of where it met the diversionary RCB.

Table 16. Continued

Section	Cotton/Bridges/Associate name for site	Map label	Proposed or existing crossing	Site description
5	Proposed Research Dr / Serrano Creek	**RDUC**	existing	● 2-arch corrugated underpass pipes that connected the Serrano Creek diversionary channel to the north to San Diego Creek to the south under Research Drive.
5	Proposed Research Dr / San Diego Creek	**RDTR**	existing	● Single arch underpass in the San Diego Creek under Research Dr. ● There was a large grate over the northeast entrance with vertical bars blocking carnivore access. ● On the southwest side, water was constantly pooled at the underpass entrance.
5	Irvine Center Drive / San Diego Creek	**ICSC**	existing	● RCB that connected San Diego Creek to the southeast channelized wall of Serrano Creek northeast of Irvine Center Dr. ● Connection was to allow animals to return to Serrano Creek to use the bridge underpass to navigate under the road. ● Water was constantly backed up inside the Serrano Creek channel from southwest of Irvine Center Dr to just north of where the ETY RCB met the diversionary RCB. ● Camera **ETISDN** monitored the animal movement path between the RCB and the road. ● Camera **ETISDS** monitored and area south of the road.
Peripheral	none	**IBLM**	existing	● RCB in the Bee Canyon Wash where it intersected Irvine Blvd at Lambert Rd. ● On the northeast side, drainage was full of rip rap and had 6' chain-link fence bordering the north side along Lambert Rd. ● 6' chain-link fence was present along Irvine Blvd in front of the University of California South Coast Research and Extension facility. ● On the southwest side, drainage was underground for about 1 km until it became an open channel at site BEAQ, which was downstream.
Peripheral	none	**BEAQ**	existing	● 3-RCB in the Bee Canyon Wash and at the break between the aircraft runways; downstream of site IBLM.
Peripheral	none	**MWFW**	existing	● Chain-link fence break near the railroad tracks and the CA-133 bridge overpasses spanning the tracks.

Figure 1. The El Toro study area was located between the Santa Ana Mountains and San Joaquin Hills in Orange County in California. Orange County, in southern California, bordered four counties and the Pacific Ocean.

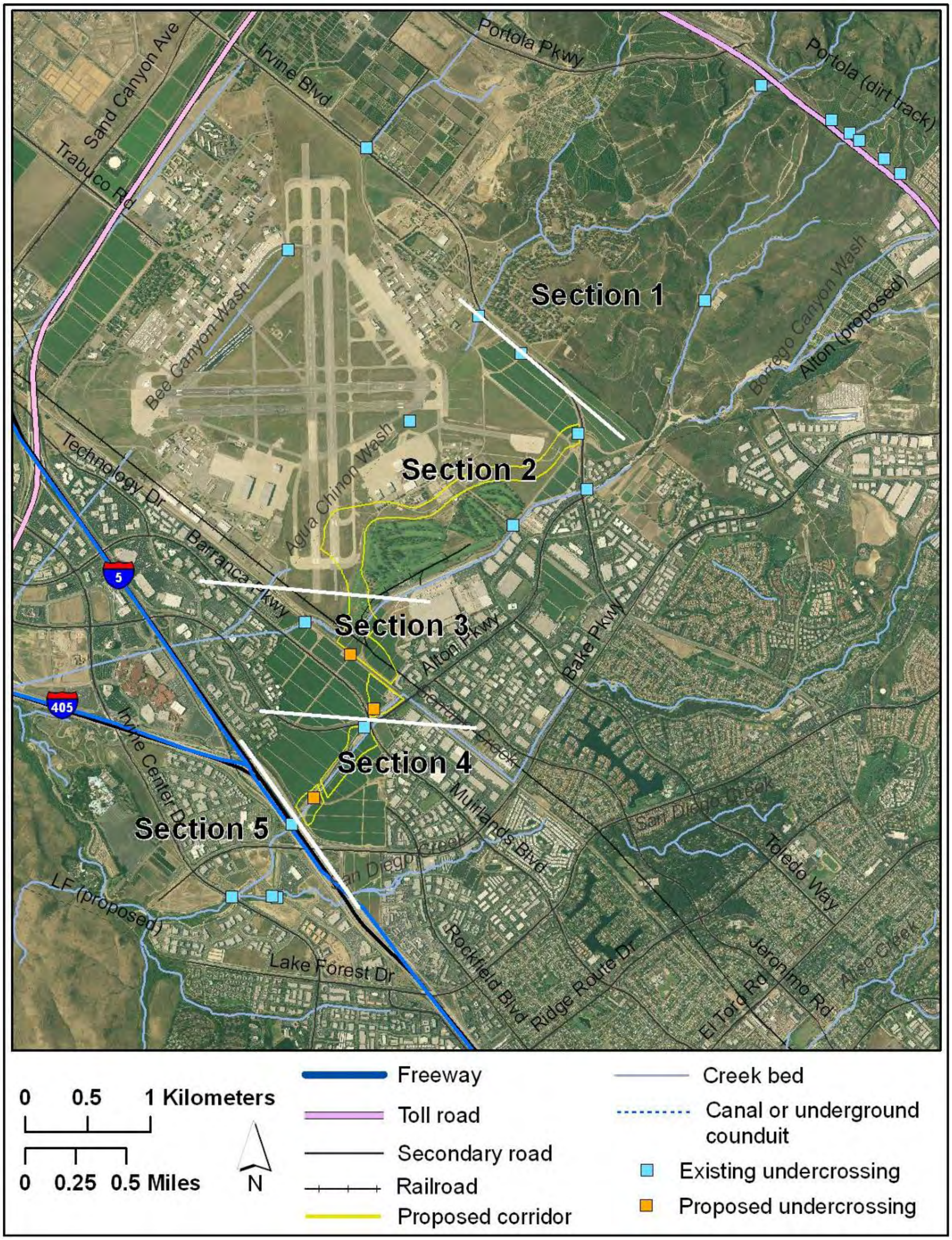


Figure 2. Sections 1-5 were approximated from Cotton/Bridges/Associates (May 2004) and marked by white lines. Undercrossings included culverts, bridges, and entrances or exits of underground creek channels.

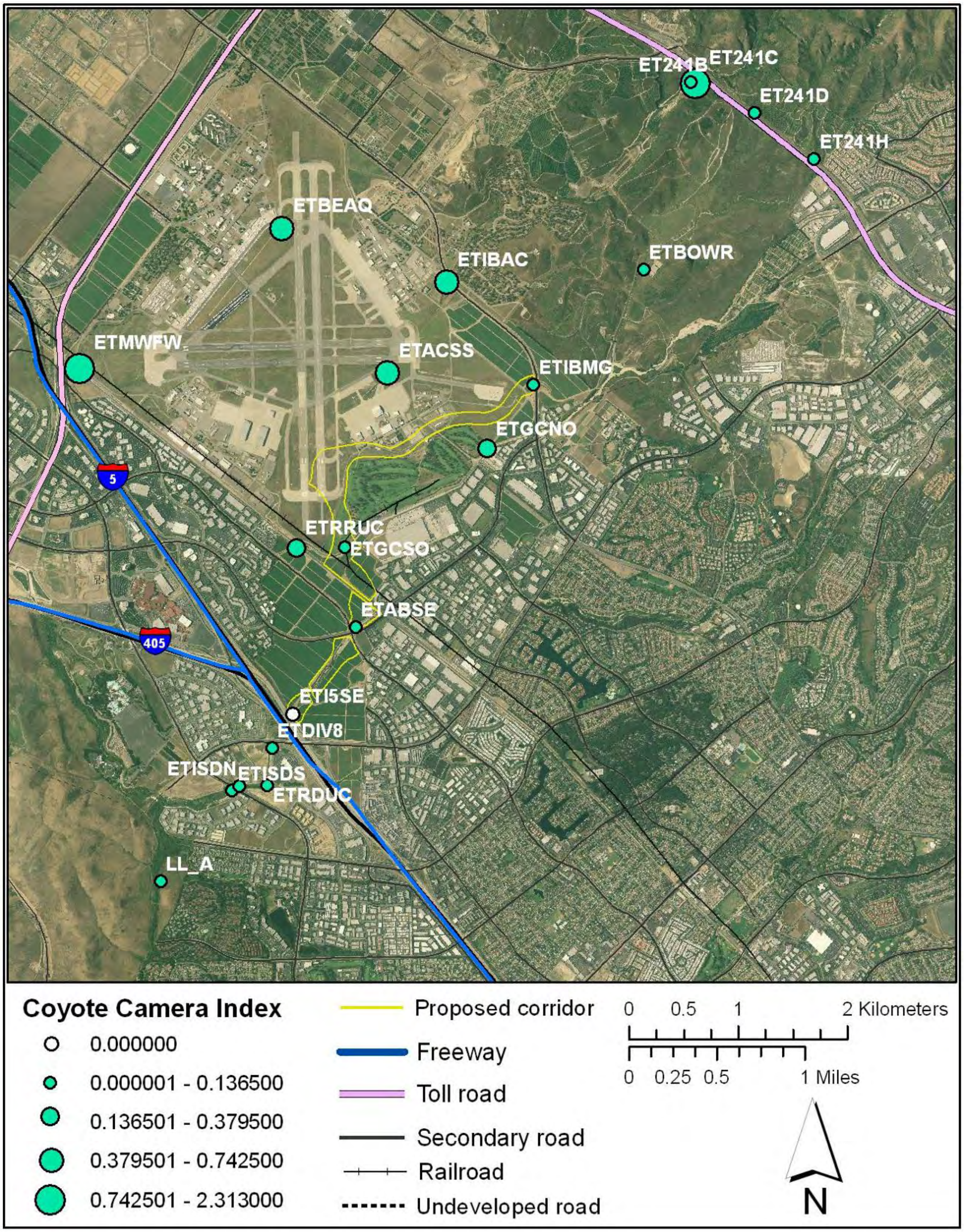


Figure 3. Camera trap results for coyote detections in the El Toro study area, Orange County, CA.

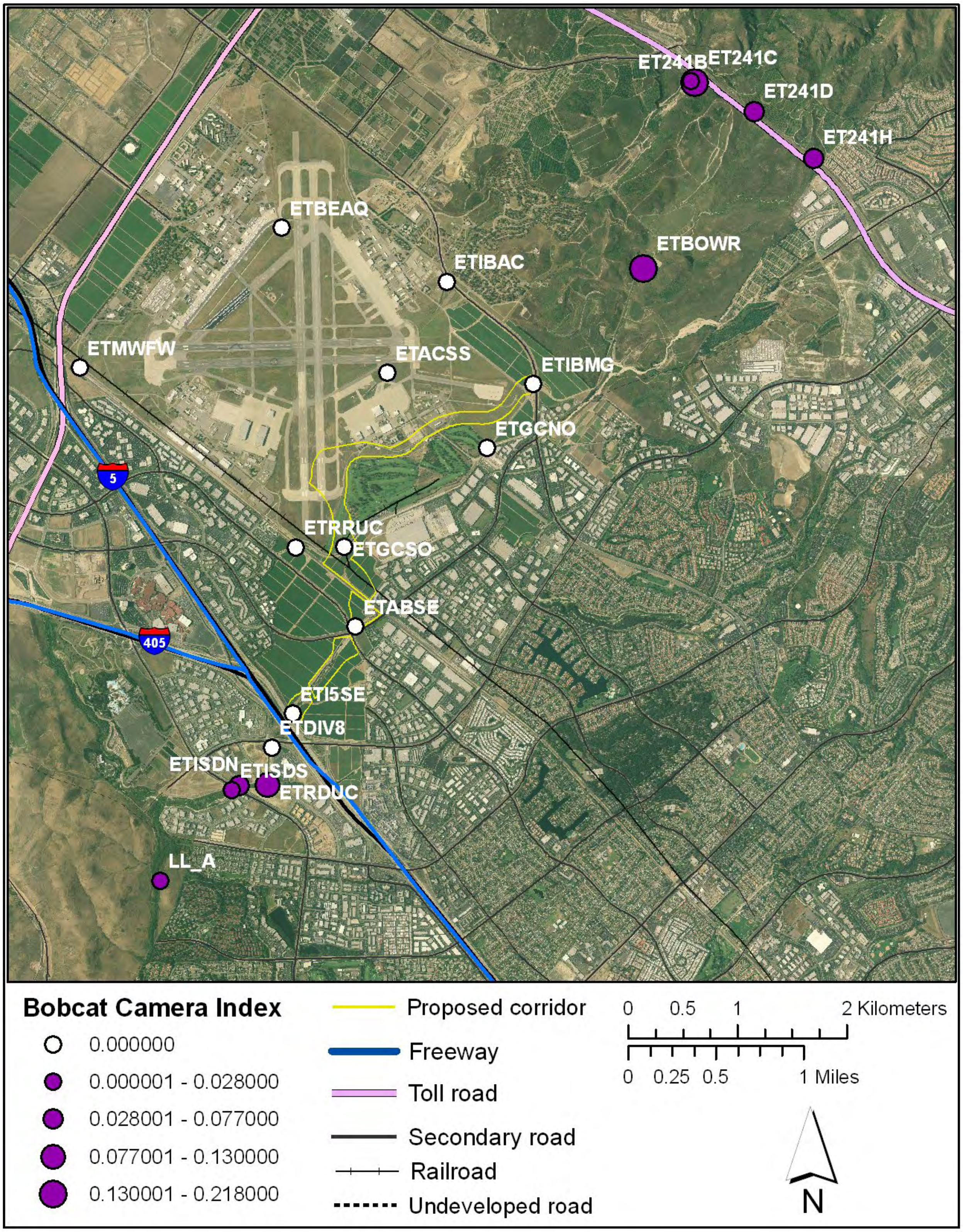


Figure 4. Camera trap results for bobcat detections in the El Toro study area, Orange County, CA.

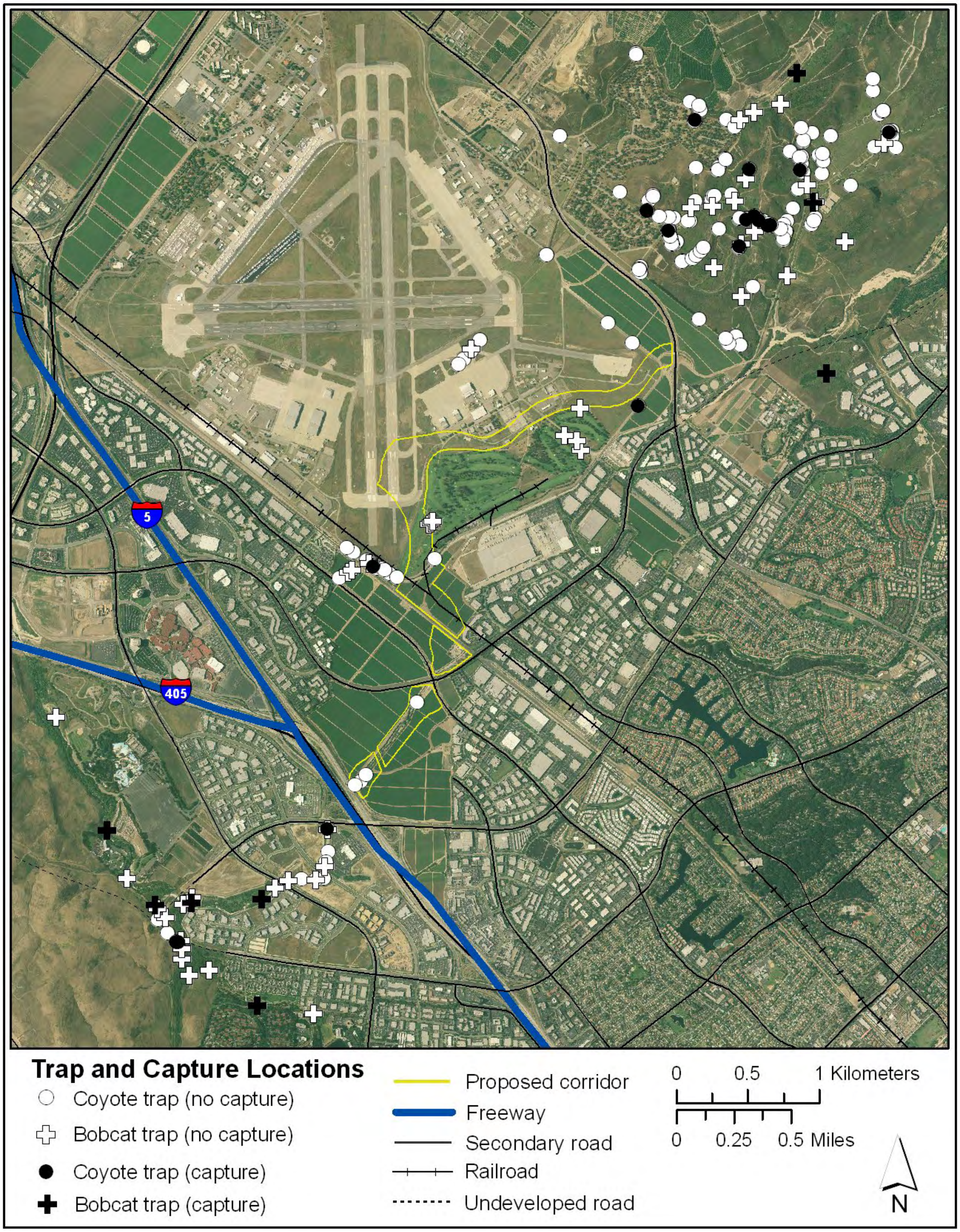


Figure 5. Coyote and bobcat trap and capture locations and in the El Toro study area, Orange County, CA.

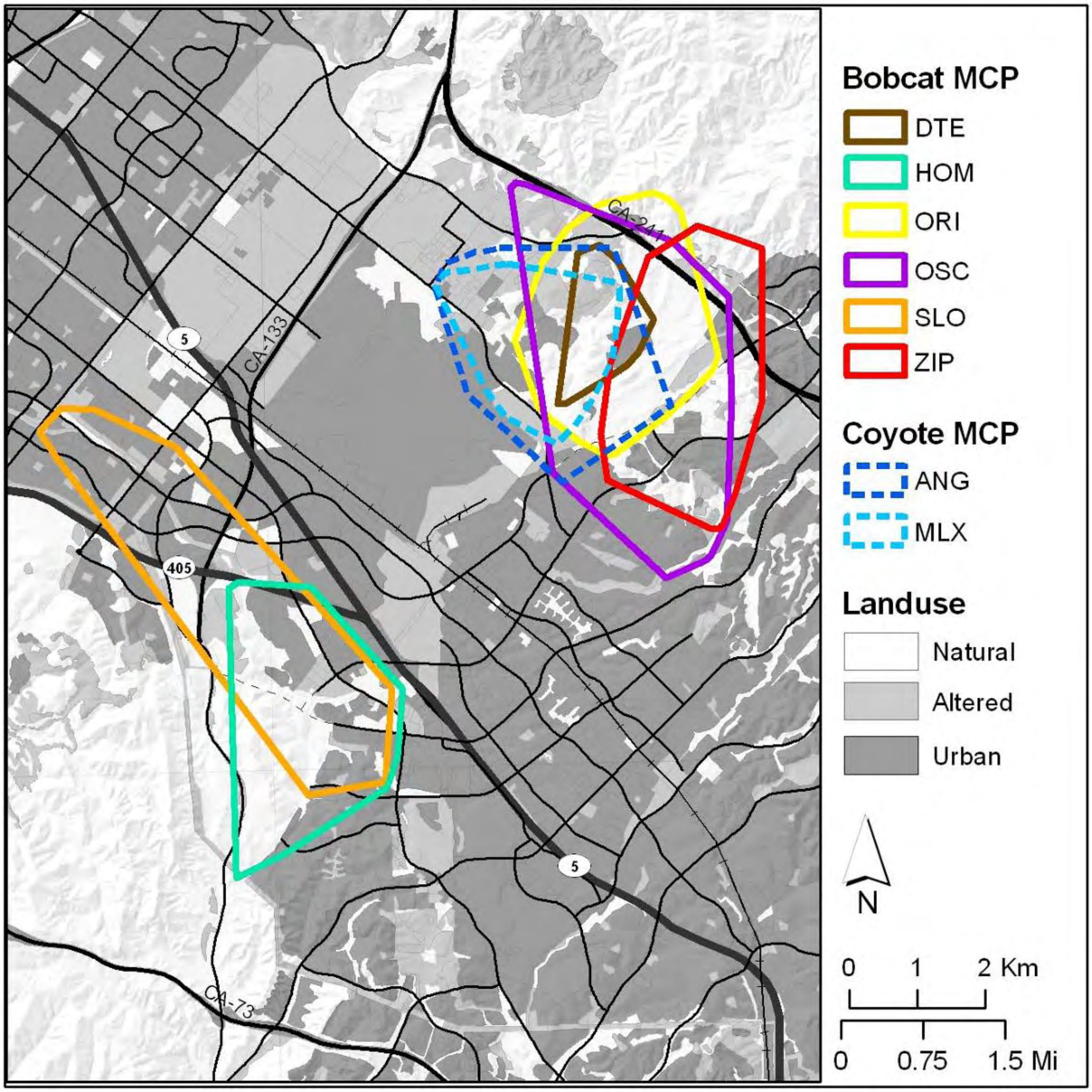


Figure 6. Minimum Convex Polygon (MCP) home ranges for bobcats and coyotes in the El Toro study area, Orange County, CA. Data for ZIP were collected after GPS-tracking of all other animals ended. All bobcats and coyotes except SLO were males.

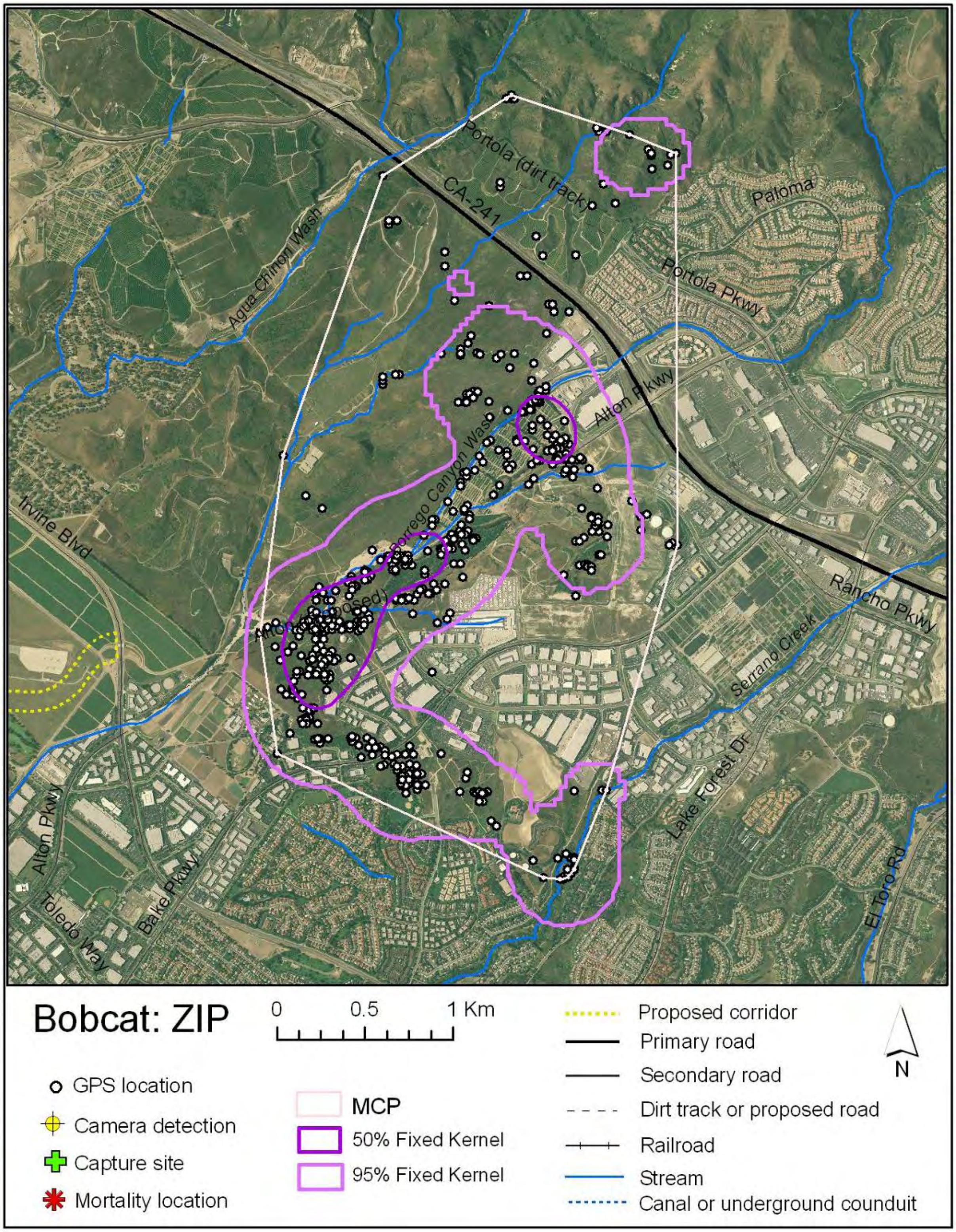


Figure 7a. Home range estimates and locations (n = 1,178) recorded for adult male bobcat ZIP from January 7 to April 3, 2008 in the El Toro study area, Orange County, CA. GPS tracking of ZIP started after the Santiago Canyon Fire had burned areas of the former El Toro Marine Base north of Irvine Boulevard.

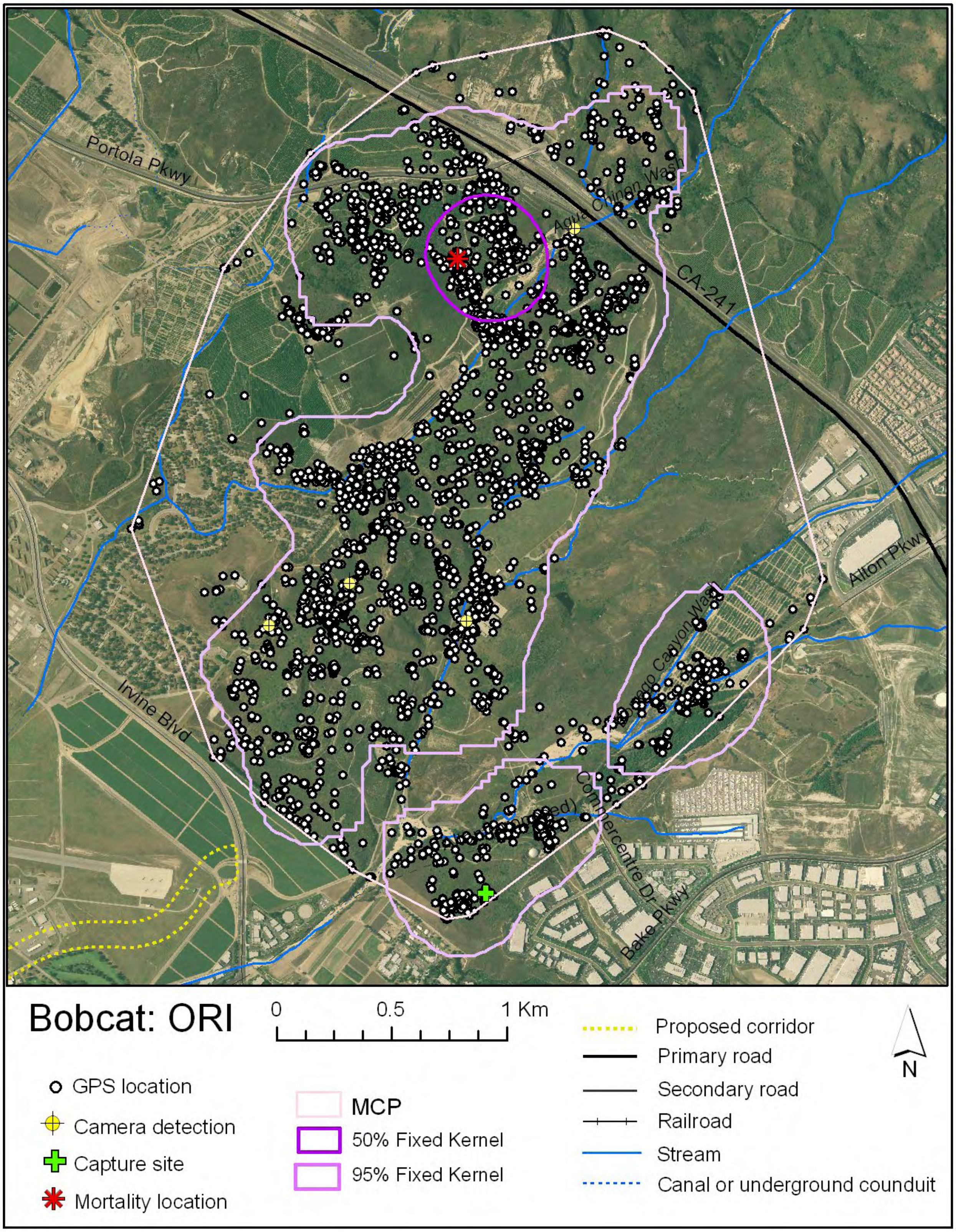


Figure 7b. Home range estimates and locations (n = 4,011) recorded for adult male bobcat ORI from February 23 to June 5, 2007, in the El Toro study area, Orange County, CA.

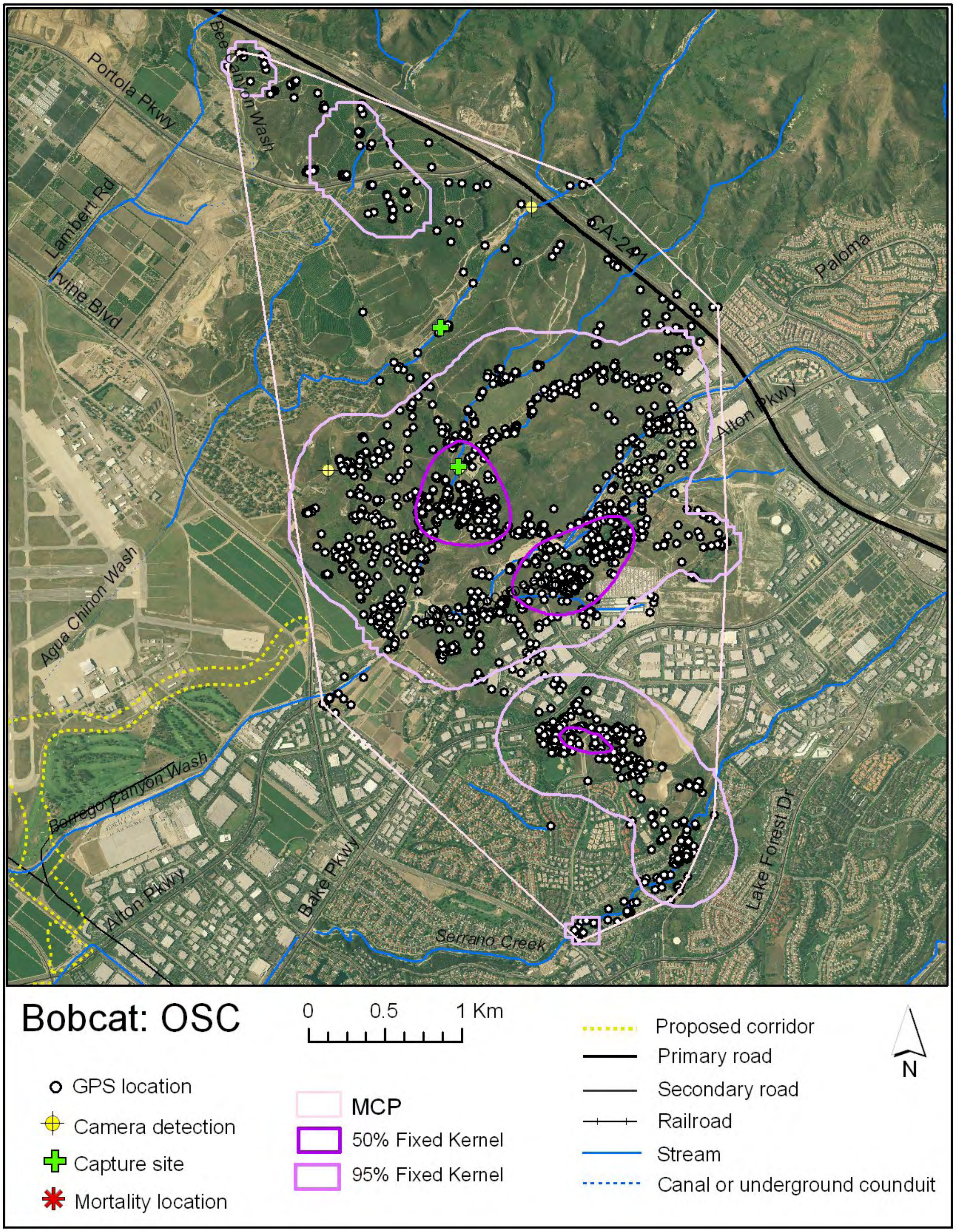


Figure 7c. Home range estimates and locations (*n* = 3,209) recorded for adult male bobcat OSC from March 7 to August 8, 2007, in the El Toro study area, Orange County, CA.

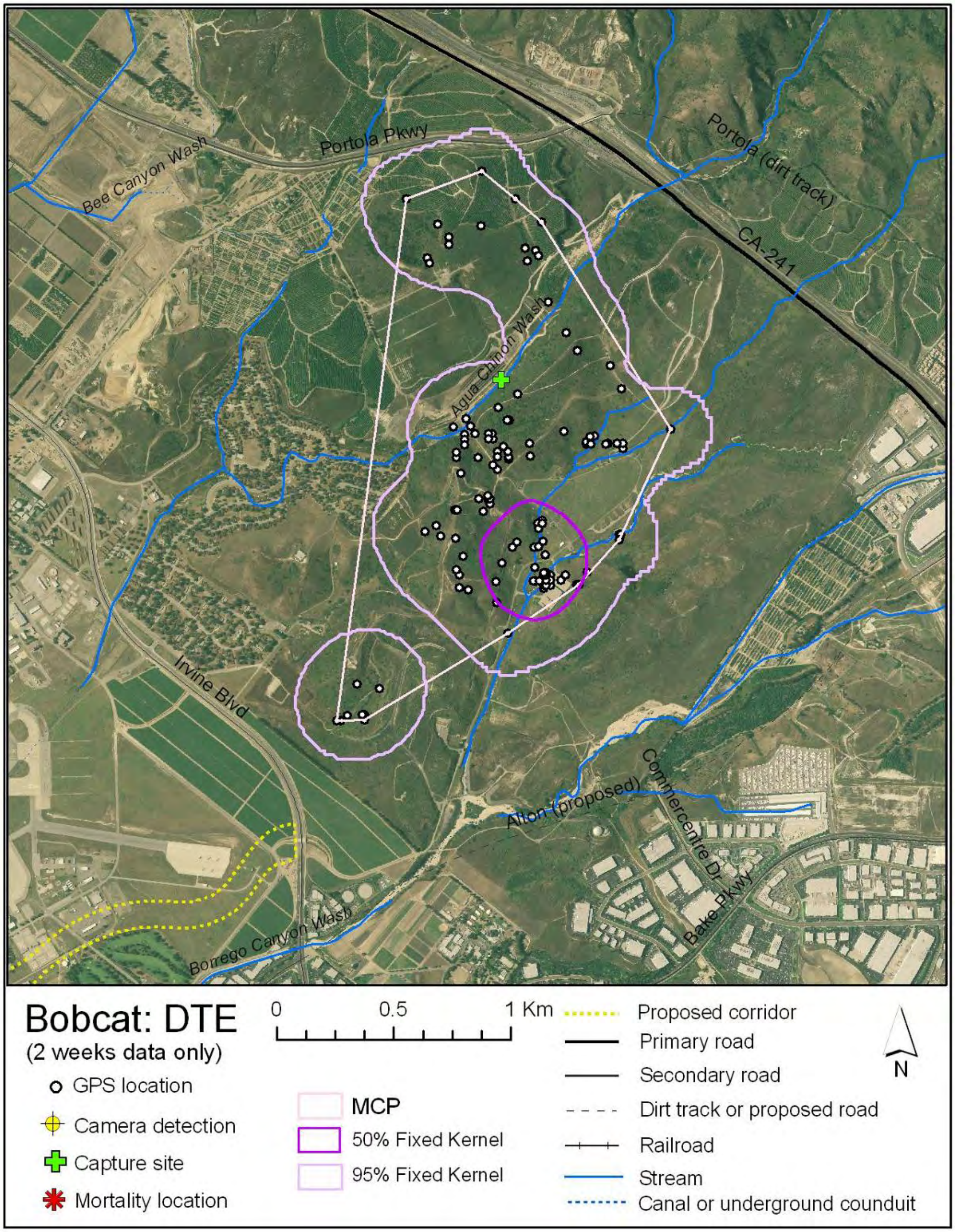


Figure 7d. Home range estimates and locations (n = 158) recorded for adult male bobcat DTE from May 10 - 25, 2007, in the El Toro study area, Orange County, CA.

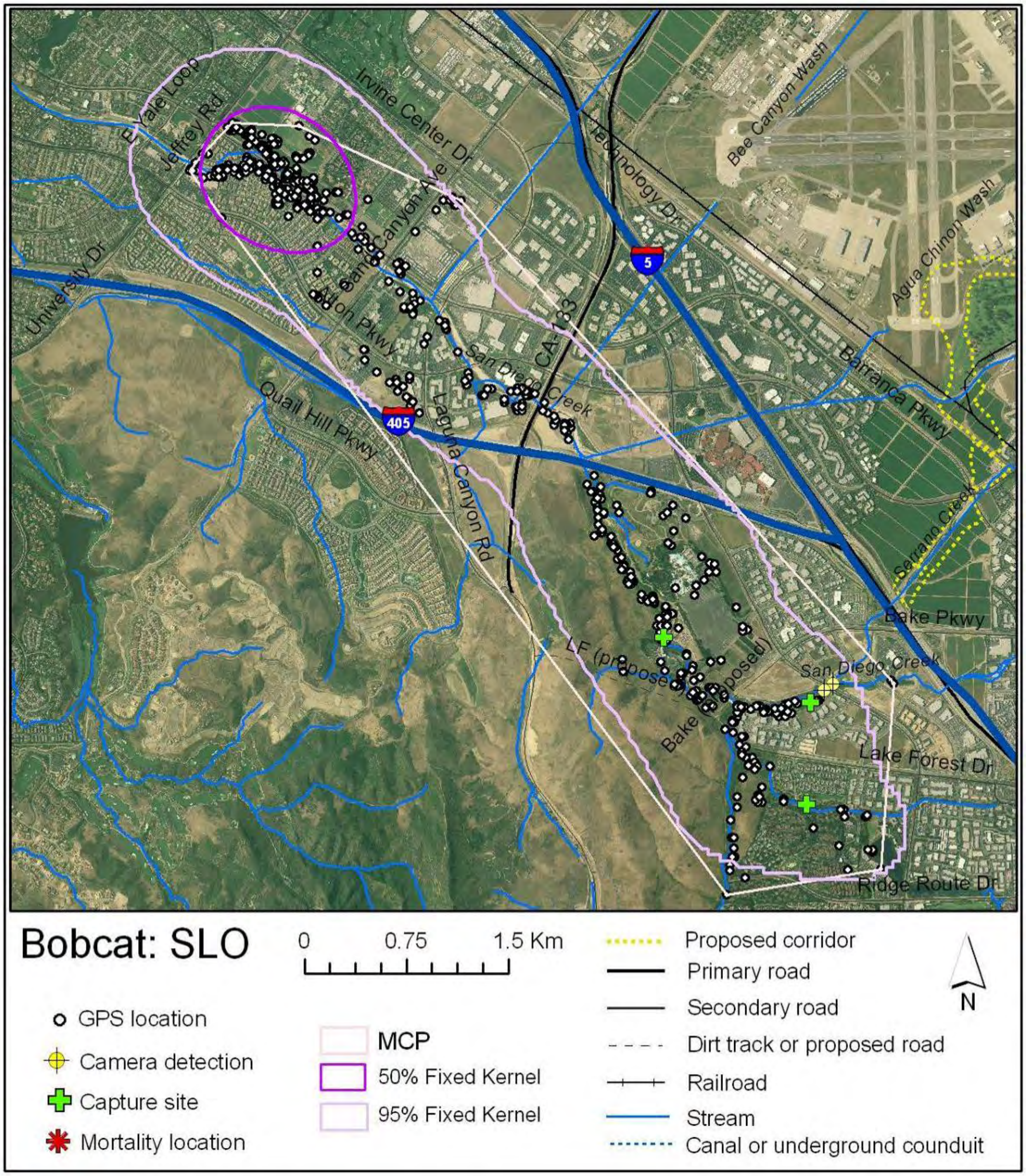


Figure 7e. Home range estimates and locations (n = 730) recorded for adult female bobcat SLO from February 7 to April 30, 2007, in the El Toro study area, Orange County, CA.

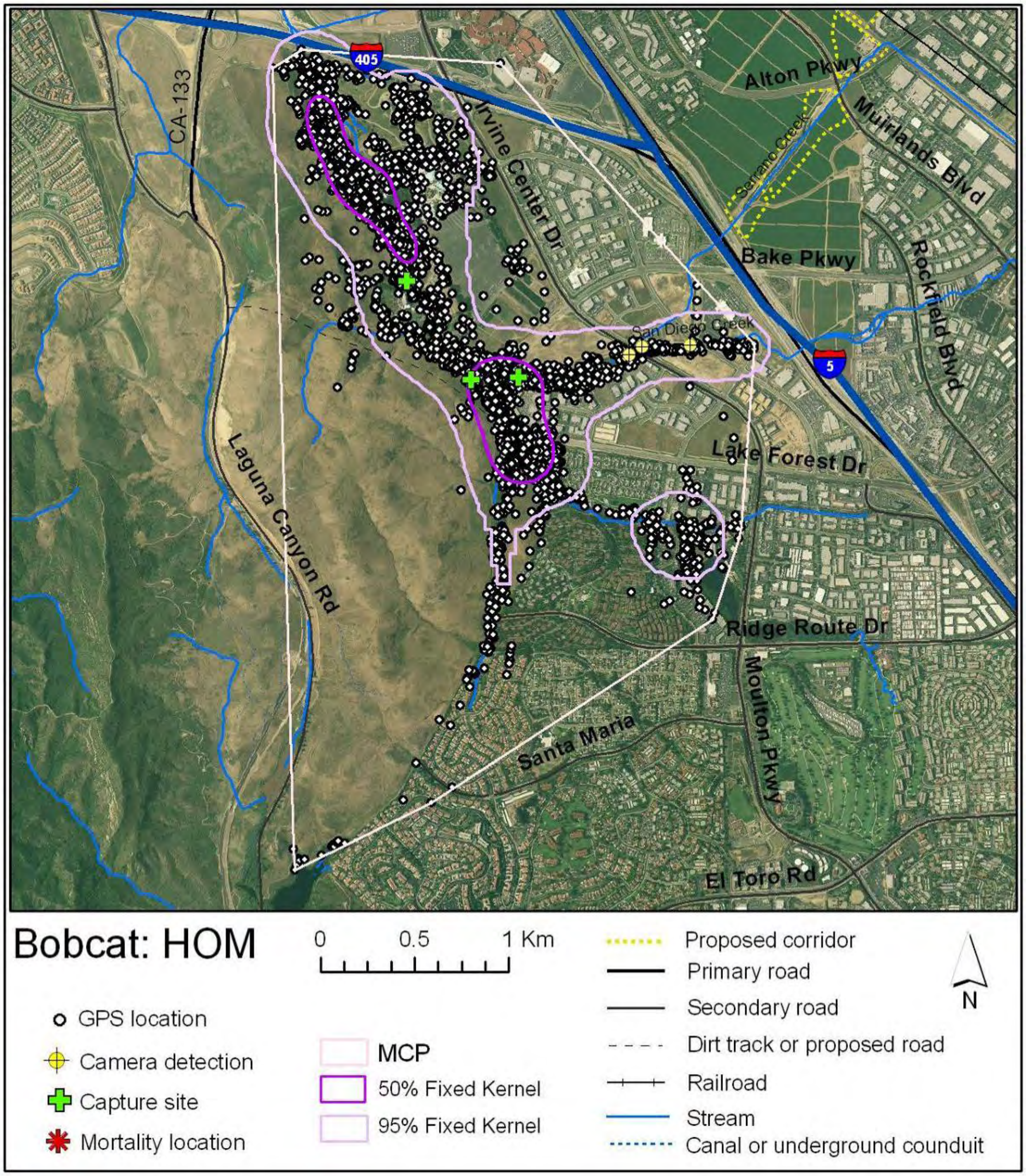


Figure 7f. Home range estimates and locations (n = 5,595) recorded for adult male bobcat HOM from January 31 to June 17, 2007, in the El Toro study area, Orange County, CA.

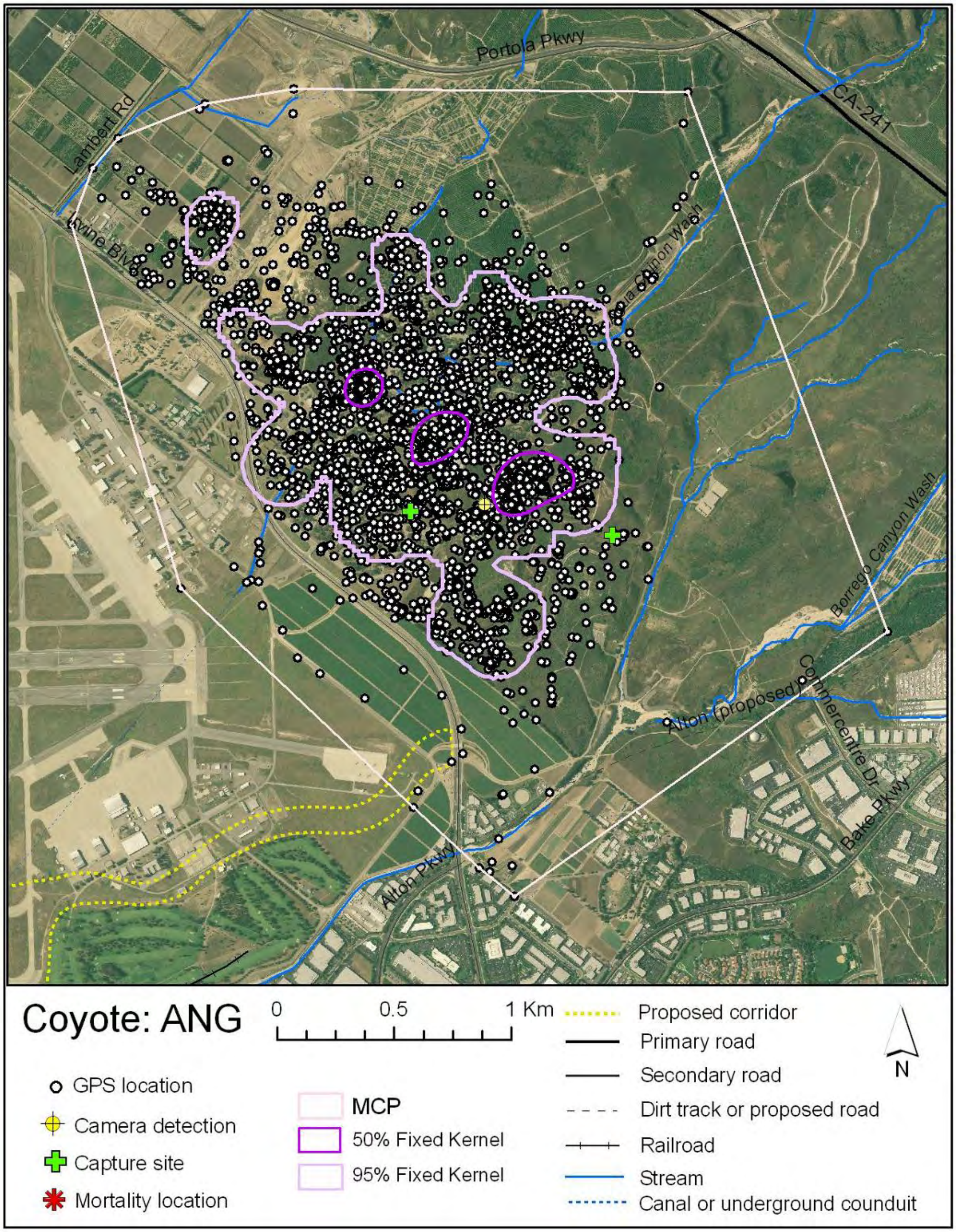


Figure 8a. Home range estimates and locations (n = 5,768) recorded for yearling male coyote ANG from November 16, 2006 to March 29, 2007, in the El Toro study area, Orange County, CA.

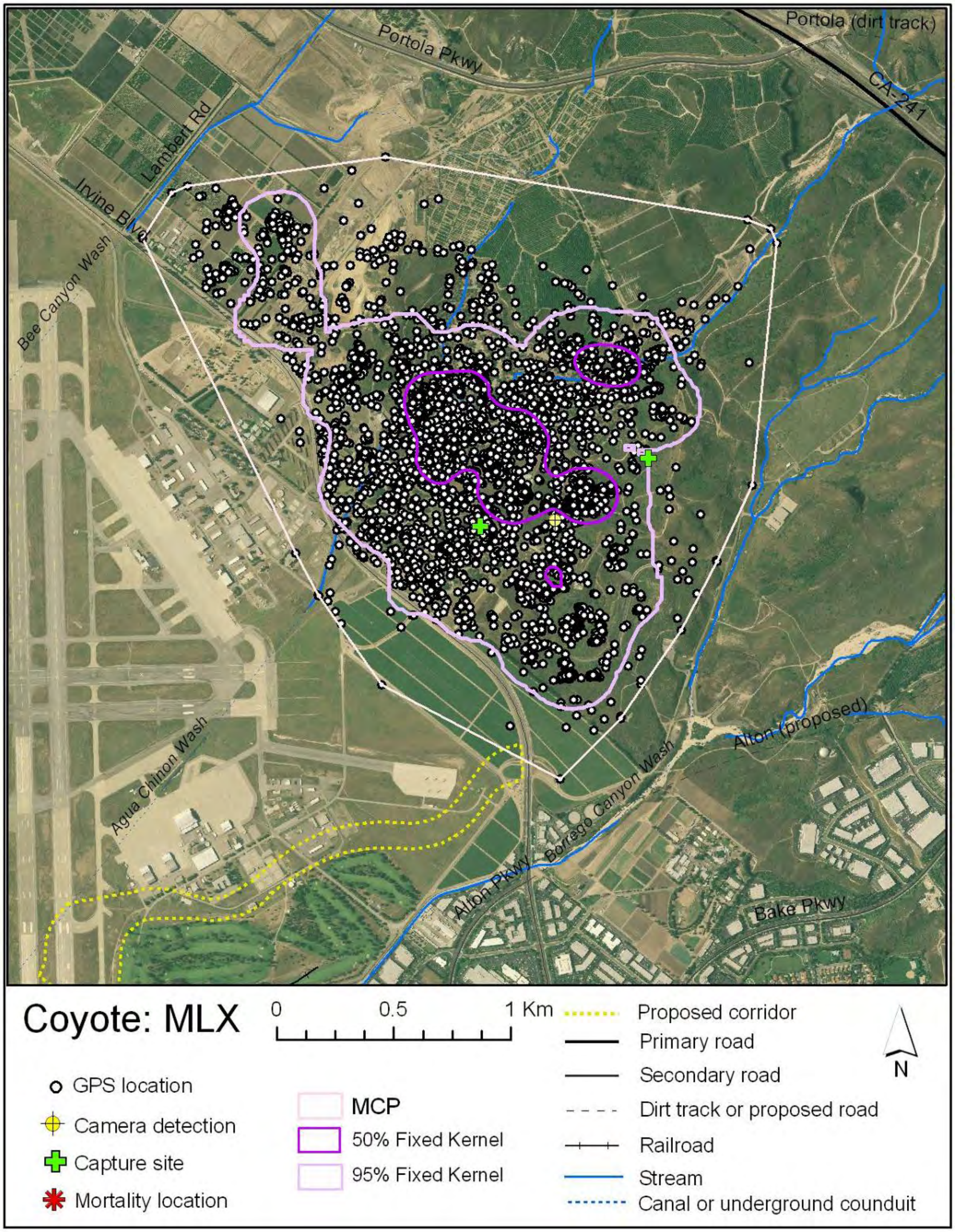


Figure 8b. Home range estimates and locations (n = 5,102) recorded for yearling male coyote MLX from November 16, 2006 to March 14, 2007, in the El Toro study area, Orange County, CA.

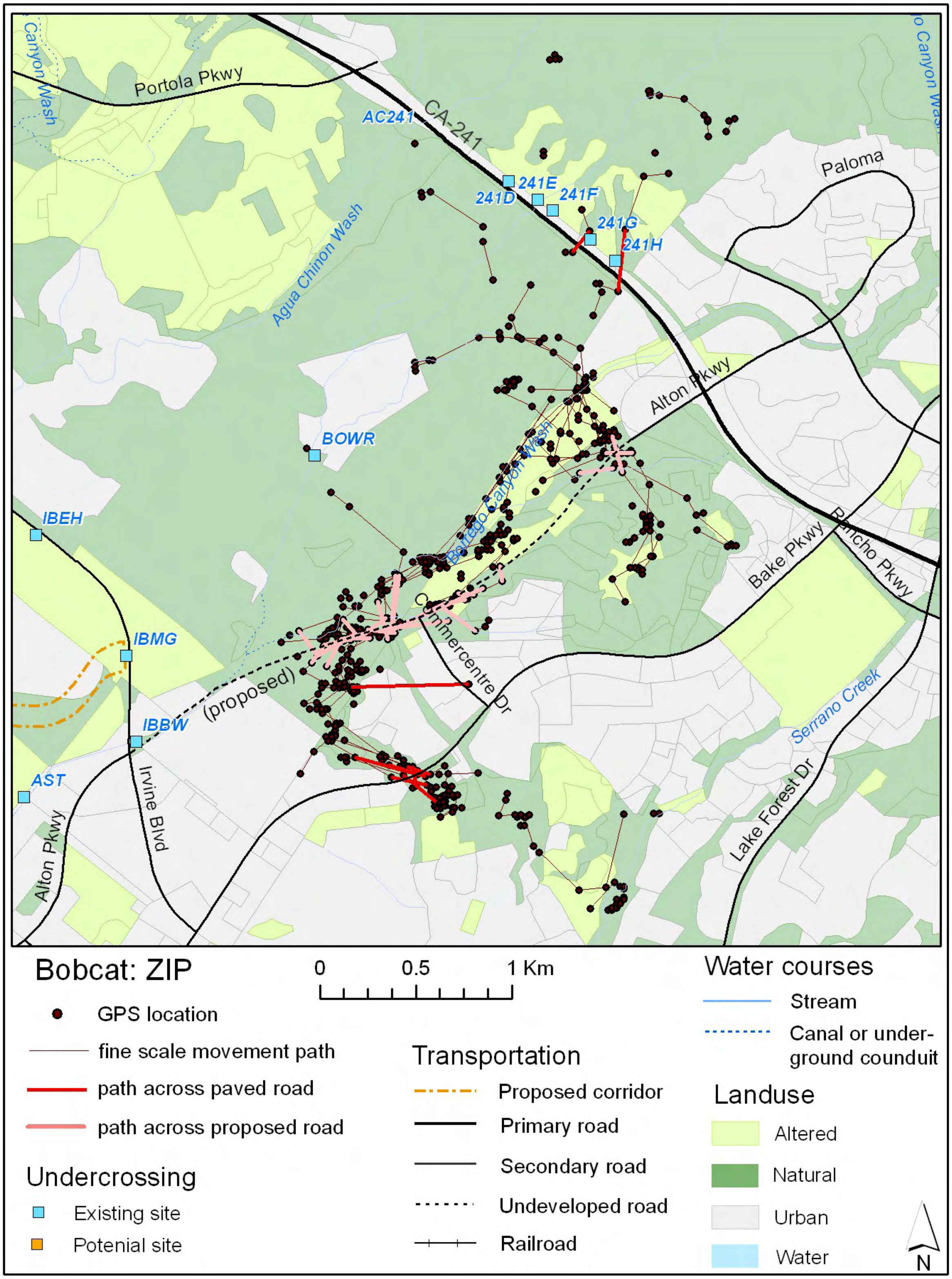


Figure 9a. GPS locations and fine-scale movement paths for adult male bobcat ZIP from January 7 to April 3, 2008, in the El Toro study area, Orange County, CA.

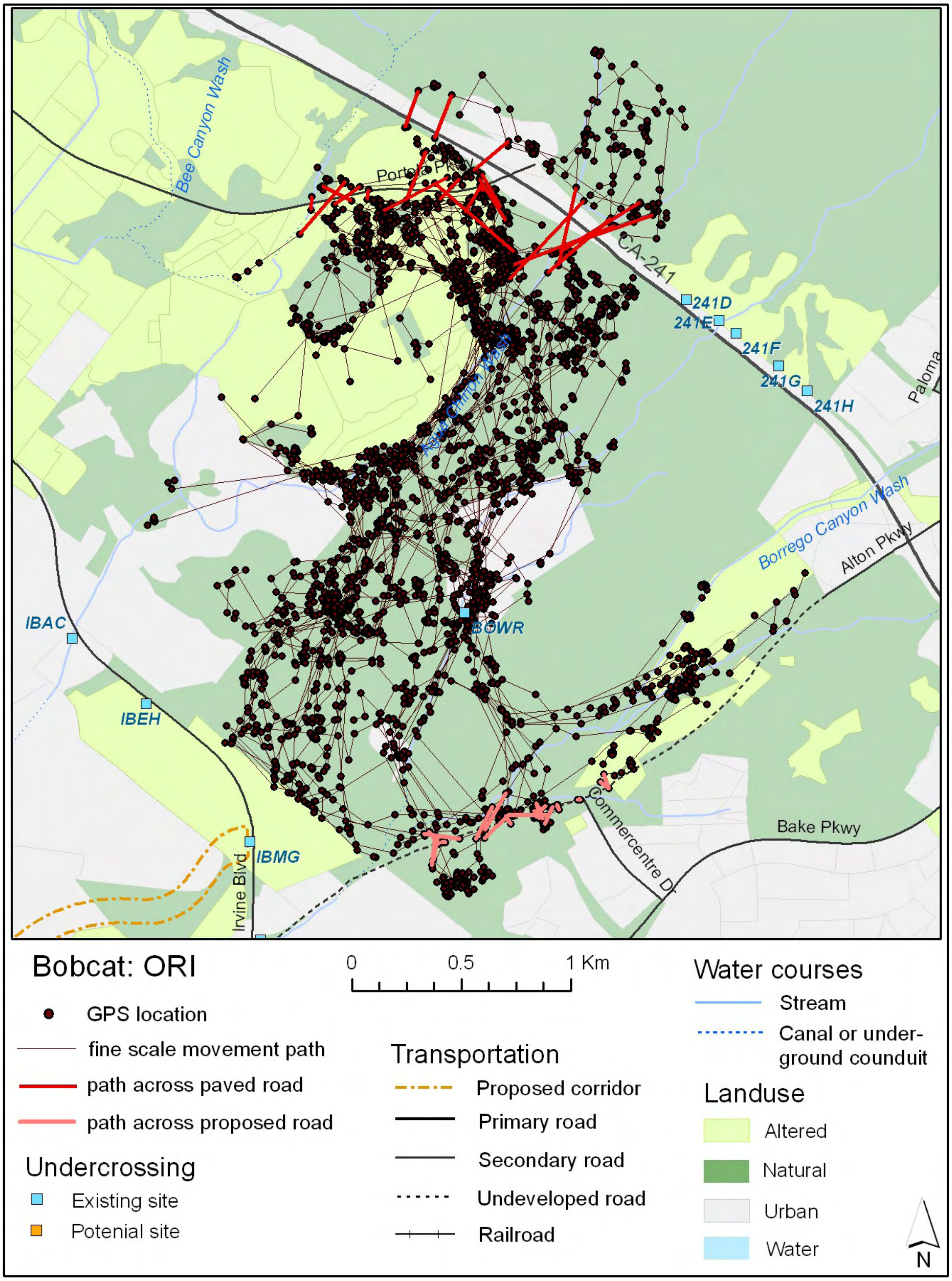


Figure 9b. GPS locations and fine-scale movement paths for adult male bobcat ORI from February 23 to June 5, 2007, in the El Toro study area, Orange County, CA.

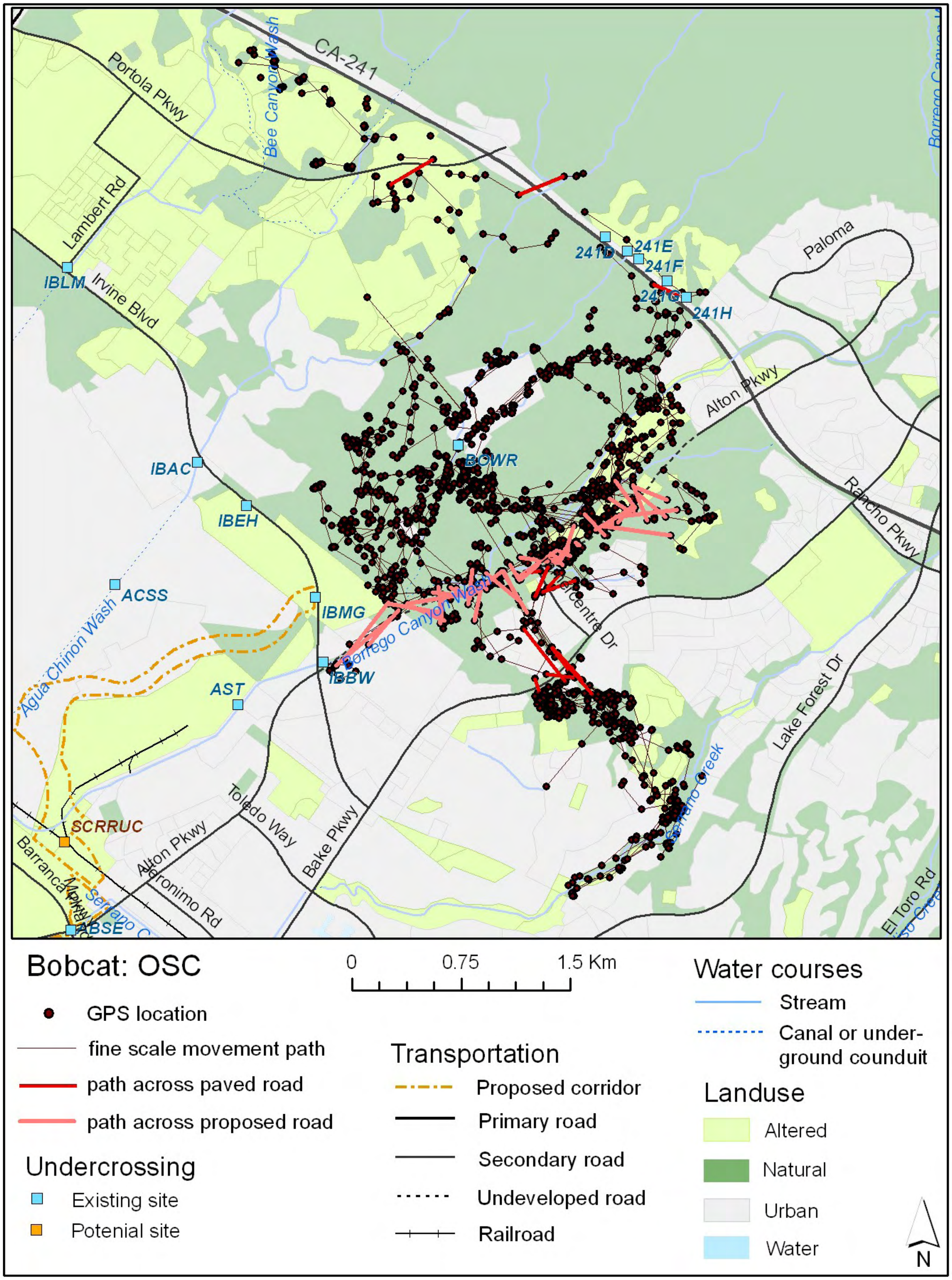


Figure 9c. GPS locations and fine-scale movement paths for adult male bobcat OSC from Mary 7 to August 8, 2007, in the El Toro study area, Orange County, CA.

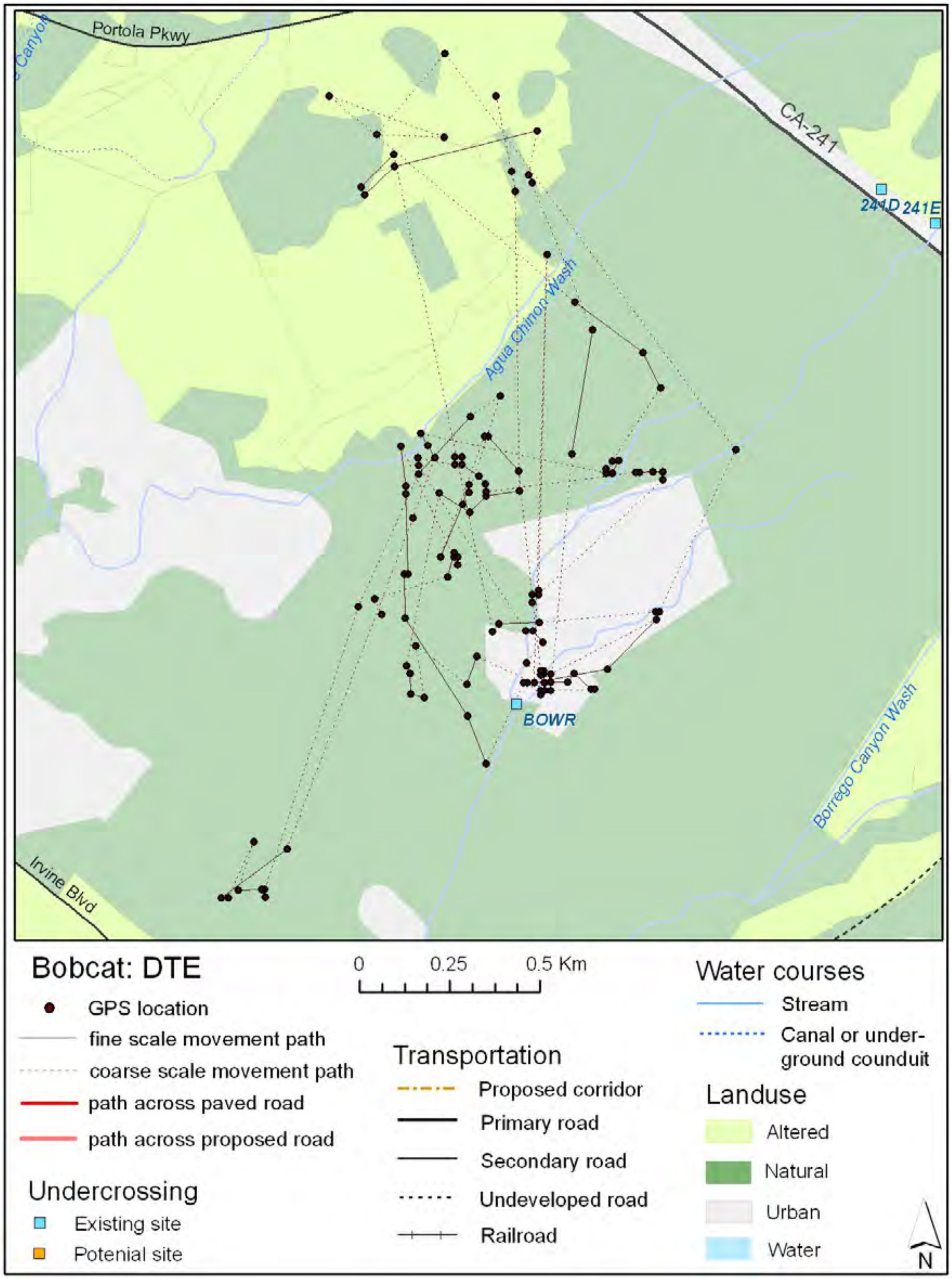


Figure 9d. Only 2 weeks (May 10 – 25, 2007) of GPS locations were obtained for adult male bobcat DTE, and thus relatively few movement paths were estimated, so both fine-scale and coarse-scale movement paths are shown here for DTE in the El Toro study area, Orange County, CA.

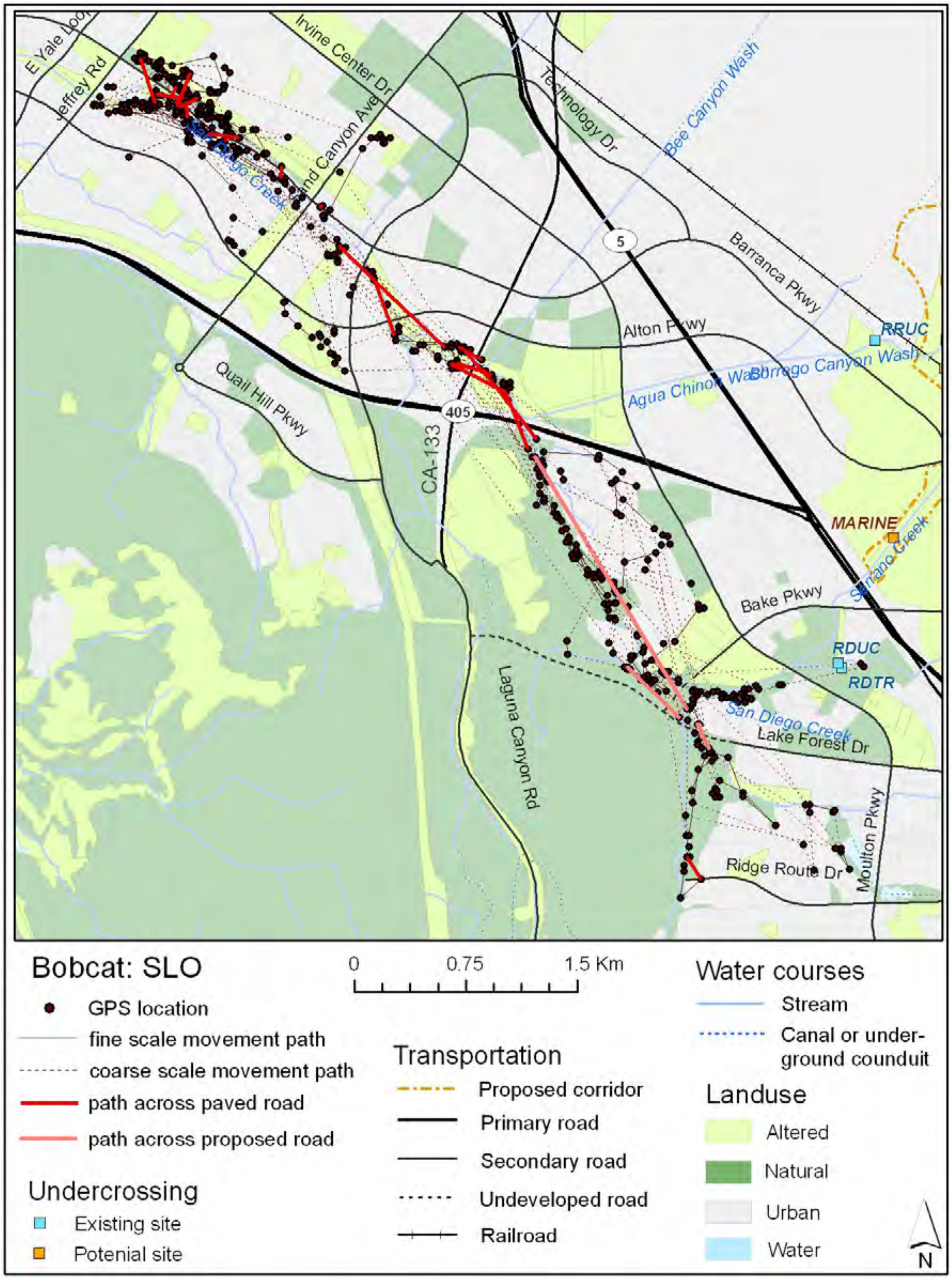


Figure 9e. GPS locations and movement paths of adult female bobcat SLO from February 7 to April 30, 2007, in the El Toro study area, Orange County, CA indicated that she usually traveled along creek beds, following San Diego Creek back and forth across I-405 and CA-133.

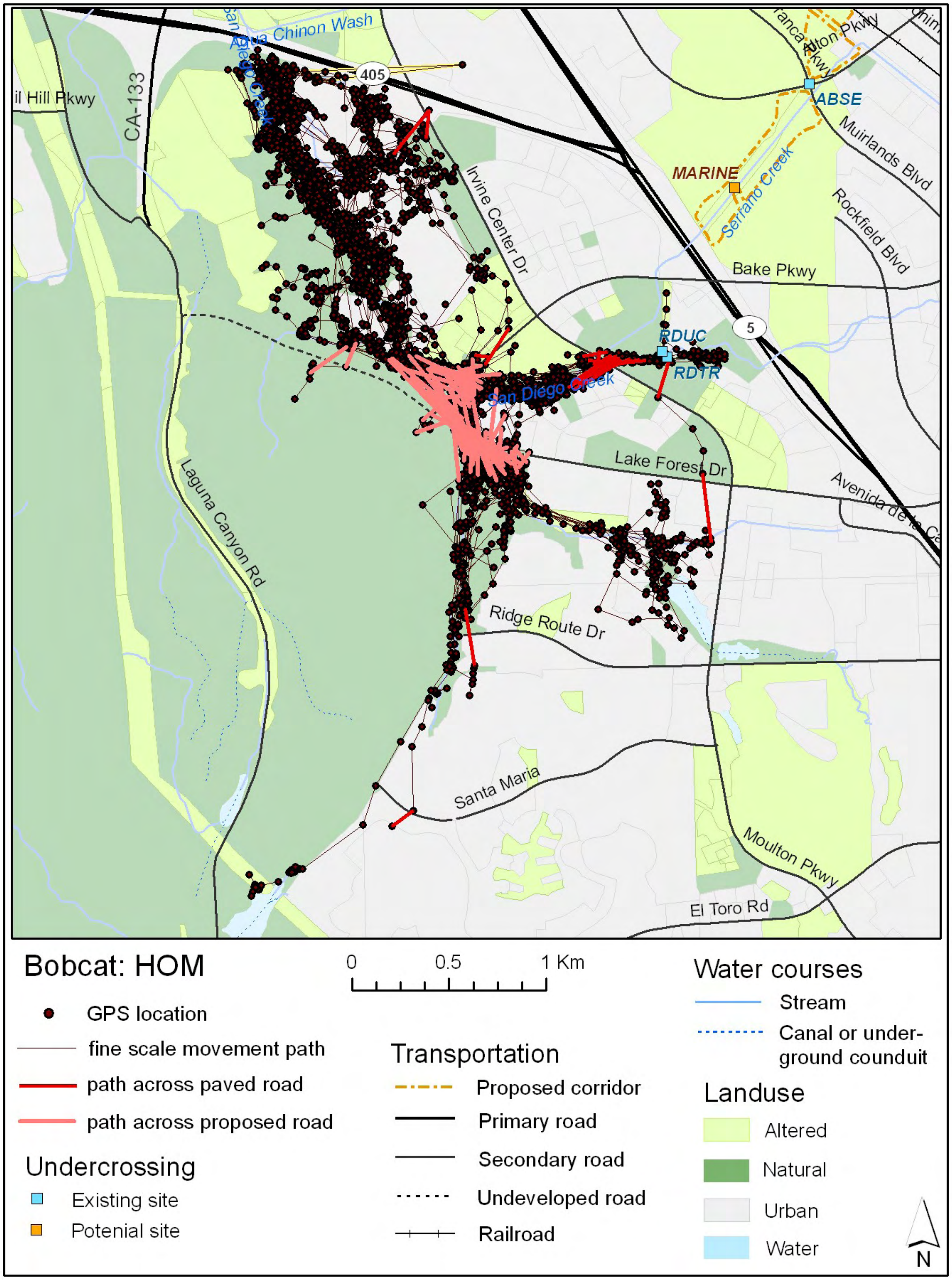


Figure 9f. GPS locations and fine-scale movement paths for adult male bobcat HOM from January 31 to June 17, 2007, in the El Toro study area, Orange County, CA.

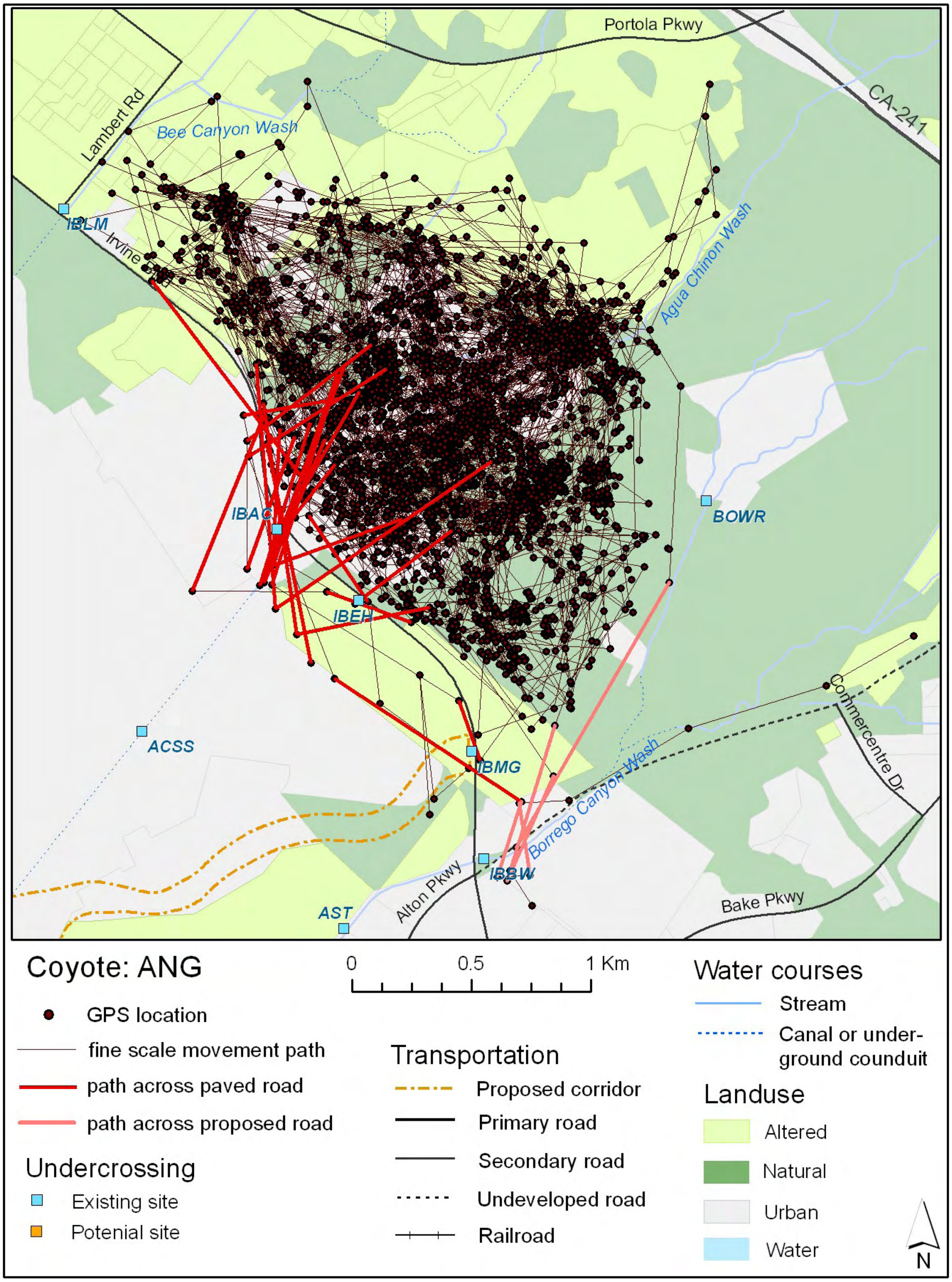


Figure 10a. GPS locations and fine-scale movement paths for yearling male coyote ANG from November 16, 2006 to March 29, 2007, in the El Toro study area, Orange County, CA.

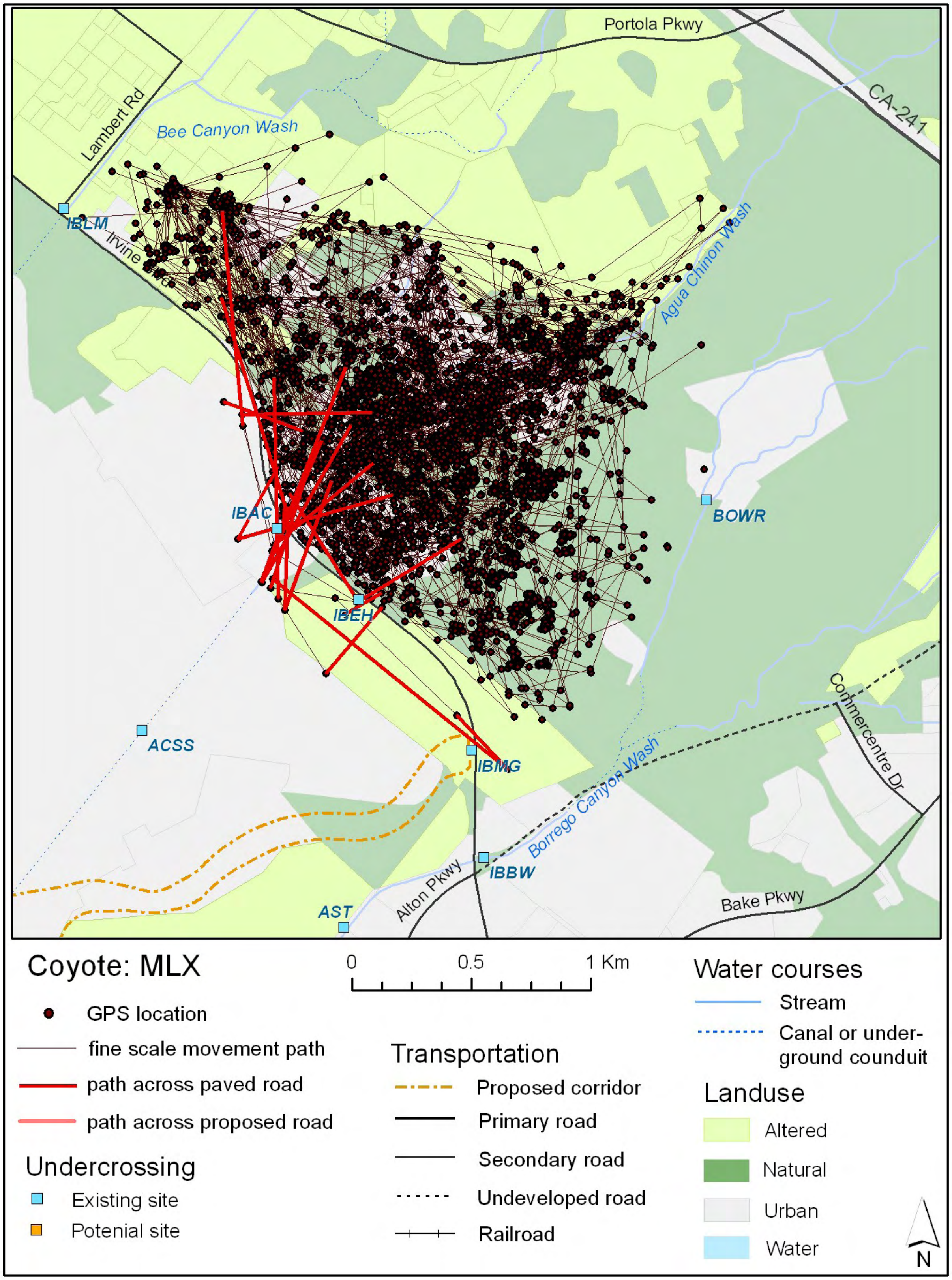


Figure 10b. GPS locations and fine-scale movement paths for yearling male coyote MLX from November 16, 2006 to March 14, 2007, in the El Toro study area, Orange County, CA.

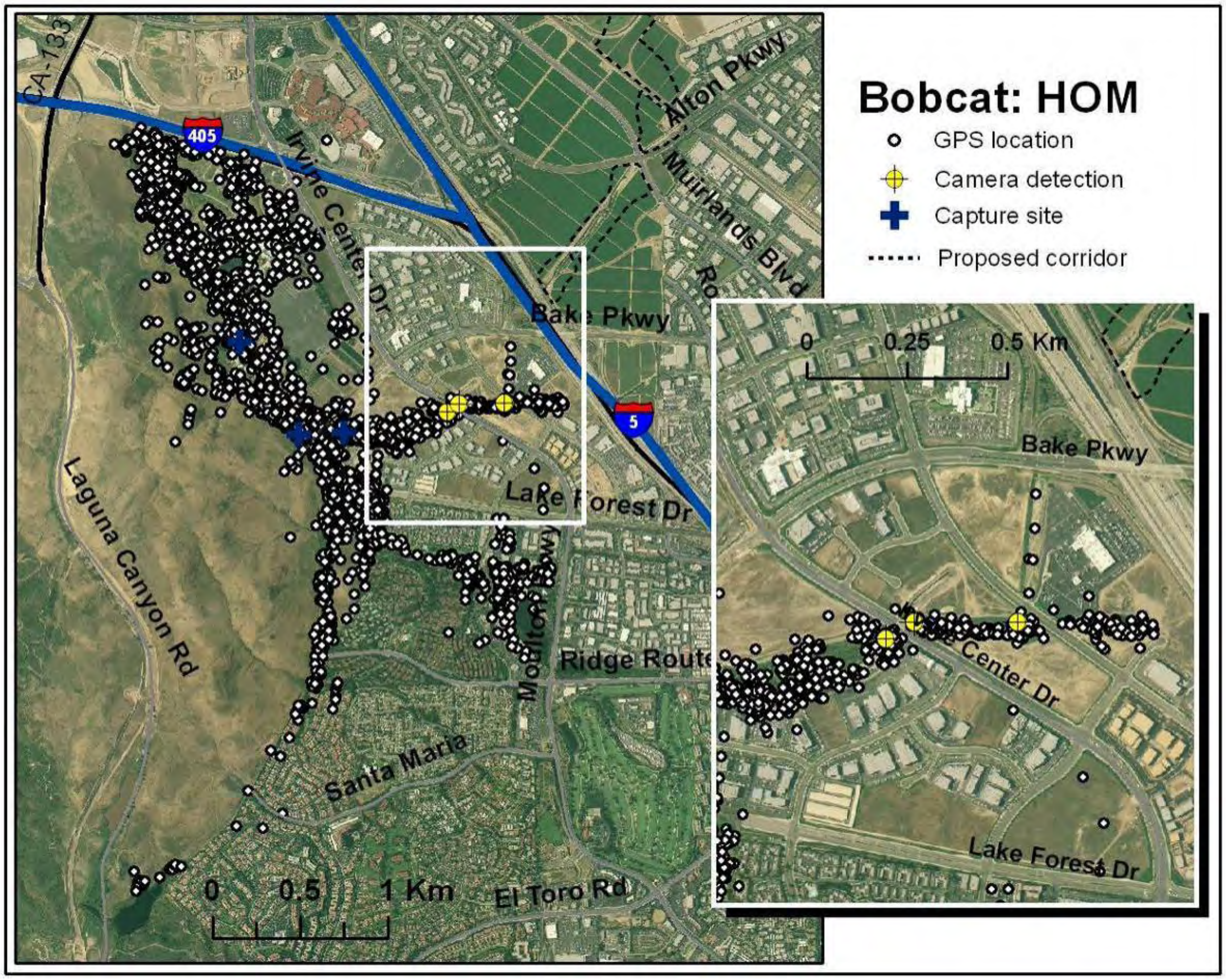


Figure 11. GPS locations indicated that adult male bobcat HOM approached undercrossing site DIV8 but did not cross through the underpass during GPS tracking in the El Toro study area, Orange County, CA.

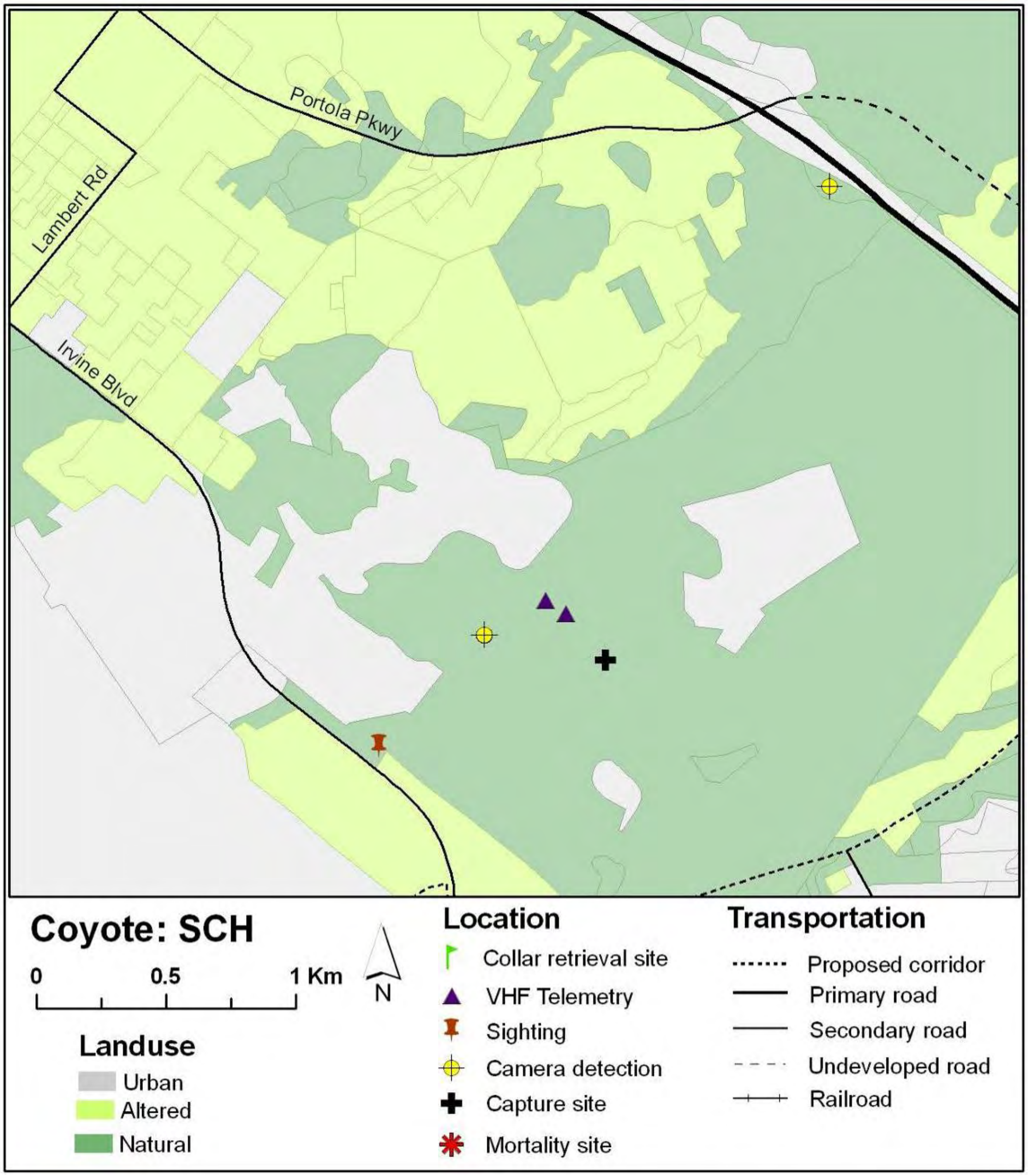


Figure 12a. VHF telemetry and other detection data for adult male coyote SCH from November 16, 2006 to February 23, 2008, in the El Toro study area, Orange County, CA.

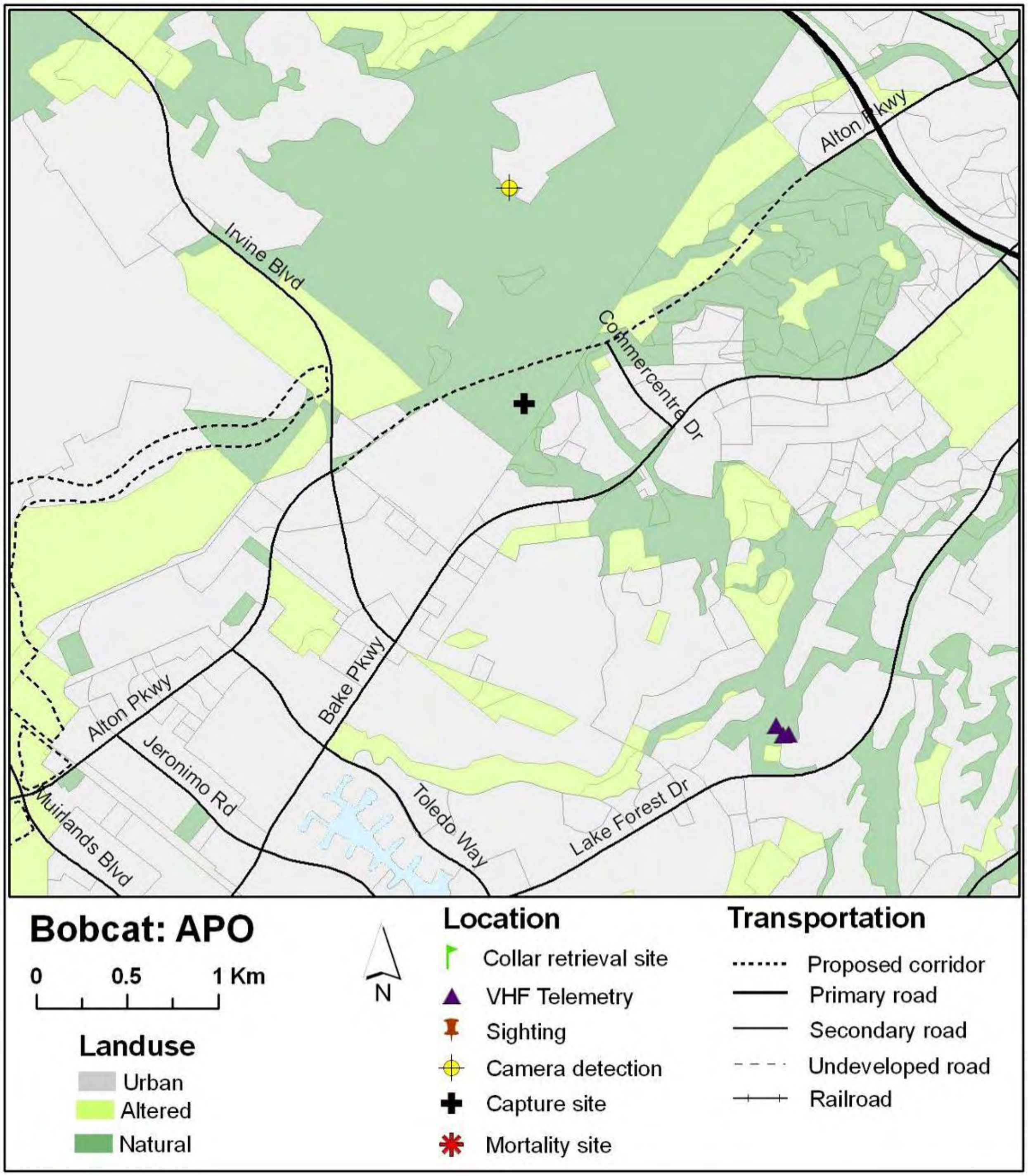


Figure 12b. VHF telemetry and other detection data for yearling male bobcat APO from February 21 to April 3, 2007, in the El Toro study area, Orange County, CA.

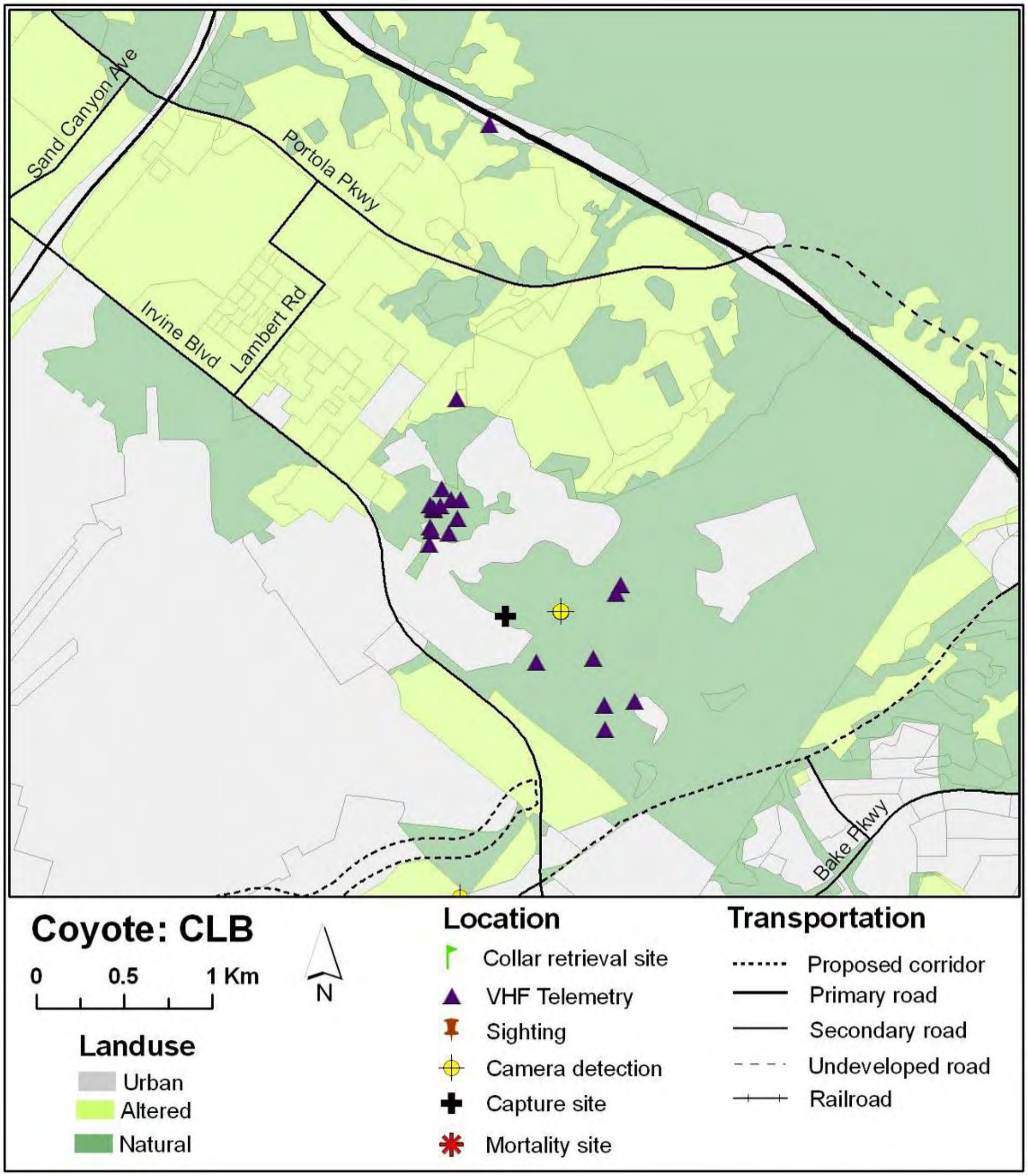


Figure 12c. VHF telemetry and other detection data for adult male coyote CLB from June 3, 2007 to March 22, 2008, in the El Toro study area, Orange County, CA.

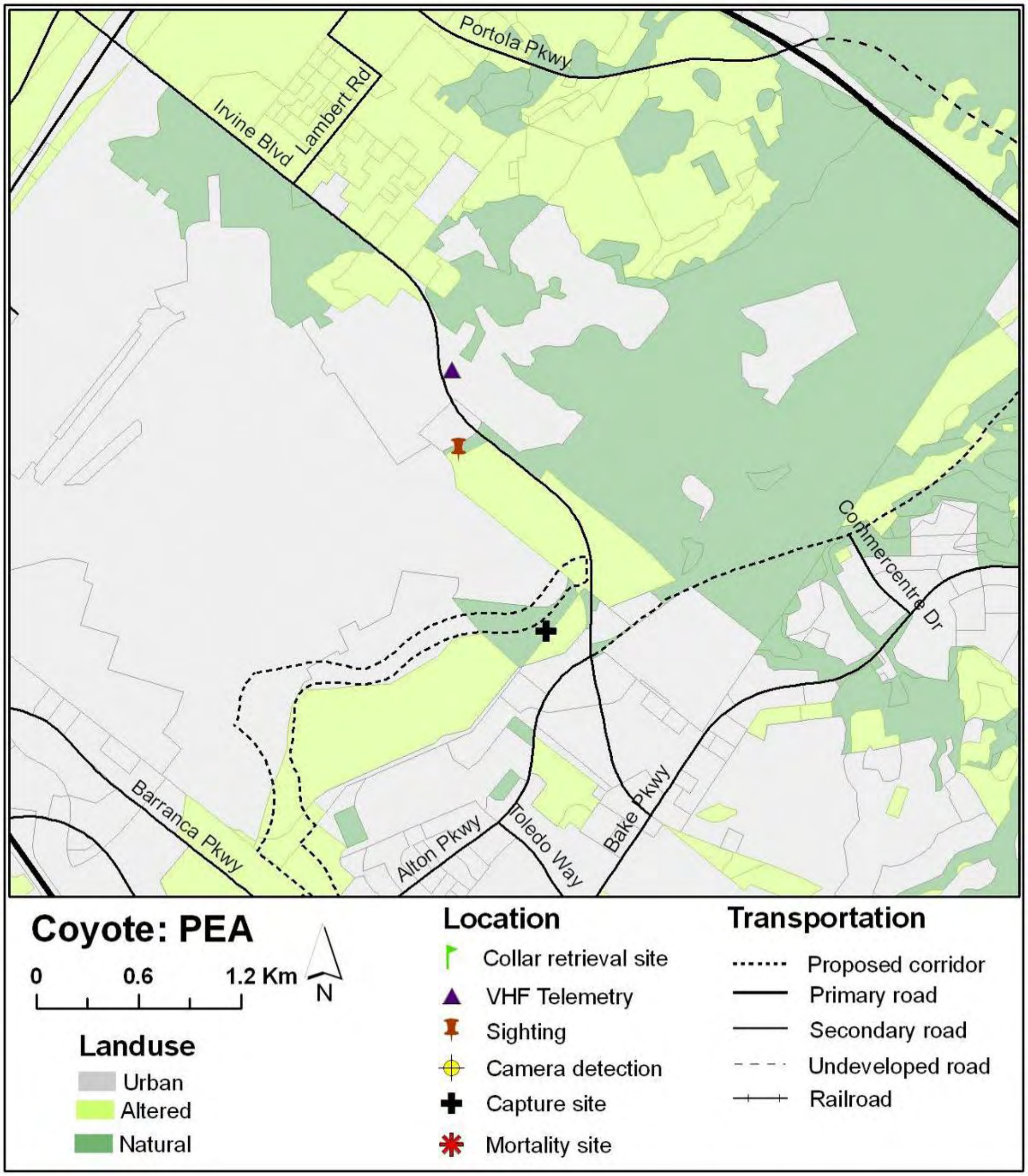


Figure 12d. VHF telemetry and other detection data for adult female coyote PEA from December 8, 2006 to January 17, 2007, in the El Toro study area, Orange County, CA.

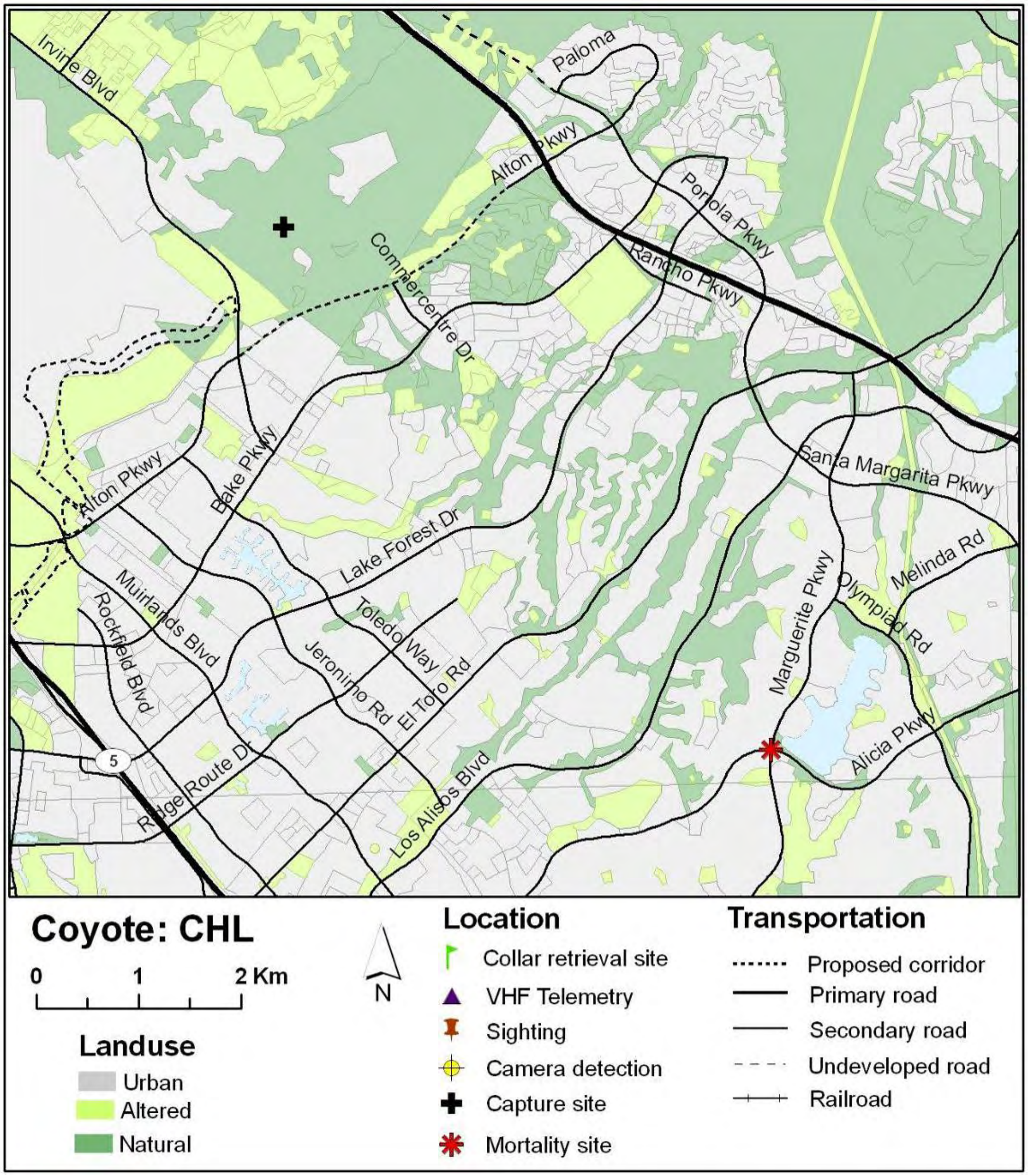


Figure 12e. VHF telemetry and other detection data for yearling female coyote CHL from June 4 to October 24, 2007, in the El Toro study area, Orange County, CA.

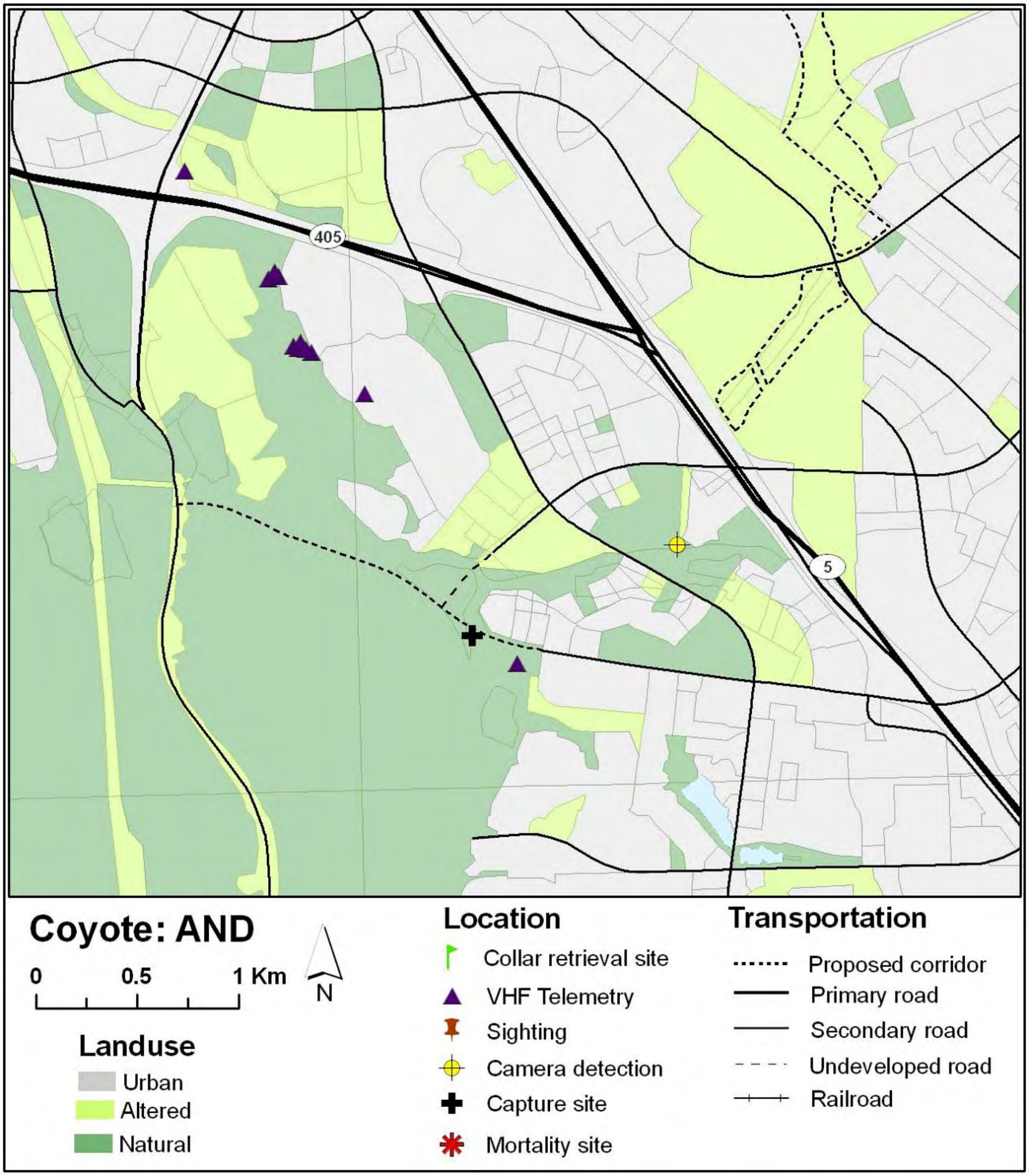


Figure 12f. VHF telemetry and other detection data for adult male coyote AND from December 5, 2006 to June 20, 2007, in the El Toro study area, Orange County, CA.

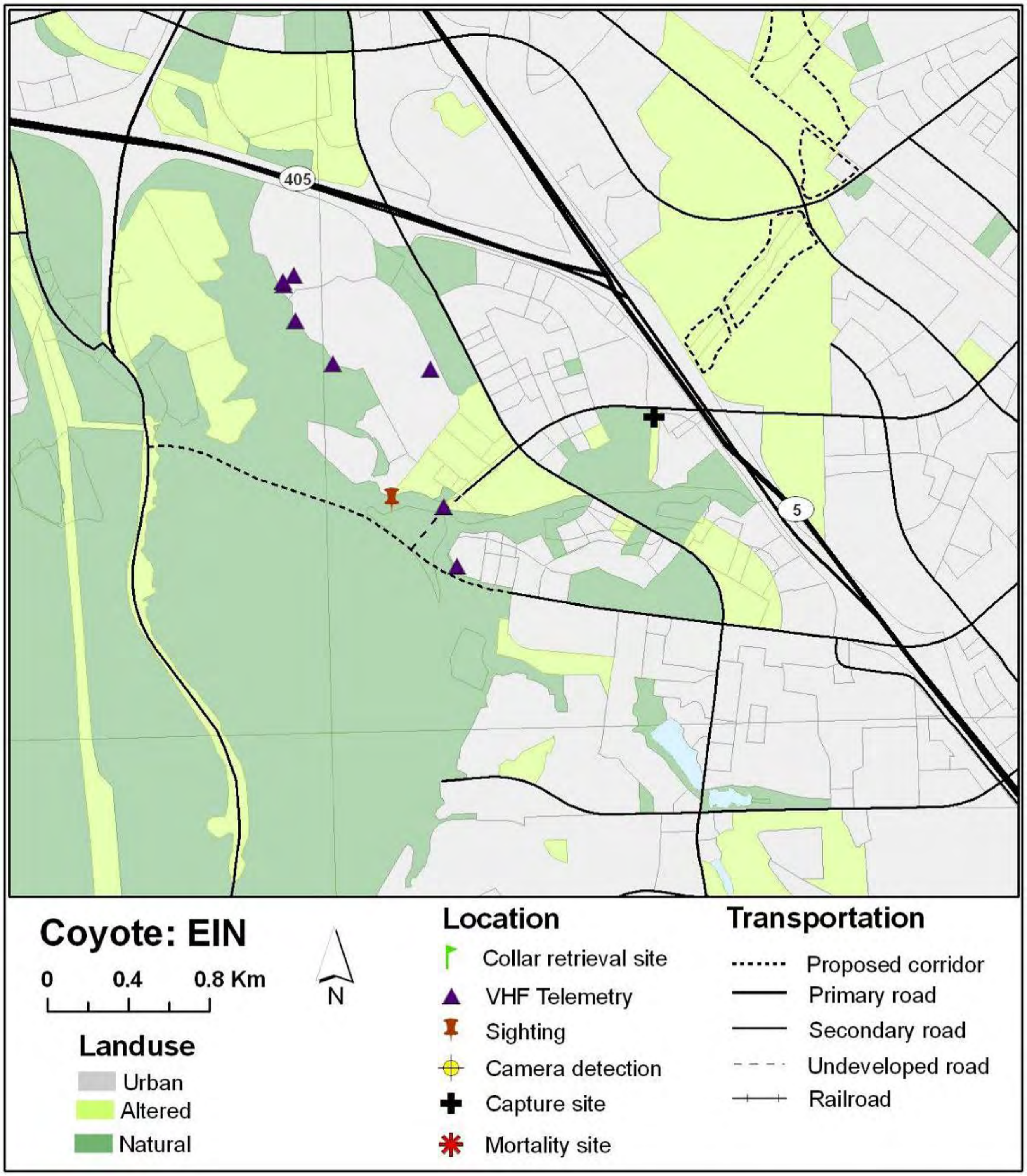


Figure 12g. VHF telemetry and other detection data for adult male coyote EIN from December 5, 2006 to April 20, 2007, in the El Toro study area, Orange County, CA.

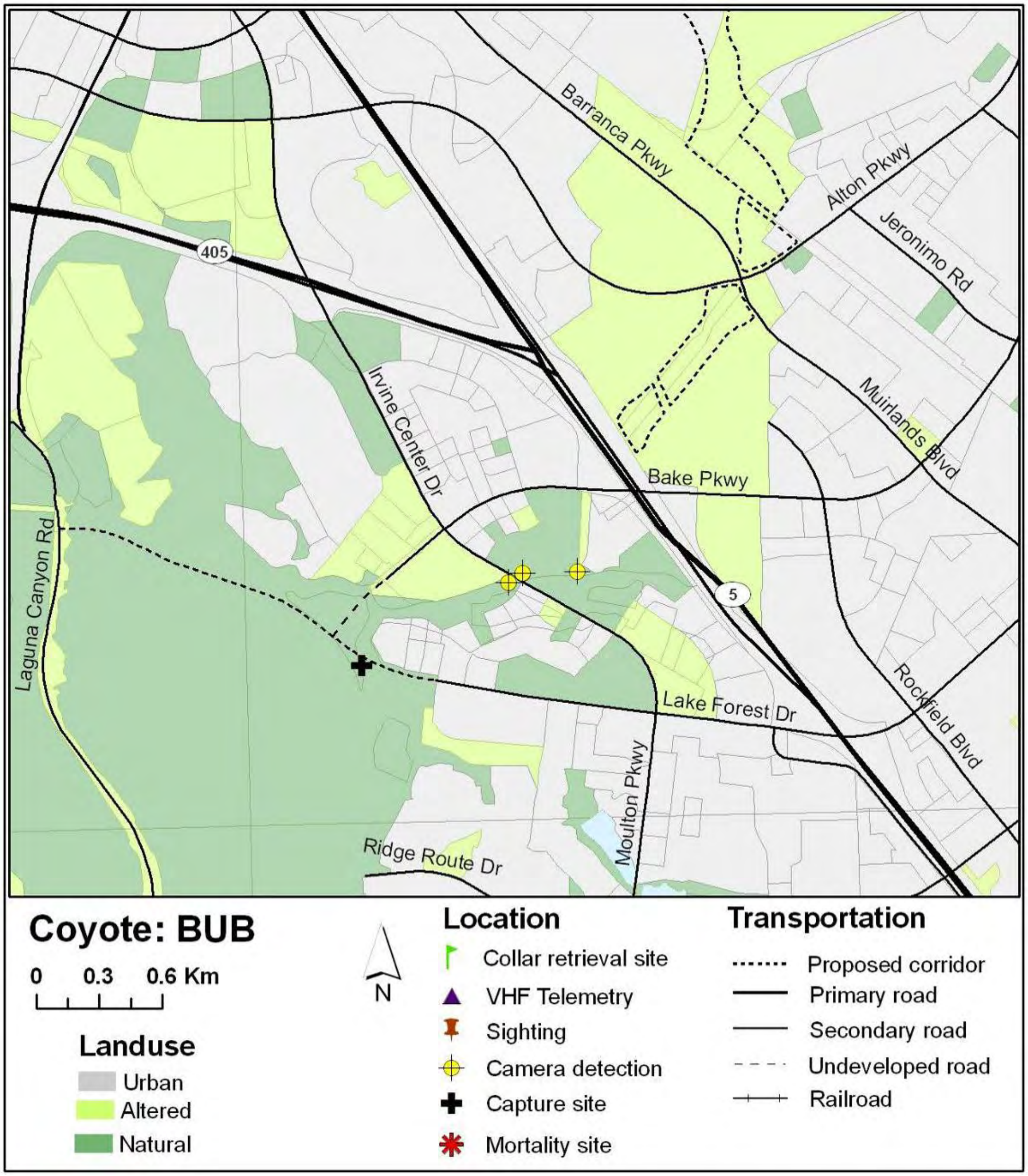


Figure 12h. VHF telemetry and other detection data for adult female coyote BUB from December 5, 2006 to May 3, 2007, in the El Toro study area, Orange County, CA.

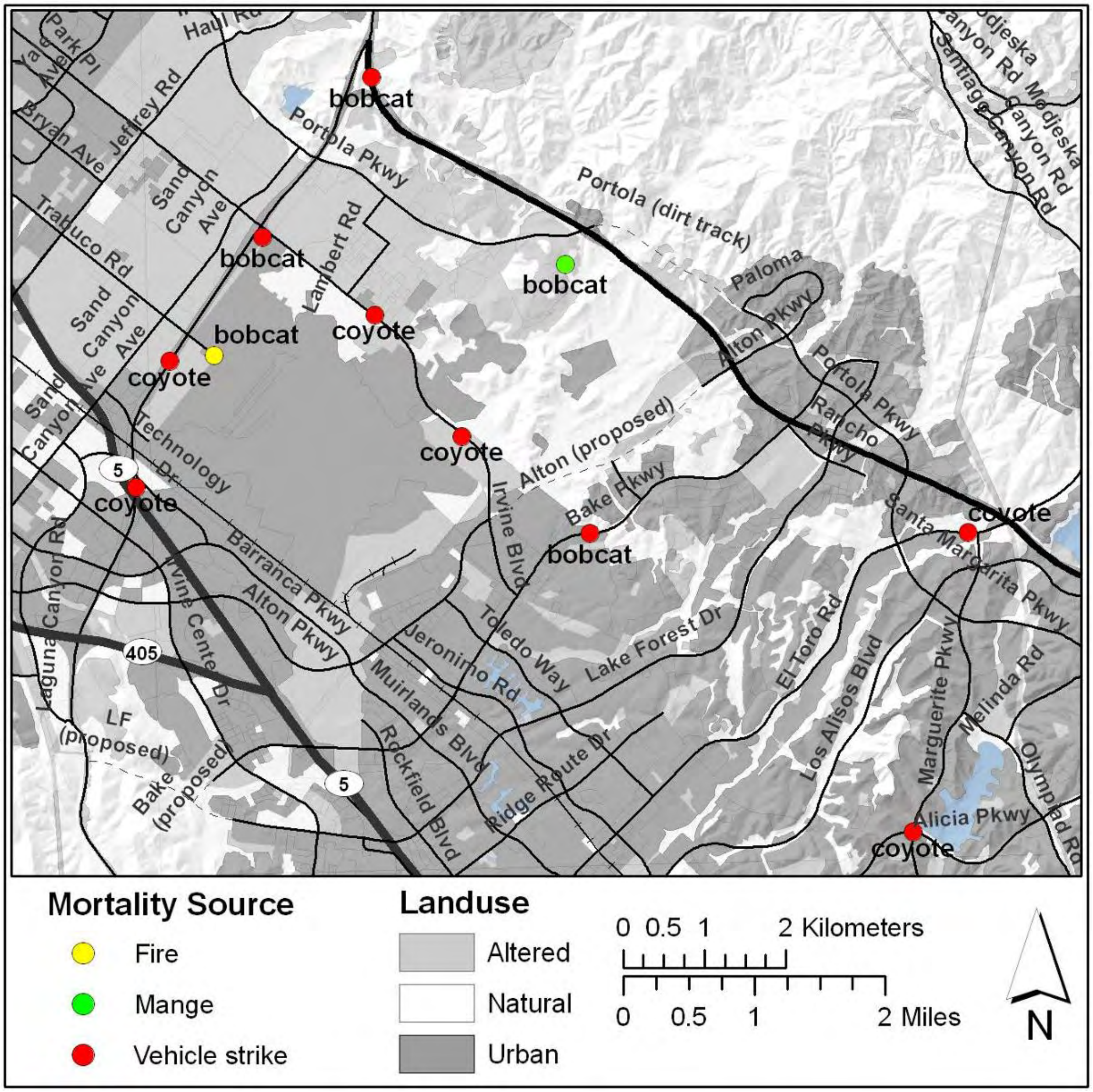


Figure 13. There were 5 bobcat and 6 coyote mortalities documented from September 2006 to January 2008 in the vicinity of the El Toro study area in Orange County, CA.

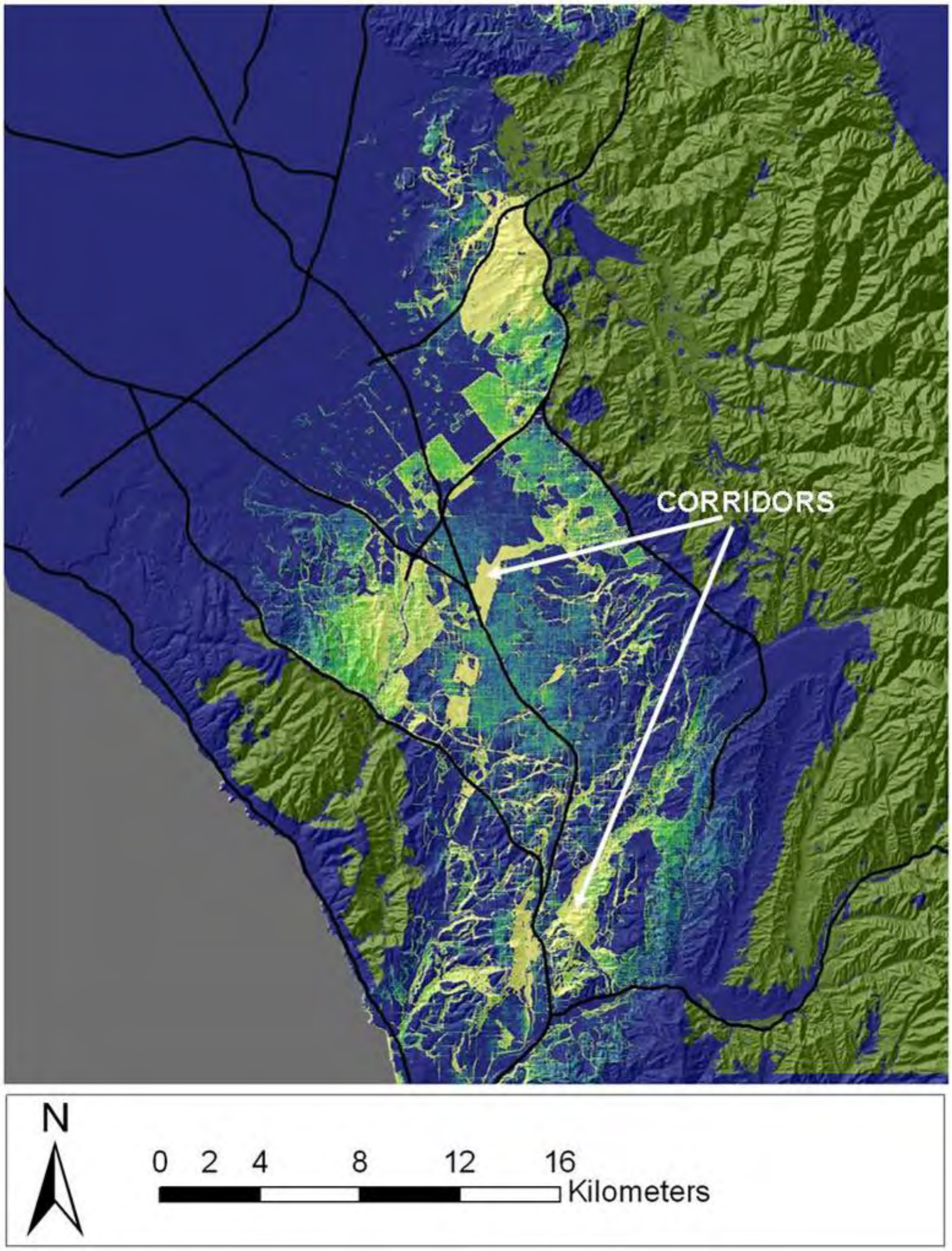


Figure 14a. Full view of the landscape-level connectivity results for southern Orange County from the (a) movement simulation approach, (b) cost-weighted distance approach, and (c) combined results. The core habitat patches are shown in dark green. The background in each figure shows the connectivity value as determined by one of the three methods. Dark blue areas have the lowest connectivity value, green areas have an intermediate value, and yellow areas have the highest connectivity value. Freeways are shown for geographic reference.

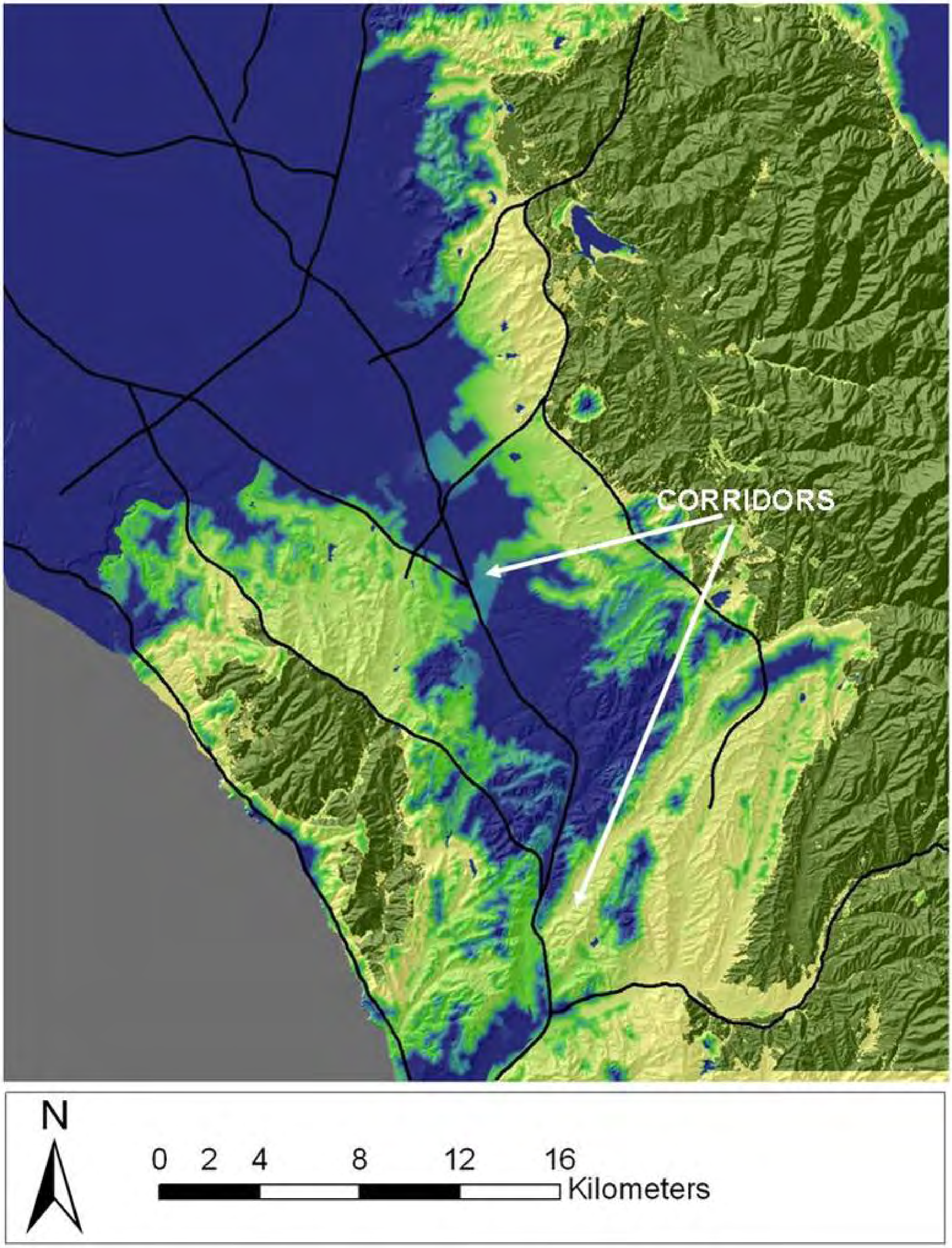


Figure 14b. Cost-weighted distance approach.

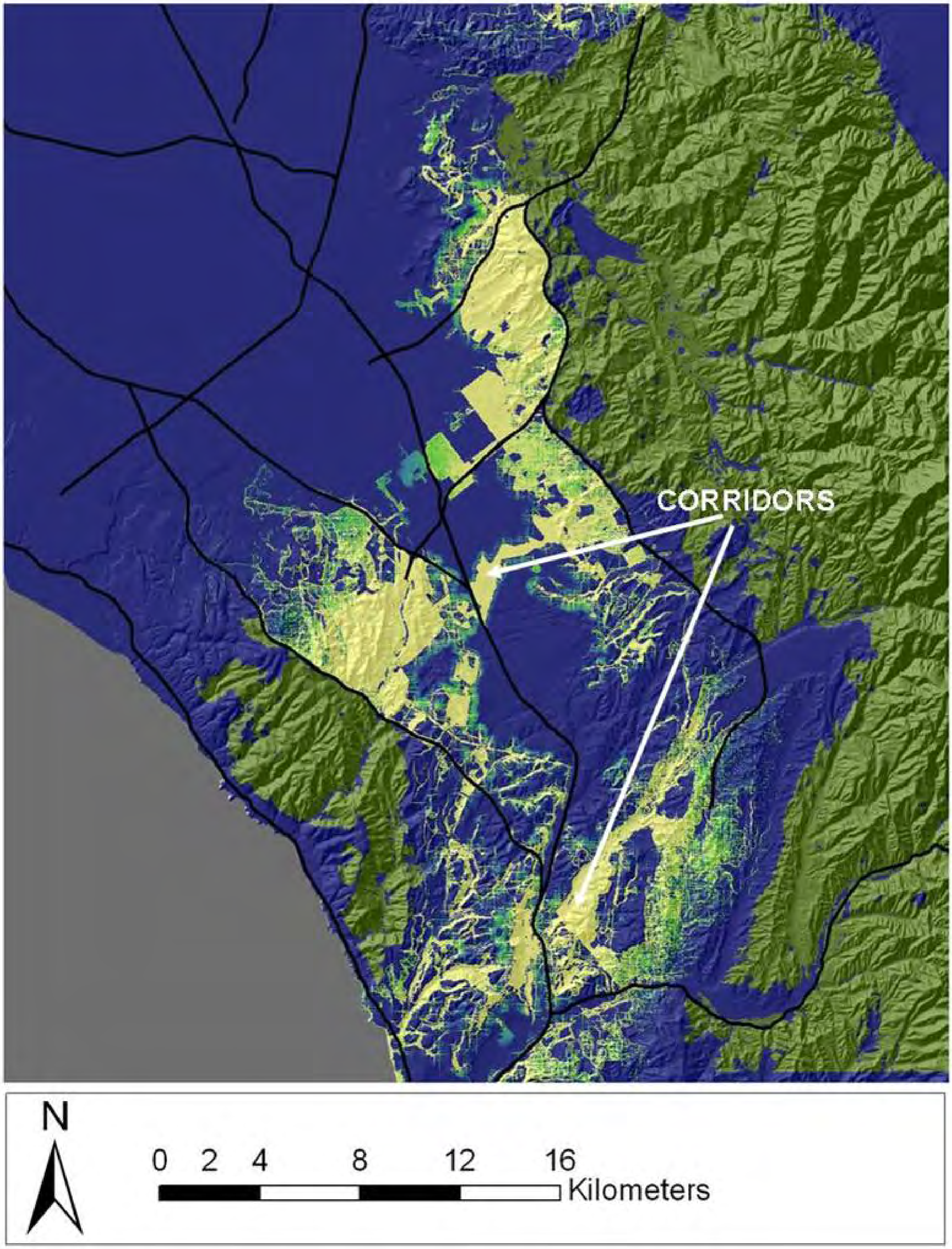


Figure 14c. Combined results.

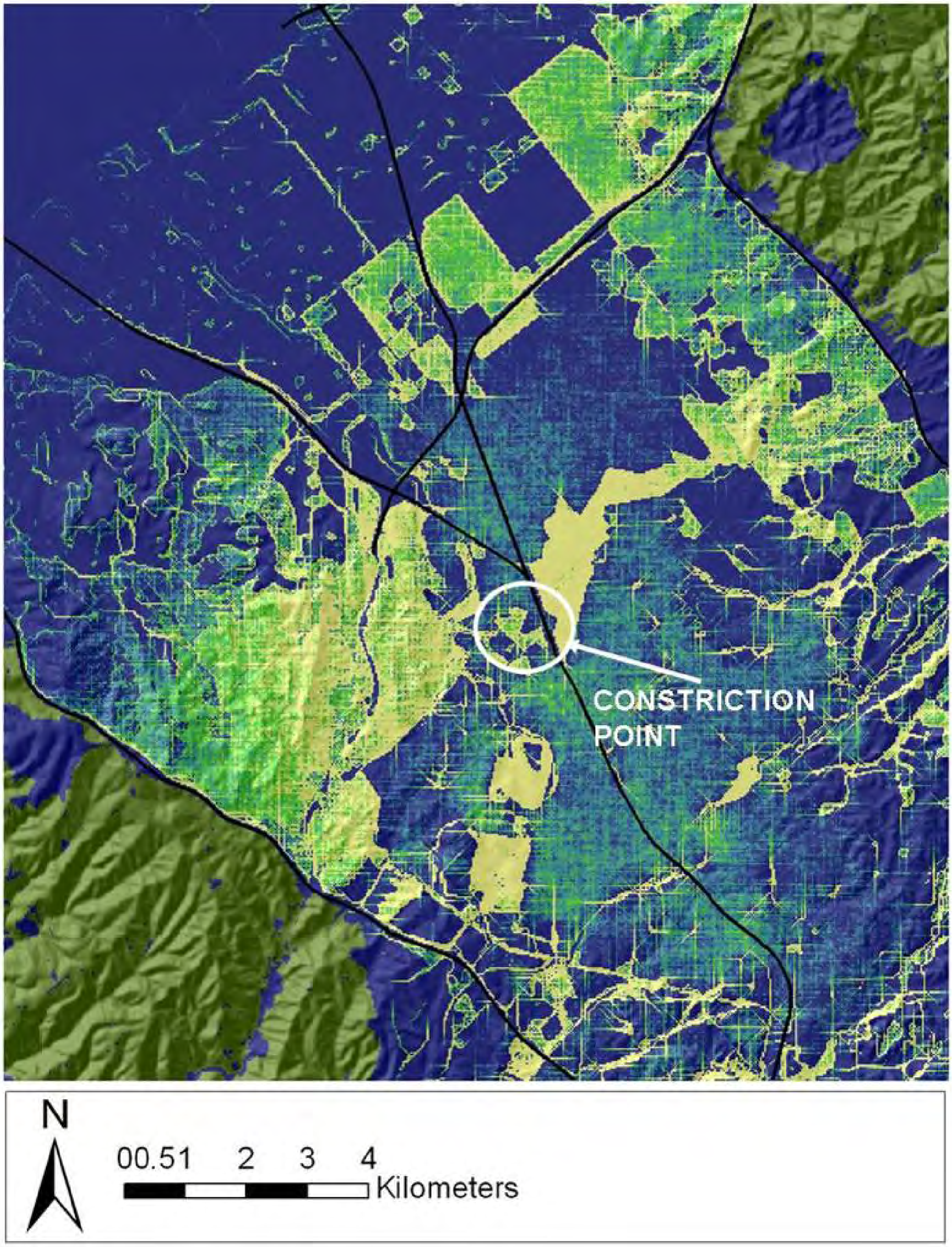


Figure 15a. Close-up view of the landscape-level connectivity results for the El Toro study area from the (a) movement simulation approach, (b) cost-weighted distance approach, and (c) combined results. The core habitat patches are shown in dark green. The background in each figure shows the connectivity value as determined by one of the three methods. Dark blue areas have the lowest connectivity value, green areas have an intermediate value, and yellow areas have the highest connectivity value. Freeways are shown for geographic reference.

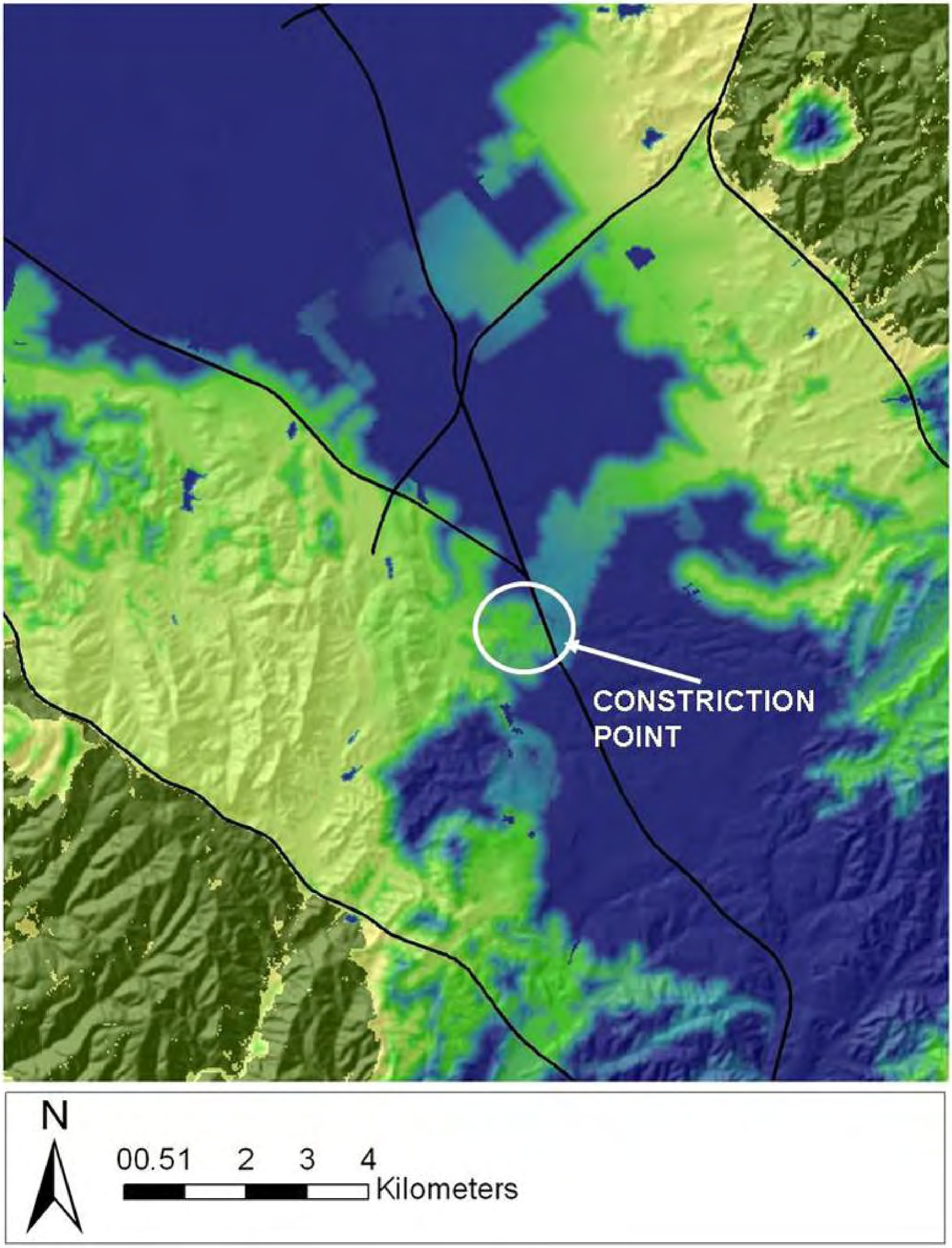


Figure 15b. Cost-weighted distance approach.

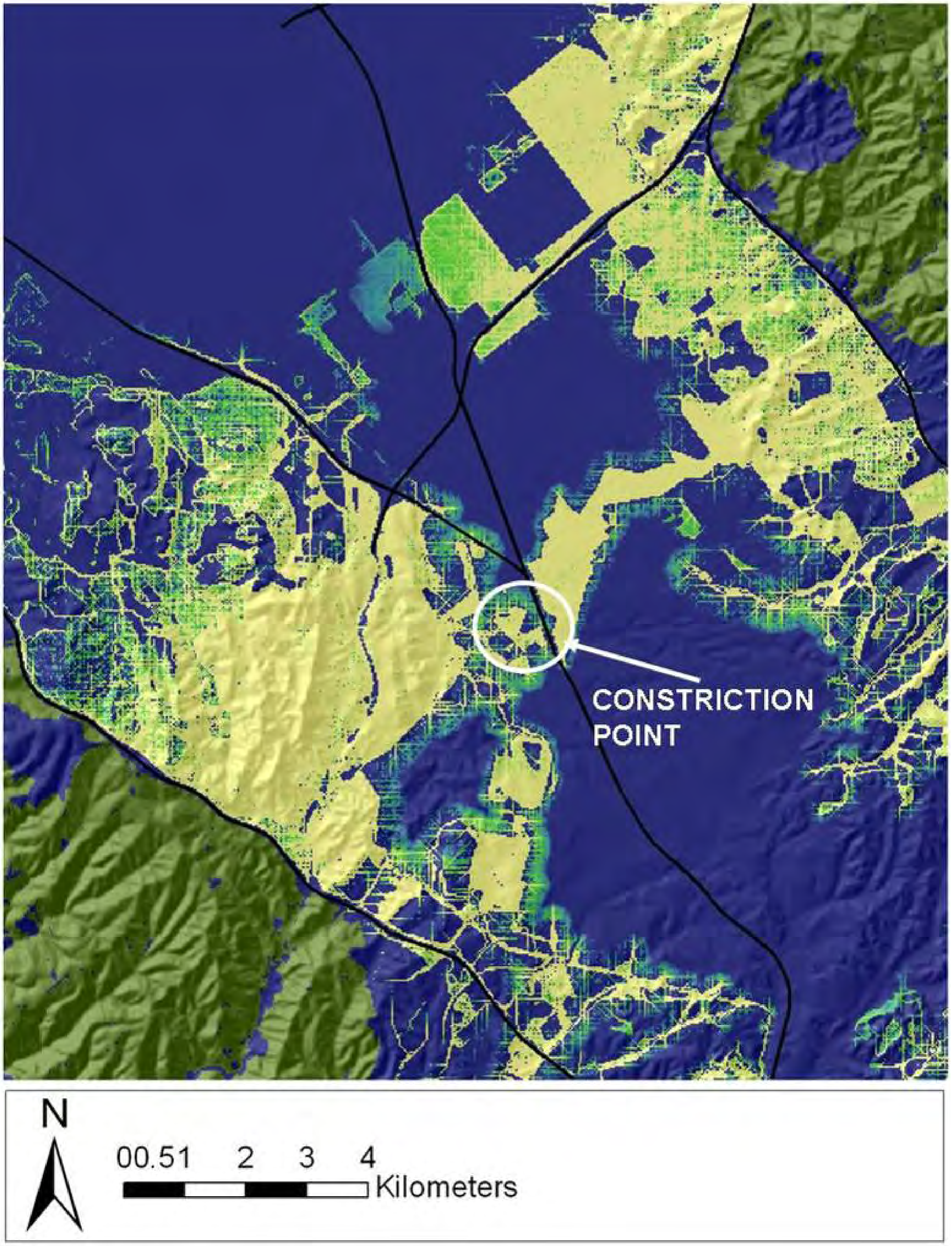


Figure 15c. Combined results.

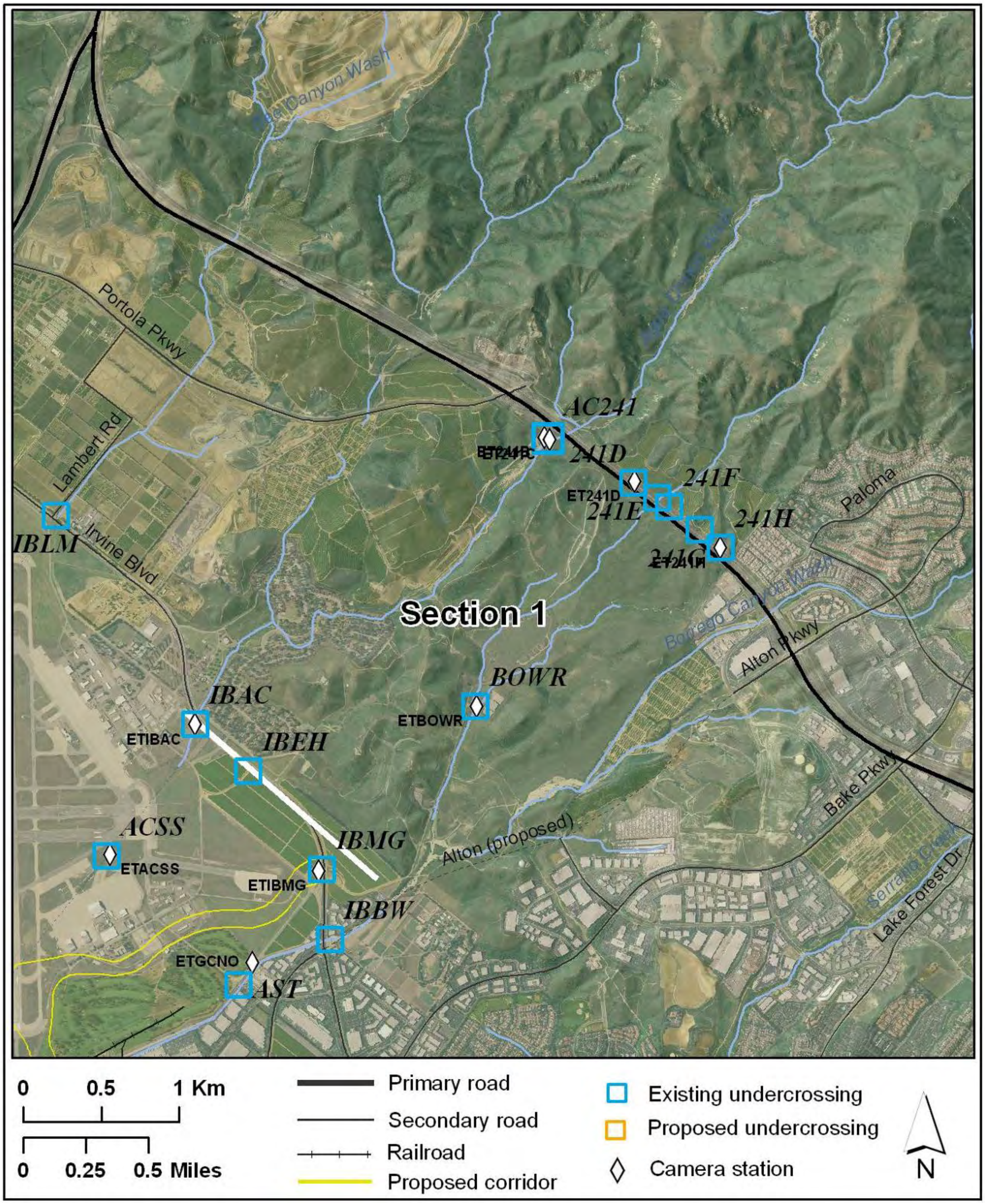


Figure 16a. Locations of local-scale constriction and connectivity evaluation sites in Section 1 and portions of Section 2 and the Peripheral area in the El Toro study area, Orange County, CA.

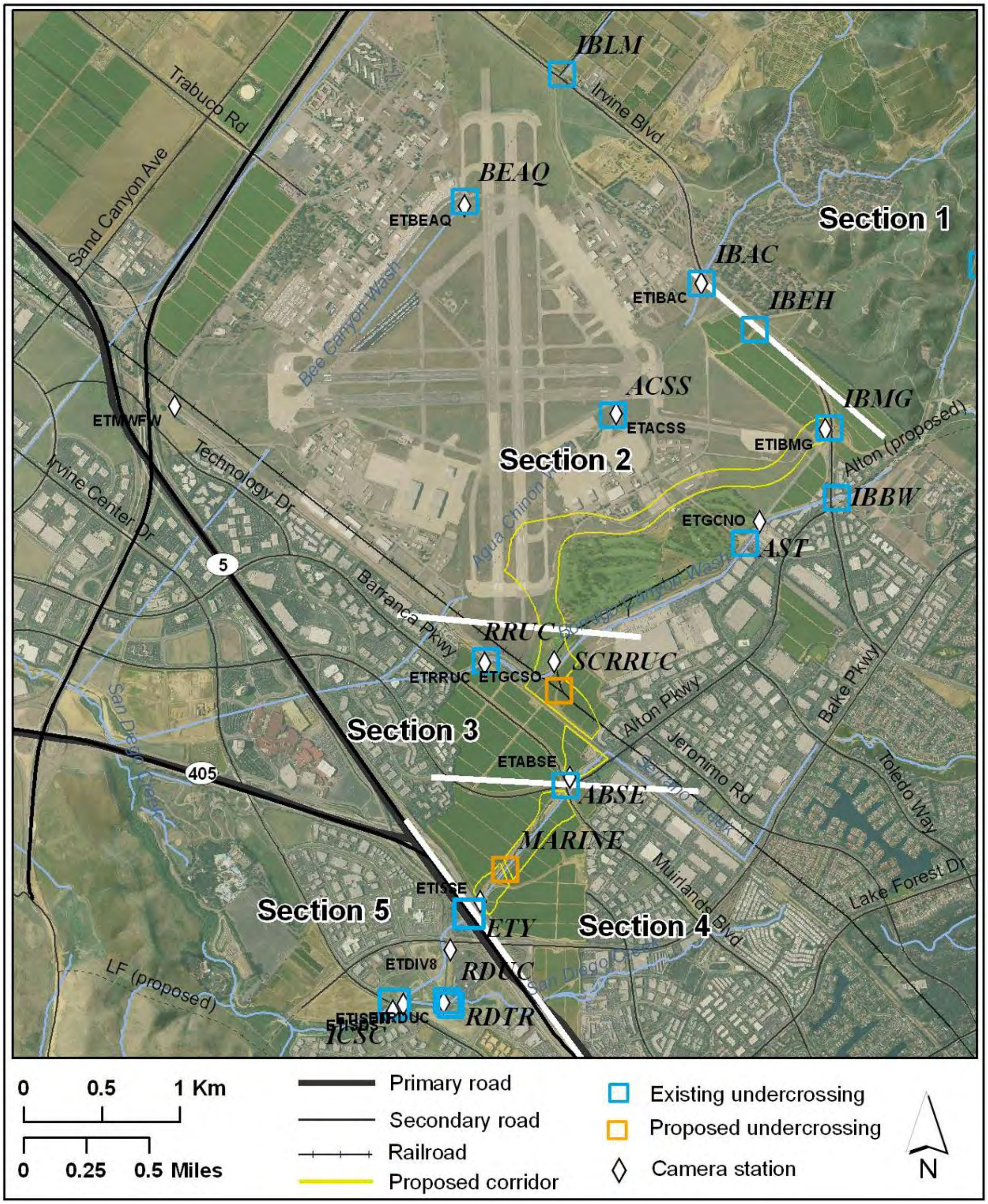


Figure 16b. Locations of local-scale constriction and connectivity evaluation sites in Sections 2, 3, 4, 5, Peripheral area, and portions of Section 1 in the El Toro study area, Orange County, CA.

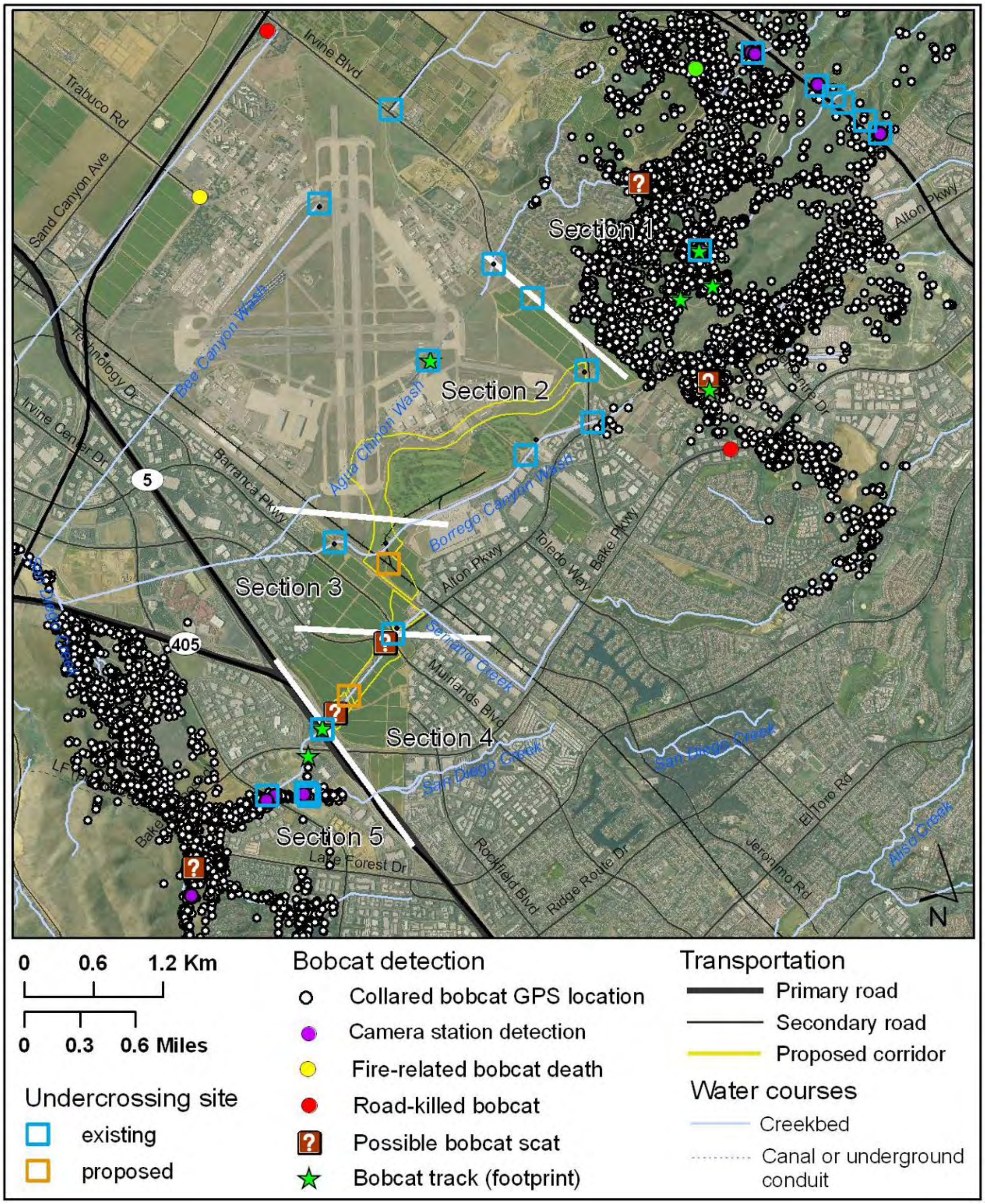


Figure 17a. Locations of bobcat detections by various sampling methods in the El Toro study area, Orange County, CA.

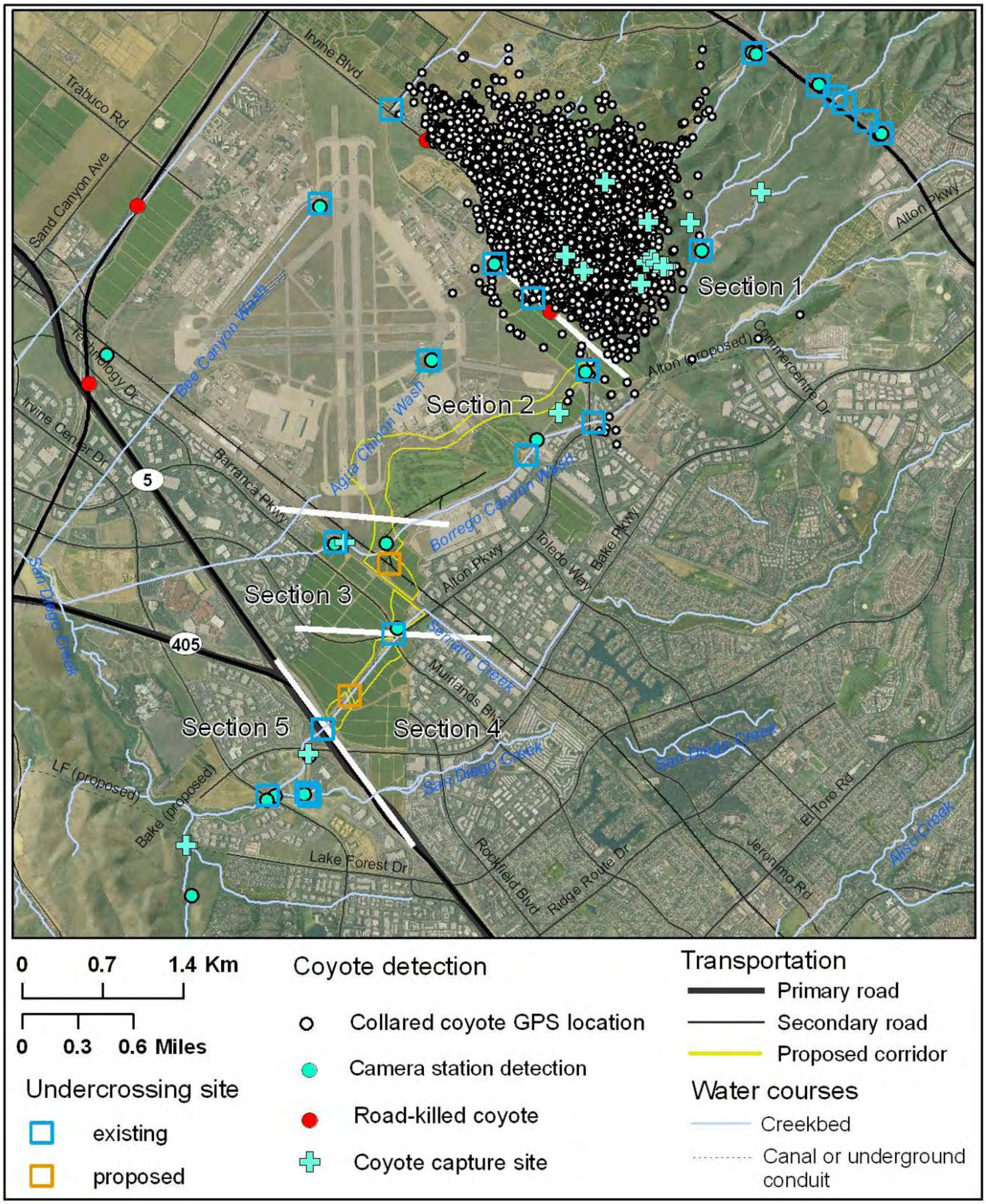


Figure 17b. Locations of coyote detections by various sampling methods in the El Toro study area, Orange County, CA.

Appendix 1. Photos of local-scale evaluation and camera station sites from north to south through the El Toro study area, Orange County, CA.

Site AC241 on the southwest side of CA-241. Camera ET241B was stationed at the left side of this picture where rip rap ends and was aimed towards the right of the picture.

Site AC241 on the southwest side of CA-241. Technican was installing 1 of 2 cameras for camera station ET241C. The second camera was installed directly across from the first on the opposite side of the channel.

Site 241D on the northeast side of CA-241. Technician was installing camera station ET241D, which was aimed towards the right of the picture.

Site 241E, northeast side of CA-241. No camera monitored this location.

Site 241F, northeast of CA-241. No camera monitored this location.

Site 241G, northeast of CA-241. Arrow points to locaton of undercrossing headwall that was obscured by brush. No camera monitored this location.

Site 241H on the northeast side of CA-241. Camera ET241H was mounted on telespar post near the right side of the picture (post is blackened by fire).

Site BOWR. Camera ETBOWR was mounted on telespar post (right side) and monitored movement through the Borrego Canyon Wash tributary and the underpass beneath the road in the foreground.

Site IBAC on northeast side of Irvine Boulevard. Camera ETIBAC monitored the southwest side of this undercrossing (below).

Site IBAC on the southwest side of Irvine Boulevard. Camera ETIBAC was mounted inside the undercrossing and attached to the cement wall. Photo taken after channel had been grubbed.

Site IBEH on the northeast side of Irvine Boulevard. No camera station installed here due to the barrier that prevented bobcat or coyote access to the underpass.

Site IBEH on the southwest of Irvine Boulevard. Chain-link fence break occurred at next fence post just off the left side of photo.

Site IBMG on the southwest side of Irvine Boulevard. Camera ETIBMG was mounted on the telespar post in front of the technician with the camera aiming towards the left of the picture.

Site IBBW on the northeast side of Irvine Boulevard. No camera station installed here due to channelization.

Site ACSS, which is downstream of site IBAC, prior to grubbing of riparian vegetation; camera ETACSS was located inside channel near the left steel door.

Site ACSS after grubbing in March 2007; camera ETACSS was located at right side of undercrossing entrance.

Site AST, which is downstream of site IBBW.

Camera location ETGCNO; camera was mounted on corner of chain-link fence aiming towards the left of the picture to monitor the north portion of the golf course.

Site RRUC. Camera ETRRUC was being installed by technicians. Camera station was positioned on the embankment since it could not be installed in the channel due to the presence of water and rip rap; camera aimed north towards bridge to monitor movement paths under bridge and across riparian channel simultaneously.

Camera location ETGCSO; camera was mounted on corner of fenced enclosure aiming north towards left side of picture to monitor the south portion of the golf course.

Site ABSE on the southwest side of Alton and Barranca Parkways intersection. Camera ETABSE 1 of 2 was mounted on the fencing to the right of the technician and was aimed towards the left of the picture. The second camera was positioned on the fencing also and directly across from the first on the opposite side of the Serrano Creek channel.

Site ETY north of the El Toro "Y". Camera ETI5SE was installed at the right (north) side of undercrossing aiming left (south) across underpass entrance. Photo was taken after Serrano Creek had been grubbed.

Site ETY south of the El Toro "Y" in the diversionary channel that connected to San Diego Creek south of Irvine Center Drive. Camera ETDIV8 was mounted on the telespar post with red post driver on top and aimed towards the left of the picture.

Site RDUC on the southwest side of Research Drive as it connected to San Diego Creek. Technician is installing camera ETRDUC. Camera was aimed towards the left of the picture.

Site RDTR on the northeast side of Research Drive in San Diego Creek. No camera station installed here due to the barrier that prevented bobcat or coyote access to the underpass.

Site ICSC on the northeast side of Irvine Center Drive at Serrano and San Diego creeks. Camera ETISDN was mounted on the telespar post and aimed at the underpass wall (background) to monitor the movement path in between the post and the wall.

Site ICSC on the northest side of Irvine Center Drive showing the inside of the reinforced concrete box that connected the San Diego Creek to the southeast channelized wall of Serrano Creek.

Site ICSC showing the reinforced concrete box entrance (red arrow) that connected the San Diego Creek to the channelized Serrano Creek, which showed standing water.

Site ICSC on the southwest side of Irvine Center Drive at San Diego Creek. Camera ETISDS was mounted on telespar post (right side) and aimed towards the left. Bridge was behind technician in orange.

Camera location LL_A was installed as part of the San Joaquin Hills bobcat study. It monitored for the presence of bobcats (and coyotes) in the Laguna Laurel peripheral area.

Site IBLM. Underpass is located in riparian channel left (north) of the blue sign. No camera monitored here.

Site BEAQ, which is downstream of site IBLM. Camera ETBEAQ was installed on the telespar post with white sign attached and aimed towards the left of the picture.

Site MWFW. Camera ETMWFW was being installed and monitored a hole in chain link fence that allowed animals access to the railroad right-of-way. CA-133 bridge overpass visible in the background.

Appendix 2. Representative photos of species detected by camera stations from north to south through the El Toro study area, Orange County, CA.
[Section 1 cameras ET241B, ET241C, ET241D, ET241H, ETBOWR]

Camera ET241B: Coyote, May 4, 2007 at 6:41 am.

Camera ET241C: Bobcat OSC, April 9, 2007 at 6:00 pm.

Camera ET241C: Two coyotes, June 25, 2007 at 7:23 am.

Camera ET241C: Mountain lion, July 1, 2007 at 9:18 pm.

Camera ET241C: Domestic dog and human, June 16, 2007 at 10:25 am.

Camera ET241D: Bobcat, March 27, 2007 at 6:23 pm.

Camera ET241D: Coyote, April 19, 2007 at 9:24 pm.

Camera ET241D: Two striped skunks, July 5, 2007 at 12:07 am.

Camera ET241D: Mule deer, May 13, 2007 at 11:57 pm.

Camera ET241H: Bobcat, March 9, 2007 at 1:47 pm.

Camera ET241H: Coyote, March 13, 2007 at 5:54 pm.

Camera ETBOWR: Bobcat ORI emaciated, June 3, 2007 at 11:26 am.
ORI was found dead with mange three days later.

Appendix 2. Representative photos of species detected by camera stations within Section 2 (cameras ETIBAC, ETIBMG, ETACSS, ETGCNO).

Camera ETIBAC: Coyote, June 25, 2007 at 2:48 pm.

Camera ETIBMG: Coyote, July 29, 2007 at 9:33 am.

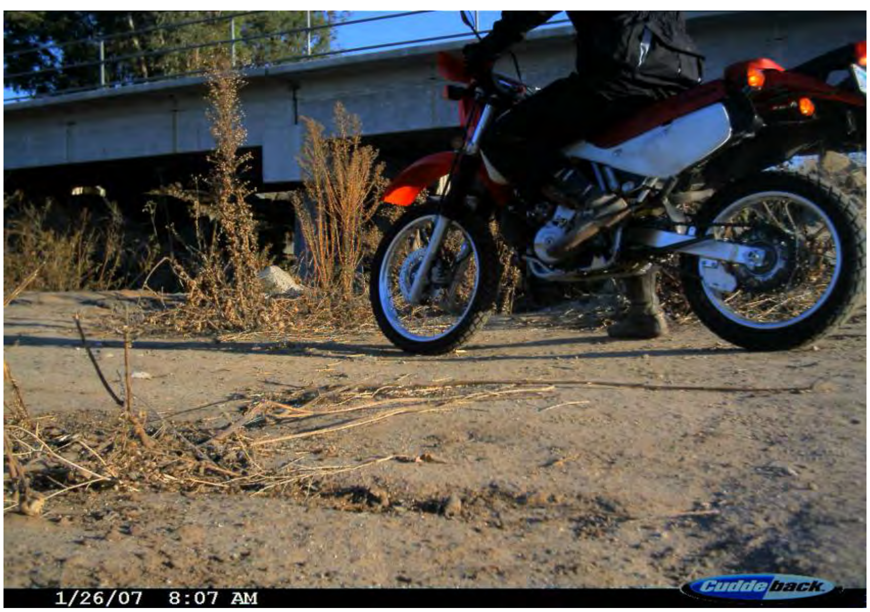
Camera ETACSS: Coyote and pup, May 22 - Jun 26, 2007. Note: structure to the right is the the steel door apparent in Appendix 1 (Site ACSS).

Camera ETGCNO: Coyote, March 25, 2007 at 7:07 pm.

Camera ETRRUC: Coyote, March 24, 2007 at 11:09 pm.

Camera ETRRUC: Coyote, July 23, 2007 at 9:59 am.

Camera ETRRUC: Human and domestic dogs (off-leash),
January 28, 2007 at 2:50 pm.



Camera ETRRUC: Vehicle (motorcycle), January 26, 2007 at 8:07 am.

Appendix 2. Representative photos of species detected by camera stations within Section 3 (cameras ETGCSO, ETRRUC).

Camera ETGCSO: Coyote, April 14, 2007 at 10:39 pm.

Camera ETGCSO: Vehicle, June 20, 2007 at 5:48 pm.

Appendix 2. Representative photos of species detected by camera stations within Section 4 (cameras ETABSE, ET15SE).

Camera ETABSE: Coyote, June 30, 2007 at 1:30 pm.

Camera ETABSE: Human, May 2 - Jun 20, 2007.

Camera ETABSE: Bikes, July 2, 2007 at 3:04 pm.

Camera ETI5SE: Humans, April 26, 2007 at 3:06 pm.

Appendix 2. Representative photos of species detected by camera stations within Section 5 (Cameras ETDIV8, ETRDUC, ETISDN, ETISDS, LL_A).

Camera ETDIV8: Coyote, December 15, 2006 at 1:50 am.

Camera ETRDUC: Bobcat HOM, February 10, 2007 at 7:29 pm.

Camera ETRDUC: Coyote, April 26, 2007 at 3:50 am. Note: coyote is standing on cement divider between the two culvert pipes possibly heading towards the road surface.

Camera ETRDUC: Coyote BUB, May 2, 2007 at 3:30 am.

Camera ETRDUC: Raccoon family of five, December 20, 2007 at 6:18 pm.

Camera ETISDN: Bobcat HOM, December 11, 2006 at 6:30 pm prior to his capture. The undercrossing entrance is in the background beyond the fencing. HOM is entering San Diego creek after completing an at-grade road crossing of Irvine Center Drive.

Camera ETISDN: Bobcat HOM, Mar 15, 2007 at 1:59 am. HOM is exiting San Diego Creek and moving towards road surface.

Camera ETISDN: Coyote with mange, December 10, 2006 at 10:49 pm. Coyote is entering San Diego Creek after completing a probable at-grade road surface crossing of Irvine Center Drive.

Camera ETISDN: Coyote, May 3, 2007 at 8:39 am. Coyote is also exiting San Diego Creek and heading towards road surface.

Camera ETISDS: Raccoon, February 25, 2007 at 8:29 am.

Camera LL_A06: Bobcat, January 22, 2007 at 11:22 am.

Camera LL_A06: Coyote, August 26, 2006 at 5:53 pm.

Appendix 2. Representative photos of species detected by camera stations within the corridor periphery (cameras ETBEAQ, ETMWFW).

Camera ETBEAQ: Coyote, March 18, 2007 at 11:36 pm. Lack of lighting prevents visibility of underpass entrance in background of photo. Coyote was unlikely to have used underpass since it is walking from channel embankment down to channel bottom.

Camera ETMWFW: Coyote with mange, April 26, 2007 at 1:51 am.

Appendix 2. Representative photos of species detected by Scouting camera stations (cameras ETBOWR*, ETMLX_UP, ETMLX_DO, ETRDUC*, ETISDN*).
[* Photos from these camera stations have already been shown in other sections.]

Camera ETMLX_UP: Bobcat ORI with mange but not emaciated, April 28, 2007 at 7:39 pm.

Camera ETMLX_UP: Coyote, April 28, 2007 at 11:40 pm.

Appendix 2. Representative photos of species detected by Scouting camera stations (cameras ETBOWR*, ETMLX_DO, ETMLX_UP, ETRDUC*, ETISDN*).
[* Photos from these camera stations have already been shown in other sections.]

Camera ETMLX_DO: Bobcat ORI, with mange but not emaciated, May 5, 2007 at 11:03 pm.

Camera ETMLX_DO: Bobcat OSC without collar, October 12, 2007 at 6:56 pm, 10 days before the Santiago Fire.

Camera ETMLX_DO: Coyote pup, July 18, 2007 at 7:49 pm.

Camera ETMLX_DO: Spotted skunk, October 30, 2007 (post-Santiago Fire) at 8:17 pm.

News Release

November 7, 2007	Erin Boydston Catherine Puckett Gloria Maender	714-508-4704 352-284-4832 520-670-5596	eboydston@usgs.gov cpuckett@usgs.gov gloria_maender@usgs.gov

USGS Cameras Capture Dramatic Wildfire-Wildlife Images

Wildlife photos from a motion-triggered camera used in wildlife research in Orange County between Los Angeles and San Diego managed to survive the fire intact, along with some astonishing photos.

Dr. Erin Boydston and Lisa Lyren, USGS researchers who have conducted carnivore research using this and other cameras, said the photos show some before and after the fire pictures – including one of a coyote apparently fleeing from the fire. Possibly the same coyote triggered the camera again one and a half days later.

The pictures were acquired using a “camera trap,” a camera wired with motion sensors to automatically take photos when the sensors detect movement in the camera’s field of view. Camera traps, said Lyren, are widely used in carnivore research because they help document the behavior and distribution of these more elusive, often-nocturnal animals.

This camera trap is on the former El Toro Marine Base, an area that burned last week in the Orange County Santiago Fire. This particular area was the southernmost extension of the fire, where it crossed over a toll road into this small peninsula of habitat surrounded on the other three sides by urban development, small agricultural fields and the main part of the former Marine Base.

Boydston, Lyren and other colleagues at the U.S. Geological Survey have been studying bobcats and coyotes in Orange County since 2002 in collaboration with Dr. Kevin Crooks at Colorado State University.

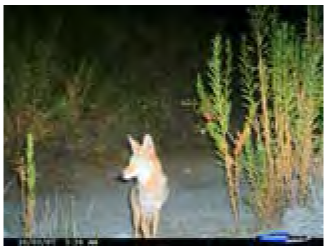
Extensive camera data and data from GPS-collared animals from before the fire provide an understanding of how carnivores were already using this complex landscape of open spaces, roads and urban areas.

“We hope that we are able to do follow-up research to help discern where the displaced carnivores go, as the options are slim between urban areas or unburned areas that already have bobcats and coyotes present who will not welcome newcomers to their territories,” Boydston said. “If so, we will have the

opportunity to understand how fires interact with patterns of carnivore behavior and ecology and what the implications are for conservation of these species, especially in habitat surrounded by urban areas.”
USGS-CSU collaborative research across Orange County has been funded by the Orange County Great Park Corporation, The Irvine Company, The Nature Conservancy, Transportation Corridor Agencies, and USGS.

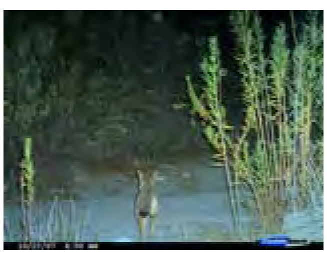
NOTE FOR EDITORS: Time stamps on the images are in Pacific Standard Time. For high-resolution, copyright-free images of the images of wildlife captured by the movement-triggered camera , click on the thumbnail images below. Please credit photos to the USGS.

For more information on USGS wildfire work, please see url: http://www.usgs.gov/hazards/wildfires

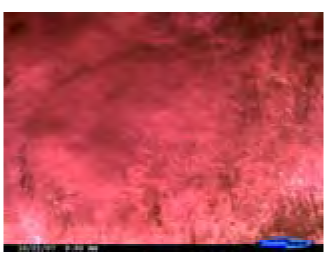


A coyote walking in dry creek bed of streamside scrub vegetation dominated by the native plant, mule fat (Baccharis salidifolia), about 20 days before the fire. In their wildlife research, USGS scientists position camera traps along trails and dry creek beds, places that are likely to be travel routes for carnivores. From this particular location in Borrego Wash, the researchers have obtained 32 photos of bobcats and 7 of coyotes since March 16, 2007. Photo credit: USGS.

Movement triggers the camera, and moving vegetation can sometimes trigger a picture. At 09:45 a.m. PST on Oct. 21, 2007, the Santa Ana winds picked up and triggered a photo, followed by additional photos that morning of the windy conditions, including this one at 10:44 a.m. PST. Photo credit: USGS.



At 4:50 a.m. PST on Oct. 22, 2007, a coyote runs into the wash, presumably fleeing from the fires. Photo credit: USGS.



After the photo of the coyote on the run, the next photo on the camera shows high-intensity flames at 9:00 a.m. PST on Oct. 22, 2007. Photo credit: USGS.

At 09:01 a.m. PST, just one minute after the intense flames, the fire seems to have passed this particular point, leaving only the skeletons of the mule fat plant and other streamside shrubs that continue to burn. Photo credit: USGS.

The camera continued to take one photo per minute for 10 minutes after the fire, until this one at 09:10 a.m. PST on Oct. 22, 2007, showing smoke, burnt and smoldering vegetation and windy conditions. The remnants of some field research equipment are lying melted under a nearby tree. Photo credit: USGS.

The next photo on the camera at 11:12 p.m. PST on Oct. 23, 2007, shows a coyote walking out of the wash at night, a day and a half after the fire, heading back in the direction from which the coyote was running on the early morning of Oct. 22, 2007. Photo credit: USGS
