

**DETECTING SHIFTS IN WILDLIFE MOVEMENT PATTERNS
ASSOCIATED WITH ROAD ENHANCEMENT: THE WILDCAT
CANYON ROAD BEFORE-AFTER-CONTROL-IMPACT STUDY**

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**Detecting Shifts in Wildlife Movement Patterns
Associated with Road Enhancement:
The Wildcat Canyon Road Before-After-Control-Impact Study**

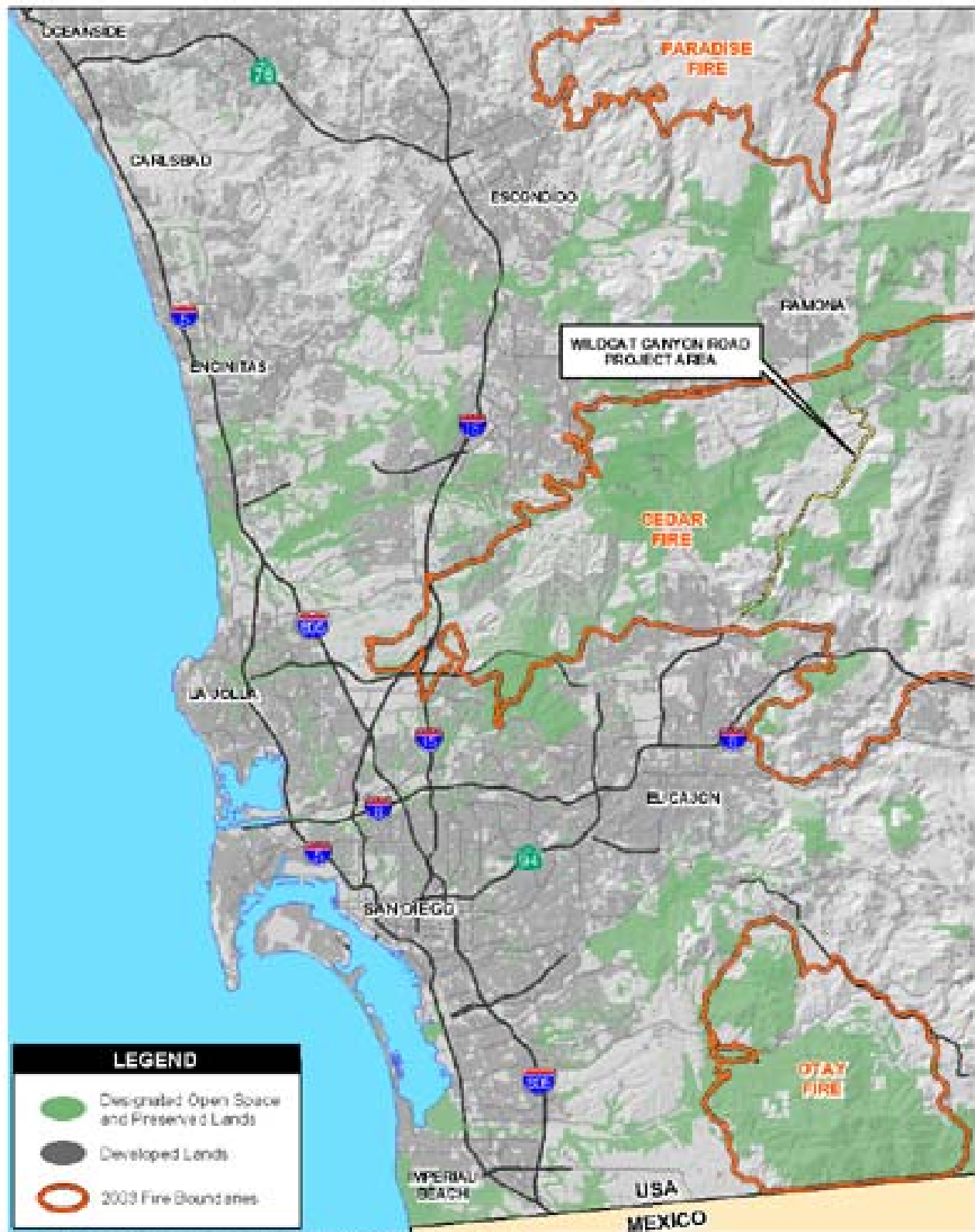
ABSTRACT

To complete a Before-After-Control-Impact Study (BACI study), mobile geographic information system (GIS), statistical analyses, and ArcView were used to collect and analyze wildlife-tracking data in rural San Diego County. The BACI study is part of a road-widening project, which includes the installation of undercrossings to facilitate wildlife movement across Wildcat Canyon Road, preventing population fragmentation. The BACI study was designed to monitor wildlife activity for 1 year pre- and postconstruction to determine if the road-widening project has changed the wildlife activity patterns in this important wildlife corridor and to test the effectiveness of the road undercrossings and directional fencing. During the preconstruction data collection, the Cedar Fire of October 2003 burned the entire study area, adding to the complexity of the data analysis. Mobile GIS, statistical analyses, and ArcView were used to identify and describe preconstruction movement trends. The postconstruction portion of the study is scheduled to begin in August 2006, using similar analyses.

PROJECT DESCRIPTION

The Wildcat Canyon Road Enhancement Project proposes improvements to Wildcat Canyon Road to reduce traffic hazards in an area that functions as a major regional wildlife corridor in rural San Diego County (Figure 1). The study area is located along Wildcat Canyon Road from the Barona Indian Resort and Casino (northern boundary) to the intersection of Wildcat Canyon Road with Willow Road (southern boundary) in Lakeside, California (Figure 2). The eastern and western boundaries of the study area are at least 1 kilometer east and west of the portion of Wildcat Canyon Road being improved.

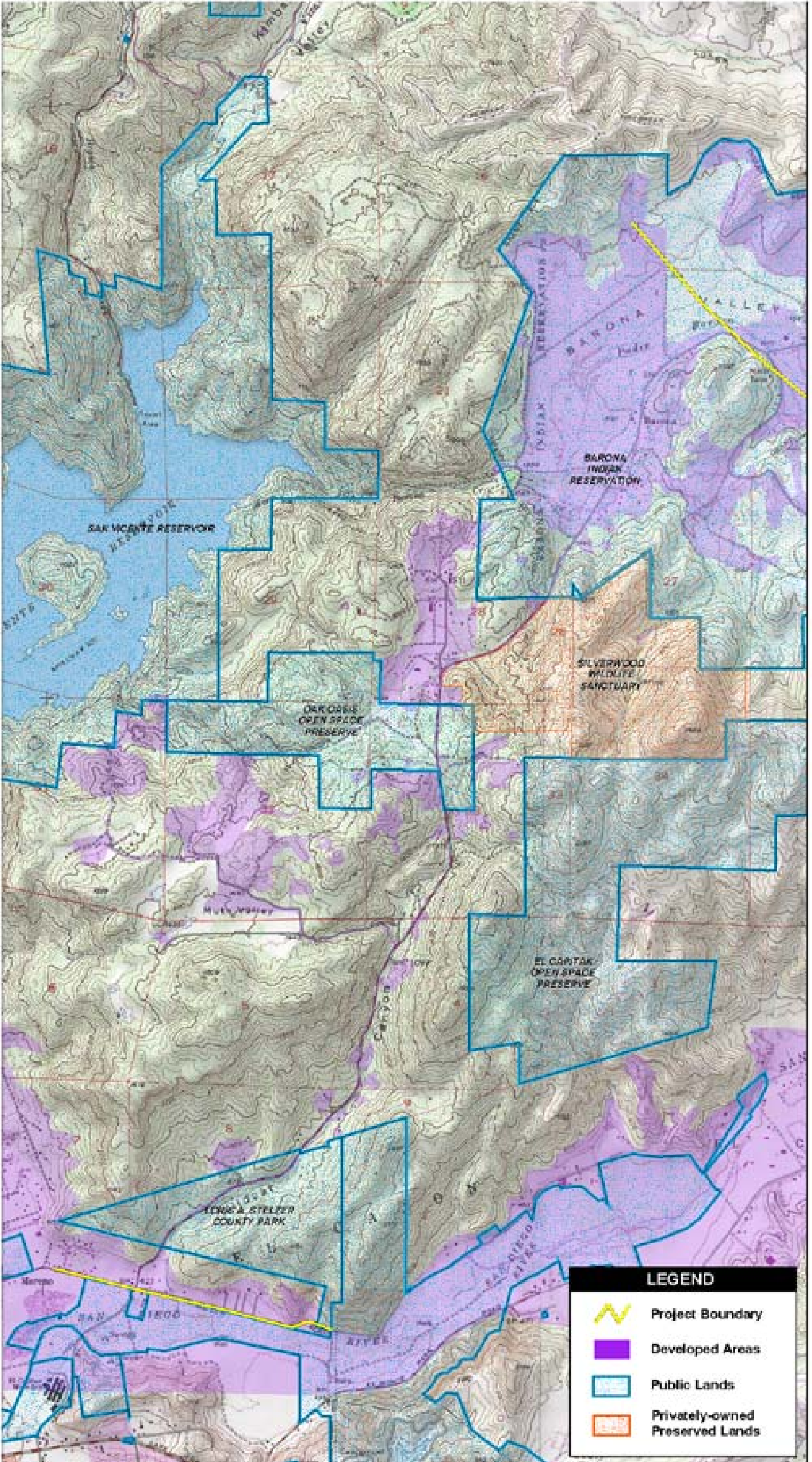
Roads and vehicles affect the mobility and survival of wildlife across a landscape and can cause population fragmentation. However, appropriately designed enhancement projects that include undercrossings and directional fencing can facilitate wildlife movement across roadways. A BACI study was designed for the project to determine impacts of the road enhancement on wildlife movement and the success of the installed crossings.



Source: SANDAG, USGS, SanGIS, (Planned North County MSCP Digitized from TAC Graphic.)



Figure 1
Regional Location Map



LEGEND	
	Project Boundary
	Developed Areas
	Public Lands
	Privately-owned Preserved Lands

Figure 2
Wildcat Canyon BACT Study
Vicinity Setting

By definition, BACI studies are designed to determine impacts of disturbances or changes on the environment (Smith 2002). The Wildcat Canyon BACI study design includes pre- and postconstruction studies to examine changes in ecological measures potentially associated with an impact (Kerlinger 2002; Underwood 1991). BACI studies function on the assumption that it is possible to replicate environmental units before and after an impact (Pollock 1994) to identify changes that are associated with the impact rather than natural changes. Because trends in the environment are common and could be caused by human activity or natural events such as drought, fire, and other natural occurrences, it is necessary to pair a treatment site (area where impact occurs) with reference or control sites (Kerlinger 2002; Paul and Bustard 2004; Pollock 1994; Smith 2002). A BACI study design assumes that the control and impact sites are subject to the same ecological trends (Smith et al. 1993) and behave in a linear relationship to each other. This assumption necessitates that sufficient data are collected for robust statistical results before the impact occurs to identify the trends and meet the assumptions of the BACI study design. This is especially important when capturing recovery trends after natural disaster, such as fire, which was a factor in this BACI study.

The Wildcat Canyon BACI study design includes data collection for 1 year prior and 1 year after construction (pre- and postconstruction) and employs transect, tracking station, and roadkill surveys to characterize wildlife movement for 14 mammal species. The Cedar Fire of October 2003 burned the entire study area between the first and second surveys. Survey results were analyzed using GIS and a variety of statistical analyses.

The goals of the BACI study are to address the following questions:

- Does the construction of a 1-mile passing lane and other traffic improvements on Wildcat Canyon Road impact wildlife movement?
- Do the wildlife crossings (to be installed or improved during project construction) facilitate wildlife movement through the project impact area?
- What further refinements to crossing structures (e.g., changes in fencing design) might improve crossing function and reduce roadkill for this project?

MEETING PROJECT OBJECTIVES WITH GIS

Most of the project objectives will be met following completion of the postconstruction portion of the BACI study. To meet the objectives of the preconstruction portion of the BACI study, and

to have the postconstruction portion be consistent and comparable with the preconstruction portion, GIS was used to solve the following problems:

- How to consistently collect data considering variables such as a large field crew and data collection over several years at multiple sample points
- How to visually represent data collected at each sample point considering that multiple survey methods were used and several species were observed
- How to visually represent movement patterns
- How to identify and quantify roadkill concentration points

METHODS

Various methods were used to select the study species, survey the project area, create maps, and analyze data collected.

Species Studied

The following 14 mammals known to occur within the project area were selected as focal species for the study: mountain lion (*Felis concolor*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), Virginia opossum (*Didelphis virginiana*), northern raccoon (*Procyon lotor*), American badger (*Taxidea taxus*), long-tailed weasel (*Mustela frenata*), ringtail (*Bassariscus astutus*), striped skunk (*Mephitis mephitis*), spotted skunk (*Spilogale gracilis*), mule deer (*Odocoileus hemionus*), black-tailed jackrabbit (*Lepus californicus*), and dusky-footed woodrat (*Neotoma fuscipes*). Species were selected based on any or all of the following factors:

- physical body size and home range size
- relative sensitivity
- indicator species for large-scale movement (Beier 1993; Gilpin and Soule 1986; Ogden 1992)

None of these species are migratory in southern California, which eliminated the need to consider migratory seasonal movement trends. However, activity levels, behavioral patterns, and movement distances may vary throughout the seasons due to such factors as mating activities, birthing activities, and resource availability.

It was determined that sustaining viable populations of many smaller mammal species occurring within the project area would not necessitate road crossings provided that large habitat patches were available on one side of the road (Gilpin and Soule 1986; Noss 1987); thus, such small mammal species as the California ground squirrel (*Spermophilus beecheyi*); cottontails and rabbits (*Sylvilagus* sp.); and species of rodentia, herpetofauna, avifauna, coleoptera, and myriapods were not studied. However, their presence was recorded on field data sheets.

Study Design – Data Collection

The study compares measurements of wildlife use in areas affected by the project (treatment), with areas not affected (controls). Controls include areas more than 1 kilometer from the road (interior control), and areas near the road (near-road controls) (Figure 3). The near-road control is located north and south of the treatment along Wildcat Canyon Road. The interior control is at least 1 kilometer east and west of the treatment.

Because 14 focal species were selected, various survey methods were used to increase the likelihood that sign of each species would be observed during the surveys. The following three survey types were used: transect, tracking station, and roadkill surveys were conducted from September 2003 through July 2004 and January 2005 through July 2005.

Transects and Tracking Stations

The layout of the study design includes systematically placed transects and tracking stations throughout the three sample units (treatment, interior control, and near-road control). A systematic design was used over a random layout to increase wildlife detection, and to avoid the undersampling of wildlife movement observations due to routes not being randomly dispersed. Based on access permission and existing topography and habitat, varying numbers of transects and tracking stations were placed within the three sample units (Table 1).

Table 1
Identification of Sample Locations

Sample unit	Transects	Tracking Stations
Treatment	14 segments	14 stations
Interior Control	74 segments	20 stations
Near-Road Control	30 segments	16 stations

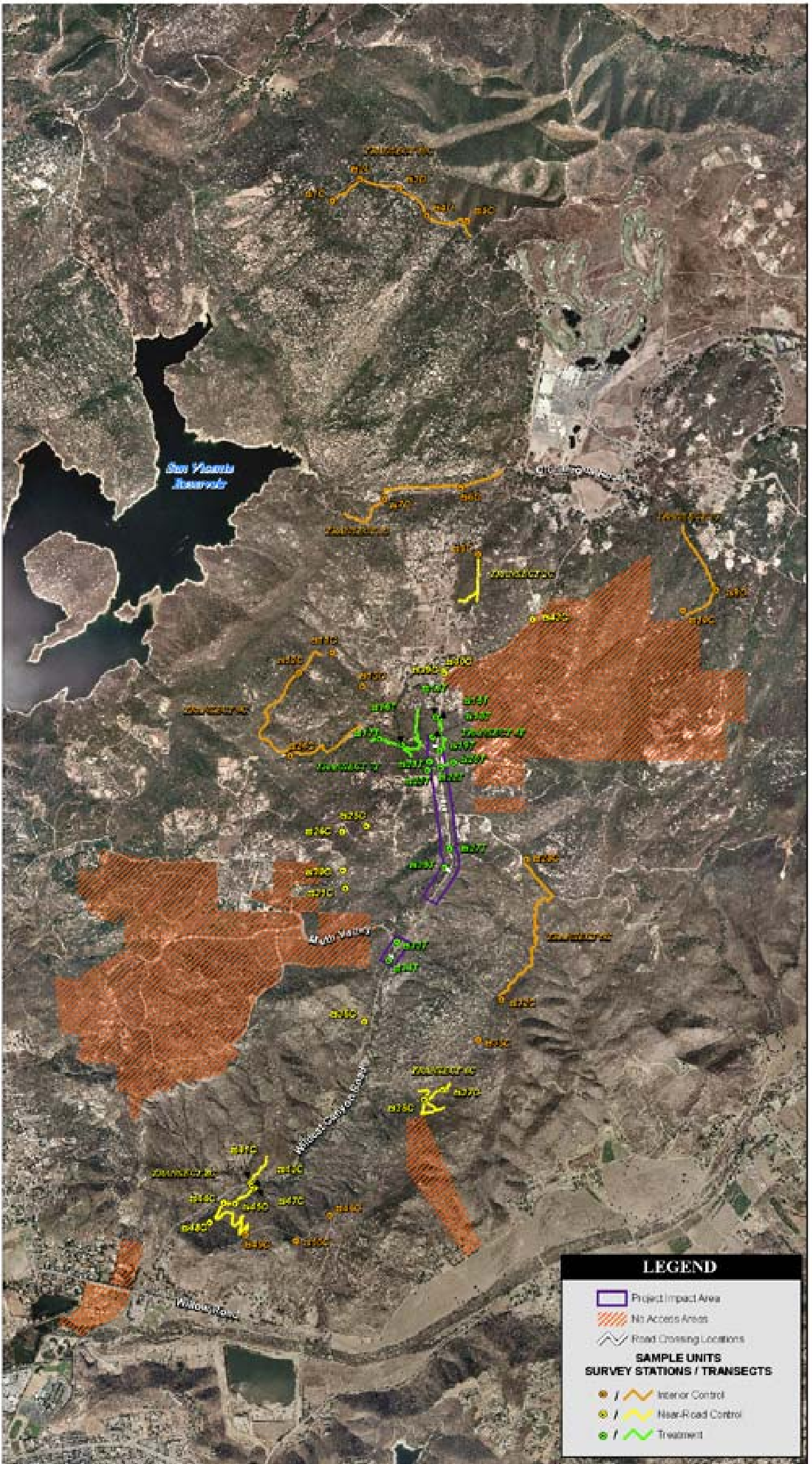


Figure 3
Study Area and Sample Units

During a reconnaissance survey conducted in July 2003, transects (Photo 1) were identified along wildlife trails, hiking trails, or dirt roads that showed evidence of wildlife use. Tracking stations (approximately 1.5-meter square area that had been swept clear and covered with fine-grain sifted soil substrate) (Photo 2) were placed along wildlife trails or road-crossing points evidenced by observation of sign during the reconnaissance survey.

Transects were walked once every other month to document the type and location of wildlife sign (tracks, scat, etc.) and the direction of individual travel. Tracking stations were monitored for 4 consecutive days once every other month to record wildlife tracks and direction of movement.

Roadkill

The roadkill survey involved walking along either side of the road within the study area for 3 consecutive days every 2 weeks to document the location and species of roadkill. All roadkill found during roadkill surveys were recorded via Global Positioning System (GPS) and marked with a small spot of spray paint to avoid duplication of data between survey days.

The study area was subdivided into four reaches that were used as sample locations for the roadkill analysis. The reaches reflect natural divisions for east-west movement patterns and are of approximately equal length. They were defined by four factors: topography, steep slopes (>33%), developed areas, and vegetation communities.

GIS Application – Data Collection

The Use of Mobile GIS

Mobile GIS allowed for consistent collection of transect and tracking station data by a large field crew over several years at multiple sample points. Mobile GIS technology allowed for field mapping applications to be undertaken with project guidelines intact, more precision, and data integrity. For this project, Trimble GPS GeoXT and ArcPad software (version 6.0.3) were used as the basis for mobile GIS. Trimble's GeoXT handheld GPS units were loaded with ArcPad software (version 6.0.3). The GeoXT handheld GPS units are lightweight, versatile, and durable, thus allowing for ease of data collection along vigorous hikes over rough terrain. The ArcPad software allowed for a common interface/menu to be used so that data collection efforts over numerous surveys by various surveyors were consistent. Having GIS available in the field allowed the survey teams to access the same maps and data as the GIS team in the office; record



Photo 1. Transect Segment



Photo 2. Tracking Station

new survey points (tracking stations or transect segments) as necessary; and observe these data points in relation to existing data in real time. After the Cedar Fire, it was often necessary to move the location of a station due to such factors as erosion and construction. Additionally, in a burned landscape, it was beneficial to have a postfire aerial with prefire survey points uploaded into the Trimble GeoXT to find, and if necessary relocate, survey points in a landscape transformed by the fire.

Mobile GIS provided the benefits of more accurate data collection, data interaction, and field verification. The ability of having data collection occur in an organized manner over a large, burned project area by multiple users was critical to obtaining accurate data in a timely manner. Using mobile GIS assisted project goals by simplifying data integration with less office time spent entering and organizing the data.

Statistics – Data Summary

Transect and Tracking Station Data

Profile analyses and canonical correlation analyses were conducted on the preconstruction data to quantitatively compare study units. These analyses also created a baseline of preconstruction results to which postconstruction data can be compared. For statistical analysis, it is important that the treatment represents the area one would expect to be affected with sufficient replicate samples for quantitative comparison. Therefore, multiple identical samples were taken over time to separate treatment effects from any other variations. Because ecological sites differ in practical settings, replication is used to estimate natural variation and to determine if the observed trends correspond to natural trends.

Statistical analyses were conducted on the following datasets: all focal species combined, individual focal species (for which substantial data for individual analysis existed), and all “other” focal species (for which data were infrequently recorded). The latter consisted of combined data for all focal species without substantial data for individual analysis. Analyses were run independently to show activity level differences between sample units and survey periods. The analyses used the time interval of survey month as the key factor for comparisons across sample units. Separate analyses including and excluding Survey #1 (prefire) were conducted to determine whether the fire caused differences in focal species detections across sample units.

Movement Patterns

Three separate approaches were used to determine movement patterns across the study area.

Preferred Direction of Movement

Small-scale directional movement preferences were determined by calculating a circular mean per dataset for each transect and tracking station. The circular mean determined the preferred direction of movement for the species. By definition, a circular mean consists of two parts, a direction (O) and a magnitude (r). Direction is indicated in units of degrees based on a geographical compass. Magnitude is a measure of the strength of the vector. Additionally, a P value was calculated for each circular mean to determine significance.

Relative Activity Levels

Relative activity levels were also calculated for each transect and tracking station to compare activity levels (number of individual passes observed) across sample points. Activity levels were calculated by standardizing data separately for either transects or tracking stations to a maximal value for the whole and then dividing every value in the dataset by that maximum. Calculated proportions were scaled to the largest recorded value.

Large-scale Movement Patterns

Large-scale movement patterns across the landscape were identified based on the profile analyses results and the visual analysis of preferred direction of movement, relative activity level, roadkill concentrations, topography, developed areas, resource availability, and vegetation communities.

Roadkill Data

Roadkill data were summarized by quantifying the raw data per species and calculating means per survey period for each reach. Preconstruction roadkill data were not statistically analyzed. Dense concentrations of roadkill were visually identified based on mapped roadkill data (Map 2). A roadkill concentration was defined as an obvious cluster of roadkill occurrences. These concentrations considered data on all observed wildlife species, not just focal species. Roadkill concentrations represent locations that appear most problematic for wildlife movement.

GIS Application – Data Summary

Preparation of Species Data Maps

Species data maps prepared for each of the six preconstruction survey periods were created using ESRI's ArcGIS software. Aerial photography, park lands, topography, and roads were used as base map data. Survey data was then overlaid from transects and tracking stations. Transect data maps for each survey reflected data per 100-meter segment along each transect. Each segment has a tally for each of the 14 focal species observed respective to each survey period. Each species was given a two-letter code and corresponding color label placed along the mapped segment showing how many individuals of each species were found at that segment. This allows the reader to easily distinguish between each segment and see the frequency and distribution of identified animals. The tracking station maps were similarly created with the exception that the stations reflect point data while the survey transects reflect linear data. Thus, the species data maps reflect the frequency of individual focal species and the biodiversity of focal species observed at each segment or station.

Movement Patterns

GIS was used in the preparation of maps reflecting the preferred direction of movement, the relative activity level, and the large-scale movement patterns datasets, as described above. These are reflected in Maps 1 and 3.

Maps showing preferred direction of movement were created using ArcGIS software. Map 1 shows the movement data for all focal species. The circular mean is symbolized by a pie chart and arrow concept to show each relative activity level, preferred direction of movement, and magnitude of directional preference. The pie chart shows a blue shaded area reflecting the relative activity level of a particular transect or station as compared to all other transects or stations. This allows an understanding of which transects and stations had the greatest and the least activity per dataset. The arrow symbol's position on the pie chart shows the mean compass-oriented direction of travel preferred by focal species at that location. The size of the arrow shows the magnitude of preference for movement in that direction. Thus, the larger the arrow is, the greater the preference of movement in that direction. Utilizing this two-pronged pie chart-and-arrow approach, it was possible to show relative activity levels and preferred directions of movement along each surveyed transect and station. Map 1 presents a visually appreciable representation of exactly where most focal species occur within the study area and in which direction most focal species tend to move at each sample point.

Large-scale Movement Patterns

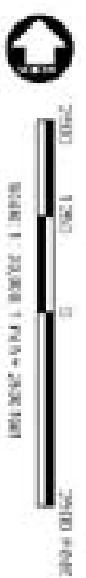
Large-scale movement patterns across the landscape are shown in Map 3. These movement patterns were developed based on the profile analysis results; the visual analysis of preferred direction of movement and relative activity levels (Map 1); roadkill concentrations (Map 2); and topography, developed areas, and vegetation communities (Figures 4 and 5). Areas with higher activity levels and statistically significant direction of movement (depicted in Map 1) were given greatest consideration in identifying these large-scale movement patterns. The results of the profile analyses, which identify differences in activity levels between sample units, were considered when determining large-scale movement patterns. These movement patterns were identified for all focal species, but not for individual species because profile analyses and circular mean values were often not significant and roadkill data for individual focal species were scarce. Roadkill concentrations (Map 2) represent local scale movement trends. These local trends were factored into the development of the large-scale movement trends. Additionally, large-scale movement patterns were identified based on topography features, absence of developed areas, and vegetation communities that facilitate wildlife movement.

Study Considerations

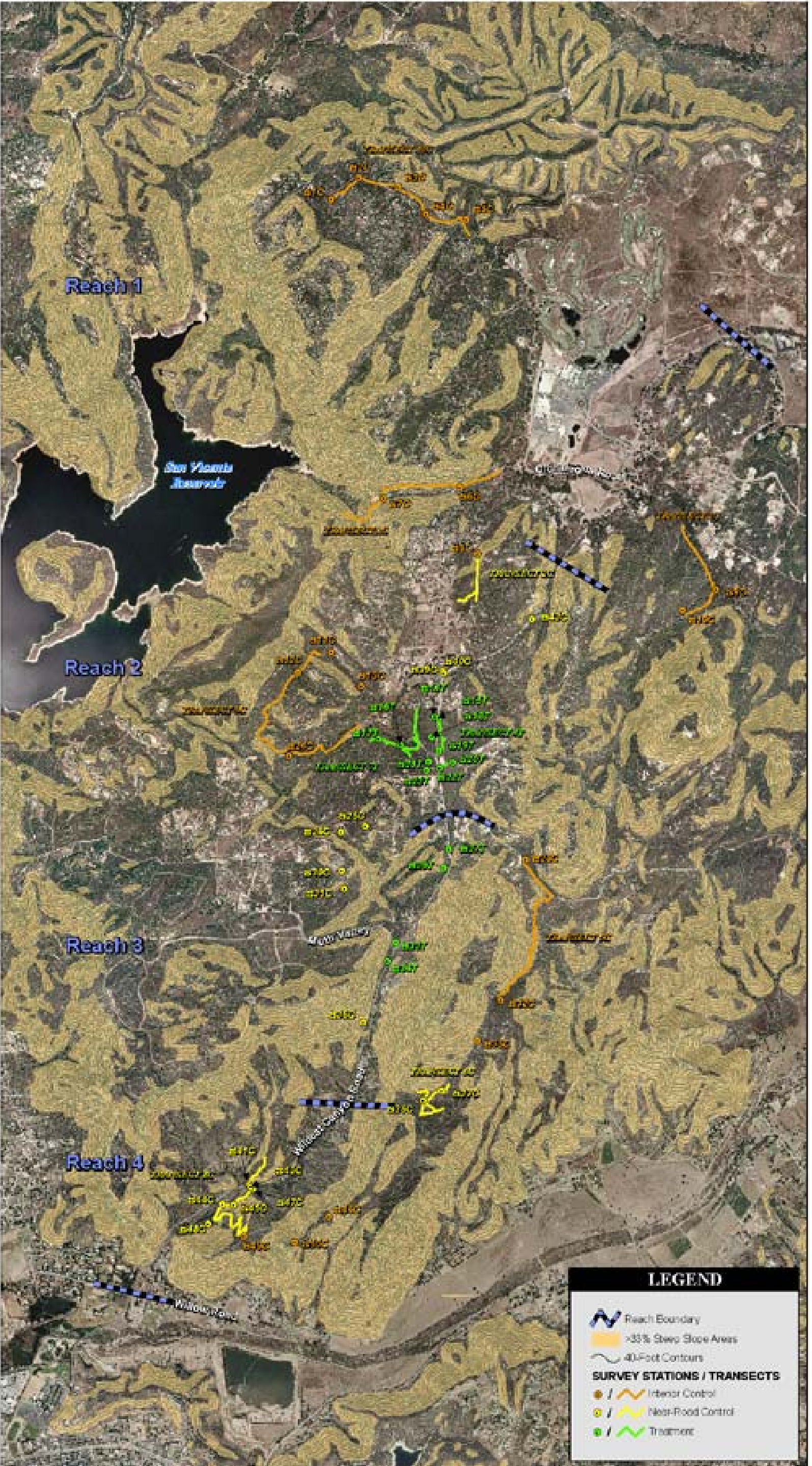
Several factors were considered when evaluating the integrity of the study design, such as access, topography, habitat types, and the Cedar Fire of 2003.

- **Access** – Multiple areas of privately owned, undeveloped land (e.g., Silverwood Wildlife Sanctuary, High Meadows Ranch) were excluded from the study design due to access restrictions, which resulted in gaps in spatial sampling coverage of the study area (Figure 3).

- **Topography and Habitat Type** –
 - Habitat types were generalized into three broad categories: chaparral, coast live oak/riparian, and coastal sage scrub/disturbed. Postfire conditions contained minimal structural distinction between habitat types. Potential biases existed between sample units based on topography or habitat type surrounding transect segments and tracking stations.
 - Track detectability along transects varied between survey periods based on variable substrate conditions. The effects of weather patterns on natural substrate, often in relation to postfire habitat recovery, created varying substrate conditions, some of which optimized track detectability, and others that minimized it.



Source: Esri/Aerial 2011, GeoEye, IGN, GeoEye/Satellite (Blended)



LEGEND

- Reach Boundary
- >33% Steep Slope Areas
- 40-Foot Contours

SURVEY STATIONS / TRANSECTS

- Interior Control
- Near-Road Control
- Treatment

Figure 4
Reaches, Topography
and Steep Slope Reference

- **Cedar Fire –**

- The most striking consideration during the study was the Cedar Fire, which burned the entire site in October 2003. The fire removed nearly all natural vegetation that would have been used as cover by focal species living in or moving through the study area. Because the fire had a relatively equal effect on the treatment and controls, it did not directly invalidate the BACI study design. However, the timing of the fire, between the first and second survey periods, meant that survey data collected before the fire might differ greatly from data collected after the fire, potentially compromising the integrity of the study design.
- For the purpose of study analysis, it was assumed that the Cedar Fire affected the entire study area equally. However, statistical analyses that included and excluded Survey #1 were run to test this assumption.

RESULTS

Based on the principles discussed above, the preconstruction survey resulted in the identification of 13 large-scale movement patterns (Map 3) that will serve as the baseline for comparison with the postconstruction conditions. Large-scale movement patterns identified within the study area were determined through interpretation of several analyses, including profile analyses, relative activity level of different species (Map 1), preferred direction of movement (Map 1), roadkill concentrations (Map 2), and general field observations.

GIS-based Solutions

The ability for the project survey teams to have consistent work flow while covering rugged terrain in varied conditions was essential to the project goals and timelines. Mobile GIS helped facilitate the goal of maintaining consistent data gathering while teams were on the move from station to station and along survey transects. The use of mobile GIS has also helped the project teams use the data more readily and easily in the office after field efforts and to compare the data of previous surveys while in the field. The use of mobile GIS on this project aided both field and office staff by saving time, avoiding duplication of efforts, and removing confusion on proper data collection techniques. This resulted in project data more readily available for mapping and analysis with a minimum of preparation and transformation from one form of data to another. The use of ArcPad software and Trimble GPS as the basis for the mobile GIS used has been a great learning experience for all staff involved from the field to the office. This project has spearheaded a whole new and different approach for our field efforts. The benefits of going to a mobile GIS have far outweighed the costs, due to the time saved and lessons learned.

Movement Patterns

Circular means for all focal species (Map 1) identified localized preferred direction of movement. Direction preferences were supported by field observations and were attributed to multiple factors, including localized trails/roads, topographic features, and locations of resources. For example, preferred direction of movement at Station 44C (Map 1) was to the southwest. This direction follows the oak riparian habitat adjacent to the road in a deep canyon. Thus, little movement in other directions would be expected. Statistically significant circular means were verified through general field observations and considered in identifying large-scale movement patterns (Map 3). For example, arrows pointing northeast or southwest at Transects 5C and 6C, and Stations 32C, 35C, and 37C (Map 2) were considered when identifying the large-scale movement arrow in this same area (Map 3). However, field observations were sometimes given stronger consideration than circular means in identification of large-scale movement patterns because the circular mean calculation is uni-directional and localized and does not consider contiguous movement across the landscape. For example, the overall observed pattern of movement around Transect 8C in Reach 4 was in a northwesterly-southeasterly direction along the transect and across the road (Map 3). However, circular mean calculations associated with these sample points do not reflect this pattern when viewed individually.

Field observations confirmed a difference in relative activity level between sample points for all focal species (Map 1). Highest localized activity level at transects and tracking stations in the interior control and the majority of the near-road control could be attributed to high-quality habitat and lack of developed areas. For example, Transects 1C and 10C, and Stations 4C, 37C, and 38C, all exhibiting high relative activity levels, are located in areas of pristine chaparral adjacent to oak riparian habitat and are at least ¼ mile from human development. These sample points are also separated from development by geographical features, such as large ridges, that provide further shelter from human-related disturbances. Lower localized activity levels in the treatment and portions of the near-road control could be attributed to factors such as proximity to developed areas (Transect 7T; Stations 39C, 40C) and postfire recovery patterns including hydroseed/nonnative grass establishment (Stations 36C, 42C). Those areas with higher localized activity levels were given stronger consideration when identifying large-scale movement patterns (Map 3).

Roadkill

Although linear features such as roads constitute a general impediment to wildlife movement (Finnis 1960; Haugen 1944), preconstruction roadkill results indicate certain portions of Wildcat Canyon Road appear more hazardous than others to crossing wildlife. These portions of the road are indicated by roadkill concentrations (Map 2) that were attributed to a variety of factors,

including concentrations caused by the surrounding environment and those caused by the existing road configuration. Factors included topography, resource availability, density of vegetation, culverts, sharp road curves, and areas of high vehicle speed.

Roadkill data collected within the preconstruction survey consisted mostly of small, nonfocal species. This may reflect several possible scenarios. With larger body sizes, focal species may be more visible to drivers and may allow for longer reaction time to reduce vehicle speed and avoid the crossing animal. Several larger focal species, such as bobcat and coyote, are capable of moving faster across the road surface than smaller mammal species and are thus more likely to avoid collision with a vehicle. The Cedar Fire may have influenced which species were observed as roadkill. Most of the roadkill data were collected immediately after the Cedar Fire, revealing a cross section of wildlife species (which happened to be mostly nonfocal species) fleeing the approaching fire. Most focal species have low density/large area requirements, meaning that fewer individuals of a focal species inhabit the study area compared to smaller mammals such as cottontail and Norwegian rats. Thus, it would be expected that smaller species such as cottontails would be proportionally affected in higher numbers by fire-flight-induced roadkill than focal species.

Several roadkill concentrations are located in the vicinity of existing undercrossings and proposed crossings. For example, Concentration 4 is located at the proposed 14-foot x 12-foot wildlife/equestrian tunnel near the northern boundary of the treatment (Map 2). Concentration 5 is located approximately 600 feet north of the existing 48-inch twin box culverts that are proposed for improvements (Map 2). Comparing preconstruction roadkill concentrations to postconstruction roadkill data may have implications on the location and design of wildlife crossings and associated fencing design. If postconstruction data reveal a decrease of roadkill concentrations in the treatment, coupled with a constant level of wildlife activity, one could assume that either the crossing design and fencing design were successful in facilitating wildlife movement, or that animals avoided this area and crossed elsewhere. The latter could result in shifted roadkill concentrations. This potential shift should be detected by increase in concentrations in the near-road control. A successful crossing design would result in a combination of the following: (1) a decrease in roadkill at this location; (2) results indicating successful use of the crossing structure; and (3) no increase in roadkill concentrations north and south of this location.

Roadkill concentrations positively identify areas of wildlife movement across the road. Concentrations were also considered in identifying large-scale movement patterns (Map 3). Concentration 2 in Reach 2 (Map 2) corresponds to the east-west large-scale movement pattern identified at this location (Map 3); Concentration 5 in Reach 3 corresponds to the northwest-

southeast large-scale movement pattern identified at this location (Map 3). Concentrations 9 and 10 in Reach 4 (Map 2) are in proximity to the northwest-southeast large-scale movement pattern identified at this location (Map 3).

One potential benefit for the future of the project success and objectives is an MS Access database. This database, compiling data from all surveys throughout the study, will allow for easier statistical analysis. It also allows for queries and overall ease of use for not only the GIS analysis and maps but also for running reports and other querying capabilities as needs arise. Another benefit for the future of the project is all the experience gained working with the project data from all standpoints of GIS and biology.

Quantifiable roadkill results conceptualizing the spatial relationships of roadkill concentration points could be achieved by performing a cluster analysis with a spatial statistics GIS extension. Cluster analysis is an exploratory data analysis tool, which aids in discovering the degree of association and patterns within a dataset. Identifying clusters is a way of looking at more than one variable. In this case, not only are we looking at the geographical location of a roadkill, but also what species it is, to see if and how the two points are related. The ArcMap spatial statistics toolbar in ArcToolbox gives several ways of mathematically searching for roadkill points within a given length of road. The cluster tools differ by their method of mathematical calculations; all the inputs by the common GIS user would be the same for each. Without intensive research on each method, the best way to decide which one is right for a particular study is to try out various types as well as research what parameters to input into the tool. The parameters are defining a minimum number of points set as a concentration as well as a maximum search area. The chosen cluster tool would then search the length of road in overlapping segments of the search area for groups containing at least the minimum number of roadkill defined as significant. The minimum parameter criteria would be defined to avoid overlap of multiple concentration points, which could occur if roadkill was sparsely distributed. The defined parameters of the roadkill concentrations should be consistent between pre- and postconstruction analyses. This type of GIS analysis would also provide geographic coordinates associated with each concentration point allowing for a spatial comparison to determine the distances between pre- and postconstruction roadkill concentration points.

DISCUSSION

The objectives of the study will be fulfilled by determining if there are differences between the treatment and controls in relationship to preconstruction and postconstruction survey periods, and if a difference can be linked to construction-related impacts. The study employs various methods to test whether there is wildlife movement, where movement occurs, and where activity

level is highest. Only after the postconstruction portion of the study can it be determined whether impacts to movement were attributed to the road enhancement project. The secondary objective of the study is to test whether designed wildlife crossings function properly, which again can only be determined after completion of the postconstruction portion of the study. Study results with relevance to the preconstruction study design and data analysis are discussed below, as well as study shortcomings and recommendations for future surveys.

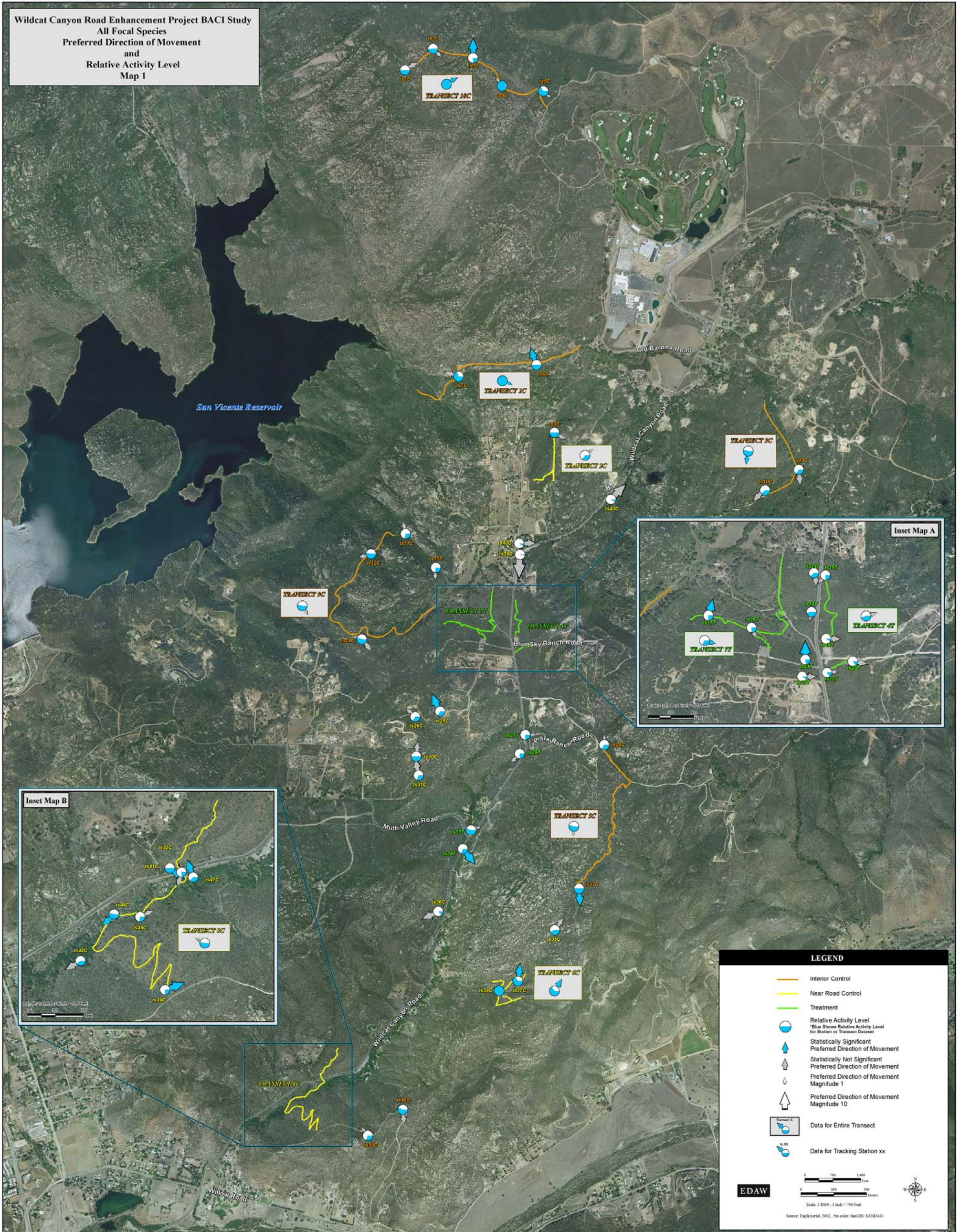
Wildcat Canyon Road is characterized by its rural character, surrounding open space, and topography, which all facilitate wildlife movement. The Multiple Species Conservation Program (MSCP) preserve design shows Wildcat Canyon Road as a regionally important north-south wildlife movement corridor. However, no controlled studies had been performed to substantiate this assumption. The large-scale movement patterns established from the preconstruction results of this BACI study demonstrate that the study area is being used as a wildlife movement corridor despite being burned during the 2003 Cedar Fire. It also shows that movement is not limited to a north-south direction but moves east-west across the study area, connecting large expanses of open space. Completion of the BACI study will determine any effects of the project on these movement patterns and the ability of the proposed undercrossings to better maintain the study area as a functioning corridor.

Many focal species analyzed in this study require multiple habitat types for large-scale movement. This movement is influenced by a variety of factors such as habitat quality, which is defined by the presence of water, forage, prey items, and cover (Jaegar 2000). Topography, dispersal routes, and species-specific seasonal activity also direct large-scale movement (Carr et al. 2002). For example, mule deer are more prone to move in areas of dense cover such as drainages (Mansfield and Miller 1975), and mule deer bucks in search of mates may move through areas during the breeding season that are not traversed during the rest of the year (Buchanan 1987). In addition, factors such as developed areas and roads with heavy traffic may influence movement direction (Lovallo and Anderson 1996).

Next Steps

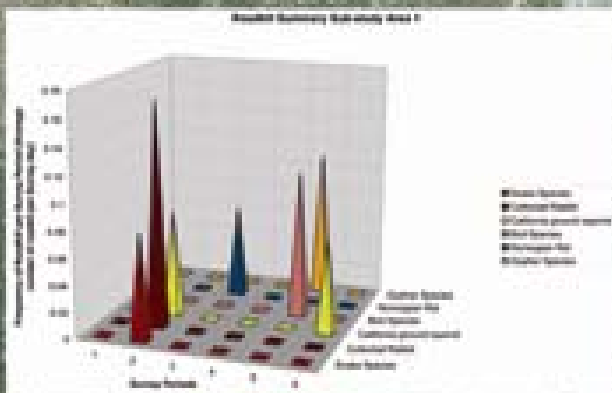
It is recommended that a statistical power analysis be run prior to future data collection to define a sufficient sample size and error rates for this study. Additional preconstruction surveys are recommended to increase the preconstruction study rigor. During future pre- and postconstruction surveys, the roadkill study area should be extended, additional sampling locations and camera stations added, and more rigorous statistical analysis provided, specifically for the roadkill data and directional movement trends. The postconstruction portion of this study will use similar analyses and is scheduled to begin in September 2006.

Wildcat Canyon Road Enhancement Project BACI Study
All Focal Species
Preferred Direction of Movement
and
Relative Activity Level
Map 1

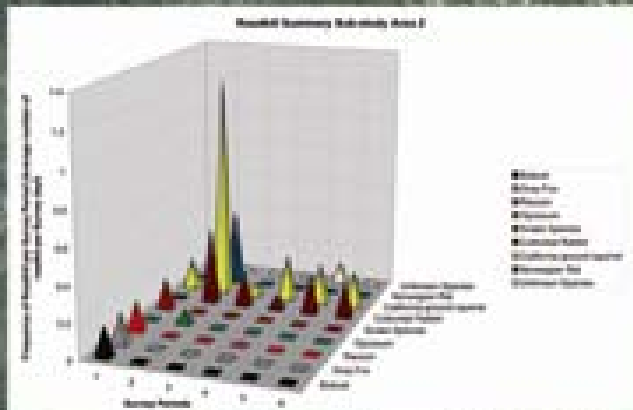


Wildcat Canyon Road Enhancement Project

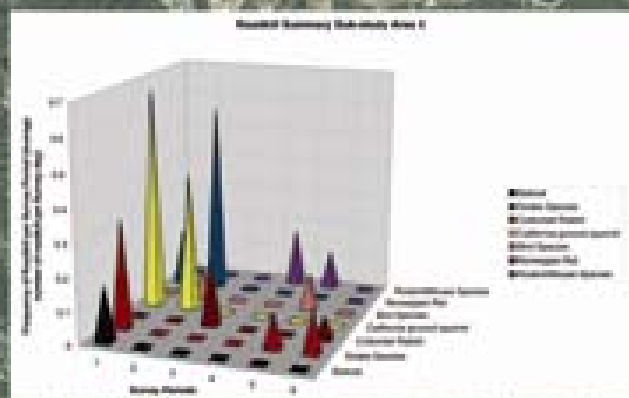
BACI Study
Roadkill Survey Data
Map 2



SUB-STUDY AREA 1

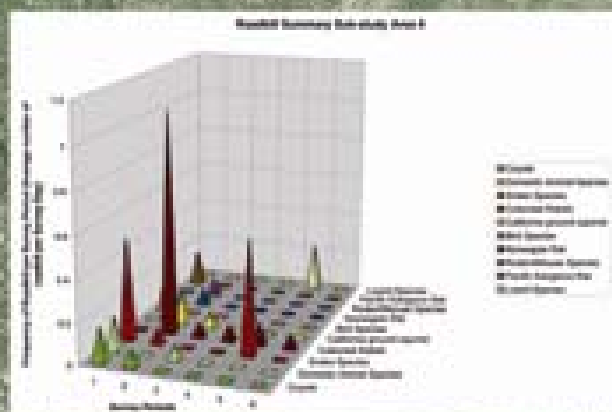


SUB-STUDY AREA 2



SUB-STUDY AREA 3

SUB-STUDY AREA 4



Roadkill Survey Data
Surveys 1-6
September 8, 2003 - July 26, 2004

Focal Species:

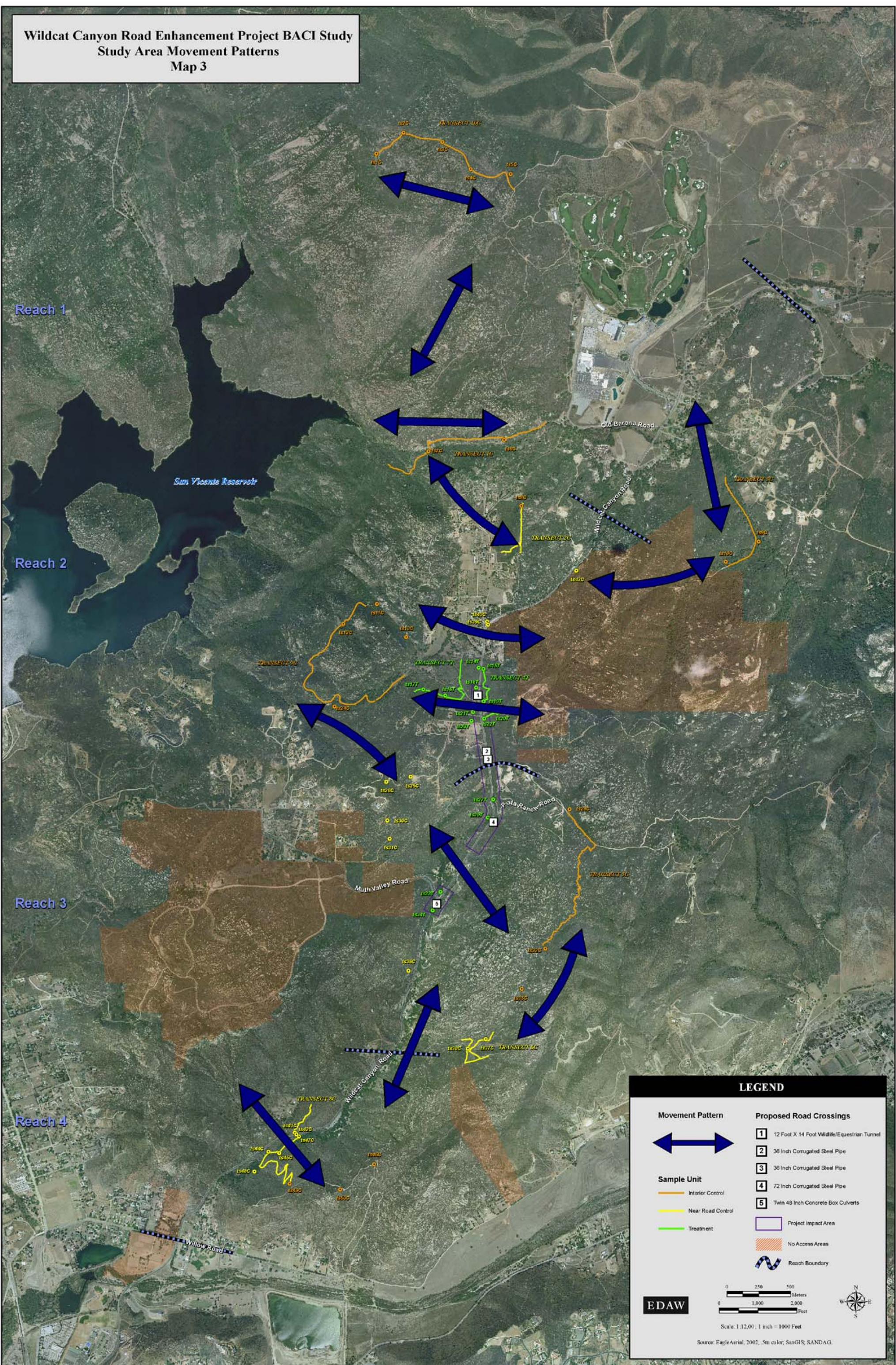
- Badger
- Coyote
- King Fox
- Skunk
- Squirrel

Other Species:

- Domestic Animal Species
- Black Bear
- California Mink
- California Ground Squirrel
- Bobcat
- Mountain Lion
- Eastern White Squirrel
- Pacific Kangaroo Rat
- Least Squirrel
- Eastern Squirrel
- Unknown Species

■ Sub-Study Area Boundary
■ Road Crossing Location
■ Project Impact Area

**Wildcat Canyon Road Enhancement Project BACI Study
Study Area Movement Patterns
Map 3**



Reach 1

Reach 2

Reach 3

Reach 4

San Vicente Reservoir

Old Barona Road

Wildcat Canyon Road

Pasta Ranch Road

Muth Valley Road

Wildcat Canyon Road

Willow Road

LEGEND

- | | |
|-------------------------|---|
| Movement Pattern | Proposed Road Crossings |
| | 1 12 Foot X 14 Foot Wildlife/Equestrian Tunnel |
| Sample Unit | 2 36 Inch Corrugated Steel Pipe |
| | 3 36 Inch Corrugated Steel Pipe |
| | 4 72 Inch Corrugated Steel Pipe |
| | 5 Twin 48 Inch Concrete Box Culverts |
| | Project Impact Area |
| | No Access Areas |
| | Reach Boundary |

EDAW

0 250 500
0 1,000 2,000
Meters
Feet

Scale: 1:12,000; 1 inch = 1000 Feet

Source: EagleAerial, 2002, .5m color, SanGIS, SANDAG

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