UNIVERSITY OF CALIFORNIA
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Designing Road Crossings for Safe Wildlife Passage: Ventura County Guidelines

A Group Project submitted in partial satisfaction of the requirements for the degree of
Master's of Environmental Science and Management
for the
Donald Bren School of Environmental Science and Management

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The Group Project is required of all students for the Master of Environmental Science and Management (MESM) degree. It is a four-quarter project in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM candidates and has been reviewed and approved by:

Frank Davis	Dean Dennis Aigner

Table of Contents

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1 Guidelines Document Overview

1.1 Document Organization

This document is designed to assist planners in conditioning discretionary land use entitlement permits with appropriate mitigations to minimize adverse impacts to wildlife movement corridors. Specifically, the document provides guidelines for designing roads and associated crossing structures to accommodate safe wildlife passage through the surrounding landscape. The sections are organized as follows:

- **Section 1**: Explains how the document is organized, includes important definitions, discusses the policy authority to implement these guidelines, and presents an overview of the Ventura County Planning Division discretionary permit process.
- **Section 2**: Details the purpose of the document, provides pertinent background information on road ecology and associated impacts to wildlife, and outlines wildlife corridor connectivity in Ventura County.
- **Section 3**: Provides universal mitigation design standards to reduce the negative impact of roads on wildlife movement. Discusses wildlife corridor identification and assessment.
- **Section 4**: Provides specific mitigation design standards for five wildlife functional groups, as well as considerations for multiples species mitigation.
- **Section 5**: Describes additional considerations for mitigation, including maintenance and monitoring, education and public outreach, and costs.
- **Section 6:** Provides a catalogue of various structure types and design features.
- **Appendix A**: Provides additional background regarding wildlife movement corridors and information regarding the literature review, and the development of the data and knowledge bases.
- **Appendix B**: Describes the methods and results from our roadkill survey and wildlife use observations in unincorporated Ventura County.

1.2 Definitions

Landscape linkage

A large, regional arrangement of habitat (not necessarily linear or continuous) that enhances the movement of animals or the continuity of ecological processes at the landscape level (Bennett 2003). A landscape linkage may include numerous wildlife movement corridors.

Wildlife movement corridor

A patch of wildlife habitat, generally vegetated, which joins two or more larger areas of wildlife habitat.

Crossing structure

A structure such as a pipe, culvert, bridge underpass, or overpass which may be used by wildlife for passage over or under a roadway. Most traditional crossing structures are primarily intended to facilitate the flow of water. However, studies have shown that crossing structures can also facilitate wildlife passage, reduce wildlife mortality from vehicle collisions, improve highway safety, and improve habitat connectivity.

Crossing scenario
A collection of road design features intended to mitigate roadway impacts on wildlife, in addition to or in place of a crossing structure, such as signage, speed control mechanisms, fencing, street lighting, and non-vegetated landscaping.

Connectivity
The degree to which the landscape facilitates or impedes movement among habitat patches (Taylor and Goldingay 2003). The concept of connectivity is used to describe how the spatial arrangement and the quality of elements in the landscape affect the movement of organisms among habitat patches (Merriam 1984, Taylor and Goldingay 2003, Forman and Alexander 1998).

Functional Group
A group of species that tend to prefer similar crossing structure design characteristics (see table in Appendix A, Section A2.1.2 for more information). Please note that this term is not a scientific classification system.

Openness Ratio
Applied to crossing structures and defined by the equation:
Openness Ratio = (Height x Width)/Length

Mortality Sink
A habitat area that is unable to support a viable long-term population by itself. A sink habitat offers suitable short-term cover, food, and water to animals, but production of young in a local population is less than the mortality rate.

Crossing Substrate
The surface material composing the bottom of a crossing structure.

Riparian
Riparian areas are plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermittent lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one of both of the following characteristics: 1) distinctively different vegetative species than adjacent areas, and 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland (U.S. Fish and Wildlife Service/National Wetlands Inventory 1997).

Wetland
Plant communities that are associated with lands which are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is periodically covered with shallow water. The frequency of occurrence of water is sufficient to support a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction. Wetlands include marshes, bogs, sloughs, vernal pools, wet meadows, river and stream overflows, mudflats, ponds, springs and seeps (*Ventura County Initial Study Assessment Guidelines* 2000).

1.3 Ventura County Wildlife Movement Corridor Policy

The *Ventura County General Plan* (Goal 1.5.1) specifically calls for the protection of wildlife movement corridors:

Preserve and protect significant biological resources in Ventura County from incompatible land uses and development. Significant biological resources include endangered, threatened or rare species and habitats, wetland habitats, coastal habitats, wildlife migration corridors and locally important species/communities.

In addition to the *Ventura County General Plan Goals, Policies and Programs*, the *Piru Area Plan* has similar requirements. Goal 1.5.1 (2) states:

Protect the Piru Creek wildlife migration corridor between the Los Padres National Forest on the north and the Santa Clara River and Oak Ridge Big Mountain habitat on the south.

These goals provide direction for the Ventura County Planning Division staff to review the impacts of discretionary land use entitlements on movement corridors. When the Planning Division receives discretionary land use entitlement project applications, they review each project according to the California Environmental Quality Act (CEQA) guidelines for individual and cumulative impacts to the environment, including movement corridors. The Planning Division and all other County agencies must adhere to the *Ventura County Initial Study Assessment Guidelines* when assessing a project's potentially significant impacts to the environment. These Guidelines assist County staff with making mandatory findings of significance to the environment, which CEQA Section 15065 (a) defines as:

The project has the potential to substantially degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of an endangered, rare or threatened species, or eliminate important examples of the major periods of California history or prehistory.

The *Ventura County Initial Study Assessment Guidelines* (2000) include language regarding the importance and protection of significant biological resources, including movement corridors. They define a movement corridor as:

An area as defined by a qualified biologist, which experiences recurrent fish or wildlife movement and which is important to fish or wildlife species seeking to move from one habitat area to another.

Qualified biologists are those biologists who conduct biological studies for land use entitlements on behalf of the County. These may include regulatory agency biologists, academics, and local area expert naturalists.

The *Ventura County Initial Study Assessment Guidelines* provide the following threshold criterion, as determined by a qualified biologist, for impacting movement corridors:

A significant impact to a migration corridor would result if a project would substantially interfere with the use of said area by fish or wildlife. This could occur through elimination of native vegetation, erection of physical barriers or intimidation of fish or wildlife via introduction of noise, light, development or increased human presence.

1.4 Ventura County Discretionary Permit Process

Any discretionary land use entitlement permit approved by Ventura County may be conditioned to require road crossing mitigation if a wildlife movement corridor is impacted by the project. Impacts to wildlife movement corridors are determined by a qualified consulting biologist. Mitigation requirements may apply to new roads or the renovation of existing road crossings in conjunction with a discretionary permit. The discretionary permit process, as it pertains to these wildlife corridor mitigation requirements, is illustrated in Figure 1.1 and summarized below:

1. Discretionary land use entitlement permit application is filed by applicant.
2. Upon receipt of the application, a Ventura County case planner begins a 30-day review process and determines if biological resources are potentially affected by the project.
3. If biological resources are believed to be affected by the project, the application is forwarded to the County's consulting biologist for an Initial Study Assessment (per *Ventura County Initial Study Assessment Guidelines*) during the 30-day review period.
4. For each discretionary permit being reviewed, the qualified biologist is expected to make the determination that a project will have:
   a) no impacts to wildlife movement corridors on a project and cumulative scale.
   b) impacts that will be less than significant on a project and cumulative scale.
   c) impacts that may be potentially significant but mitigation measures could reduce the impacts to less than significant on a project and cumulative scale.
   d) potentially significant impacts could result from the project that cannot be mitigated on a project and cumulative scale.
5. After review, the discretionary permit application will have one of the following findings:
   a) **Unmitigable Impact:** If feasible mitigation measures for project impacts cannot be developed, an initial study CEQA review can be elevated to an Environmental Impact Report (EIR) or an applicant may choose to retract his/her application. EIRs are typically conducted on large scale projects for which environmental impacts are foreseen; however, they may also be conducted for projects that have been found to have a potentially significant effect on the environment during an Initial Study that cannot be mitigated. An EIR requires project alternatives that offer solutions to minimize impacts to significant environmental resources.
   b) **Impact Requiring Negative Declaration:** If the project impacts a wildlife movement corridor(s) and is mitigable, the project description may be revised to incorporate wildlife movement corridor mitigation (per this document), resulting in a Negative Declaration.
   c) **Impact Requiring Mitigated Negative Declaration**: If the project impacts a wildlife movement corridor(s) and is mitigable, but does not incorporate mitigation into the

project description, the project is required to adhere to the wildlife movement corridor mitigation requirements, resulting in a Mitigated Negative Declaration.

6. If the consulting biologist identifies mitigable impacts to existing wildlife movement corridor(s) resulting from the project, they will work with the case planner to specify appropriate mitigation measures (per this document).
7. Regardless of type of impact, the imposed conditions and required mitigations will include fees to ensure monitoring and maintenance activities are carried out by the responsible party, and funds are available for the Ventura County Planning Division to evaluate mitigation and condition compliance.

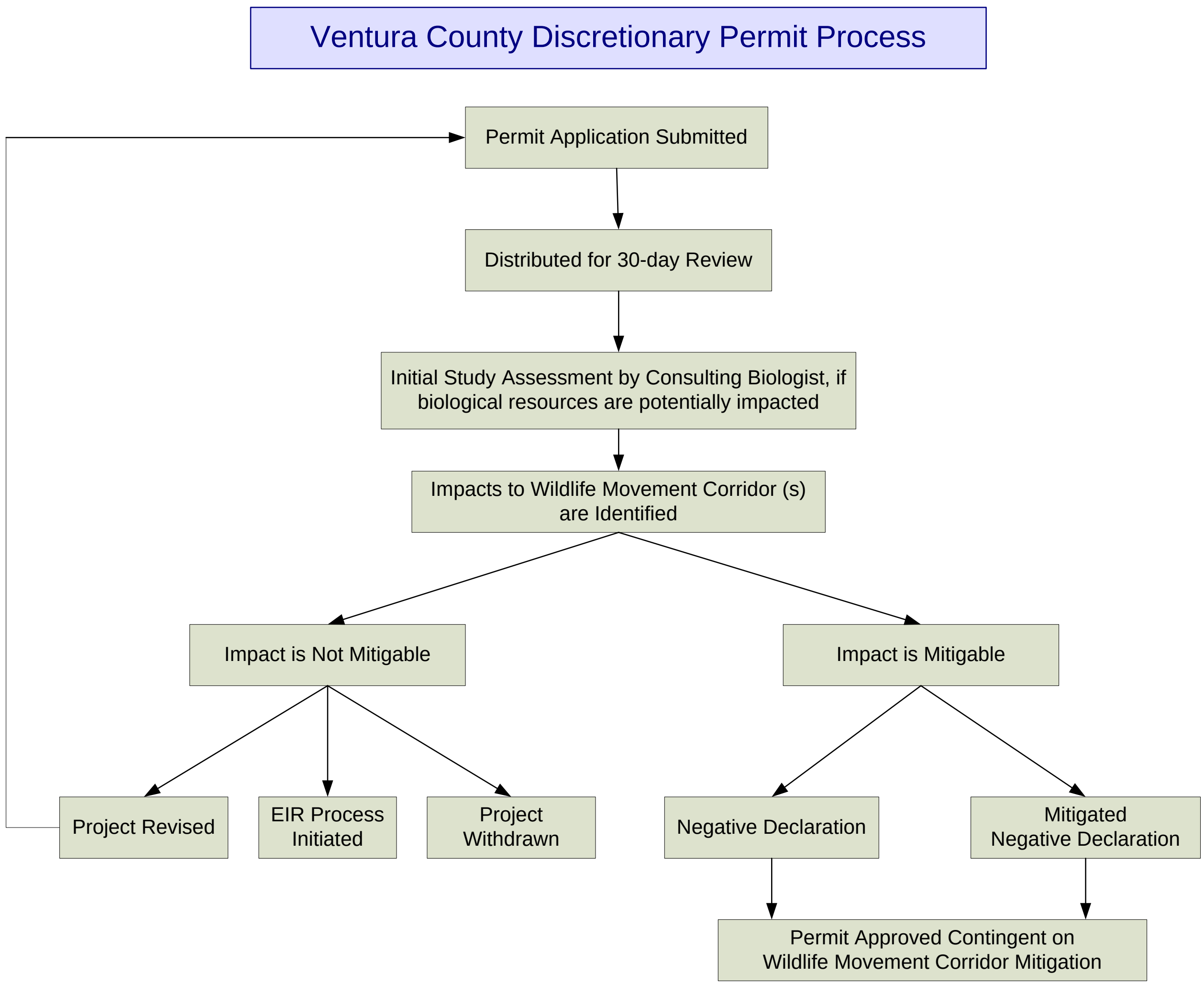


Figure 1.1

2 Purpose and Background

2.1 Purpose

The purpose of these guidelines is to assist planners as they review and condition discretionary land use entitlement permits that will adversely impact wildlife movement corridors. These guidelines are intended to provide specific mitigation recommendations to best accommodate wildlife movement and connectivity throughout Ventura County, CA. The recommendations are based on information obtained from a literature review conducted from April 2004 to January 2005, and supported by field surveys conducted within unincorporated Ventura County, CA from July 2004 to February 2005. Experience and knowledge from local experts is also included.

According to the U.S. Department of Transportation's Federal Highway Administration, there are more than 3.9 million miles of public roads that span the United States. Each day, an estimated 1 million animals are killed on roads, making roadkill the greatest direct human-caused source of wildlife mortality in the country (Forman 1998).

Road avoidance by species has an even greater ecological impact, impeding animal movement and restricting habitat connectivity. Roads are also responsible for the loss and fragmentation of habitats, causing isolation and leading to problems such as genetic drift, inbreeding, resource depletion, reduction of biodiversity, and even extinction of wild populations (Soule 2001).

Efforts to mitigate negative wildlife-roadway interactions increasingly incorporate the use of modified culverts, pipes, and bridges as wildlife crossing structures. Most crossing structures are engineered to prevent roads from inhibiting the flow of water. However, with proper refinements and modifications these structures may also facilitate wildlife movement and habitat connectivity. Though efforts to utilize this type of mitigation have been researched and discussed since the mid 1970's, much remains to be done to synthesize and incorporate the current knowledge into planning policy.

The promotion of wildlife movement through crossing structures decreases wildlife mortality from vehicle collisions and associated risk to humans. It may also enhance species viability in areas where roads have fragmented habitat and restricted wildlife movement. The intent of this document is to provide a framework to achieve these goals based on the current level of knowledge, while providing a means to incorporate new information as it becomes available.

2.2 Wildlife Corridor Connectivity Within Ventura County

An average of 6 million vehicle miles are traveled daily on Ventura County's 88 miles of freeway. There are and additional 185 miles of conventional highway within the County (California Department of Transportation 2004), with the unincorporated portion of the County containing a total of 85 non-arterial roads (Ventura County Transportation Department 2004).

According to Conservation International, the California Floristic Province (of which southern California is part) is one of the world's top 25 most biologically diverse and threatened regions.

Thus, the loss of any landscape linkage in southern California threatens some of the world's rarest and most precious biodiversity. Ventura County is located within the California Floristic Province and has multiple landscape linkages and many wildlife corridors. The Los Padres National Forest in the northern part of the County and the Santa Monica Mountains in the southwest portion of the County are critical core habitat areas.

Although highly fragmented by urbanization and extensive road networks, the County is committed to preserving existing connectivity throughout the landscape. In fragmented landscapes, connectivity can be maintained through:

- A close spatial arrangement of small habitat patches serving as stepping-stones,
- Corridors that link habitats like a network, and/or
- Artificial measures such as wildlife passages (Bennett 2003)

Wildlife movement barriers in the County were first addressed in the *Missing Linkages: Restoring Connectivity to the California Landscape* report (Penrod et al. 2001). Biologists who participated in the Missing Linkages workshop identified landscape linkages throughout the State and underscored the importance of addressing connectivity choke-points. The conference defined a landscape linkage as large, regional connection between habitats meant to facilitate movements between different sections of the landscape. Connectivity choke-points were defined as narrow, impacted, or otherwise tenuous connections between habitat blocks. An example is an underpass of a major roadway.

The South Coast Missing Linkages Project was initiated in 2001 by the South Coast Wildlands Project (SCWP), a non-profit organization. The goal of this project was to address 15 of the 69 critical landscape linkages most in need of protection in the South Coast region. Three of these 15 landscape linkages are located in Ventura County.

In 2002, the South Coast Wildlands Project and the UCSB Donald Bren School Group Project, *Wildlife Corridor Design and Implementation in the Southern Ventura County* (Casterline et al. 2003), initiated a Geographic Information System (GIS) analysis to address the wildlife connectivity needs and landscape linkage planning areas in Ventura County. In the fall of 2001, SCWP held a workshop where local biologists identified species of plants and animals that require connectivity within Ventura County and adjacent areas.

In 2003, a study entitled *Use of highway undercrossings by wildlife in southern California* (Ng et al. 2004) attempted to determine if wildlife utilizes underpasses and drainage culverts beneath highways for movement. The study area encompassed the eastern edge of Ventura County along three highways: US Highway 101, State Route 23, and US Highway 118. Each of these highways borders the Simi Hills on the south, west and north, respectively. Even though these crossings were not originally designed for wildlife movement, the study revealed that crossing structures in these locations were used by various species, providing important, safe passage for animals. The study also identified the importance of suitable habitat and fencing.

To summarize, the aforementioned studies have delineated a number of landscape linkages in Ventura County, some of the terrestrial species requiring connectivity, and the important role of crossing structures with specific design features in facilitating wildlife movements.

3 Mitigation Guidelines

Reducing the negative impacts that roads have on wildlife movement requires consideration of several fundamental parameters. These parameters are discussed briefly below, and are detailed further in the sections that follow.

Assessment of Wildlife Movement Corridors

Proper placement of wildlife crossing structures is one of the most important considerations for successful mitigation. Most studies indicate that placing the crossing structure near traditional movement routes will increase effectiveness. Studies conducted in Florida determined that structures placed without regard to traditional movement paths failed (Hartmann 2003).

Required Design Elements

Wildlife crossing structures may consist of many shapes and sizes to accommodate the variety of species that inhabit an area. Though each species has different specific needs, there are some required design elements that serve to make road crossings more permeable for all species (Figure 3.1).

The design elements determined to be essential for success include:

- Suitable Habitat
- Minimal Human Activity
- Funneling/Fencing
- Wildlife Accessibility
- Ongoing Maintenance and Monitoring

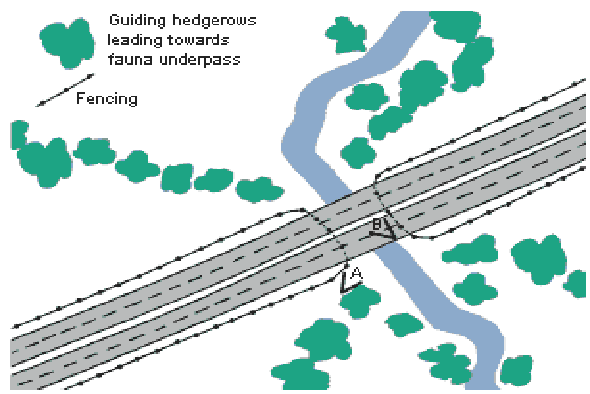


Figure 3.1: Example of a crossing scenario

The design elements determined to be highly recommended include:

- Traffic Control Measures
- Appropriate Road Design Elements
- Appropriate Structure Design (Shape, Size, Noise, Temperature, Light, Moisture)

Species Functional Group Specific Design Standards

Not surprisingly, the literature indicates that individual species have different needs regarding structure features. In particular, physical characteristics such as size and substrate will be very important to some species, but irrelevant to others. For example, a moist substrate is essential for amphibian use, while large mammals are generally indifferent to the substrate surface. To accommodate these varying needs, specific design standards are provided for five different wildlife functional groups. The wildlife functional groups include:

- Large Mammals
- Medium Mammals
- Small Mammals
- Amphibians/Riparian Reptiles
- Upland Reptiles

Though structure design elements for fish passage are not included, this issue is being addressed by multiple state and federal agencies and may be applicable. If the County's consulting biologist determines negative impacts to fish will occur, particularly steelhead trout, California Fish and Game (CFG) and the National Oceanic and Atmospheric Administration (NOAA) will require additional crossing structure mitigation. These requirements must be included in addition to, and not in lieu of, the required design elements in this document.

Consideration of Multi-Species Mitigation

These recommendations review mitigation measures that can be implemented to alleviate negative impacts from roadways on multiple functional groups. As a general rule of thumb, mitigations should attempt to satisfy as many species moving through the area as possible.

3.1 Assessment of Wildlife Corridors

To function as a wildlife movement corridor an area must (Ogden 1992):

1. Link two or more patches of isolated habitat;
2. Conduct animals to areas of suitable habitat without excessive risk of directing them into a "mortality sink" – an unsuitable area where the death rate is higher than the rate of replacement; and
3. Allow individuals of the target species to use the corridor frequently enough to facilitate demographic and genetic exchange between separated populations.

As required by the *Ventura County Initial Study Assessment Guidelines*, a qualified wildlife biologist will assess the proposed project area to determine if a wildlife movement corridor(s) exists within the project site and/or the surrounding area, and if the project will adversely impact the corridor(s). A checklist for assessment and mitigation determination of wildlife corridors is provided in Table 3.1. The recommendations provided in this document are based on the assumption that mitigations will be implemented in the most appropriate and desirable location within the impacted wildlife movement corridor, as determined by a qualified wildlife biologist and through consultation with appropriate regulatory agencies.

If a wildlife movement corridor is present within a proposed project site, and if the wildlife biologist determines that the project will adversely impact the corridor, mitigation measures must be implemented or changes to the project design must be made. These mitigation measures may include, but are not limited to, crossing scenario mitigations. Crossing scenario mitigations should be implemented at the exact location where the proposed project intersects or overlaps the wildlife movement corridor, as determined by a qualified wildlife biologist. It is assumed that the best alternative for road placement within the project site will be implemented, as required by the CEQA process.

To date, wildlife corridors in Ventura County have been identified by consulting with local wildlife biologists and using least cost path modeling and suitability analysis. Several groups have been involved in this process including the South Coast Wildlands Project (SCWP), the Donald Bren School of Environmental Science and Management, Conception Coast Project, the National Park Service, the California Department of Transportation, universities, and biological consulting firms working in Ventura County.

Table 3.1: Wildlife Movement Corridor Assessment and Mitigation Determination

Step	Assessment Criteria	Answer
1	Does the proposed project site contain an existing roadway and/or require the construction of a new roadway with the project site? If YES, continue to Step 2. If NO, wildlife movement corridor mitigation is **NOT** required	Yes No
2	Does a wildlife movement corridor(s) exist within the proposed project site as determined by a County qualified biologist? If YES, continue to Step 3. If NO, wildlife movement corridor mitigation is **NOT** required	Yes No
3	Will the proposed project result in a significant adverse impact to the wildlife movement corridor(s) as a result of a new or existing roadway? If YES, continue to Step 4. If NO, wildlife movement corridor mitigation is **NOT** required	Yes No
4	Is the significant adverse impact to the wildlife movement corridor(s) mitigable? If YES, continue to Step 5. If NO, the project may require an EIR, be revised, or be withdrawn	Yes No
5	Please circle the Functional Group(s)* that contains the species of concern within the impacted wildlife movement corridor(s), then continue to Step 6	Large Mammals Medium Mammals Small Mammals Amphibian/ Riparian Reptiles Upland Reptiles
6	Wildlife movement corridor mitigation is **REQUIRED** for every Functional Group circled in Step 4. Please consult Sections 3 through 5 of the *Designing Road Crossings for Wildlife Passage: Ventura County Guidelines* for road crossing mitigation requirements	

* Please refer to Section 4 for a description of species Functional Groups

3.2 Required Design Elements for All Functional Groups

The following mitigation measures apply to any species functional group(s) in the project area.

3.2.1 Suitable Habitat

In habitats fragmented by a road network, crossing structures can facilitate wildlife movement provided that suitable habitat is present on both sides of the road in the proximity of the crossing structure.

Several studies suggest that natural vegetation surrounding and leading up to the entrance of a crossing structure is important for wildlife usage (Smith 2003, Ng et al. 2004, Clevenger et al. 2001, Clevenger et al. 2003). Natural vegetation provides continuity of the habitat and may encourage animals to approach a crossing structure, while abrupt changes in the vegetation may discourage animals from approaching. Additionally, low stature vegetative cover surrounding a structure entrance can provide smaller animals with protection by concealing them from predators (Little et al. 2002). Therefore, the natural habitat of the wildlife corridor and vegetation at the entrance of the crossing structure must be maintained. If the habitat is unsuitable in the location where the crossing structure is planned, the County should require restoration of the habitat to its natural condition, as determined by a qualified biologist

3.2.2 Minimal human activity

Biologists have reported that crossing structures may be ineffective if human activity is not controlled (Clevenger and Waltho 2000). To reduce the risk of species avoidance due to human presence, it has been suggested that human foot trails be relocated and human use of underpasses be restricted. By placing structures away from areas that are frequently used by humans and restricting human use of passages, it is likely that the structures will be more appealing wildlife (Hartmann 2003).

3.2.3 Funneling/Fencing

Studies suggest wildlife funneling, typically using fences, is necessary for effective crossing structures. Fencing will guide animals towards a structure entrance and deter animals from approaching a roadway (Bissonette and Hammer 2000, Cain et al. 2003, Clevenger and Waltho 2003, Dodd et al. 2004, Feldhamer et al. 1986, Falk et al. 1978, Taylor and Goldingay 2003).

Roadkill can be dramatically reduced on roadways that have both fencing and crossing structures. In Wyoming, road kills of mule deer have been reduced by 90% while there has been a 97% decrease in the number of elk killed in Banff National Park in Canada (Hartmann 2003). In Paynes Prairie State Preserve, Florida, roadkill mortality of all animals (excluding hylid treefrogs, which easily trespass the barrier system) was reduced by 93.5% after construction of a barrier wall-culvert system (Dodd et al. 2004).

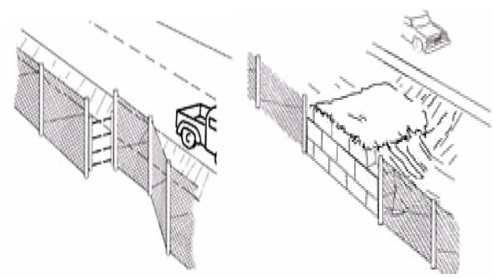
Fencing is beneficial only when used in conjunction with an appropriate crossing structure. In fact, extensive stretches of fencing may actually contribute to fragmentation and isolation. In addition, studies suggest that predators have learned to use fencing as a trapping mechanism (Hartmann 2003). In Banff National Park, coyotes have been observed running bighorn sheep into the fence along the Trans-Canada Highway. In other areas, wolves and cougars have been documented herding deer up against highway fencing (Foster and Humphrey 1995). For these reasons, fencing should be used primarily as a means to funnel animals towards and into an appropriate crossing structure and only secondarily as a mechanism to deter animals from approaching the road.

Figure 3.2: Lipped concrete wall

Fence height and material are important considerations. Fence height may range from 1.5 ft for smaller animals to a minimum of 8 ft for large mammals. Fencing material should not be penetrable by the species of interest and be constructed of chain link, wood, galvanized tin, aluminum flashing, plastic, vinyl, concrete, or a very fine mesh. Fencing should also be buried to prevent animals from digging under the fence, while a preventative fence top such as barbed wire, lipped wall (Figure 3.2), or overhang is recommended to discourage animals from climbing over the fence. Some animals have been observed climbing vegetation growing along funneling mechanisms despite the presence of preventative fence tops (Dodd et al. 2004). Routinely removing or trimming back vegetation acting as "natural ladders" decreases this risk.

The extent of fencing is another important factor. Generally speaking, fencing should extend far enough on either side of a structure to reasonably guide the species functional group of interest to the crossing structure and away from the road. For large animals, this could be the entire length of the parcel boundary, while smaller animals would likely require less. It may also be appropriate to fence up to a natural break in an animal's ability to traverse the landscape, such as a steep slope or habitat edge. When extensive fencing is utilized on only one side of a crossing structure, one-way gates or escape ramps (Figure 3.3) should be included to prevent animals from being trapped on the road (Bissonette and Hammer 2000, Danielson and Hubbard 1998, Conover 2002).

Figure 3.3: One-way gate and escape ramp



For recommended fence dimensions, materials, and extent specific to each Functional Group, please refer to [Section 4: Specific Design Standards for Functional Groups].

3.2.4 Accessibility

A crossing structure will only be effective if it is accessible to the species that will potentially utilize it (Veenbaas and Brandjes 2002, Jackson 2000, Jacobson 2002). A variety of physical factors influence the accessibility of a structure; the steepness of the slope leading to the structure, the structure entrance height above the ground surface, as well as the cross-sectional height and width (Figure 3.4).

Figure 3.4: Perched pipe.

Figure 3.5: Culvert with standing water.

Measures to minimize erosion around the structure entrances should be incorporated into the structure design. If a crossing structure is used to convey water as well to facilitate animal movement, it should be designed to prevent water from pooling inside or at the opening of the structure. Such standing water will render the structure less accessible to many animals (Figure 3.5).

3.2.5 Maintenance and Monitoring

Monitoring and maintenance plans should be prepared to ensure that mitigation systems continue to function over time. Maintenance of a crossing structure should include clearing debris or other impediments to movement through the structure, maintaining the surrounding fencing, vegetation, and habitat, as well as ensuring overall structural integrity.

The success of a crossing structure can only be assessed through careful and consistent monitoring (Hardy et al. 2003). It may take months or even years to fully asses the effectiveness of a crossing structure.

For further discussion on development and implementation of maintenance and monitoring programs, please refer to Section 5: Additional Mitigation Considerations.

3.2.6 Traffic Control Measures

Vehicle Speed

Reducing traffic speed via speed limit signs and/or speed bumps can greatly reduce wildlife mortality from vehicle collisions. To ensure driver and animal safety, enforcement of speed limits should be enhanced in mitigated areas.

Wildlife Crossing Signs

Wildlife crossing signs inform the public of the potential presence of sensitive, slow moving species on the roadway (Figure 3.6). This may encourage drivers to slow down and be more observant of the roadway in the area, thereby reducing mortality from animal-vehicle collisions.

Figure 3.6: Wildlife crossing sign

3.2.7 Appropriate Road Design Elements

Mitigation measures include road design elements in the area adjacent to and surrounding a structure.

If a crossing structure is not incorporated into a proposed project design, then the following road design measures are still recommended to mitigate adverse impacts on wildlife corridors. For instance, if a potential project proposes an at-grade rural residential road that impacts a wildlife corridor but can not structurally accommodate a crossing underpass, then appropriate road design will be required as a mitigation measure.

When a crossing structure is present, the goal of appropriate road design is to make the option of using the crossing structure more appealing to an animal than the option of crossing the road. For example, the road in the crossing structure proximity should appear dark and quiet, while the road in the surrounding area should be bright and noisy, particularly when vehicles are present.

Non-Vegetated Roadway

The immediate roadside should have minimal vegetation. Dense, concealing vegetation may encourage animals to approach the road. The crossing structure entrance, however, should have denser vegetation to be more appealing to the animals than the surrounding road area.

Appropriate Road Design in Structure Proximity

Street Lighting

To encourage animals to approach a structure, the area in proximity to the entrance should be unlit and resemble ambient conditions. Street lighting should be placed away from structure entrances (Reed et al. 1981, Hartmann 2003, Jackson 2000).

Traffic Noise

Reducing traffic noise in the proximity of the structure is recommended. Traffic noise may discourage animals from approaching a structure, specifically animals that are sensitive to noise and/or human presence. A noise level of 45 db or less in the vicinity of the crossing structure has been recommended in one study (Rincon Consultants 2002). Examples of noise mitigation measures include sound walls, dense vegetation at the structure entrance, and ensuring a smooth roadway to reduce noise from friction. Traffic noise mitigation is especially important on more heavily trafficked roads.

Appropriate Road Design in Surrounding Area

Street Lighting/Headlight Reflectors

If the surrounding area is artificially lit, the animals may be drawn to the darker area of the structure entrance. For this reason street lighting or headlight reflectors should be located on the roadway at an appropriate distance on either side of the structure.

Traffic Noise

There is no need to reduce traffic noise at an appropriate distance on either side of the crossing structure. The noise will most likely discourage animals from approaching the roadway and make the quiet crossing structure entrance more appealing.

3.2.8 Appropriate Structure Design Standards

The following provides universal mitigation standards for structure design. Design standards specific to species functional group are detailed in Section 4: Specific Design Standards for Functional Groups.

Structure Types

The four main types of crossing structures are:

- Pipe culverts
- Box culverts
- Bridge Underpasses
- Overpasses

Pipe Culverts

Pipe culverts (Figure 3.7) are made of smooth steel, corrugated metal, or concrete material. Their primary purpose is to convey water under roads, though a variety of wildlife has been observed using them as passageways. They typically range in size from 1ft to 6 ft in diameter and are the least expensive wildlife crossing structure.

Figure 3.7: Pipe culvert

Box Culverts

Box culverts (Figure 3.8), used to transmit water during brief periods of runoff, are usually dry for much of the year and are used by a variety of wildlife (Rodriguez et al. 1996, Yanes et al. 1995, Clevenger and Waltho 2000). Unlike a bridge, they have an artificial floor such as concrete, though this floor may be covered by sediment and/or vegetation. Box culverts generally provide more room for wildlife passage than large pipes. Though they are less expensive than expanded bridges, they may also be less effective (Beier 1995).

Figure 3.8: Box Culvert

Bridge Underpass

Figure 3.9: Bridge underpass

When roads and highways cross rivers, streams, and other roads, bridges can provide a passageway for many species of wildlife that may utilize stream corridors and road underpasses for travel (Figure 3.9). Bridges are large underpasses that provide relatively unconfined passage for wildlife and water. Bridges with open medians provide a certain amount of intermediate habitat for small mammals, reptiles, and amphibians. However, open median designs are much noisier than continuous bridges and may be less suitable for species that are sensitive to human disturbance (Jackson and Griffin 2000). Human activity within or around underpasses may significantly reduce their effectiveness for wildlife (Clevenger and Waltho 2000). While less expensive than overpasses, wildlife bridges are relatively costly.

Overpass

Wildlife overpasses (Figure 3.10) have been constructed in Europe, the U.S., and Canada. The most effective overpasses range in width from 165 ft wide on each end narrowing to 25–115 ft in the center, to structures up to 650 ft wide. Soil on these overpasses, ranging in depth from 1.5 to 7 ft, allows for the growth of herbaceous vegetation, shrubs, and small trees. Some contain small ponds fed by rain water. Wildlife overpasses appear to accommodate more species of wildlife that do underpasses. Primary advantages relative to underpasses are that they are less confining, quieter, and can maintain ambient conditions of rainfall, temperature, and

Figure 3.10: Bridge overpass

light. Further, overpasses can serve both as passageways for wildlife and intermediate habitat for small animals such as reptiles, amphibians, and small mammals. By providing intermediate habitat, overpasses may provide a feasible alternative for various species to cross highways, especially small animals. The major drawback is that they are expensive (up to $2 million dollars for a four lane divided highway (O'Malley 2004)) and, therefore, they should be reserved for areas that are identified and designated as important travel corridors or connections between areas of significant habitat (Jackson and Griffin 2000).

Appropriate Structure Dimensions

Appropriate structural dimensions are determined by several parameters: road width, structure type, and the functional group(s) of species that will potentially use the structure. Many studies suggest that openness ratio is important for large and medium mammals (Cain et al. 2003, Clevenger and Waltho 2005, Jacobson 2002). The openness ratio of a crossing structure opening (Openness Ratio = (Height x Width)/Length) is a function of structure length, which corresponds to the width of the roadway. Therefore, for large and medium mammals, appropriate structural dimensions will be determined by road width. Most studies do not recommend a specific openness ratio for small mammals, reptiles, or amphibians. Generally, the literature advises that smaller cross-sectional areas and openness ratios are more appealing for small animals.

For recommended structural dimensions specific to a functional group, please refer to Section 4: Specific Design Standards for Functional Groups.

Passage Alternatives

Elevated concrete ledges (Figure 3.11), or "catwalks", lining one or both interior walls of the structure may allow wildlife to pass through a crossing structure when it is filled with water (Barnum 1999, Cain et al. 2003, Forman and Alexander 1998, Hartmann 2003, Jacobson 2002). A ledge should line the entire length of the interior, extend to a height above peak water flow, and be covered with natural substrate consistent with the external habitat. Interior ledges must be wide enough to accommodate species of concern.

Figure 3.11: Elevated ledge with vegetation

In general, incorporation of ledges is recommended for structures that facilitate continuous or occasionally heavy flow of water. Alternatively, if the dimensions of the crossing structure are too narrow to accommodate an interior ledge, an additional elevated culvert may be incorporated to allow animals to pass under a road when the existing structure is filled with water.

Internal Habitat

Natural Substrate

While the literature and field observations do not necessarily demonstrate that a natural substrate bottom is essential for animals to use a crossing structure, some studies do suggest that providing a natural substrate throughout the entire length of a crossing structure will maintain habitat continuity and, therefore, encourage animals to pass through the structure (Yanes et al. 1995, Jackson 2000, Hartmann 2003). A desirable crossing structure incorporates a bottom lined with natural substrata that is consistent with the external habitat surrounding either side of the structure and appropriate for the functional group(s) of interest.

Natural Lighting

Studies suggest that artificial light deters animals from using a crossing structure (Reed et al. 1981, Jackson 2000, Hartmann 2003). A crossing structure may look more appealing to animals if ambient lighting conditions are maintained inside the structure. For instance, a larger cross-sectional area entrance, ensuring a larger openness ratio or the use of open medians can achieve natural lighting that will appeal to large mammals. Conversely, a smaller cross-sectional area entrance or low stature vegetation, such as stumps, rocks, or shrubs, will achieve a darker environment more likely to be favored by small mammals, amphibians, and reptiles.

Natural Temperature

Animals will be more willing to use a crossing structure if the internal temperature is consistent with the external temperature (Jackson 2000). This can be achieved by including slotted grates above the structure or designing crossing structures to be larger and more open. However, slotted grates may increase traffic noise inside the structure if it is located below a heavily trafficked roadway. In addition, larger structures may be uninviting to smaller animals that prefer smaller structures.

Reduced Noise

The majority of studies assert that human presence deters animals from using a crossing structure (Clevenger and Waltho 2000, Clevenger and Waltho 2005, Jackson 2000, Hartmann 2003, Smith 2003). Many animals are sensitive to noise, especially from traffic and other human noise disturbance associated with roads (Jackson 2000, Hartmann 2003). To provide a more natural setting and reduce noise inside a crossing structure, certain materials may be more sound proof than others. When choosing a material for a pipe or box culvert, consideration should be given to materials that reduce noise transmission. Dense vegetation adjacent to the structure entrance that does not impede water flow, or sound walls on the road shoulder in proximity of the structure, may also reduce exposure to traffic noise.

4 Specific Design Standards for Functional Groups

Functional groups are species which tend to prefer similar crossing structure characteristics. Each project should be scrutinized by a consulting biologist to identify the specific species likely to be present in the project area, and to determine the most appropriate mitigation actions. Mitigation for domesticated animals is not considered in these recommendations, but an analysis of their structure preferences is included in the technical appendix. Table 2 summarizes the minimum required and best mitigation design elements for each wildlife functional group, which are detailed further in Sections 4.1 through 4.5.

Table 2: Mitigation Measures for Wildlife Functional Groups

Scale of Effectiveness

Minimum Required	Best	Non Applicable
■	□	×

Wildlife Functional Group / Mitigation Measures	Large Mammals	Medium Mammals	Small Mammals	Amphibians/ Riparian Reptiles	Upland Reptiles
Required Mitigation Measures					
Maintain natural habitat	■	■	■	■	■
Minimize human activity	■	■	■	■	■
Fencing/Funneling	■	■	■	■	■
Accessibility	■	■	■	■	■
Highly Recommended Measures					
Speed control	□	□	□	□	□
Wildlife crossing signs	□	□	□	□	□
Non-vegetated roadway	□	□	□	□	□
Road Design In Structure Proximity					
No street lighting	□	□	□	□	□
Traffic noise mitigation	□	□	□	□	□
Road Design In Surrounding Areas					
Maintain street lighting	□	□	□	□	□
No traffic noise mitigation	□	□	□	□	□
Structure Types					
Pipe culvert	■	■	□	□	□
Box culvert	■	■	□	□	□
Bridge Underpass	□	□	■	■	■
Overpass	□	□	■	■	■

Table 2 (continued): Mitigation Measures for Wildlife Functional Groups

Mitigation Measures \ Wildlife Functional Group	Large Mammals	Medium Mammals	Small Mammals	Amphibians/ Riparian Reptiles	Upland Reptiles
Structure Design Standards					
Achieve minimum openness ratio	■	■	×	×	×
Field of view	■	×	×	×	×
Opening cover	×	□	■	■	■
Achieve minimum height	■	■	■	■	■
Ledges	■	■	■	■	■
Natural substrate bottom	□	□	□	□	□
Natural lighting	□	□	□	□	□
Natural temperature	□	□	□	□	□
Moisture	×	×	×	■	×
High frequency of placement	×	×	■	■	■
Other					
Education and Public Outreach	□	□	□	□	□
Maintenance	■	■	■	■	■
Monitoring	■	■	■	■	■

4.1 Mitigation Standards for Large Mammals

The Large Mammals functional group includes species such as mountain lion, deer, bear, coyote, and bobcat. Large mammals generally stand at least 1.5 ft at the shoulder, and have a length of at least 2 ft (not including tail). Large mammals are especially impacted by habitat fragmentation because of their need for significant home ranges and slow population growth rates, which results in lower population densities. As suggested by many studies, large mammals typically prefer large, open crossing structures, such as bridge underpasses and box culverts (Singer and Doherty 1985, Foster and Humphrey 1995, Reed et al. 1981, Clevenger and Waltho 2005, Jacobson 2002, Ng et al. 2004, Barnum 1999, Cain et al. 2003). This conclusion is also supported by field survey results (see Technical Appendix).

Figure 4.1: Large Mammals passing through box culverts (ICOET Proceedings, 2003)

To be conducive for use by Large Mammals, crossing structures must:

- Be at least 6 feet high
- Have an openness ratio of at least 0.75, but preferably 0.9
- Be easily accessible
- Incorporate funneling that extends the length of the parcel boundary or just beyond a natural break in the animal's ability to traverse the landscape

Further detail and additional strongly recommended mitigation design elements for Large Mammals are described below.

Funneling/Fencing

A fence height of approximately 8 ft is usually sufficient to prevent large animals from jumping or climbing over (Clevenger and Waltho 2000, Putman et al. 2004, Cain et al. 2003). Many studies recommend chain link fencing for large mammals (Singer and Doherty 1985, Foster and Humphrey 1995, Falk et al. 1978). To prevent animals from digging under it (e.g. coyotes and deer), fencing should be buried to a depth appropriate for the type of species in the area (Jacobson 2002). Additionally, there should be no "natural ladders" adjacent to the fence, such as trees, large bushes, etc., which could facilitate an animal climbing over the fence. Fencing should extend on either side of the structure the entire length of the parcel boundary or just beyond a natural break in an animal's ability to traverse the landscape. When extensive fencing is utilized on only one side of a crossing structure, one-way gates or escape ramps should be included to prevent animals from being trapped on the road (Bissonette and Hammer 2000, Danielson and Hubbard 1998, Conover 2002).

Structural Dimensions

Most studies suggest that crossing structures should be at least 6 ft high to accommodate large mammals (Jacobson 2002, Foster and Humphrey 1995, Reed et al. 1981). Some studies suggest a negative correlation between length of a crossing structure and its use by large mammals (Yanes et al. 1995, Smith 2003, Clevenger and Waltho 2005). Results from the field survey indicate preferences for structures that are taller in height, shorter in length, with larger cross-sectional areas and openness ratios.

In general, the cross-sectional area of the structure entrance should become larger as the length of the structure increases to maintain a minimum openness ratio of 0.75. For a typical two-lane road (approximately 30 ft wide), the cross-sectional area of the structure opening should be 22 sq ft to accommodate a large mammal. For a typical four-lane road (approximately 60 ft wide), the cross-sectional area of the structure opening should be 45 sq ft. For a road with six or more lanes (75 ft or wider), the cross-sectional area of the structure opening should be 60 sq ft.

Field of View

Many studies indicate that an open field of view must exist in order for large mammals to use a crossing structure (Jackson 2000, Jacobson 2002, Foster and Humphrey 1995). A large mammal is more to likely pass through a crossing structure if suitable habitat is clearly visible on the other side (Figure 4.2). The need for an open field of view also correlates with the preference for a large openness ratio.

Figure 4.2: Underpass with open field of view for large mammals

4.2 Mitigation Standards for Medium Mammals

The Medium Mammals functional group includes species such as opossum, skunk, raccoon, fox, and rabbit. Medium mammals generally range in height between 6 inches to 1.5 ft at the shoulder, and range from 16 inches to 2 feet in length. Although the field survey results show that medium mammals use a mix of crossing structure types, most studies suggest that medium mammals may tend to prefer box or pipe culverts (Clevenger et al. 2003, Forman and Alexander 1998, Taylor and Goldingay 2003).

To be conducive to use by Medium Mammals, crossing structures must:

- Be at least 3 feet high
- Have an openness ratio of at least 0.4
- Be easily accessible
- Incorporate funneling that extends just beyond a natural break in the animal's ability to traverse the landscape

Further detail and additional strongly recommended mitigation design elements for Medium Mammals are described below.

Opening Cover

Studies suggest that natural vegetation surrounding the approach and entrance of a crossing structure is important for medium mammals (Ng et al. 2004, Smith 2003, Clevenger et al. 2001, Clevenger et al. 2003).

Structure Placement

Travel distance between structures may influence structure use by medium mammals, for even relatively mobile species. For projects that span over 0.5 miles of roadway, structures should be incorporated every 500 to 1,000 ft (Clevenger et al. 2003).

Funneling/Fencing

A fence height of approximately 3-6 ft is generally sufficient to prevent medium mammals from jumping or climbing over (Dodd et al. 2004, Taylor and Goldingay 2003). A fence material such as chain link is suggested (Taylor and Goldingay 2003). To prevent animals from digging under, fencing should be buried to a depth appropriate for the type of species in the area (Jacobson 2002). Additionally, there should be no "natural ladders" adjacent to the fence, such as trees, large bushes, etc., which could allow an animal to climb over fence. In general, fencing should extend just beyond a natural break in the animal's ability to traverse the landscape and guide them to the crossing structure.

Structural Dimensions

A structure designed specifically for medium mammals should be at least 3 ft high (Taylor and Goldingay 2003). Some studies suggest a negative correlation between the length of a crossing structure and use by medium mammals (Yanes et al. 1995, Smith 2003). Results from the field survey indicate preferences for structures that are taller in height, shorter in length, with larger cross-sectional areas and openness ratios.

In general, the cross-sectional area of the structure entrance should become larger as the length of the structure increases to maintain a minimum openness ratio of 0.4. For a typical two-lane road (approximately 30 ft wide), the cross-sectional area of the structure opening should be 12 sq ft to accommodate a medium mammal. For a typical four-lane road (approximately 60 ft wide), the cross-sectional area of the structure opening should be 24 sq ft. For a road with six or more lanes (75 ft or wider), the cross-sectional area of the structure opening should be 30 sq ft.

4.3 Mitigation Standards for Small Mammals

The Small Mammals functional group includes species such as squirrels, rats, voles, and mice. Small mammals are generally a few inches high and up to 16 inches long. Most studies suggest that small mammals will use a mix of small pipes, box culverts, or pipe culverts. Field survey results show that small mammals have a preference for using box and pipe culvert (see Technical Appendix).

To be conducive to use by Small Mammals, crossing structures must:

- Be at least 1 foot high
- Provide low stature opening cover
- Be easily accessible
- Incorporate funneling that extends just beyond a natural break in the animal's ability to traverse the landscape

Further detail and additional strongly recommended mitigation design elements for Small Mammals are described below.

Opening Cover

Studies suggest that low stature natural vegetation surrounding the approach and entrance of a crossing structure is essential for use by small mammals (Hunt et al. 1987, Ng et al. 2004, Smith

2003, McDonald and St. Clair 2004, Clevenger et al. 2001, Clevenger et al. 2003). Field survey results further support this assertion.

Structure Placement

Travel distance between structures may influence structure use by small mammals. Since many smaller animals are less mobile than medium or large mammals, movement corridors may be defined on a much smaller scale. This suggests that smaller structures should be placed with a frequency that corresponds to the spatial scale over which targeted species move (Hardy et al. 2003). As a result, studies specify the importance of high frequency of structure placement for small mammals, generally at least every 150 - 300 ft (Clevenger et al. 2003).

Funneling/Fencing

A fence height of at least 3-4 ft is generally sufficient to prevent small animals from jumping or climbing over (Dodd et al. 2004). Studies recommend mesh (Figure 4.3) as the most appropriate impenetrable fencing material for small mammals (Bank et al. 2002, Lode 2000). To prevent animals from digging under, fencing should be buried to a depth appropriate for the type of species in the area (Jacobson 2002). Additionally, there should be no "natural ladders" adjacent to the fence, such as trees, large bushes, etc., which could allow an animal to climb over fence. In general, fencing should extend just beyond a natural break in the animal's ability to traverse the landscape and guide them to the crossing structure.

Figure 4.3: Fine mesh fence for small animals

Structural Dimensions

Generally, the literature advises that smaller cross-sectional areas and openness ratios are more appealing for small animals. A cross-sectional area of 2 to 4 sq ft for the structure entrance is highly recommended for small mammals (Clevenger et al. 2001, Goosem et al.2001).

Interior Cover

Small mammals usually prefer some type of low stature cover on the interior of the structure to function as protection from predators (Smith 2003, Hartmann 2003, Hunt et al. 1987). Typically, small mammals will pass through a structure along the interior wall because it may feel more protected. Vegetation or other naturally occurring substrate, such as tree stumps, hollow logs, or rocks, will provide small animals with cover from predators, encouraging them to pass through a structure.

4.4 Mitigation Standards for Amphibians and Riparian Reptiles

The Amphibians/Riparian Reptiles functional group includes species which prefer wet or moist environments such as frogs, toads, salamanders, turtles and some species of snakes. Although amphibians/riparian reptiles have been known to use a mix of crossing structure types, most studies suggest they tend to prefer small pipes, as well as box or pipe culverts, with moist substrates. Larger crossing structures (bridges) can be modified to accommodate amphibian/riparian reptiles by incorporating smaller tunnels along the sides of the crossing structure.

To be conducive to use by Amphibians/Riparian Reptiles, crossing structures must:

- Be at least 1 foot high
- Provide low stature opening cover
- Be easily accessible
- Have a moist substrate
- Be placed at a high frequency along the road through relevant habitat
- Incorporate funneling that extends just beyond a natural break in the animal's ability to traverse the landscape

Further detail and additional strongly recommended mitigation design elements for Amphibians/Riparian Reptiles are described below.

Opening Cover

Amphibians and riparian reptiles are prey species and rely on low stature cover for protection from predators (Smith 2003, Jackson 2000, Jacobson 2002, Yanes et al. 1995). If low stature cover around the structure entrance is absent, these animals may be reluctant to enter. Furthermore, preserving the natural vegetative cover is important for maintaining habitat continuity.

Structure Placement

Travel distance to the crossing structure can be an important factor in facilitating movement of amphibians/riparian reptiles. Although there is evidence that mammals can learn to use crossing structures and may transfer this knowledge to future generations, this is unlikely to be the case with amphibians/riparian reptiles (Jackson and Griffin 2000). This suggests that smaller structures, such as pipes and culverts, should be placed with a frequency that corresponds to the spatial scale over which targeted species move (Hardy et al. 2003). Structures should be placed at least every 150 to 300 ft (Puky 2003).

Funneling/Fencing

A fence height of approximately 1.5 to 2.5 ft with a preventative fence top, such as a lipped wall or overhang, is generally sufficient to prevent amphibians/riparian reptiles from jumping or climbing over (Puky 2003). Possible impenetrable materials to use include galvanized tin, aluminum flashing, plastic, vinyl, concrete, or a very fine mesh. To prevent animals from digging under, fencing should be buried to a depth appropriate for the type of species in the area (Jacobson 2002). In general, fencing should extend just beyond a natural break in the animal's ability to traverse the landscape and guide them to the crossing structure.

Snakes and treefrogs have been observed climbing vegetation along funneling mechanisms (Dodd et al. 2004). The vegetation offered access to the road and some of the animals observed dead on the roadway undoubtedly obtained access in this manner. To minimize this risk, vegetation must be regularly cleared, particularly during the growing season (Dodd et al. 2004).

Structural Dimensions

Generally, amphibians and riparian reptiles utilize both concrete box culverts and metal structures such as pipes provided the appropriate internal habitat is present (see below). Migrating amphibians and riparian reptiles generally prefer structures with opening dimensions of 2 to 9 sq ft (Puky 2003, Jackson and Griffin 2000).

Internal Habitat

Amphibians and riparian reptiles use cover to protect themselves from the drying heat of the sun and predators. These animals will readily use a crossing structure with a natural substrate if it has adequate moisture and hiding cover that functions as protection. Low stature vegetation or other naturally occurring substrate, such as tree stumps, hollow logs, or rocks, will provide amphibians and riparian reptiles with cover, encouraging them to pass through a structure.

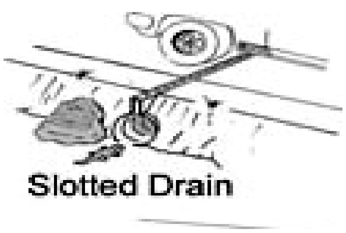


Figure 4.4: Slotted culvert

Because moisture is an important consideration for amphibians and riparian reptiles, a moist substrate is a vital feature of a suitable crossing structure. However, standing water prevents most species from utilizing a structure. Culverts that accommodate amphibians and riparian reptiles must maintain moist travel conditions, without creating standing water or flooded conditions. Therefore, proper drainage of the crossing structure is another important consideration. In larger culverts, maintaining or replicating stream bed conditions facilitate use by amphibians and riparian reptiles (Jackson and Griffin 2000). Slotted drain culverts have proven to be successful in maintaining proper moisture and drainage, while also providing ambient light (Figure 4.4). Ongoing maintenance of these structures to clear debris and maintain openness is essential.

4.5 Mitigation Standards for Upland Reptiles

The Upland Reptiles functional group includes classes of species which prefer dry, sunny environments such as lizards, tortoises, and some species of snakes. Upland reptiles have been known to use a mix of crossing structure types, including bridges, box culverts, and dry pipes. However, the field survey results indicate a preference for box culverts to either bridges or pipes (see Technical Appendix).

To be conducive to use by Upland Reptiles, crossing structures must:

- Be at least 1 foot high
- Provide low stature opening cover
- Be easily accessible
- Be placed at a high frequency along the road through relevant habitat
- Incorporate funneling that extends just beyond a natural break in the animal's ability to traverse the landscape

Further detail and additional strongly recommended mitigation design elements for Upland Reptiles are described below.

Opening Cover

Upland reptiles rely on cover for protection from predators (Smith 2003, Jackson 2000, Jacobson 2002, Yanes et al. 1995). If low stature cover around the structure entrance is absent, upland reptiles may be reluctant to enter. Furthermore, preserving the natural vegetative cover is important for maintaining habitat continuity.

Structure Placement

Travel distance to the crossing structure can be an important factor in facilitating movement of upland reptiles. Although there is evidence that mammals can learn to use crossing structures and may transfer this knowledge to future generation, this is unlikely to be the case with upland reptiles (Jackson and Griffin 2002). This suggests that smaller structures should be placed with a frequency that corresponds to the spatial scale over which targeted species move (Hardy et al. 2003). Structures should be placed at least every 150 to 300 ft (Puky 2003).

Funneling/Fencing

A fence height of approximately 1.5 to 2.5 ft with a lipped or preventative fence top, such as a lipped wall or overhang, is generally sufficient to prevent upland reptiles from scaling or climbing over (Puky 2003). Possible impenetrable materials to use include galvanized tin, aluminum flashing, plastic, vinyl, concrete, or a very fine mesh. To prevent animals from digging under, fencing should be buried to a depth appropriate for the type of species in the area (Jacobson 2002). In general, fencing should extend just beyond a natural break in the animal’s ability to traverse the landscape and guide them to the crossing structure.

Snakes have been observed climbing vegetation along funneling/fencing mechanisms (Dodd et al. 2004). The vegetation offered access to the road and some of the animals observed dead on the roadway undoubtedly obtained access in this manner. Applying herbicide along the funneling/fencing mechanism may temporarily resolve the problem; however, vegetation must be removed from barriers regularly, particularly during the growing season (Dodd et al. 2004).

Structural Dimensions

Generally, the literature advises that upland reptiles utilize bridges, concrete box culverts, as well as metal structures such as pipes, provided the appropriate internal habitat is present. Given the wide range of structures used by upland reptiles, it is suggested that structure openings should be a minimum height of 1 sq ft.

Internal Habitat

Upland reptiles use cover to protect themselves from overheating in the sun, as well as from predators. Upland reptiles will readily use a crossing structure with a natural or fabricated substrate if it has adequate hiding cover that functions as protection from predators. Low stature vegetation or other naturally occurring habitat, such as tree stumps, hollow logs, or rocks, will provide upland reptiles with cover from predators, encouraging them to pass through a structure.

4.6 Considerations for Multiple Functional Group Mitigations

The recommendations presented in Sections 4.1 through 4.5 are intended to provide the most desirable crossing structure characteristics for individual species functional groups. However, in many cases mitigation will be required for multiple functional groups. In these instances, designing a cross-functional group structure will require the discretion and innovation of both planners and biologists. Some ideas and examples provided in the current literature are outlined below.

Funneling/Fencing

Appropriate funneling mechanisms vary widely across functional groups. To accommodate several species, a fine mesh wire fence or flashing is often applied to the bottom one-third to one-half of a taller fence to prevent both small and large animals from accessing the road right-of-way (Figure 4.5). Additional measures include combining fencing for large mammals along the road with lipped walls for amphibians and reptiles along the banks for the structure entrance (Figure 4.6).

Figure 4.5: Wide mesh chain fence for large mammals, with a fine mesh fence border for small mammals and amphibians (FHWA/US DOT 2002)

Figure 4.6: Arch culvert with fence for large mammals and lipped wall for amphibians (FHWA/US DOT 2002)

Structure Approach

Vegetation surrounding the approach to the structure is an important consideration when designing for multiple functional groups. While some level of natural vegetation is important to maintain habitat continuity, the type of vegetation can play an important role in structure use. Most small mammals, amphibians, and reptiles will prefer low stature cover in the form of vegetation, rocks, and logs to protect them from predators. Medium and large mammals that are prey species (rabbits, deer) may be wary of using structures with extensive vegetation where predators can hide. Eliminating potential predator ambush opportunities, while providing good visibility for medium and large mammal prey species, will encourage their use of a crossing structure (Jackson and Griffin 2000).

Structure Design

While considering the variety of internal habitats preferred by different functional groups, it is not surprising that the specific design elements for particular species may be contradictory. For example, open-top culverts may provide favorable lighting, temperature, and moisture conditions for amphibians but may be too noisy for some mammals. Structures can be designed to facilitate multiple functional groups by incorporating design elements preferred by each. For instance, a large bridge underpass designed to facilitate the movement of large mammals could also accommodate small mammals by incorporating low stature vegetation or other naturally occurring substrate, such as tree stumps, hollow logs, or rocks, in the interior of the structure. Similarly, a structure could accommodate small mammals, amphibians, and riparian reptiles by maintaining moisture in the bottom of the structure but also providing a dry elevated ledge.

Alternatively, multiple structures in the same area could be incorporated to accommodate several functional groups. A large box culvert that accommodates large and medium mammals could be flanked by smaller pipes on either side to accommodate smaller mammals, amphibians, and reptiles. This option addresses the need for different light, noise and moisture needs particularly well.

Ultimately, there is no simple single approach to mitigation. A variety of alternatives can and should be explored. A structure that incorporates as many mitigation design elements as possible will most likely be the most successful at accommodating wildlife movement.

5 Additional Mitigation Considerations

5.1 Education and Public Outreach

An additional element of a successful mitigation strategy is public education and outreach. Educating the local community about sensitive species in the area provides citizens with a heightened awareness of the impacts of roads on wildlife. For instance, a person driving on a road which crosses a wildlife corridor may be more likely to respond to wildlife signs or traffic control measures if he or she is educated about the sensitive wildlife in the area.

Figure 5.1: Wildlife corridor sign

Forms of public education and outreach may include, but are not limited to:

- Public educational seminars
- Mail flyers
- Local cable access TV commercials
- Wildlife crossing signs
- Wildlife corridor signs (Figure 5.1)
- Informative brochures
- Volunteer programs

While there is no requirement to implement a public education and outreach program, some type of public education is strongly recommended, in addition to crossing scenario mitigation. The County should not underestimate the importance of public education in mitigating wildlife-roadway impacts.

5.2 Maintenance and Monitoring

Prior to approval of projects that require wildlife corridor mitigation, a project-specific maintenance and monitoring program must be developed. The party or parties responsible for maintaining and/or monitoring the proposed mitigation should be specifically identified.

The maintenance and monitoring program should include the following elements:

- Description of party/parties responsible for maintenance
- Maintenance and monitoring schedule, including time frame and frequency
- Maintenance procedures
- Monitoring approach and procedures
- Contact information

Structure use can be monitored with a variety of tools and techniques such as gypsum track plates, motion-detection cameras, and trap-and-release. The approach to structure monitoring will depend on the type of crossing structure, as well as the targeted species. Individual species behavior and spatial and temporal movement patterns will influence the monitoring technique and frequency of observation. A qualified biologist should be consulted to develop a monitoring program and determine an appropriate monitoring frequency and time frame. For best results, long-term monitoring must be conducted to fully assess structure use and effectiveness (Barnum 1999, Hardy et al. 2003).

The frequency and extent of maintenance will depend upon the type, size, and functionality of the crossing structure. For instance, smaller structures or structures that also facilitate water flow may require more frequent maintenance than a large, relatively dry bridge underpass. During periods of heavy rain, water flow through culverts typically increases dramatically, causing silt accumulations and erosion to occur. A heavy build-up of silt could eventually diminish the area available for wildlife passage (Dodd et al. 2004), and erosion can greatly reduce accessibility, especially for smaller animals. Furthermore, soil erosion occurring in the immediate proximity of the crossing structure can reduce wildlife accessibility. Ongoing maintenance efforts should include filling eroded landscape to match the grade of the surrounding habitat and ensure wildlife accessibility into the crossing structure.

Funneling/fencing mechanisms will require regular maintenance because animals are likely to attempt to dig under barriers and take advantage of holes. In addition, vegetation immediately adjacent to the funneling/fencing mechanism that may act as natural ladders for an animal to climb over must be removed regularly, particularly during the growing season.

5.3 Cost

Designing roads for safe wildlife passage is necessary to maintain species biodiversity, but can be costly. Many structures that are installed to facilitate the flow of water can be modified to better accommodate wildlife passage, for instance, by incorporating a ledge into a concrete box culvert. The required and recommended design standards described in this document represent the most desirable set of crossing scenario mitigation measures. A proposed project must incorporate all of the required design standards, and incorporate all additional desirable mitigation measures, within economic feasibility.

An important consideration is short-term versus long-term costs. While a structure may initially be less costly, the cost of maintenance and retrofitting over the lifetime of the structure can be considerable. The lifetime cost of alternative crossing structures must be considered to accurately assess the total cost of mitigation. Although the cost of mitigation can be substantial in the short-run, the cost of avoiding mitigation can potentially result in even greater long-term costs associated with wildlife-vehicle collisions. Wildlife-vehicle collisions constitute an estimated 4.6% of all US automobile accidents, with more than 1.5 million accidents a year, 150 deaths and $1.1 billion in vehicle damage (Perrin and Disegni 2003).

6 Catalog of Structure Designs

Fencing Applications

Figure 6.1: Various fence applications in Europe (FHWA/US DOT, 2002)

Figure 6.2: Wide mesh chain fence for large mammals, with a fine mesh fence border for small mammals and amphibians (FHWA/US DOT, 2002)

Figure 6.3: Fine plastic mesh fence for small animals and amphibians (Puky, 2003)

Figure 6.4: Chain link fence for large animals overlaid with fine plastic mesh fencing for small animals and amphibians (Puky, 2003)

Figure 6.5: Concrete trench and drop inlet with one-way pipe for amphibian crossing (FHWA/US DOT, 2002)

Figure 6.6: Fence for small animals and amphibians with turned-back end to prevent animals from approaching the road (Puky, 2003)

Figure 6.7: Lipped walls for amphibians (Critter Crossings Website, 2002)

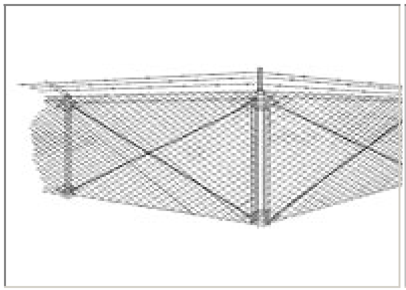
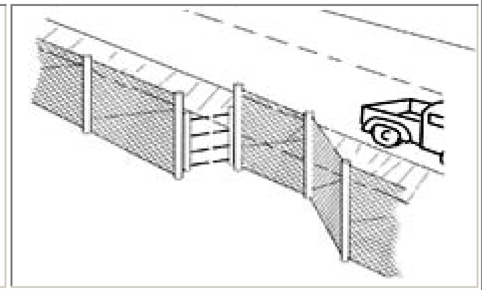
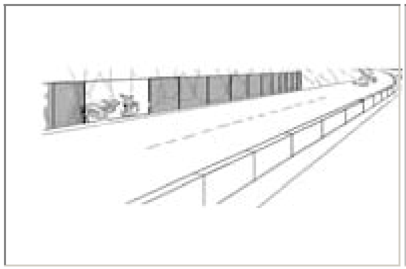
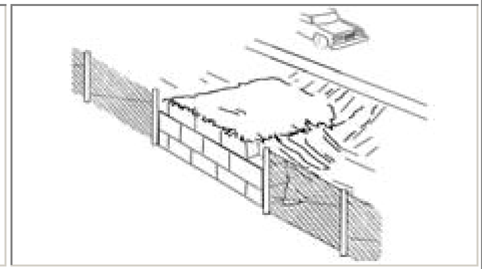
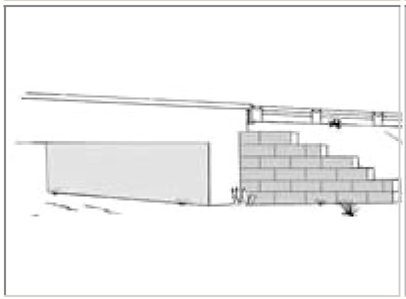
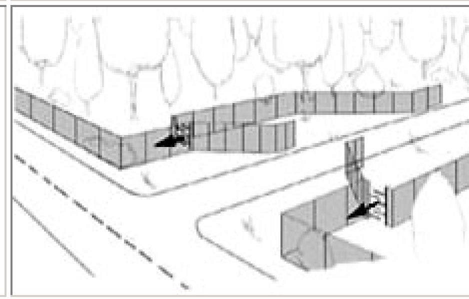
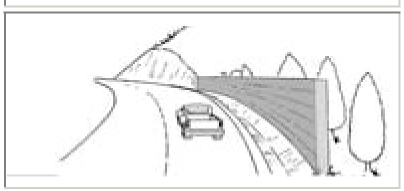
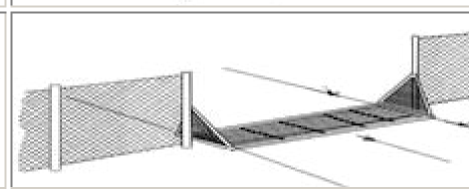
Fence		One-way Gate	
Jersey Barrier		Ramp	
Wall		Funnel Fence	
Sound Wall		In-roadway Barrier	

Figure 6.8: Various deterrence and escape mechanisms (Wildlife Crossing Toolkit)

Pipes Culverts

Figure 6.9: Small pipe culvert with mesh fence for small mammals and amphibians (FHWA/US DOT, 2002)

Figure 6.10: Arch culvert with fence for large mammals and lipped wall for amphibians (FHWA/US DOT, 2002)

Figure 6.11: Amphibian tunnel (Maibach, 2004)

Figure 6.12: Pipe culvert with fencing for medium mammals (NCHRP)

Figure 6.13: Various types of box culverts (Wildlife Crossing Toolkit)

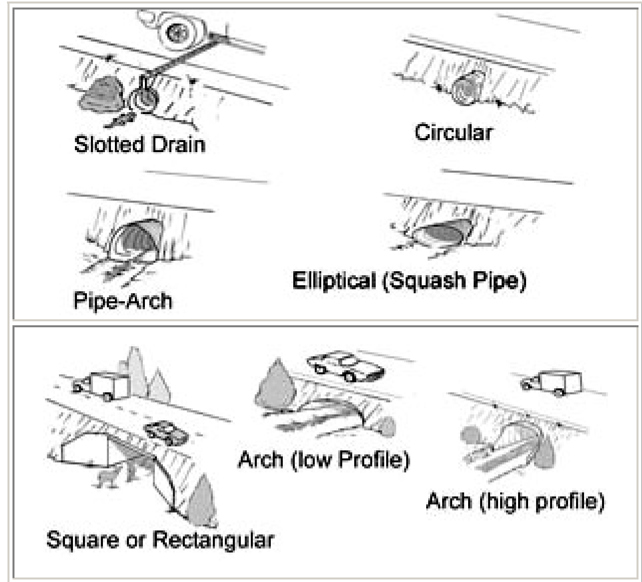


Figure 6.14: Small pipe culvert for small animals and amphibians (Critter Crossings, 2004)

Box Culverts

Figure 6.15: Fenced underpass for large wildlife (Defenders of Wildlife)

Figure 6.16: Box culvert underpass and fencing for multiple species (Puky, 2003)

Figure 6.17: Lipped wall and box culvert for amphibians (Puky, 2003)

Figure 6.18: Box cuulvert underpass with chain link fence for large animals (Cemagref, 2002)

Figure 6.19: Small box culvert for amphibians and small animals (Maibach, 2004)

Figure 6.20: Box culvert (National Cooperative Highway Research Program (NCHRP))

Ledges


Figure 6.21: Box culvert modified with ledge for wildlife passage (FHWA/US DOT, 2002)


Figure 6.22: Box culvert modified with ledge for small animal passage (Jackson, 2004)

Underpasses

Figure 6.23: Underpass to accommodate large and medium mammals, with stumps and vegetative cover for small animals (FHWA/US DOT, 2002)

Figure 6.24: Creek underpass in Banff National Park, Canada (Clevenger, 2004) http://www.pc.gc.ca/pn-np/ab/banff/docs/routes/chap1/sec1/routes1b_e.asp

Figure 6.25: Wildlife underpass in Banff National Park, Canada (Clevenger, 2004) http://www.pc.gc.ca/pn-np/ab/banff/docs/routes/chap1/sec1/routes1b_e.asp

Figure 6.26: Wildlife underpasses (National Cooperative Highway Research Program (NCHRP))

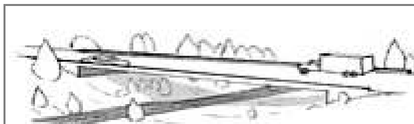
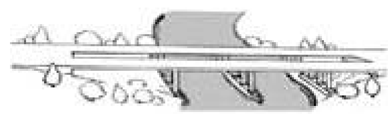
Structure Type	Description	Image
Single span bridge	The structure rests on abutments with no intermediate support columns. Also called *open span bridge*.	
Multiple span bridge	One or more intermediate support columns between abutments.	
Viaduct	Long, multiple-span bridge	
Causeway	Same as viaduct, only often over wetlands.	

Figure 6.27: Common underpasses (Wildlife Crossing Toolkit)

Overpasses

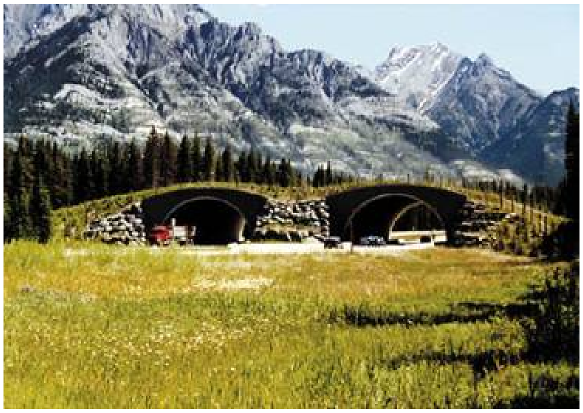


Figure 6.28: Overpass in Banff National Park, Canada (CPAWS, 2004)

Figure 6.29: Wildlife overpass (Deer-Vehicle Crash Information & Research Center)

Figure 6.30: Wildlife overpass to accommodate multiple species (FHWA/US DOT, 2002)

Figure 6.31: Wildlife overpass, or "green bridge" (NCHR)

Figure 6.32: Wildlife overpass (Jackson)

Wildlife Crossing Signs

Figure 6.33: Wildlife corridor informational sign from Riverside, CA

Figure 6.34: Frog crossing signs

Figure 6.35: Elk crossing sign ([www.teresco.org/ pics/signs](www.teresco.org/pics/signs))

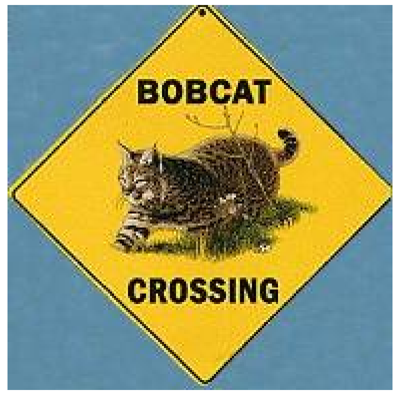


Figure 6.36: Bobcat crossing sign

Figure 6.37: Deer crossing sign with flashing lights (Friedman, 2005)

Figure 6.38: Seasonal crossing sign

Figure 6.39: Wildlife crossing sign for birds (Takahashi1999)

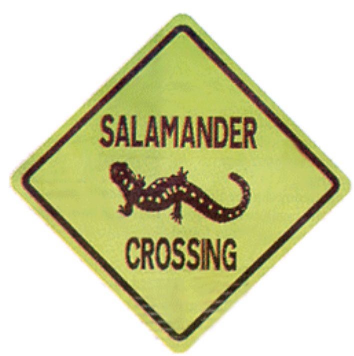


Figure 6.40: Salamander crossing

Problems to Avoid

Figure 6.41: Perched pipe.

Figure 6.42: Culvert with standing water.

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Appendix A

A1 Ventura County Wildlife Movement Corridors

A1.1 Identified Wildlife Movement Corridors and Landscape Linkages

The *Ventura County General Plan* (Goal 1.5.1) specifically calls for the consideration of wildlife movement corridors, however no policy is set. To help meet this goal, the Ventura County Planning Division has collected corridor and linkage data from a number of independent studies in the region to determine the location of potential movement corridors. From these studies, the Planning Division has compiled a map (Figure A1.1) of identified landscape linkages and wildlife corridors within unincorporated Ventura County. This map will continually be updated as new data are analyzed. As this information evolves, the Ventura County Planning Division will gain a greater understanding of where wildlife movement corridors exist and how important each corridor is to habitat connectivity for local species. This knowledge will help target areas where mitigation is needed most. The following is a list of current projects working on this issue.

South Coast Wildlands

http://scwildlands.org

South Coast Wildlands Project (SCWP) is a non-profit organization with a mission "to protect, connect, and restore…the South Coast Ecoregion by establishing a system of connected wildlands." The South Coast Ecoregion of the United States is a region bounded by "the Sierra Madre Mountains and Tehachapi Mountains to the north, the Antelope Valley, Little San Bernardino Mountains, Coachella Valley, and Imperial Valley to the east, Baja [Norte, Mexico] to the south, with the Pacific ocean forming the western boundary" (Penrod et al. 2001). Through the *South Coast Missing Linkages Project*, SCWP uses least-cost permeability and suitability analyses to identify and prioritize the conservation of landscape linkages crucial for connectivity between native habitats for focal native species. SCWP has also identified specific wildlife corridors for Ventura County that are important for movement of species native to the area.

Conception Coast

http://www.conceptioncoast.org

The Conception Coast Project provides scientific expertise for conservation and restoration projects through landscape modeling and habitat mapping. Conception Coast models landscape connectivity using a least-cost path function to determine the territories and movement corridors of mountain lions in the southern California region.

Envicom Corporation

http://www.envicomcorporation.com

Envicom Corporation provides environmental and urban planning consultation through biological surveys, habitat restoration plans, and best use analysis. Envicom Corporation has also been involved in modeling landscape linkages in the Santa Susana Mountains within Ventura County.

Santa Monica Mountains National Recreation Area

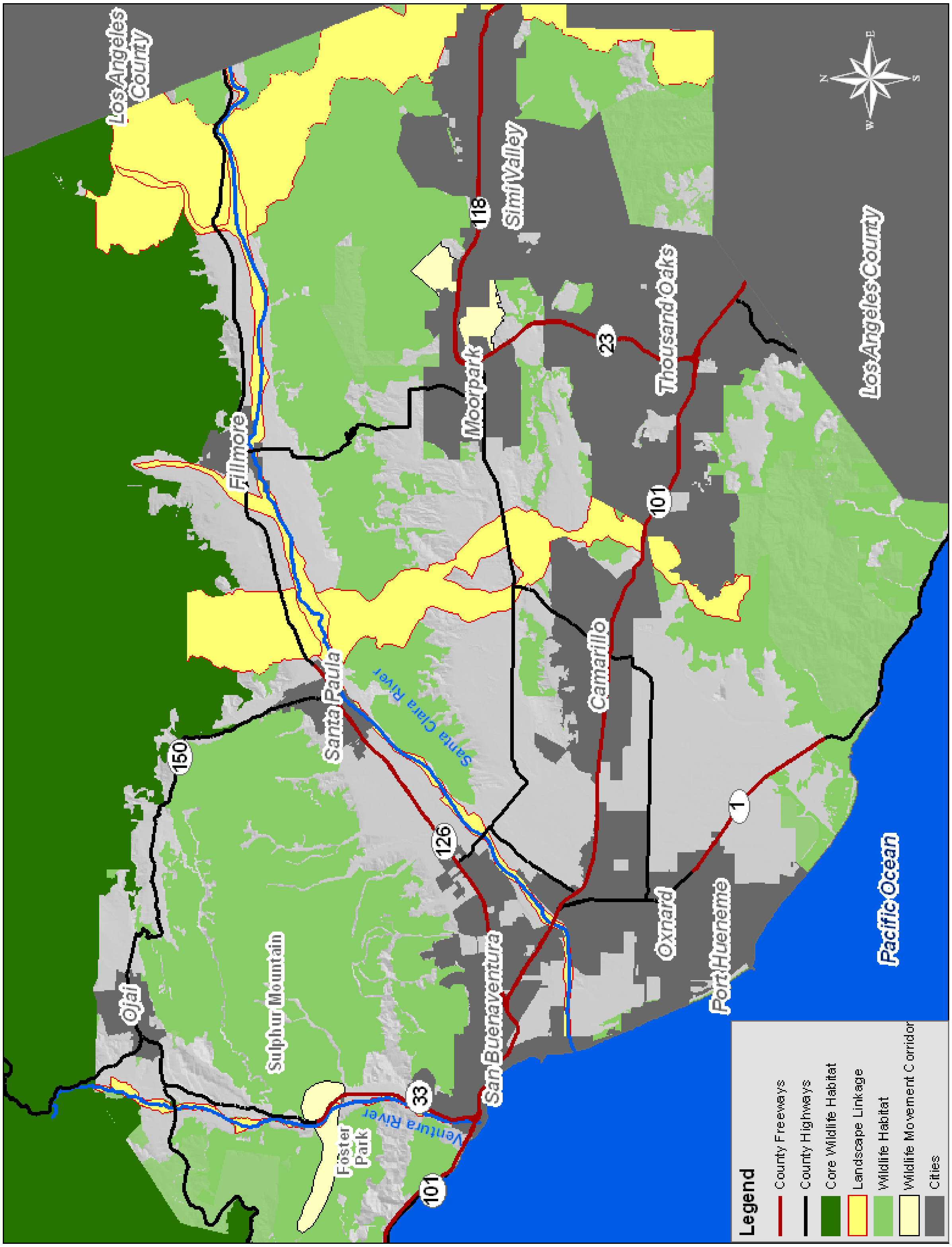
http://www.nps.gov/samo

Ray Sauvajot (Chief of Planning and Science Resource Management) and biologists at the Santa Monica Mountains National Recreation Area are conducting an ongoing study on the territorial range and movement patterns of mountain lions in the Santa Monica Mountains. By tracking the mountain lions with radio collars, they hope to validate predicted mountain lion wildlife movement corridors and determine the use and effectiveness of highway undercrossing structures designed for this species.

Green Visions Plan

http://www.greenvisionsplan.net
In 2003, the University of Southern California Center for Sustainable Cities, in partnership with state land conservancies in southern California, launched its Green Visions Plan to "provide a guide to habitat conservation, watershed health and recreational open space for the Los Angeles metropolitan region." The plan includes identification of "smaller scale habitat patches and corridors that are appropriate for species more apt to persist in the urbanized portion of the Plan area."

Figure A1.1: Identified Wildlife Movement Corridors in Ventura County, CA



A2 Knowledge Synthesis

A2.1 Literature Review

A literature review, conducted from April 2004 through January 2005, assessed and compiled information relating to road impacts on wildlife movement. We divided the literature into four topics of interest:

- Road Impacts & Ecology
- Wildlife Corridor Assessment
- Structure Design Characteristics
- Structure Effectiveness

This review incorporated a variety of scientific journals, peer-reviewed articles, conference proceedings, and relevant public and private reports. Of the 92 documents reviewed, 61 documents specific to structure design characteristics and effectiveness were selected for detailed review and inclusion in a database provided to the Ventura County Planning Division (Section A2.1.2).

State of Knowledge

Our review of the literature uncovered a fair amount of information on road ecology and wildlife-roadway interactions. Transportation departments in Europe have been studying these interactions for several years, and the United States is quickly learning from the European examples (COST 341 2003). Despite limitations of past research on wildlife crossings, it is now possible to identify some of the factors believed to influence species' use of wildlife crossings.

Very few of the wildlife crossing studies stated a hypothesis and/or predefined study criteria for measuring crossing success. Stated objectives and measures of effectiveness are necessary to determine whether a crossing is successful. Typical measures of success are related to wildlife movements (i.e. crossing use) and animal mortality. Many of the studies from scientific journals focused on one species or group of species. However, the interaction of species and the need for multiple species requirements of wildlife crossings may limit the applicability of these studies (Forman et al. 2003).

Most studies measure wildlife crossing success by total frequency of use by one or more species (Forman et al. 2003). This measure of success tends to ignore the fact that the frequency of crossings is not only related to the distribution and abundance of a species in the area, but also the time of the year. A more appropriate measure of success would be to compare the observed crossing use by a species to its expected crossing frequency. Almost none of the studies have properly compared the animal usage impacts of different wildlife crossing types (e.g. underpasses and overpasses) and other crossing design variables (Forman et al. 2003).

Literature Review Database

A total of 61 documents specific to structure design characteristics and effectiveness reviewed and summarized into a Microsoft Access database. We recorded the applicability of the information present to specific species groups. The database stores relevant information about each of the crossing structure design characteristic discussed in the Guidelines. Of the 61 documents reviewed, 44 (72%) provide information on large mammals. By comparison, medium mammals, small mammals, and herptiles (reptiles and amphibians) were addressed in only 16 (26%) studies each.

The database captures specific information such as structure type (e.g. bridge, box, pipe), fence height and material, specific structural dimensions, and relevant comments. A complete listing of the topics can be viewed in Figure A2.1. The ranking structure and a glossary of the database fields is shown below.

This Microsoft Access database, as well as the 61 individual studies and reports were provided to the Ventura County Planning Division.

Ranking Structure

Design characteristics are ranked on the scale shown below:
Strong evidence: Statistical analysis supports the effect
Weak evidence: Evidence is anecdotal, based on observations, or opinion of author

3	Strong evidence of positive effect
2	Weak evidence of positive effect
1	Strong evidence of neutral effect
-1	Weak evidence of neutral effect
-2	Weak evidence of negative effect
-3	Strong evidence of negative effect

Glossary of Database Fields

Functional Group	**Species**
Large Mammal	Mountain Lion, Bobcat, Coyote, Deer, Bear,
Medium Mammal	Fox, Opossum, Rabbit, Raccoon, Skunk, Badger, Weasel
Small Mammal	Mouse, Rat, Squirrel, Gopher
Upland Reptile	Lizard, Snake, Tortoise
Riparian Reptile/Amphibian	Frog, Toad, Turtle
Domestic	Cat, Dog, Cow, Horse, Human

General	
Reference:	The primary authors last name and a shortened or condensed version of the title.
Functional group:	Large mammal, medium mammal, small mammal, upland reptile, riparian reptile/amphibian
Road type:	Highway, secondary/residential, rural
Surrounding habitat:	Agriculture, urban, natural, mix

Road Design	
Headlight Reflectors:	Do headlight reflectors have a positive or negative effect on deterring animals from approaching the roadway?
Street Lighting:	Does a well lit street have a positive or negative effect on deterring animals from approaching the roadway?
Non-Vegetated Landscape:	Does a non-vegetated landscape have a positive or negative effect on deterring animals from approaching the roadway?
Noise Mitigation:	Does roadway noise mitigation have a positive or negative effect on deterring animals from approaching the roadway?

Traffic Control	
Speed Bumps:	Do speed bumps have a positive or negative effect on controlling traffic speed and reducing animal mortality?
Speed Limit:	Does an enforced or appropriate speed limit have a positive or negative effect on controlling traffic speed and reducing animal mortality?
Signage:	Does signage (such as wildlife crossing sign) have a positive or negative effect on controlling traffic speed and reducing animal mortality?

Approach	
Type:	What type of structure is being examined (bridge underpass, overpass, box culvert, pipe culvert)?
Opening Cover:	Does vegetation near the opening of the structure entrance have a positive or negative effect on promoting animal use of the structure?
Accessibility:	Does an accessible structure have a positive or negative effect on promoting animal use of the structure?
High Frequency of Placement:	Do frequently placed structures along a roadway have a positive or negative effect on animals' use of the structure?

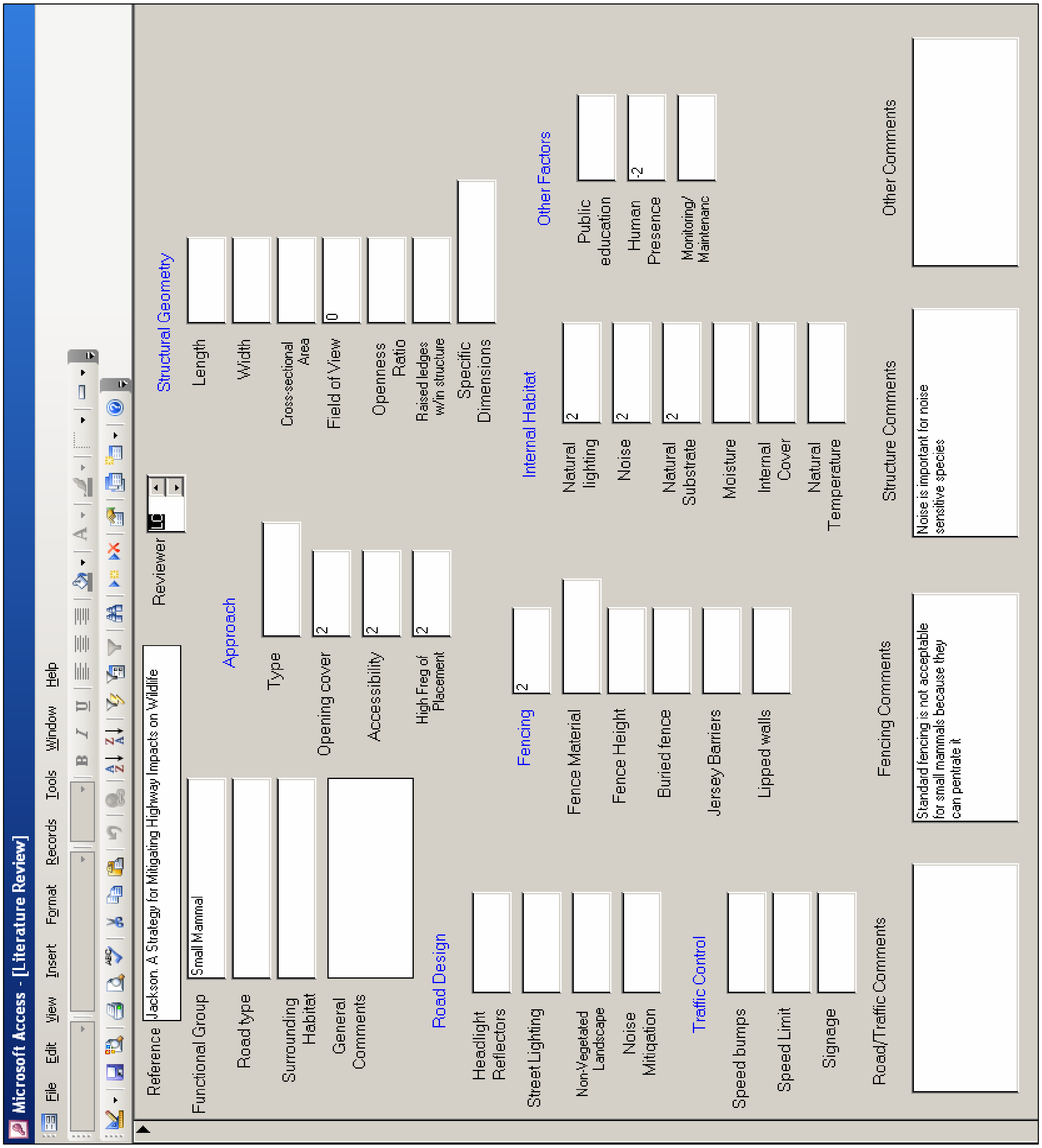
Fencing	
Fencing:	Does the use of fencing have a positive or negative effect on keeping animals from the roadway and/or guiding animals towards the structure?
Fence Material:	What is the material of the fencing?
Fence Height:	What is the height of the fence?
Buried Fence:	Does a buried fence have a positive or negative effect on keeping animals from the roadway and/or guiding animals towards the structure?
Jersey Barriers:	Do jersey barriers have a positive or negative effect on keeping animals from the roadway and/or guiding animals towards the structure?
Lipped Walls:	Do lipped walls have a positive or negative effect on keeping animals from the roadway and/or guiding animals towards the structure?

Structural Geometry	
Length:	Does length have a positive or negative effect on animals' use of the structure?
Width:	Does width have a positive or negative effect on animals' use of the structure?
Cross-Sectional Area:	Does cross-sectional area have a positive or negative effect on animals' use of the structure? (Cross Sectional Area = Height x Width in square ft)
Openness Ratio:	Does openness ratio have a positive or negative effect on animal use? (Openness Ratio = (Height x Width)/ Length in unit-less ratio)
Raised Ledges w/in Structure:	Do raised ledges inside of the structure have a positive or negative effect on animals' use of the structure?
Specific Dimensions:	What are the dimensions (length, width, and height) of the structure being studied?

Internal Habitat	
Natural Lighting:	Does natural lighting in the structure have a positive or negative effect on animal's use of the structure?
Noise:	Does roadway noise in the structure have a positive or negative effect on animal's use of the structure?
Natural Substrate:	Does the presence of a natural substrate on the bottom of the structure have a positive or negative effect on animal's use of the structure?
Moisture:	Does moisture within the structure have a positive or negative effect on animal's use of the structure?
Internal Cover:	Does cover available inside the structure (such as rocks, stumps, low vegetation) have a positive or negative effect on animal's use of the structure?
Natural Temperature:	Does natural temperature inside the structure have a positive or negative effect on animal's use of the structure?

Other Factors	
Public Education:	Does public education have a positive or negative effect on reducing animal mortality on roadways?
Human Presence:	Does human presence have a positive or negative effect on animals' use of the structure?
Monitoring/Maintenance:	Do monitoring and/or maintenance programs have a positive or negative effect on animals' use of the structure?

Figure A2.1: Literature Review Database Interface



A2.2 Expert Consultation

In addition to reviewing pertinent literature, we conducted online searches and consulted with biologists and road ecology experts regarding state and federal programs with respect to wildlife crossings. The following are illustrative examples of programs and mitigation strategies implemented internationally, as well as within the United States at the federal, state, and county levels.

International Program

COST 341

http://cost.cordis.lu/src/home.cfm

In 1971, the European CO-operation in the field of Scientific and Technical Research (COST) was founded as an intergovernmental framework allowing the coordination of nationally funded research throughout Europe. Countries develop universally numbered "COST Actions," which are developed and implemented based on national priorities. A COST 341 reports detail actions to "promote a safe and sustainable pan-European transport infrastructure through recommending measures and planning procedures with the aim of conserving biodiversity and reducing vehicular accidents and resulting fauna casualties" (CORDIS website 2005). Sixteen of the 35 COST member countries have developed COST 341 reports, including: Austria, Belgium, Cyprus, Czech Republic, Denmark, France, Hungary, Ireland, the Netherlands, Norway, Portugal, Romania, Spain, Sweden, Switzerland, and the United Kingdom.

United States Federal Programs

Critter Crossings

http://www.fhwa.dot.gov/environment/wildlifecrossings

The Critter Crossings website was developed by the U.S. Department of Transportation, Federal Highway Administration's Office of Natural Environment. The website describes the adverse impacts of transportation networks on wildlife and highlights commendable projects and programs that are helping to mitigate these impacts.

Keeping it Simple

http://www.fhwa.dot.gov/environment/wildlifeprotection

This website was created by the Federal Highway Administration's Natural and Human Environment Office. The purpose of this site is to offer both transportation professionals and the general public easy ways to reduce highway impacts on wildlife.

Wildlife Crossings Toolkit

http://www.wildlifecrossings.info

The Wildlife Crossings Toolkit project was initiated by the USDA Forest Service, in partnership with the Federal Highway Administration and Western Transportation Institute. The toolkit is designed to assist engineers and wildlife biologists with mitigating the impacts of highway infrastructure on wildlife resources. The Toolkit is a "searchable database of case histories of mitigation measures, and articles on decreasing wildlife mortality and increasing animals' ability to cross highways."

State and County Programs

California

California Department of Transportation (CalTrans) conducted an assessment of wildlife crossing structure use by large and medium sized mammals along State Route 118 (SR-118) around Simi Valley in Ventura and Los Angeles Counties. Camera and track stations were used to collect data on how and when animals use known wildlife corridors and crossing structures in the study area. Based on the results of their study, CalTrans has been convening a task force of agency stakeholders and the public to discuss future road design projects and how they will mitigate the impacts to wildlife crossing.

U.S. Geological Survey biologists discovered that some desert tortoises were using water drainage culverts to traverse under State Route 58, located in the Mohave Desert in San Bernardino County. CalTrans erected fences to guide the tortoises away from the road and toward the culvert resulting in a 93 percent reduction in vehicle mortality over four years.

In June 2004, Riverside County adopted a "comprehensive, multi-jurisdictional Habitat Conservation Plan" entitled the *Western Riverside County Multiple Species Habitat Conservation Plan*. The plan has the "overall goal of maintaining biological and ecological diversity within a rapidly urbanizing region" and will streamline conservation efforts within the western region of Riverside County. Within the plan are "Guidelines for Construction of Wildlife Crossings" which includes specifications for varied species groups.

Florida

Florida is currently considered one of the leaders in wildlife crossing mitigation in the United States. Florida's Department of Transportation has developed and implemented an Efficient Transportation Decision Making Process, which ensures that Florida's natural resources are protected. Using a Geographic Information System and a checklist of criteria, projects are screened for their social and environmental impacts.

Many projects throughout Florida have incorporated crossing structures into roads. For example, in southern Florida, when Interstate 75 was upgraded from a two-lane state road to a four-lane highway, 24 wildlife underpasses and 11-foot high fencing were included in the design. Researchers used roadkill and telemetry for a target species (Florida panther) to determine the best locations for the underpasses. Through monitoring, many species are known to successfully use the structures, including panthers, bobcats, raccoons, deer, and wading birds.

Other areas of high wildlife mortality are also attempting to retrofit roads. In both Lake Jackson, near Tallahassee, and Payne's Prairie State Preserve, south of Gainesville, projects to construct "ecopassages" are being developed. These structures are concrete walls that line the road, provide passage under the road, and include a lip at the top of the wall to prevent wildlife from scaling up the wall and crossing the road.

Montana

The State of Montana proposed a project to widen 56 miles of Highway 93 for motorist safety. This highway runs through the Flathead Indian Reservation on the western side of the Rocky Mountains. The project also proposed incorporating 50 crossing structures for safe wildlife passage, including fencing to funnel animals to the crossings. Crossing mitigations ranged from small fish culverts to bridge underpasses to a wide-span overpass in order to accommodate multiple species. In addition, signs informing drivers of potential wildlife crossings and crossing structures were incorporated into the mitigation strategy.

The goal of this project was to restore habitat areas fragmented by roads and development. Species of concern in the area included grizzly bear, white-tailed deer, mule deer, pronghorn, elk, tortoise, bighorn sheep, birds, and fish. The project identified habitat areas and migration patterns; used roadkill data, tracking information, and sightings to determine crossing locations; and identified historical movement corridors in need of restoration. This was used to determine the best locations for structure placement for specific species.

Washington

Highway 101 near Sequim, Washington, was modified with a crosswalk for elk. Elk in the area were outfitted with radio-transmitting collars that activated warning signs along a three-mile stretch of highway where the herd regularly crossed. As members of the herd approach the highway, the radio collars activate signs to warn drivers that elk are near. The project was funded by a $75,000 grant under Transportation Enhancement Program.

Wyoming

Wyoming is studying the effectiveness of a driver warning system called FLASH, or Flashing Light Animal Sensing Host. This system is designed to alert drivers only when there may be an animal on the road. The FLASH system is triggered by an animals' body heat. When an animal travels through the infrared sensors, the system activates flashing lights on a sign indicating that an animal may be on the road.

Pima County, Arizona

Pima County in southern Arizona has developed Environmentally Sensitive Roadway Guidelines for proposed projects. The guidelines include a checklist "to identify biological resources and evaluate the impacts of proposed roadway projects." The checklist requires a survey and assessment of resources, an evaluation of effects and impacts, and identification of potential conservation measures and treatment options. The guidelines also include recommended crossing structure designs.

Knowledge Base

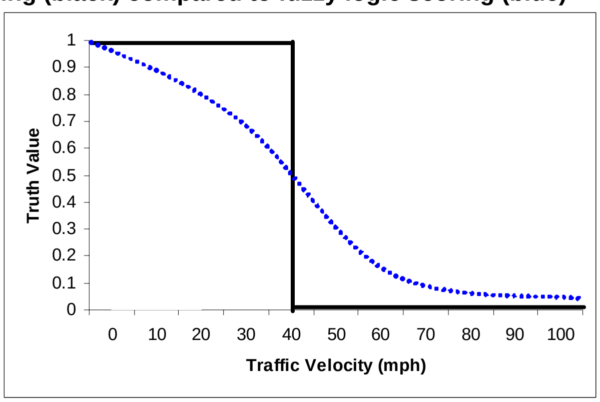
Based on the detailed review of studies and reports and our consultation with experts regarding effective wildlife crossing structure designs, we developed a knowledge base to assist in the assessment of current and proposed mitigations. A knowledge base is "an expert system that contains facts and rules needed to solve problems" (Answers.com). The knowledge base includes features of structure crossing design that are organized into a framework, which allows interactive manipulation. It also provides a formal logical system for evaluating wildlife crossing structures by a specific wildlife functional group. Figure 2.2 is a visual representation of the knowledge base of design features suitable for medium mammals.

The knowledge base uses “knowledge base reasoning”, which is a general modeling methodology in which phenomena are described in terms of (1) abstract entities and (2) their logical relations to one another. There are two basic reasons for using knowledge base reasoning:

- The entities or relations involved in the problem to be solved are inherently abstract so the mathematical models of the problem are difficult or perhaps impossible to formulate.
- A mathematical solution is possible in principle, but current knowledge is too imprecise to formulate an accurate mathematical model.

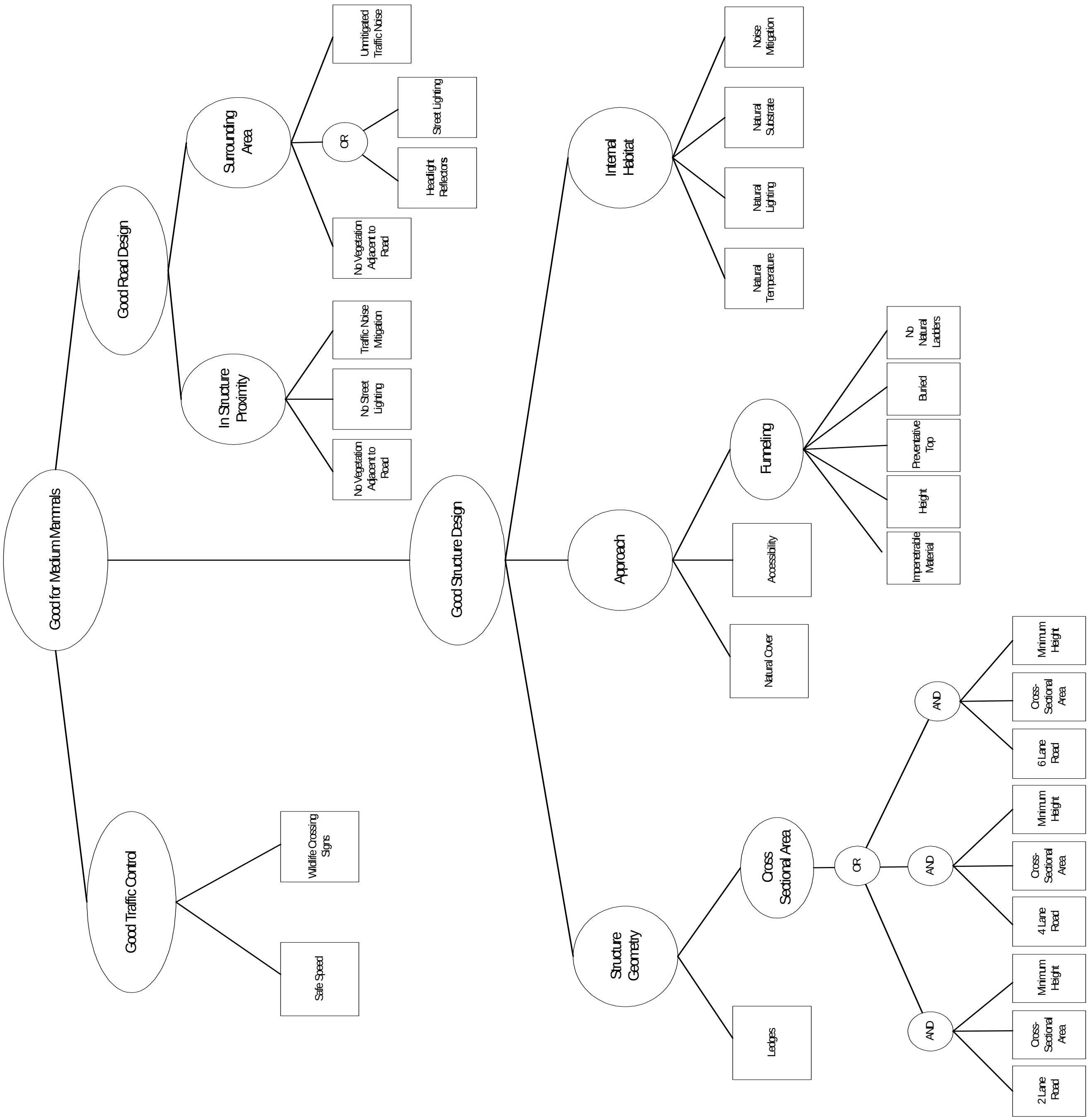
The primary advantage of such a system over a rule-based system is the ability to evaluate a decision process using multiple criteria that are not necessarily interchangeable. For example, inclusion of wildlife crossing signs is not a one-to-one replacement for wildlife accessibility. Furthermore, in rule-based systems, a rule is either true or false. A knowledge base system using fuzzy logic allows for varying levels of “trueness” based on the likelihood that a design characteristic is effective or detrimental to safe wildlife passage (Figure A2.3). For example, it makes intuitive sense that a traffic velocity of 10 mph would be beneficial to wildlife passage, while a traffic velocity of 80 mph would be highly detrimental. A fuzzy logic system can express the effects of a full spectrum of traffic velocities.

Figure A2.3 Rule-based scoring (black) compared to fuzzy logic scoring (blue)



We prepared the model using the NetWeaver knowledge base development system for Microsoft Windows platforms. It provides a graphical environment in which to construct and evaluate knowledge bases. The NetWeaver software was developed at Penn State University by Michael C. Saunders and Bruce J. Miller. The NetWeaver development system (visual interface) was created by Rules of Thumb, Inc. to provide interactive access on the Microsoft Windows platform.

Figure A2.2: Knowledge Base Evaluating Crossing Structure Effectiveness for Medium Mammals



Appendix B

B1 Study of Unincorporated Ventura County

We conducted our own field research to analyze the current state of road impacts on wildlife movement in unincorporated Ventura County by examining:

- Locations where wildlife crossings are a problem by compiling roadkill data for unincorporated Ventura County
- The effectiveness of existing crossing structures in facilitating wildlife movement by monitoring crossing structure use

From our field studies, we found that roadkill is widespread in Ventura County and is especially high in areas of known wildlife movement corridors. Though many crossing structures exist along State and County roads within our study area, these structures do not appear to adequately facilitate wildlife movement.

We also found that findings of wildlife crossing structure use patterns were consistent with the findings in the literature review. Large and medium mammals prefer larger, wide-open structures; medium and small mammals prefer crossing structures with vegetative cover; and large and small mammals tend to avoid structures with a high human presence.

From our knowledge synthesis and our assessment of the County based on our field observations, we can provide mitigation recommendations, not only for conditioning new projects, but also to increase the effectiveness of existing structures and target areas where mitigation is needed most.

B2 Roadkill Patterns in Ventura County

We evaluated roadkill patterns in unincorporated Ventura County to determine where areas of high concentrations or “problem areas” of roadkill exist. We also compared the distribution of roadkill data to the distribution of culverts which could potentially be used to facilitate wildlife movement across roads. This assessment of roadkill patterns will aid in determining where mitigation efforts should be focused in Ventura County.

B2.1 Methods

Roadkill data for southern Ventura County was collected from June 2004 through January 2005. California Department of Transportation (CalTrans) and volunteers from the Ventura County Planning Division recorded roadkill sightings throughout the County. Additional roadkill data was acquired from Ventura County Animal Regulation for January 2003 through November 2004. Though many of the observations could not be classified to the species level, the family and, in most cases, genus of the roadkill was identified.

Roadkill locations were digitally mapped and plotted using ArcGIS (Figure B2.1). Attribute data recorded included species name and functional group. For our analysis, we excluded any data recorded that could not be associated with an exact location, usually due to a lack of an address in rural areas of the unincorporated county. Altogether, 2,029 roadkill data points were analyzed.

Though high roadkill densities were observed throughout the county, State Route 33 (SR-33)/ North Ventura Avenue was selected for a roadkill density analysis for three reasons:

- A large amount of data was available for this roadway.
- This roadway intersects an identified wildlife corridor.
- This roadway encompasses portions of both a state highway and a secondary county road.

The southern portion of SR-33 is a highly trafficked 4-lane state highway that parallels the Ventura River. Just north of Casitas Vista Road, SR-33 becomes a 2-lane county road called North Ventura Avenue. This roadway is a heavily traveled route for commuters between the cities of Ojai and Ventura.

To analyze the data, State Route 33/North Ventura Avenue was divided into 54 0.25-mile segments and labeled alphabetically. We determined roadkill and crossing structure density for each 0.25-mile segment (Figures B2.2 and B2.3). Forty-seven points were evaluated along the 13.5 mile stretch of roadway between the city limits of Ojai and Ventura. We compared roadkill patterns of SR-33 (highly trafficked state highway) with roadkill patterns of North Ventura Avenue (secondary county road). Roadkill density along SR-33/North Ventura Avenue was also compared to culvert density along this roadway to determine whether roadkill distribution reveal patterns of reduced mortality around crossing structures that could potentially be used to facilitate wildlife movement.

Figure B2.1 Map of Roadkill Distribution for Ventura County

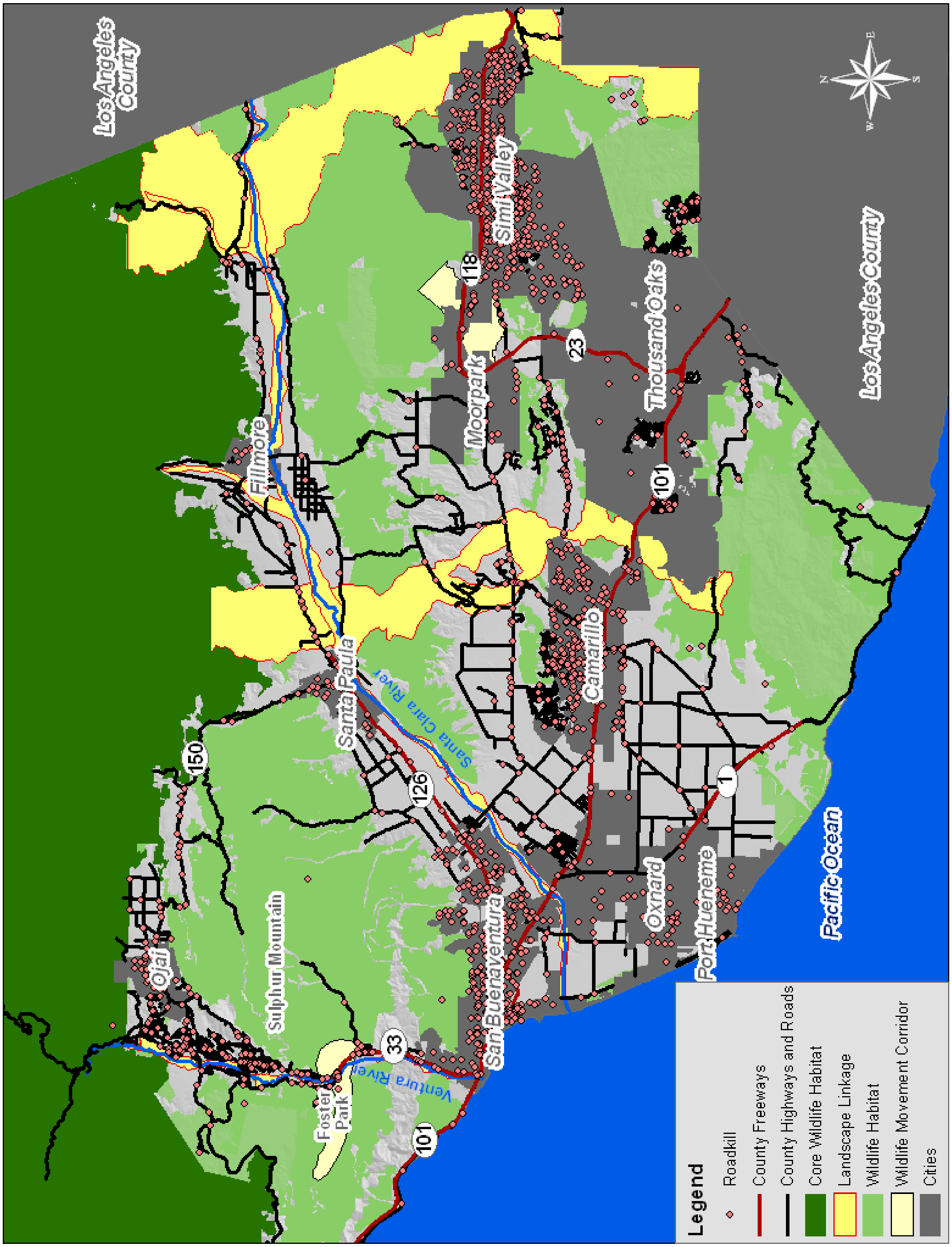


Figure B2.2 State Route 33/North Ventura Avenue Study Area

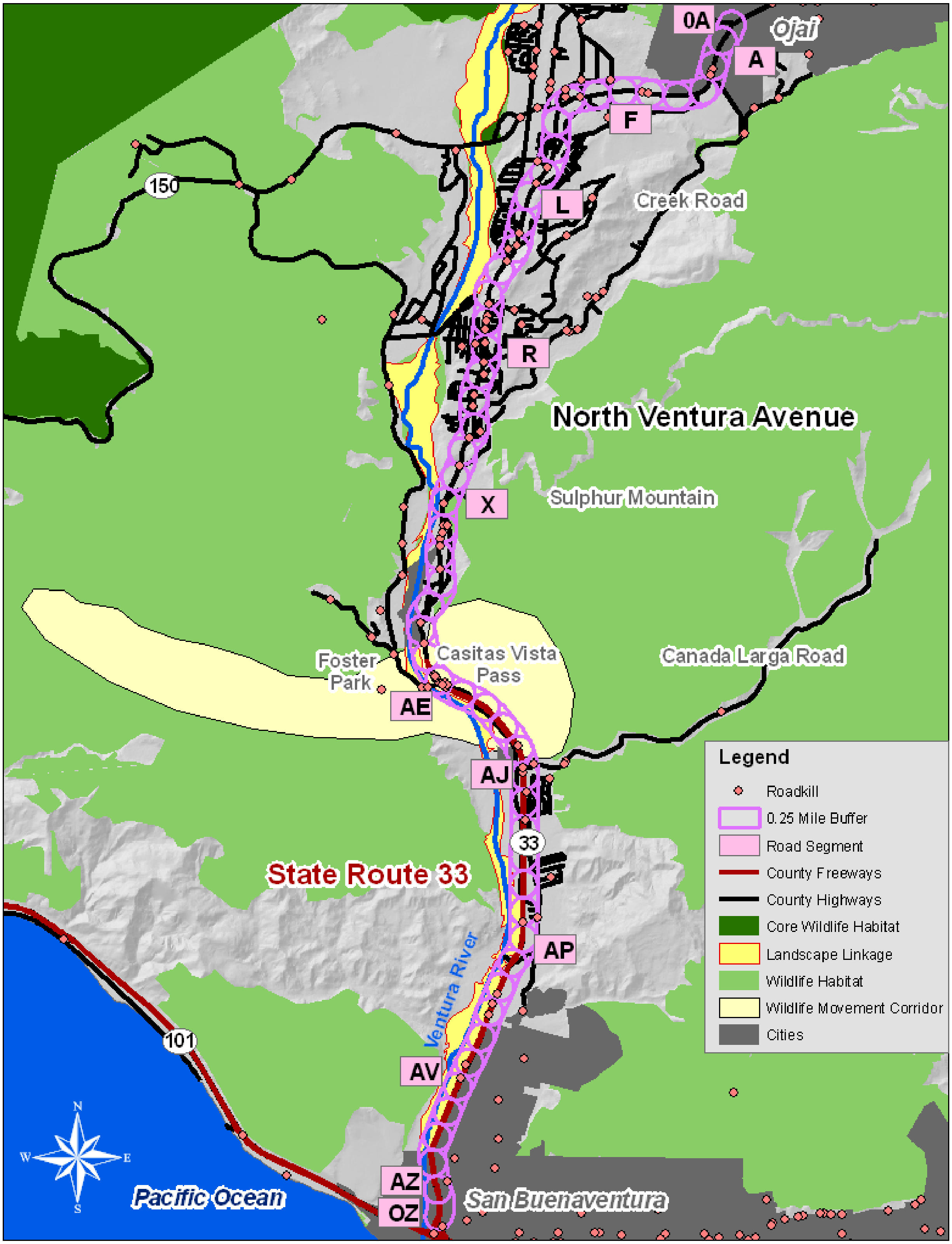
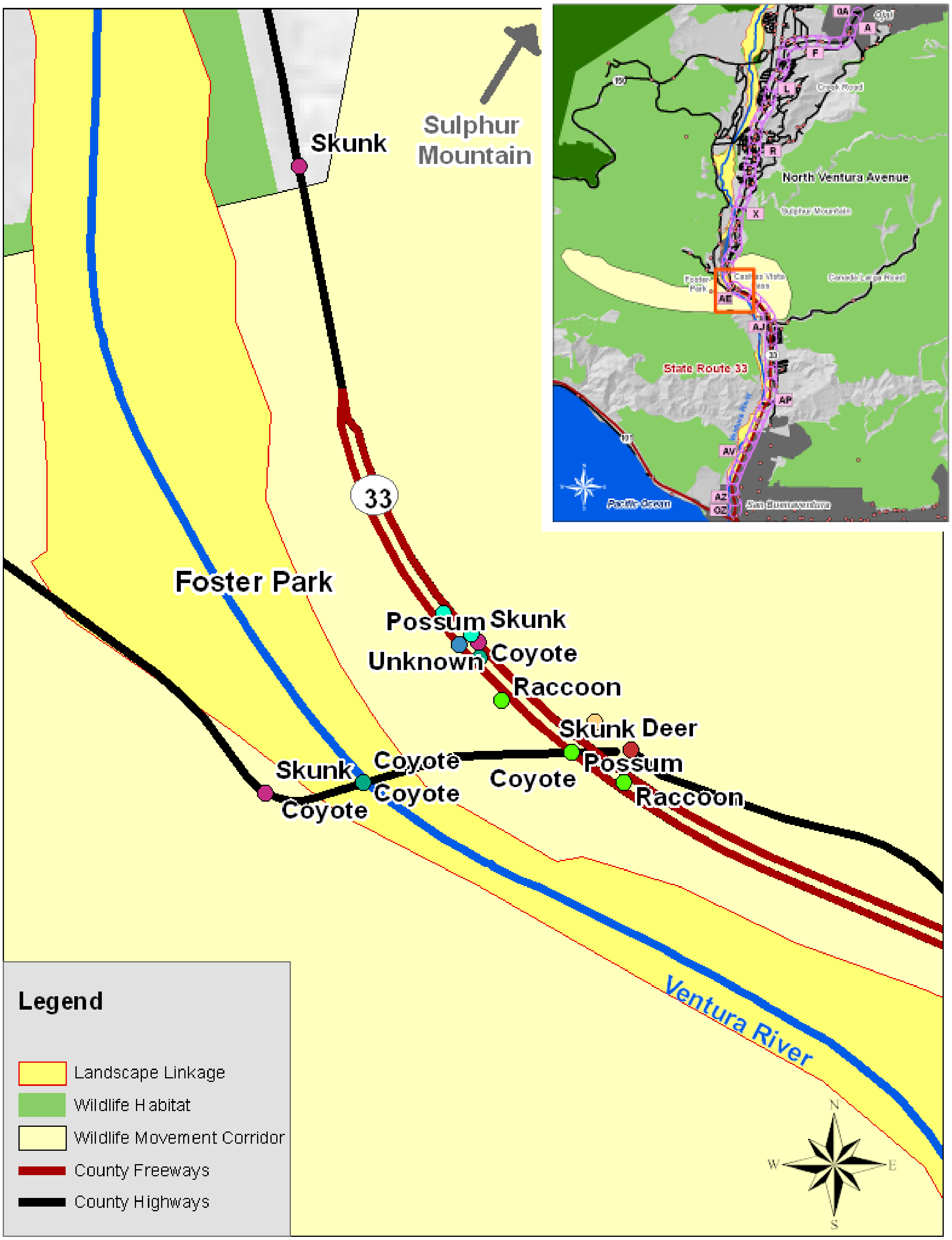


Figure B2.3 Close-Up of State Route 33/North Ventura Avenue Study Area Within an Identified Wildlife Movement Corridor



B2.2 Results

B2.2.1 County-wide Trends

The highest concentrations of roadkill occur on the outskirts of cities, notably Ventura, Camarillo, and Simi Valley (Figure B2.1). This is probably due in part to greater citizen reporting in these areas. (Ventura County Animal Control removes and records roadkill along County roads in response to citizen reports. However, due to funding shortages, Ventura County Animal Control will no longer record the location of roadkill.) High concentration of roadkill in these areas may also be due to the close proximity of these cities to wilderness areas. For example, the Santa Clara River, a recognized wildlife corridor, flows through the cities of Santa Paula and Ventura; Camarillo and Simi Valley are both in the vicinity of the Santa Monica Mountains National Recreation Area; and Ojai is in close proximity to the Los Padres National Forest.

The majority of roadkill data collected is also highly concentrated near heavily trafficked freeways, major highways, and secondary roads in areas with higher local traffic volumes. Most of the roadkill are opossums, which comprise 42% of the data collected. Birds, squirrels, rabbits, raccoons, and coyotes were also frequently recorded roadkill in the data. (Note: Birds of various species were grouped together into the same classification.) These six species groups make up 85% of roadkill in Ventura County (Table B2.1).

Table B2.1: Species Composition of Roadkill for Ventura County

Animal	Number of Roadkill	% of Total Roadkill	
Opossum	859	41.66%	85.46%
Bird	224	10.86%	
Squirrel	205	9.94%	
Rabbit	178	8.63%	
Raccoon	139	6.74%	
Coyote	129	6.26%	
Bat	68	3.30%	
Skunk	60	2.91%	
Unknown	41	1.99%	
Snake	35	1.70%	
Rat	25	1.21%	
Bobcat	16	0.78%	
Deer	14	0.68%	
Cat	14	0.68%	
Fox	5	0.24%	
Dog	4	0.19%	
Gopher	4	0.19%	
Lizard	2	0.10%	
Mouse	2	0.10%	
Weasel	2	0.10%	
Badger	1	0.05%	
Bear	1	0.05%	
Tortoise	1	0.05%	
Total Roadkill	**2029**	**100%**	

Roadkill was also analyzed by classifying species into five functional groups (see table in Appendix A, Section A2.1.2). For this analysis, domestic dog and cat were grouped in the large mammal and medium mammal functional groups, respectively. Medium mammals comprise the majority of the roadkill data collected in the County (74%). Small mammals, made up mostly of squirrels, are the second largest class of roadkill followed by large mammals (Table B2.2). Upland reptiles are the least commonly recorded roadkill, and no riparian reptile/amphibian road mortalities were recorded in this study.

Table B2.2: Functional Group Composition of Roadkill for Ventura County

Functional Group	Animal	Number of Roadkill	Total	% of Total Roadkill
Large Mammal	Coyote	129	164	9.67%
	Bobcat	16		
	Deer	14		
	Dog	4		
	Bear	1		
Medium Mammal	Opossum	859	1258	74.17%
	Rabbit	178		
	Raccoon	139		
	Skunk	60		
	Cat	14		
	Fox	5		
	Weasel	2		
	Badger	1		
Small Mammal	Squirrel	205	236	13.92%
	Rat	25		
	Gopher	4		
	Mouse	2		
Upland Reptile	Snake	35	38	2.24%
	Lizard	2		
	Tortoise	1		
	Total Roadkill*		**1696**	**100%**

*Data for birds, bats, and unknown roadkill were excluded from functional group analysis.

The most commonly reported medium mammals are opossums, rabbits, raccoons, and skunks. Opossums are the most frequently recorded species in vehicle-wildlife mortalities, most likely due to their slow nature and instinct to freeze and "play dead" when threatened. Accounts of small mammal, upland reptile, and riparian reptiles/amphibian functional groups are most likely underrepresented due to difficulty in detecting them. Also, the roadkill survey was conducted during the dry period of the year when amphibians are not moving between upland areas and breeding sites.

B2.2.2 State Route 33/North Ventura Avenue

In our analysis of SR-33/North Ventura Avenue, we found that the roadkill was rather evenly distributed along the two segments: 4-lane highway versus 2-lane secondary road. This is surprising as we expected less roadkill on the southern 4-lane highway portion of the road. This portion of SR-33 is slightly elevated, making it more difficult to access, and runs through a partially developed industrial area where fewer animals are expected to naturally occur.

The exception to the observed trend of even distribution is shown by Segment AE where roadkill was noticeably concentrated (Figures B2.3 and B2.4). This area is where an identified wildlife movement corridor intersects SR-33. The corridor connects natural the open space of Sulphur Mountain in the east with the open space of Foster Park in the west. The Ventura River is an added incentive for animals to move through this area. Further, the gently sloping hillsides of Sulphur Mountain allow animals to easily access the roadway. Roadkill recorded in the proximity of this wildlife corridor include deer, bobcat, coyote, opossum, skunk, and raccoon. Additionally, mountain lions have been observed in Sulphur Mountain and may also utilize this corridor. Similar to County-wide trends, medium mammals are the most frequently killed in vehicle collisions. Opossums and raccoons were the most abundant roadkill (Figure B2.5).

Roadkill density was compared to crossing structure density along SR-33/North Ventura Avenue, however no relationship was found. Although crossing structures are relatively evenly distributed throughout main roads and highways, these structures, which can potentially be used for wildlife crossings, are not facilitating wildlife movement across this road segment.

Figure B2.4: Roadkill vs. Crossing Structure Density

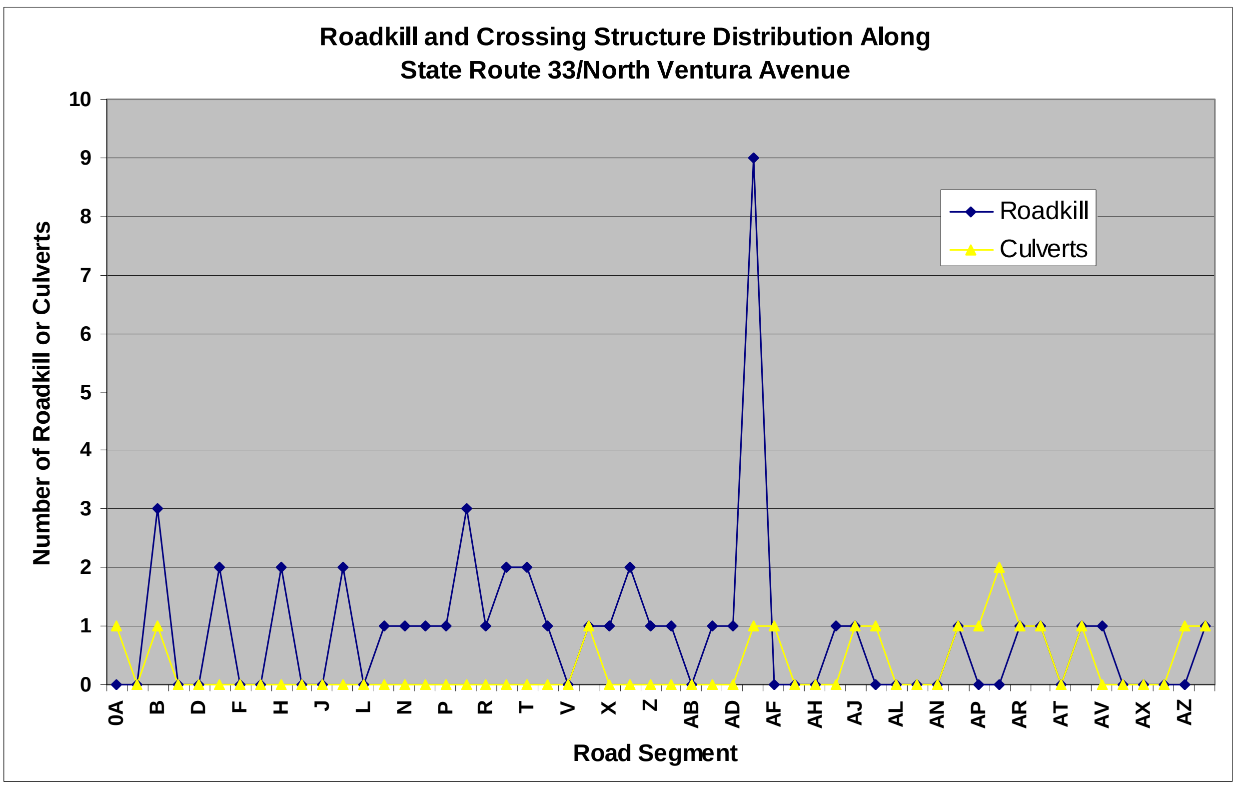
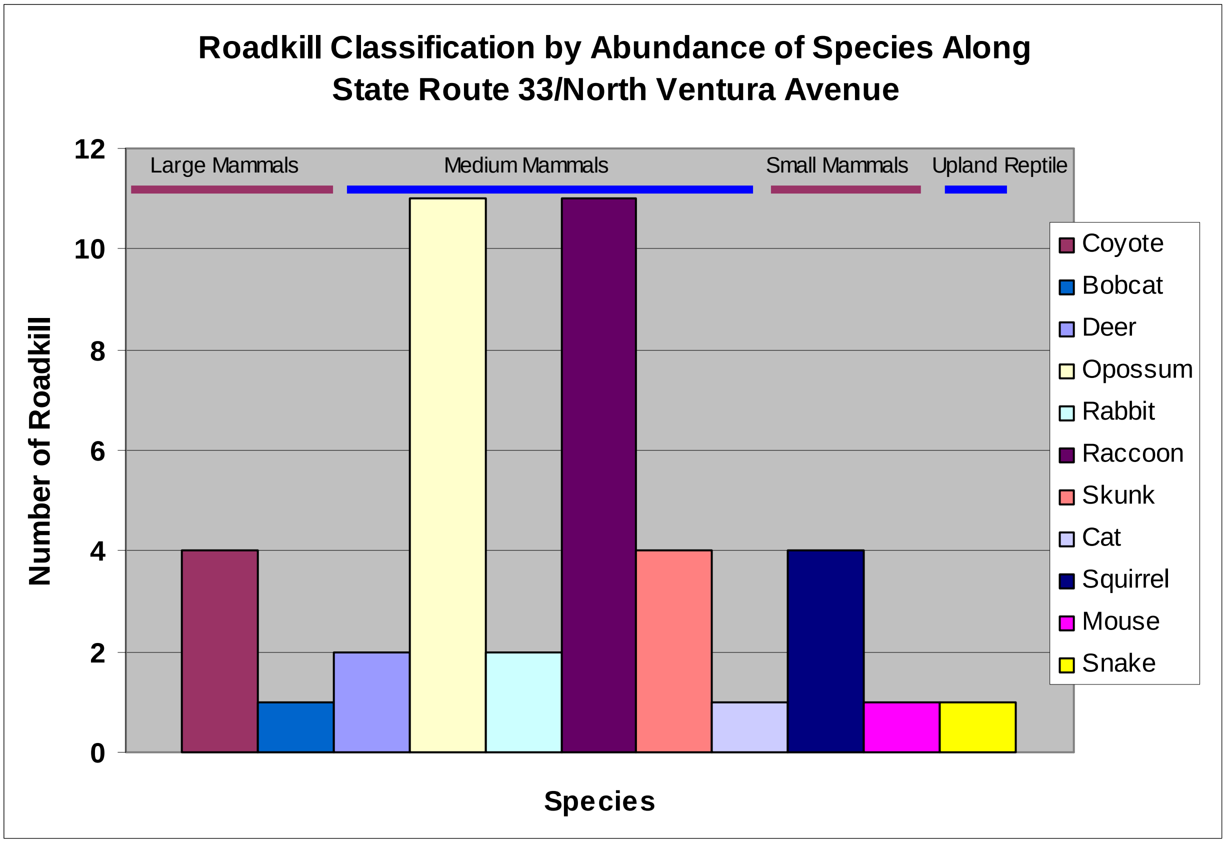


Figure B2.5: Species Composition of Roadkill for State Route 33/North Ventura Avenue



B2.3 Discussion

Though there are many potential crossing structures along State and County roads, roadkill is widespread in Ventura County. Animal mortality is especially high in areas of identified wildlife movement corridors and on the outskirts of cities. Roadkill rates can most likely be reduced by funneling wildlife to crossing structures that are more attractive and more accessible.

From our field observations, we have identified priority areas where mitigation efforts should be targeted within our study area. The following sites have concentrated vehicle-wildlife collisions and overlap with identified wildlife corridors, and are thus high priority for mitigation efforts.

- State Route 33 at the Casitas Vista Pass
- Harbor Boulevard

Additionally, field studies and consultation with local biologists and residents of the Ventura County area have identified Cañada Larga Road as an additional area of high wildlife movement and roadkill mortality, though it is not formally recognized as a wildlife corridor. Mitigation in this area is highly recommended to prevent wildlife mortality, reduce the risk of animal-vehicle collisions, and promote connectivity.

Although our survey did not evaluate eastern Ventura County, this area supports important landscape linkages and wildlife movement corridors and is known to have considerable amounts of roadkill. In eastern Ventura County, roadkill surveys were conducted along Highways 23, 118, and the 101 by Ng et al. (2004) and along the 118 by CalTrans (LSA 2004). Ng et al. found that roadkill was greatest along Highway 23, which has the lowest level of traffic volume and is also the most accessible roadway. Highways 118 and 101, respectively, had slightly less roadkill reported. All three highways bisect vital landscape linkages and wildlife movement corridors that are located between the Santa Monica Mountains in the southeast and the Los Padres National Forest in the north. CalTrans is currently convening a taskforce to develop mitigations for wildlife crossing along Highway 118 around Simi Valley. In addition, the National Park Service continues to monitor roadkill along Highway 23 and will propose mitigation following the completion of its study.

B2.4 Limitations

The roadkill analysis was limited by a number of factors.

- The roadkill data provided was collected from multiple sources at varying levels of accuracy, which confounded our analysis of the data.
- Because the roadkill survey conducted by the County and CalTrans was completed during the dry season, there was a lack of roadkill data for the wet season.
- Hazardous road conditions often prevented the identification of roadkill down to species level.
- The poor condition of many specimens made identification impossible.
- The majority of large mammal data provided by Ventura County Animal Regulation did not include specific location data.

In addition, because the roadkill data was somewhat biased towards urban areas, the urban locations of roadkill data are most likely overrepresented in our analysis. The County planners who volunteered to collect data all live and work in urban areas, so their data reflects the areas where they travel the most and not necessarily where roadkill occur the most. Also, the majority of the Animal Regulation data is within city limits, because roadkill is reported more frequently in urban areas. In addition, CalTrans, which is responsible for road maintenance, is more likely to frequent highly traveled areas than rural secondary roads to do maintenance, thus the data collected would include more roadkill around urban areas.

CalTrans does not normally inventory collected roadkill, but did so at our request. In the next year, CalTrans is planning to have a web-based roadkill data collection form available on the internet for volunteers to submit roadkill data. Hopefully, this will standardize data collection and provide year-round data for future analyses.

B3 Wildlife Structure Use of Existing Crossings

B3.1 Study sites and Methods

To evaluate wildlife use of existing crossing structures, 14 structures with varying attributes were monitored from September 2004 to January 2005. These structures occur along a 50-mile loop formed by Highways 33, 150, and 126 of unincorporated Ventura County (Figure B3.1). These roads encircle the foothills of Sulfur Mountain and pass through the communities of Casita Springs, Oak View, Ojai, Sulfur Springs, and Santa Paula. We selected this study area due to its proximity to Sulfur Mountain and the natural, wild habitat of the surrounding landscape. It was also chosen for its ease of accessibility and wide array of land use and traffic settings. Our study area included natural forests, grasslands, riparian environments, grazing and agricultural lands, and urbanized and residential zones.

The 14 selected structures were stratified based on structure type, surrounding land use, and traffic conditions.

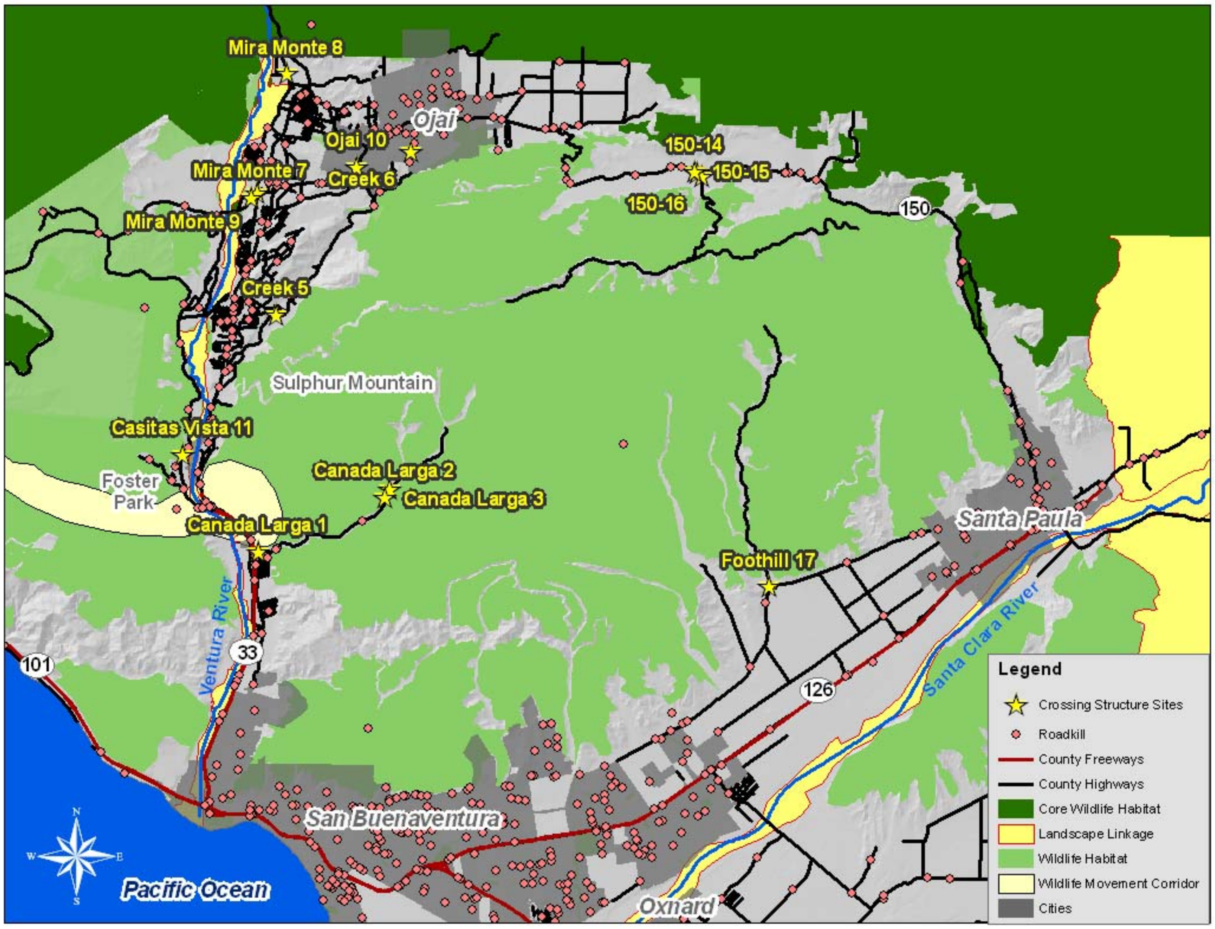
Table B3.1: Crossing Structure Study Sites and Site Characteristics

	Cañada Larga 1	Cañada Larga 2	Cañada Larga 3	Creek 5	Creek 6	Mira Monte 7	Mira Monte 8	Mira Monte 9	Ojai 10	Casitas Vista 11	150-14	150-15	150-16	Foothill 17
Site Characteristics														
Structure Type														
Bridge	x		x											
Box Culverts				x	x			x		x	x	x	x	x
Pipe Culverts		x				x	x		x					
Road Type														
Highway									x		x	x		
Secondary/Residential				x	x			x		x			x	x
Rural	x	x	x			x	x							
Land Use*														
Natural	x		x				x		x	x				x
Agriculture		x	x	x	x	x					x	x	x	x
Developed	x			x	x	x	x	x	x		x	x		
* Sites may encompass more than one land use type														

Several additional attributes for each structure site were recorded.

- Amount of vegetative cover near the openings of the structure (high, medium, or low)
- Amount of human presence (high, medium, or low)
- Dimensions of the structure (height, width, length)

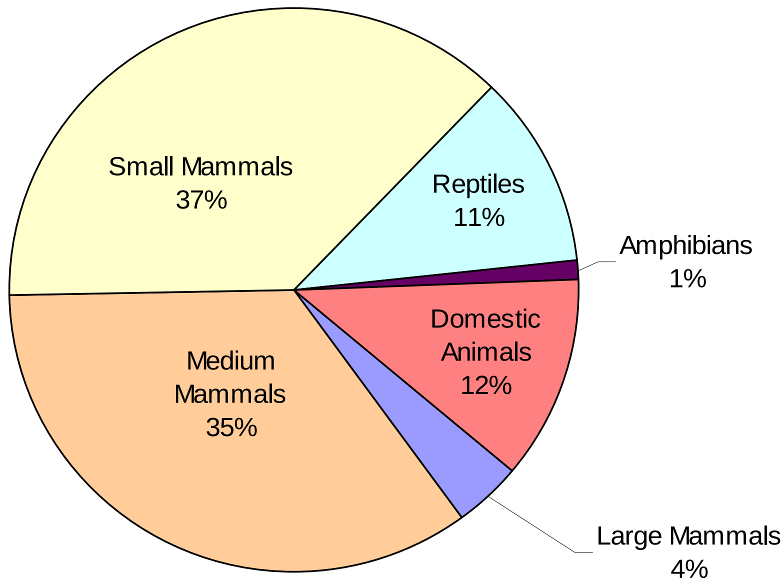
Figure B3.1: Crossing Structure Study Sites



Tracking plate and visual surveys were conducted two to three times a week from August to October 2004. Tracking plates with dimensions of 4 feet by 2 feet were placed at each of the fourteen sites. Plate surfaces were covered with a 0.5 inch thick layer of gypsum powder to capture the tracks of animals using the structures. We installed track plates on both sides of all of the bridges and box culverts. Plates were also set halfway through the longer structures with the short side set against the wall. This arrangement captured the movement of smaller mammals that prefer to move along the walls. Gypsum powder was also sifted on the ground at some sites. For pipe structures, gypsum powder was sifted at both ends of the pipe, or as close to the outlet as possible. Wildlife could then be tracked entering and exiting the pipe. There were 603 data points of structure use. In addition to monitoring the tracking plates, we recorded wildlife sightings along riparian corridors and along the study area route.

Crossing structure use was analyzed by functional groups (see table in Appendix A, Section A2.1.2) across all sites. Though we recorded observations of animals in areas surrounding the structure, only on-site, or actual use within the structure, was analyzed. For each crossing structure design element, we determined the average number of recorded uses by functional group. Standard errors for each average were also computed. For large mammals, no statistical tests were conducted due to an insufficient amount of data collected. For medium mammals, small mammals, reptiles, and domestic animals, paired t-tests ($\alpha = 0.10$) were used to determine significant differences between the average uses for each design element. Where no significant differences were determined, a general trend was examined for conclusions. For amphibians, no statistical analysis was conducted or general trends determined because there were only four observations of amphibians using structures. Figure B3.2 provides a breakdown of the data by functional groups.

Figure B3.2: Crossing Structure Use by Functional Group



B3.2 Definitions of Crossing Structure Design Elements

B3.2.1 Structure Type

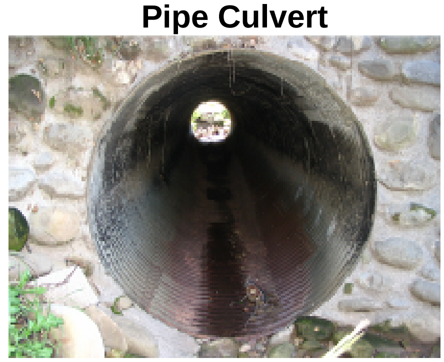
Bridge

Bridge structures have natural stream bed bottoms.

Box Culvert

Box culverts have concrete bottoms.

Pipe Culvert



Pipes within study area were made of corrugated steel.

Road Type	
Highway:	Multi-lane road with higher speeds
Secondary/Residential:	Connects highways to residential areas with moderate speeds
Rural:	Narrow road with limited use, and usually slower speeds

Surrounding Habitat	
Natural:	Open space with minimal human disturbance
Agriculture:	Row crops, orchards, or cattle grazing
Developed:	Residential or commercial buildings

Vegetative Cover	
High:	Dense trees and shrubs that provide substantial cover over entrance of culvert
Medium:	Larger shrubs (approximately 2 to 4 ft) and some small trees that provide moderate cover over entrance of culvert
Low:	Low, small shrubs (< 2 ft height*)* with little to no ground or overhead/canopy cover

Human Presence	
Low:	Natural, undeveloped areas nearby and no sign of human use
Medium:	Agriculture or developed areas nearby, but no sign of human use of culverts
High:	Large amount of and/or graffiti either inside culvert or on adjacent property

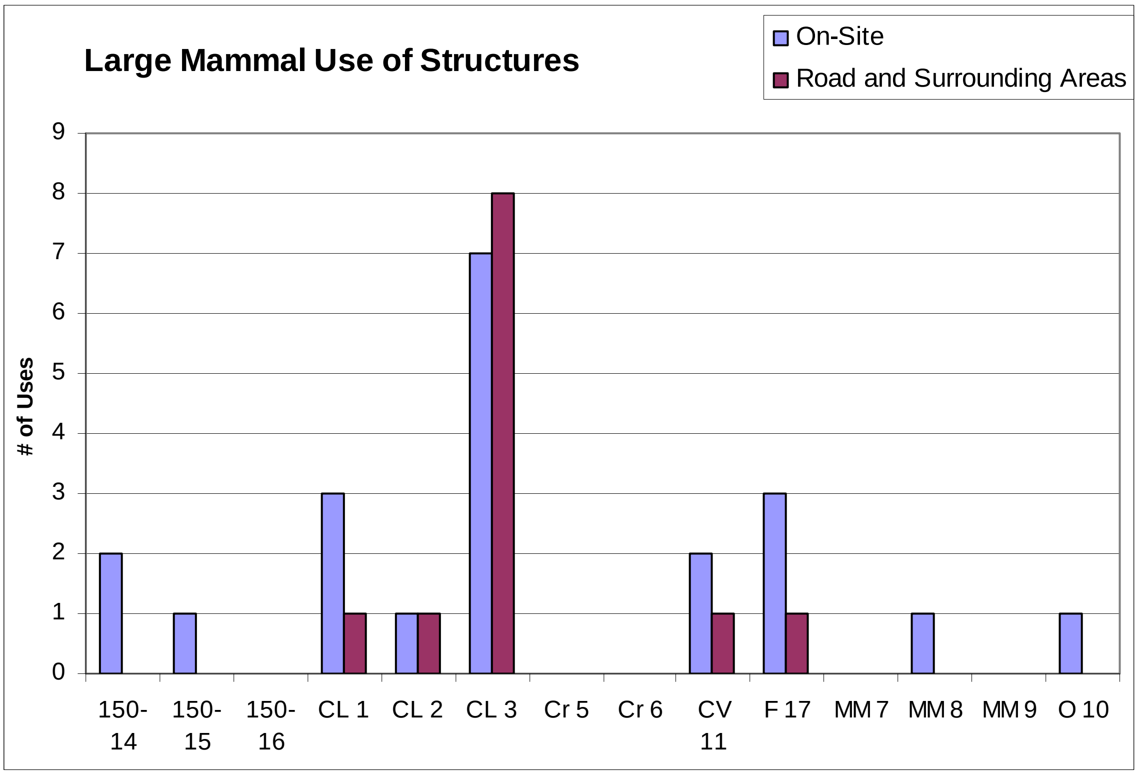
Dimensions	
Width (W):	Measure from side to side of opening of structure in feet.
Height (H):	Measure from top to bottom of the opening of structure in feet.
Length (L):	Measure from opening to opening under the roadway in feet. Usually approximate to the width of the roadway.
Cross-sectional Area:	Calculation of W x H in square feet
Openness Ratio:	Calculation of W x H (or cross sectional area) / L. Displayed as a unit-less ratio.

7.3

B3.3 Results

B3.3.1 Structure Use by Large Mammals

Structure Cañada Larga 3, a bridge located under a rural road in a natural and agricultural area, had seven occurrences of use, the highest number of uses of all of the structures. Structures 150-16, Creek 5, Creek 6, Mira Monte 7 and Mira Monte 8 recorded no indications of large mammal use either within or surrounding the structure.

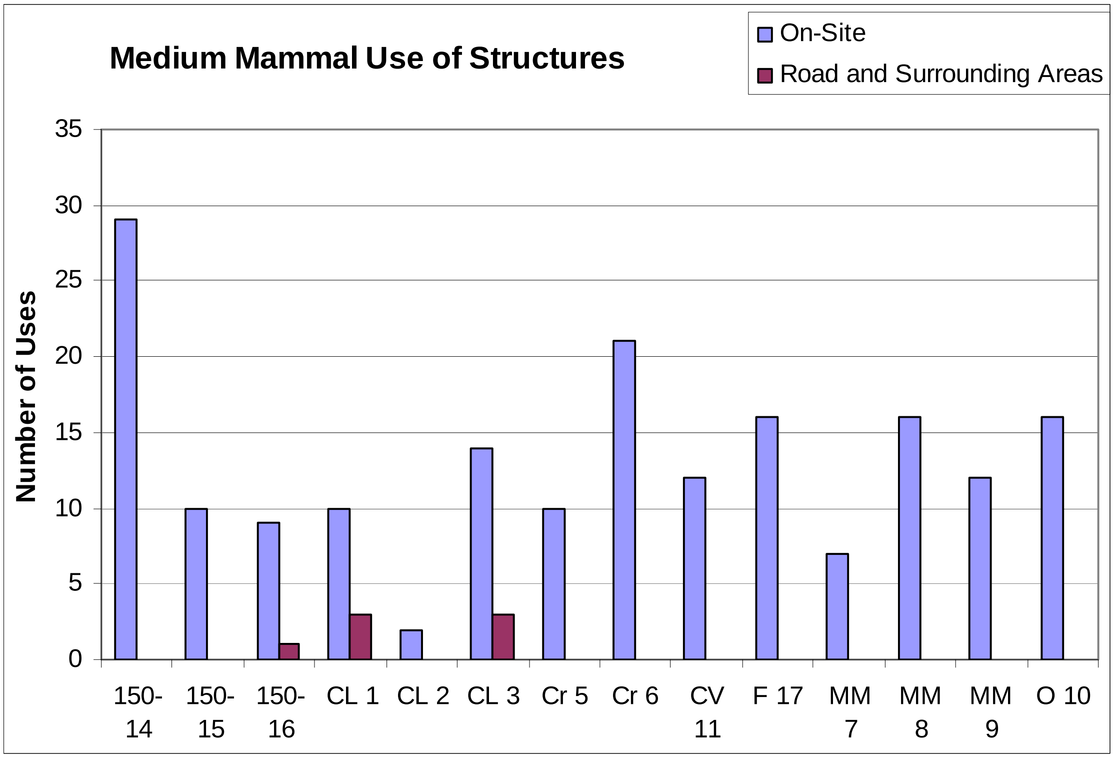


Overall, large mammals preferred to use bridge structures in natural areas with low human presence. This result may be skewed because both of the bridge structures were located in natural or rural areas, with low human presence. Large mammals also preferred structures with high or medium vegetation cover at the openings over structures with low vegetation cover.

Observed structure use indicates that large mammals prefer larger structures that are shorter (in length), wider, and taller structures than other structures. This combination of dimensions produces larger cross-sectional areas and higher openness ratios.

B3.3.2 Structure use by Medium Mammals

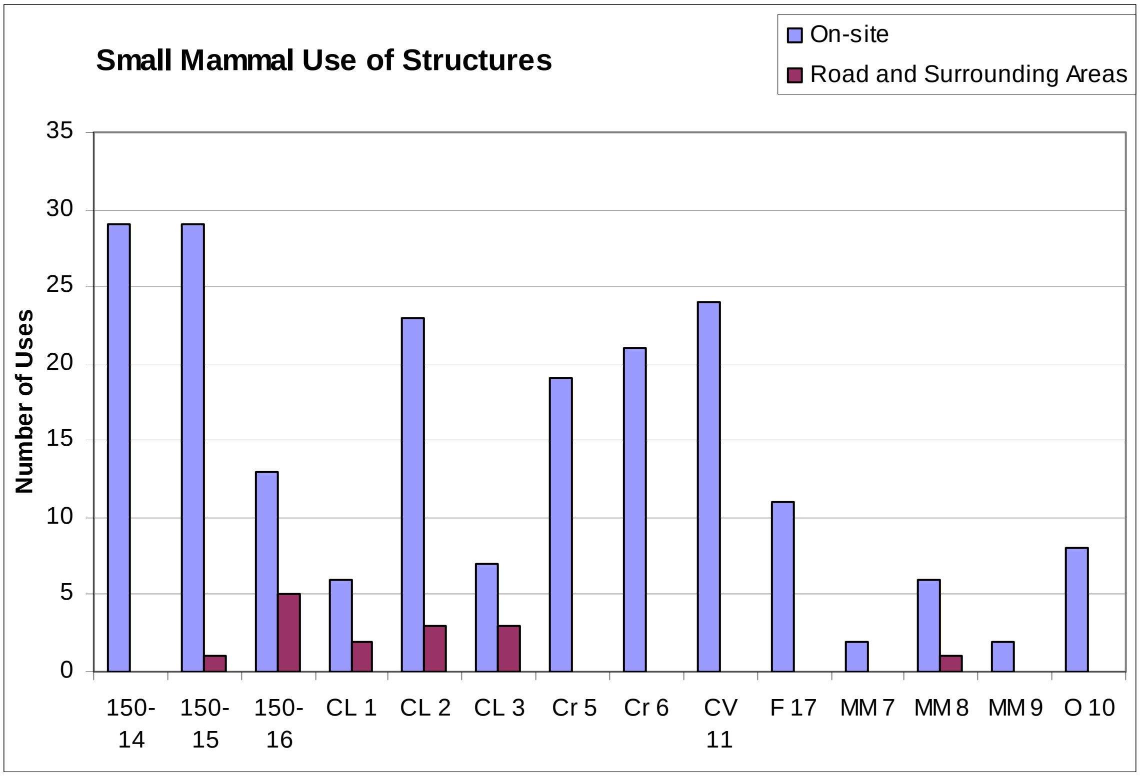
Structures 150-14 and Creek 6 had the highest number of uses recorded at 28 and 22 occurrences, respectively. Structures Cañada Larga 2, Mira Monte 7, and 150-16 recorded the lowest number of uses, all of which were less than nine.



The analysis indicated no significant preferences among the varied culvert types, road types, surrounding habitats, or human presence. This may be because this group is mainly composed of generalist species. However, this group did prefer structures with high vegetation cover over those with lower vegetation cover (p-value=0.085). In addition, a linear regression showed that the level of vegetation significantly predicted the level of structure use (p-value=0.0055). These results may suggest attempts to avoid exposure to larger predators. Further, these animals preferred shorter (in length), taller, and wider structures with greater cross-sectional areas and larger openness ratios.

B3.3.3 Structure use by Small Mammals

Structures 150-14 and 150-15 had the highest occurrences of uses with 28 recorded uses each. Structures Mira Monte 7 and Mira Monte 8 experience the least amount of activity with only two recorded occurrences.



The analysis indicated a significant preference for box culverts over bridges (p-value=0.0084). However, there was no significant preference between pipe culverts and box culverts, nor pipe culverts and bridges. In addition, no significant differences among the road types or surrounding habitats were found.

Significant differences were observed for other structure characteristics. Small mammals used structures with high vegetation cover as opposed to those with either medium or low vegetation (p-values=0.1014 and 0.1379, respectively) and preferred low or medium human presence over structures with high human presence (p-values=0.028 and 0.044, respectively). The preference for vegetation cover encourages small mammals to use those structures that may decrease exposure to predation.

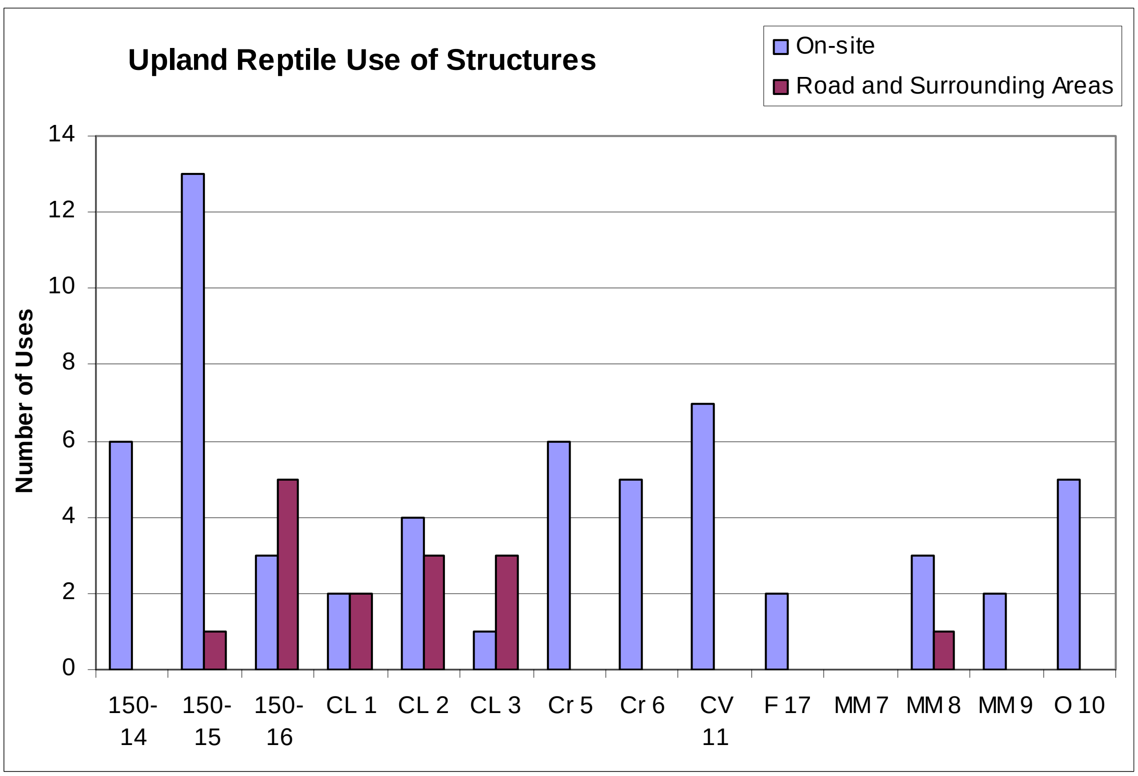
Statistical analysis on the data revealed no significant relationships between the dimensions and use of structures. However, general trends did show that small mammals preferred shorter (in length) structures.

B3.3.4 Structure Use by Amphibians

Since few observations were recorded at only 3 structures (Structure 150-14, Cañada Larga 3, and Ojai 10), there was not enough data to conduct an analysis on amphibian structure use. There were, however, fifteen observations of amphibians in the areas surrounding the structures. Since amphibians reside near water, all of the amphibian observations surrounding structure sites were found in or around pools of standing water near the structures. Structure 150-15 and Ojai 10 had the greatest occurrences of amphibians around the structure. The paucity of amphibian data is most likely a consequence of the study being conducted outside of the breeding season.

B3.3.5 Structure Use by Upland Reptiles

Structures 150-15 and Casitas Vista 11 had the highest recorded number of uses for this group with 13 and 7 uses, respectively. Structures Cañada Larga 3 and Mira Monte 7 recorded one and zero records of activity, respectively.

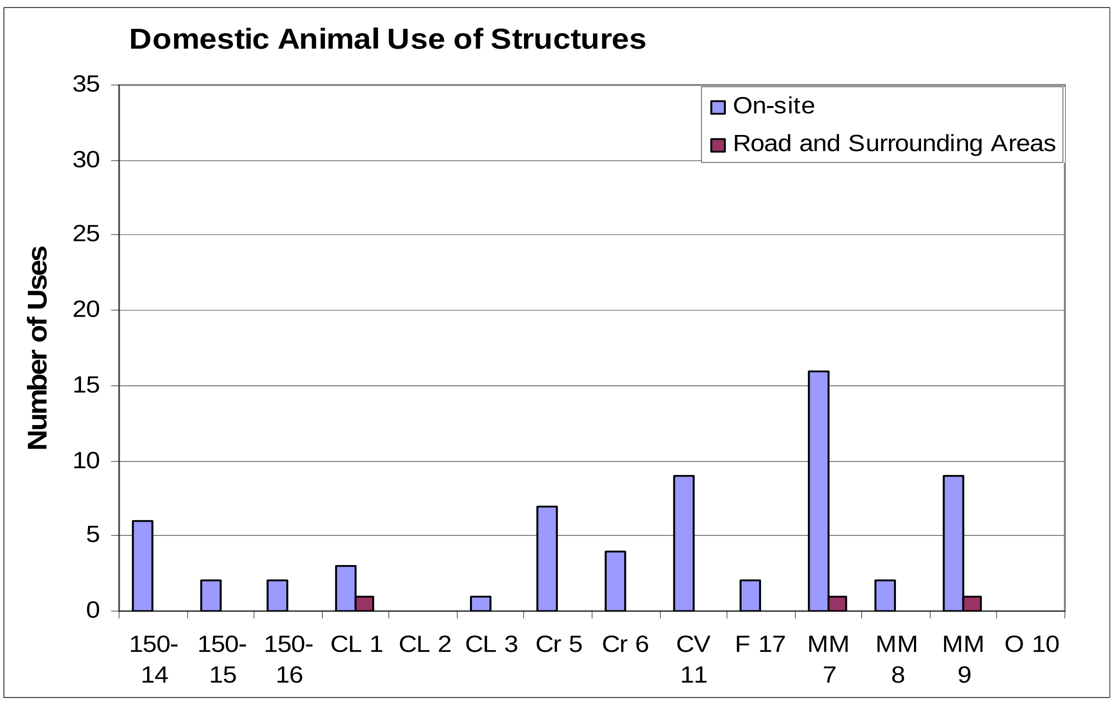


The analysis indicated a significant preference for box culverts over both bridges and pipe culverts (p-values=0.01886 and 0.1663, respectively). Structures under highways were preferred over structures under rural roads (p-value=0.1310) while structures under residential roads were preferred to rural roads (p-value=0.08606). No significant differences were determined for surrounding habitats, vegetation cover at openings, or human presence. In analyzing the affect of dimensions on structure use, no statistical analysis was conducted and no visible trends were seen.

A majority of the data points collected for this functional group are lizards. One explanation of the preference for structures under highways may be the small range of lizards, which reside in or around structures. Therefore, the higher incidence of reptiles found around structures near highways may be due to the attractive environment offered by the structure with few options for alternative habitats in the proximity of a busy roadway. Western pond turtles were not observed using structures, which is most likely a result of the observations being collected during their aestivation period.

B3.3.6 Structure use by Domestic animals

Data on humans, cattle, and horses were also observed in these sites, but was excluded due to the assumption that humans would accompany cattle and horses. As predatory species of many types of smaller wildlife, we were specifically interested in the effect that domestic cats and dogs would have on wild species using the structures. Structures Mira Monte 7, Mira Monte 9, and Casitas Vista 11 recorded the highest amount of activity with 16 uses for Mira Monte 7 and 9 uses for both Mira Monte 9 and Casitas Vista 11. Structures Cañada Larga 2 and Ojai 10 experienced no recorded activity.



The analysis indicated a preference for box culverts over bridge culverts (p-value=0.1021) by cats and dogs. No other significant preferences for road type, surrounding habitat, vegetation cover at openings, or human presence were determined. No statistical analysis was conducted on the relationship of use and structure dimension and no general trends were seen.

This functional group appears to contain generalist animals. Domestic cats and dogs can be predatory, but are small enough for the size of a structure to have little effect. However, there was a high significance for domestic use being dependent on small and medium mammal use of structures.

B3.3.7 Summary of Structure Use Analysis

Overall, larger animals had more design elements preferences than smaller animals. This finding, however, may be biased given the structures were not evenly distributed over all types. There were 8 box culverts, 2 bridges, and 4 pipe culverts, which represented 57%, 14%, and 29% of the study sites, respectively.

Mammals exhibited a preference for vegetative cover at structure openings, while amphibians, reptiles, and domestic animals did not. Only larger mammals and small mammals were more likely to use structures with limited human presence.

Larger animals, specifically large and medium mammals, showed preferences for specific structure dimensions. Overall, these groups used larger structures, while smaller animals showed no preference. Further, large mammals preferred natural habitat (with no human presence). The other functional groups appear more generalized and, therefore, show less preference with regard to habitat.

B3.4 Limitations of Structure Analysis Field Assessment

Many limitations to the field assessment exist. These are related to time constraints, sample size, and data collection methods. Due to the time constraints (less than one year) and structure of a Bren School group project, data collection only occurred for two and one-half months (August to October 2004). A proper data collection period should have been longer to include seasonal differences of animal movement and water flow. With the current data, only animal movement occurring during the dry season was analyzed.

Sample size proved to be a challenge. We found limited availability of structures due to location, property rights, physical inaccessibility, and structure size. Due to time constraints, structures needed to be selected so that they could be checked and monitored on a regular basis. Therefore, sites were chosen in such a way that allowed for efficient monitoring.

In addition, since one of our project objectives was to obtain field data on amphibian and riparian species, we selected structures located near riparian areas. Structures that were completely dry and clearly did not channel water regularly were eliminated from site selection in favor of structures with a higher potential to channel water that would more likely serve as passage for riparian species.

Further, we were restricted to structures located on public land, as many property owners are apprehensive about County staff conducting studies on their property. In addition, during our initial evaluation of structures in the study area, we found that many structures were physically inaccessible for animal use, as many pipes throughout the County are perched.

Structure size created some issues with respect to how best to survey the area. Many bridges were difficult to survey because gypsum powder could not be set across the entire expanse of the opening and permits were required to funnel species toward tracking plates. Permits to handle or alter behavior of wildlife were not feasible due to time constraints. Pipe culverts posed the opposite problem. Many were too small to determine if animals traveled completely through the structure. While gypsum powder was placed at both ends of the pipe, it could not be placed in the middle of the smaller structures to determine how far animals did travel through the structure. With these limitations, it was difficult to obtain an even sample across multiple variables.

While tracking plates are an accepted method of surveying, it is not always the most complete method. More complete data methods include motion-triggered cameras and radio tracking. Cameras were not used due to the expense and high potential for vandalism. We experienced small amounts of vandalism with the tracking plates in terms of overturned and broken boards. While the supplies are inexpensive, two to three days worth of data was still lost. In addition to vandalism, weather caused a loss of data, when rain would wash away the gypsum powder and some tracking plates. In order to radio collar animals, permits are required to trap, tag, radio collar, or track animals by electronic means. The limited time frame of our project restricted us from acquiring the necessary permits to directly track wildlife.

Many of these limitations could have been overcome with the availability of more time. Further research should be designed with these limitations in mind in order to conduct a more thorough survey of animal movement through culverts.

B3.5 Future research

Once the recommendations for improvements are implemented for the study site crossing structures, thorough monitoring will determine mitigation effectiveness and how well or ill-suited our recommendations are to Ventura County. A monitoring program, together with an extended monitoring of roadkill around the study areas, will indicate whether the mitigating crossing scenarios put into practice are reducing vehicle-wildlife mortality and facilitating wildlife movement and habitat connectivity.