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Identifying the best locations to provide safe highway crossing opportunities for wildlife

Author
Barnum, Sarah

Publication Date
2003-08-24

IDENTIFYING THE BEST LOCATIONS TO PROVIDE SAFE HIGHWAY CROSSING OPPORTUNITIES FOR WILDLIFE

Sarah A. Barnum (Phone: 303-329-6429, Email: sbarnum@carbon.cudenver.edu), Ph.D. Program in Design and Planning, University of Colorado at Denver, 1132 Jasmine St., Denver, CO 80220

Abstract: Providing mid- and large-sized mammals with safe opportunities to cross roadways can reduce the impacts of highways on wildlife. To maximize effectiveness, this type of mitigation must be placed in locations where animals naturally approach and cross the highway. Results of a study funded by the Colorado Department of Transportation indicate that mid- and large-sized mammals focus crossing activity at specific locations that are correlated to features of the surrounding habitat and the roadway itself. Therefore, both the design of a highway and its placement in the landscape should be considered when creating mitigation projects to help wildlife safely cross a highway. It is important to note that no single set of variables identifies all preferred crossing locations.

Because every landscape and every highway is unique, identifying the best location for each mitigation project must be approached individually. However, the study results suggest a set of guidelines, comprising the following: (1) use habitat suitability as the primary indicator of crossing activity; (2) consider how landscape structure interacts with habitat suitability to either increase or decrease the level of use an area of suitable habitat receives by a particular species; (3) consider how the design of the existing highway interacts with habitat suitability and landscape structure to influence crossing behavior; (4) synthesize this information by mapping the landscape and roadway features/conditions likely to be associated with crossing or that are attractive/repellant to the species present. Use these maps to identify the most likely crossing locations. Finally, because the preferred habitat and behavior of a given species can vary across its range, it is important to employ professionals familiar with the landscapes and species of concern on the analysis team.

Introduction

Results of a study (No. 32.40) funded by the Colorado Department of Transportation (CDOT) investigated whether mid- and large-sized mammals cross highways randomly, or whether they instead focus crossing activity in locations that can be correlated to characteristics of the surrounding habitat and/or the roadway itself. The study recorded the locations where wildlife crossed two Colorado highways for two years, then compared the characteristics of crossing locations to random locations along the roadside.

The study results apply directly to Colorado's mountain environments and the common species that live there. However, they also provide insight into identifying the best locations to provide safe crossing opportunities for other mid- to large-sized mammal species in a variety of habitats. A brief description of the methods is presented below, followed by a summary of the primary findings. Strategies to identify the crossing locations for mitigation, based on the study results, are then discussed. A complete description of the study areas, methods, and results is available at http://dot.state.co.us/publications/PDFFiles/wildllifecrossing.pdf (note the double l in "wildllife"). This web document also includes a detailed discussion of project planning practices that will help to foster highway projects that reduce wildlife/highway conflicts.

Methods

Study Site Descriptions

One study area was located in the Trout Creek Pass area along US 24 (MP 116.0 – 126.0), a low-volume, two-lane highway. The northern part of this study area was rolling, and cover type consisted of grasslands communities west of US 24, and mixed coniferous forests to the east. The terrain in the south end of the study area was rugged and highly dissected by dry washes and rocky outcroppings. Elevations in the study area range from 2,830m at the Pass to 2,420m at MP 216.0, and the main source of human disturbance, apart from the highway itself, was about 20 homes located mainly in the southern end of the study area. US 24 intersected six major drainages in the study area that were bridged by large, three-chambered concrete box culverts with concrete floors or by smaller bridge structures with natural floors. This area acted as both summer and winter range for mule deer and elk. Other common terrestrial species included red fox (*Vulpes vulpes*), gray fox *(Urocyon cinereoargenteus*), coyote (*Canis latrans*), mountain lion, bobcat, long-tailed and short-tailed weasel (*Mustela frenata, M. erminea*), and mountain cottontail (*Sylvilagus nuttallii*).

The other study area was located in the Vail Pass area along I-70 (MP 183.0 – 195.0), a moderate- to high-volume, four-lane highway. Along this section of I-70, the alignments of the east- and westbound lanes were independently sited and varied in location and elevation. Vail Pass, located at approximately MP 190, divided the study area into an east side and a west side. The median separating the east- and westbound lanes varied in width from less than a meter in some places on the west side of the Pass, up to 260m on the east side. To a large extent, the natural cover and topography was maintained within the wide median area on the east side. On the west side, Jersey barriers separated the east and westbound lanes in locations where they were at the same elevation. Stepped retaining walls were used to separate the lanes in locations where one lane was at a higher elevation than the other.

The primary cover type in this study area was mixed coniferous forest interspersed with aspen stands, sub-alpine meadows, and willow carrs. The elevation of the study site ranged from 2,730 to 3,165m, and sources of human-induced disturbance, aside from the highway itself, included a rest area, truck turn out and maintenance shed at the summit and the Copper Mountain Resort at the base of the east side. I-70 intersected 18 large drainages in the study area, and bridges spanned 11 of them. These bridges provided high quality highway crossing opportunities for wildlife as the drainages they spanned are wide (up to 230m), and the natural cover below most was largely undisturbed. Common terrestrial wildlife species in this study area included red fox, bobcat, mule deer, elk, and mountain lion during the snow-free months. Snowshoe hare *(Lepus americanus*), coyote, long-tailed and short-tailed weasels, and American marten (*Martes americana*) were present year-round.

Tracking

I recorded locations throughout both study areas where medium- and large-sized mammals (mule deer, elk, coyote, fox, bobcat, mountain lion) crossed the highway, as indicated by their tracks. At TCP and VP I checked 10 roadside transects 200m in length for tracks during each field session. To ensure transects were distributed throughout a study area and did not overlap, I used a stratified random selection approach, varying transect location for each data collection session. At each transect, a field assistant or I walked along the highway at the pavement's edge and looked for animal tracks left in the unpaved shoulder. At TCP, traffic was light, and I crossed the highway to walk along both sides of it, recording tracks from both sides. At VP, however, I only walked along the outer edges of the west- and east-bound lanes. Due to high traffic volumes and speeds, I considered crossing the highway to access the median-side roadside unsafe.

I recorded track locations using a hand-held GPS device\data logger (Geo Explorer II, Trimble) that automatically recorded location while I entered information through a menu-driven interface. All tracks of the same species observed within a five-meter stretch were recorded as a single track record (TR). Each TR included species of animal, number of animals, location (UTM coordinates) and date. I downloaded data files from the data logger and used Trimble's proprietary software to convert them to Excel spreadsheet and ArcView shapefile formats for analysis.

Snow tracking was conducted at VPS December through March during both 2000/2001 and 2001/2002. I did not implement snow-tracking protocols at TCP because sufficient snow cover at this site was infrequent, unpredictable, and ephemeral. Thus, even on the few occasions when there was snow on the ground at TCP, the standard tracking procedures described above were followed. Using snow-tracking methods, I observed the entire VPS study area, as opposed to a subset of transects, for tracks. Far fewer animals are present in the Vail Pass area during winter than during the summer, and finding and recording all trails present was a reasonable task. I located all animal trails that entered the roadway within the study area by driving slowly (<25km/h) along the shoulder. When a trail was observed it was identified by species, and crossing success determined. Using the GPS device/data logger, I recorded species, number of individuals, date, and the UTM coordinates of the trail's intersection with the highway.

Underpass Monitoring

In addition to monitoring the roadside for tracks, I monitored some highway structures (bridges, oversized concrete box-culverts) at both study sites for use by animals to cross under the highway. Although only one of the monitored structures was constructed specifically to act as a highway underpass for wildlife, I will refer to all these structures as "underpasses." All underpasses monitored spanned either narrow, perennial streams or intermittent drainages that only carried water during spring run-off or during storm events, and offered plenty of dry substrate for animals to use when they passed through. I created track beds from locally available sand and soil at both ends of each monitored structure. An animal was recorded as passing through a structure only when I observed a matched set of tracks at both ends.

Habitat Measurements

I made all measurements of landscape structure for landscape-scale comparisons from digital data layers, using the ArcView software package. At both study sites, the landscape I measured was the area encompassed by the ridgelines that provided visual boundaries surrounding the highway. I derived the vegetation patterns of these landscapes from the National Land Cover Data (NLCD) vegetation maps and the topographic patterns from the USGS' Digital Elevation Models (DEMs).

I collected the locations of roadway features, including bridges (representing the locations of both underpasses and drainages) and roadside barriers (cliffs, walls, guardrails, Jersey barriers) in the field. I collected these data using the GPS device's setting for recording continuous data along a line. Using a roof-mounted antenna, I drove slowly (20-25km/h) along each feature of interest and collected positions for the entire length of each feature, then converted the positions into ArcView shapefiles using Trimble's proprietary software package.

In addition to making field measurements of the roadside habitat, I also used aerial photos and existing digital data layers to make some local-scale measurements. I digitized lines representing the forest boundaries from aerial photos, then used that data layer to measure the distance of crossing location to the nearest forest edge with ArcView. Additionally, I used the digital vegetation and topographic data layers described above to compare the cover, slope and aspect classes associated with crossing locations to what was available along the entire roadside.

Analysis
I defined concentrated crossing areas as those areas along the highway where tracks were more clustered than expected by chance. I determined the expected distribution of tracks using a GIS-based Monte Carlo simulation. A complete description of the analysis is available at http://dot.state.co.us/publications/PDFFiles/wildllifecrossing.pdf. Concentrated crossing areas were correlated to features from the landscape and the roadside using Monte Carlo simulations as well as simple statistical comparisons (e.g., chi-square tests, t-tests). A complete description of the comparisons made, the tests applied, and the statistical significance of the results is also available at the above-referenced Web site.

Results: The Habitat and Roadway Features Correlated with Crossing

At-Grade Crossing
Study results indicate that mid- and large-sized mammals select road-crossing locations based on features from both the landscape scale and the local (roadside) scale. Concentrated crossing activity by these species was evident at both scales. At the landscape scale, there were long (>2km) segments of roadway that were crossed more often than other segments. This pattern occurred even where the highway was entirely surrounded by suitable habitat. These landscape-scale highway segments that were crossed most often can be thought of as *conflict zones*, because animals on the roadway risk being hit by vehicles, and they create a safety hazard for highway users. At the local scale, there were crossing hotspots, i.e., the locations within a highway segment that had the highest rates of crossing, relative to the rest of the segment. Hotspots occurred both within conflict zones and in segments with lower crossing rates, but there were more hotspots within conflict zones. Because hotspots varied in length from about 30 up to 600m in length, it is best to think of them as *crossing zones*, rather than point locations. The features correlated to crossing activity within both types of zone are discussed below.

Landscape-Scale Features Correlated with Conflict Zones
The study indicated that certain qualities of the landscape were correlated with conflict zones. They include suitable habitat, linear guideways, and slope steepness and complexity. These qualities are discussed in detail below.

Suitable Habitat. The presence of suitable habitat on both sides of the road was the baseline condition required for animals to cross the roadway on a regular basis. The better the habitat, the higher the rates of crossing. This may be the single most important factor for species that have narrow habitat preferences. Species that have broad habitat preferences (e.g., deer, elk, coyotes) have a greater opportunity to be affected by other factors.

Linear Guideways. Linear guideways can either encourage or discourage crossing, depending on their orientation to the roadway. Highway segments located in landscapes that contain guideways oriented perpendicular to the roadway had higher rates of crossing than segments located in landscapes where guideways ran parallel to the roadway. Guideways that lead animals through the landscape included drainages, ridgelines, and sharp breaks in cover type. Other potential guideways include fence lines, sharp changes in land use, and side roads that receive low rates of human use.

Slope Steepness/Complexity. Highway segments located in landscapes comprising relatively moderate slopes with low complexity (i.e., landforms are not too rugged) adjacent to the roadway had higher crossing rates. This effect was most pronounced in large areas of suitable habitat where animals had the opportunity to pick the easiest travel routes. If a species preferred rugged terrain (e.g., bighorn sheep, mountain goats) the opposite effect would be expected

Local-Scale Features Correlated with Crossing Zones
Results of the study indicate that features from the roadway itself and the habitat immediately surrounding the roadway were correlated to crossing zones. They include barriers, the distance to cover, and linear guideways and are discussed in detail below.

Barriers. Deer, elk, and coyotes avoided jumping over barriers (Jersey barrier, guardrails, walls, and steep road cuts) to enter a roadway, although they readily jumped Jersey barrier and guardrails to exit. Animals commonly entered the roadway at the ends of barriers, and rarely wandered along between the barrier and the road before crossing, if the space was narrow. However, animals sometimes walked hundreds of meters along roadsides before crossing if a barrier did not confine them. Other researchers report similar results (Carbaugh et al. 1975).

Distance to Cover. The species that commonly crossed the road in this study were most likely to approach the roadside in areas where a moderate amount of cover (i.e., suitable habitat) was present. However, they did not require cover up to the road's edge in order to approach the roadside. The amount cover within 90m of the roadside was not correlated with the location of crossing zones. Instead, crossing zones tended to be located along highway segments that had smaller average distances from the roadside to the cover's edge throughout the segment. The characteristics of crossing locations of species that prefer dense cover or no cover at all are expected to vary accordingly.

Linear Guideways. The intersection of linear guideway with a roadway often created a well defined, intensely used crossing zone. This effect is most pronounced for drainages, because drainages tend to be well defined. Ridgelines also guided animals to the roadside, but tended to create more diffuse crossing zones, as the ridgelines themselves are less discrete. In addition, when a ridgeline and a roadway intersect, extensive cutting is often required, and the slopes that are created may be steep, further diffusing the crossing activity at that location.

Below-Grade Crossing

In addition to at-grade crossing, below-grade crossing opportunities were monitored for use by all wildlife during the study. Monitored structures included large concrete box culverts (CBCs) and bridges. Dimensions of the structures varied widely, but dry footing was present in all. Roadside barriers did not force animals to use any of the monitored underpasses; at all locations, animals had the option of crossing at-grade if they preferred. Although the study design precluded quantitative evaluation of the underpass date, a qualitative assessment indicated the following:

- A wide variety of culvert and bridge designs were used frequently by a wide variety of species, including mule deer, coyotes, mountain lion, bobcat, fox, American marten, rabbits, and small mammals.
- Deer were most likely to use underpasses at least 2.5m in height and with a natural bottom.
- The surrounding habitat, as well as the design of the structure, played a role in which underpasses were used most frequently.
- The evidence suggests that mid- and large-sized mammals species may prefer to use high quality below-grade crossing opportunities instead of crossing at-grade, in locations where they have a choice.

For all species, both the characteristics of a structure itself and the surrounding habitat appeared to play a role in the level of use it received. For example, at Trout Creek Pass, underpasses varied in design, including single chamber CBCs, multi-chamber CBCs, and single span bridges with natural floors. One of the bridges was the most open (height x width/length) structure checked for tracks, and it received the most consistent levels of use, including large numbers of deer, as well as some bobcats and coyotes. However, a high openness value and a natural floor did not guarantee use. A single span bridge located in the north end of the study received lower rates of use than any of the CBCs. Habitat suitability factors limited at-grade crossing at north end of Trout Creek Pass and probably had a similar effect on underpass use.

The underpasses at the Vail Pass study area were all over-sized bridge structures and provided exceptionally high-quality, below-grade crossing opportunities for wildlife. They ranged from 3.9 to 13.5m in height and from 21.9 to 218.0 m in width. Because of these generous dimensions, the natural ground cover, including trees, grew underneath many of them. The use of these structures appeared to be most heavily influenced by the pairing of underpasses that allowed animals to cross under both the east- and the westbound lanes of traffic with ease. The two most heavily used underpasses differed greatly in dimension but were both located on the west side of the pass, where the east- and westbound alignments were side-by-side. On the east side of the pass, the alignments were separated by a wide (>200m) median, and the underpasses along the eastbound lanes were not mirrored in the westbound lanes. The underpasses on the east side of the pass were otherwise similar in construction and dimension to the west side underpasses. Therefore, the ease of crossing the entire highway, rather than an underpass' design and dimensions appeared to play the major role in regulating an underpass' rate of use.

On the east side of the pass, the uneven distribution of underpasses also appeared to influence the rate and location of at-grade crossing. Exactly twice as many at-grade crossing events were recorded in the westbound lanes, which had only a single underpass, as compared to the eastbound lanes, which had four underpasses. Further, the crossing zones in the westbound lanes were roughly aligned with underpasses in the eastbound lanes. These patterns suggest that mid- to large-sized mammals prefer to use high-quality below-grade crossing opportunities when they have a choice.

Applying the Results: A Framework for Identifying Crossing Locations for Mitigation

Identifying Conflict Zones

As described above, the relative importance of different landscape features in creating conflict zones varies from location to location. For example, deer and elk will travel through steep, rugged terrain that they might otherwise avoid if that area has the most suitable habitat, compared to adjacent areas. However, if they have a choice within the area of suitable habitat, they are likely to choose the easiest travel route. The effect of landscape composition on crossing behavior is also influenced by roadside and roadway features of existing highways. For example, the presence of extensive roadside retaining walls will prevent animals from crossing in locations where landscape structure might otherwise induce them to do so. Finally, local habitat preferences and behavior can play a significant role in how a species responds to landscape structure. For example, the habitat preferences of elk vary across their range and some populations of elk are sensitive to human disturbance, while other populations are not. Determining the effect of recreational activities on habitat suitability near a highway, and the consequent likelihood of elk approaching the roadside in that area, requires local knowledge about both the habitat preferences and the behavior of that population. Thus, understanding how landscape composition and habitat preferences affect crossing locations requires familiarity with the landscape in question and the species likely to be present.

The information discussed above indicates the following strategy for identifying areas with a high potential to be conflict zones:

- Employ professionals familiar with the landscapes and species of concern.
- Use habitat suitability as the primary indicator of a potential conflict zone.
- Consider how landscape structure may interact with habitat suitability and either increase or decrease the level of use an area receives by a particular species.
- Consider how design of the existing highway affects the expression of habitat preference at the roadside.
- Consider accident data as an auxiliary source of information.

<u>Methodology Note:</u> A variety of commercial digital data products are available to assist with landscape level analyses. These include digital elevation models (DEMs) and national land cover data (NLCD) from the U.S. Geological Survey. Other products, such as digital aerial photography and local or statewide land cover data, are also available from local agencies and commercial sources, or can be commissioned through contractors.

Identifying Crossing Zones

Crossing zones are relatively short stretches of highway that have the highest probability of being crossed by wild animals. As discussed in above, features from both the surrounding habitat and the existing highway focus crossing activity, creating a crossing zone. However, as with conflict zones, there is no single suite of variables associated with all crossing zones. Local conditions and interactions between variables mediated the influence a variable exerted at a particular study site.

An important local condition that regulates whether a feature may be useful for identifying crossing zones is the amount of variability in that feature. For example, crossing zones at four out of the six sub-areas studied were positively associated with highway segments that were closer than expected to the cover's edge. In contrast, on the west side of Vail Pass, the design and construction of the roadway resulted in a very consistent distance between the pavement and the forest edge. Consequently, there was little variability that animals could cue on, and distance to forest edge was not correlated with crossing zone locations in this sub-area.

Unique local conditions can also play a key role in determining the influence a feature has on crossing zones. For example, at five of the six study site sub-areas, the locations where drainages intersected the roadway were strongly correlated with crossing zones. However, at the north end of the Trout Creek Pass the positive association of crossing zones with the forest edge was so strong that it created a negative association with drainages. Reasons for the strength of the relationship with the forest edge include the following: the cover type along the roadside was mostly open grasslands at this site, creating a relatively narrow tongue of forest leading to the roadside; the forest edge was generally a long distance from the roadside in this sub-area, magnifying its effect where it came close to the roadway; there were few other well-defined features, such as drainages or barriers, which could also act to focus crossing activity. Those that were present were far away from the highway segment near the forest edge. None of these three conditions existed at any of the other five sub-areas.

Another example of a unique local condition overriding other variables that might otherwise act as cues to crossing is the presence of the Copper Mountain ski area at the foot of Vail Pass. In wintertime, the lure of food sources associated with the resort and easy travel on the compacted snow of the ski runs was a strong attractant for coyotes in the area. As a result, neither the locations of barriers nor the distance to the forest edge was important to them when they crossed the road, and they showed a weak negative association with drainages. Additionally, coyotes crossing I-70 near Copper Mountain used all slope classes consistent with their availability, even though animals crossing I-70 in the rest of the Vail Pass study area in winter showed a strong preference for shallow slopes.

As with landscape-scale variables and conflict zones, the relationships of the local-scale variables to crossing zones differed by location. However, they made sense to someone familiar with the resources available in the landscapes in question, as well as the habitat preferences and behavior of the species under consideration. In summary, the information discussed above suggests the following strategy for identifying locations with a high potential to be crossing zones:

- Employ professionals familiar with the landscapes and species of concern.
- Locate and map features likely to be associated with crossing zones and known to be important to the species present. Pay special attention to the location of drainages, barriers, special habitat features (e.g., food sources), and the distance to cover (for species that use cover).
- Using these maps, determine the relative abundance of each feature, and how much variation it exhibits along the roadside.
- Place greater reliance on features that are highly attractive to resident species, especially if those features are rare, and to features that are relatively variable.

<u>Methodology Note:</u> Maps of roadside and roadway features are easy to create by driving slowly along a roadside and identifying features of interest. A handheld GPS devise/data logger and a laser range-finder can be used to collect positional information about these features (Carson et al. 2001; Barnum 2003). These data can then be displayed and analyzed in the office using standard GIS software.

Animal/Vehicle Collisions and Crossing Locations

Because conflict zones are crossed more often by wildlife than surrounding highway segments, they may also have higher-than-average rates of reported animal/vehicle collisions (AVCs) than surrounding segments. However, because AVC rates are dependent on traffic volume as well as the number of animals crossing the roadway (Roof and Woodling 1996; Barnum 2000), this effect may not be apparent for low-volume roads. Therefore, although AVC data can help identify conflict zones, they cannot replace incorporating information about the surrounding habitat and landscape structure into an analysis of crossing locations, as described below. It is also important to note that AVC data are not useful for identifying crossing zones. The primary source of these data is usually State patrol accident reports, which often estimate collision location to the nearest milepost, and rarely more precisely than the nearest tenth of a mile. Therefore, AVC data provide adequate precision to identify conflict zones, which are generally over 2km in length, but not for crossing zones, which are generally 30-600m in length.

<u>Conclusions and Recommendations</u>

Some of the negative impacts of highways on wildlife can be eliminated if animals can safely and easily cross the highway. Because both landscape structure and features of the highway itself influence where animals naturally come to the roadside, a strategy that considers both types of features is needed to effectively identify crossing locations. The primary components of such a strategy are to:

- Use habitat suitability as the primary indicator of crossing activity.
- Consider how landscape structure interacts with habitat suitability to either increase or decrease the level of use an area of suitable habitat receives by a particular species.
- Consider how the design of the existing highway interacts with habitat suitability and landscape structure to influence crossing behavior.

- Synthesize this information by mapping the landscape and roadway features/conditions known to be associated with crossing or to be attractive/repellant to the species present. Use these maps to identify the most likely crossing locations.

In addition to identifying the most likely crossing zones, highway planners and designers should incorporate the following principles into their planning process to reduce highway wildlife conflicts:

- Evaluate each highway project individually. Not all crossing locations are associated with the same set of variables.
- Incorporate wildlife considerations into initial project planning and design to maximize cost and biological effectiveness,
- Because of local variation, employ professionals familiar with the landscapes and species of concern on the design team.
- Work with the entities that manage landscapes surrounding project areas to minimize animal crossing and/or maintain the landscape structure cues that bring animals to mitigated crossing locations.

Biographical Sketch: Sarah A. Barnum, M.S., Ph.D., graduated with an undergraduate degree in wildlife biology from the University of Vermont in 1988. After conducting research on nest site selection by the American Coot in the marshes of the Great Salt Lake, she received a master's degree in wildlife biology from Utah State University in 1994. She spent the next five years doing environmental impact assessments with a focus on T&E issues, first for a private consulting firm in Denver, then as an employee of the Colorado Department of Transportation. After enrolling in the University of Colorado at Denver's Urban and Regional Planning Ph.D. program in 1999, Ms. Barnum joined CDOT's Environmental Planning and Policy unit. Ms. Barnum received her Ph.D. from UCD in 2003, after successfully conducting a research project focused on wildlife/highway interactions.

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