Title
Linking Colorado's landscapes

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Habitat fragmentation is now recognized as one of the greatest threats to biodiversity and the decline of species worldwide (Ehrlich 1986; Wilcove et al. 1998), a trend expected only to increase across the Southern Rockies (SREP 2004). Transportation infrastructure in particular is a significant cause of habitat fragmentation, with negative impacts on wildlife (e.g., Harris and Gallagher 1989; Maehr 1984; Reed et al. 1996).

Animals are frequently killed on roads as they move from one part of their range to another (Forman et al. 2003) or they may avoid roads altogether (Gibeau and Heuer 1996; Jalkotzy et al. 1997), limiting their habitat area and ability to fulfill certain needs. The impacts are pervasive—Forman (2000) estimates that 20 percent of the land in the U.S. is directly influenced by public roadways. In Colorado alone there are over 85,000 miles of roads administered by the state Department of Transportation, including 953 miles of designated interstate highways (CDOT 2004). In addition, there are countless miles of county, private, and Forest Service roads that further serve to fragment the landscape.

Mitigation to protect and restore habitat connectivity is both complex and costly. A broad, comprehensive landscape analysis provides the most efficient means for focusing conservation efforts in the most critical linkages.Linking Colorado’s Landscapes was designed to focus conservation efforts on areas of the landscape that provide important connectivity functions for native wildlife. The purpose of this work was to identify and prioritize wildlife linkages across the state of Colorado to promote safe passage for wildlife.

Linking Colorado’s Landscapes is a two-phase project led by the Southern Rockies Ecosystem Project (SREP) in collaboration with the Federal Highway Administration (FHWA), the Colorado Department of Transportation (CDOT), Colorado State University (CSU), and the Colorado Chapter of the Nature Conservancy (TNC), the Colorado Division of Wildlife (CDOW), the U.S. Fish and Wildlife Service, and the U.S. Forest Service.

Phase I

The primary objective of Phase I of Linking Colorado’s Landscapes was to identify broad linkage zones that facilitate movement for Colorado’s diverse array of wildlife species and to prioritize amongst them for further study. Building upon the methodology developed by the South Coast Missing Linkages Project (SCML) in California (Penrod et al. 2001), we developed a science-based approach integrating local and regional expertise (via a series of workshops) and computer modeling. Recognizing that connectivity is a function of individual species’ perceptions of suitable habitat and barriers in the landscape, a focal species approach was employed as the basis for linkage identification in both the workshops and the modeling. By integrating both qualitative and quantitative processes, we were able to produce a comprehensive biological assessment of the most critical wildlife linkages in the state.

In total, 176 linkages were identified via expert workshops, with additional linkages modeled for Canada lynx, gray wolf, and pronghorn. In prioritizing linkages for further analysis in Phase II, we also considered: the presence of local partners; stretches of roadway with frequent animal-vehicle collisions; planned transportation projects projected by CDOT through 2030; and the distribution of linkages across the state and their complementary contributions to landscape connectivity. Twenty-three linkages were selected and were grouped into 12 high-priority linkage complexes based on similarities in species usage patterns and geography.

Phase II of Linking Colorado’s Landscapes provides an in-depth assessment of each high-priority linkage. Based on this compilation of site-specific information, we will next provide recommendations for possible crossing structures, management alternatives, and other measures to improve permeability in these linkage areas. Phase II analyses include: an assessment of additional species that utilize the linkage; identification of specific crossings; an assessment of land ownership and management within the linkage; and an evaluation of existing natural or man-made features that facilitate or impair movement. The resulting linkage assessment packages and recommendations will be distributed in spring 2006 and will serve as a guide for the Colorado Department of Transportation (CDOT) and other local and regional transportation planners, community leaders, and conservationists working to develop more wildlife-friendly landscapes and transportation networks.
existing research on wildlife movement, local knowledge from agencies and other informed individuals, and spatial modeling of predicted movement paths for several different wildlife species. By integrating both qualitative and quantitative processes, we intended to produce a more accurate and complete picture of the most critical wildlife linkages in the state, highlighting clear priorities for further in-depth analysis in Phase II.

Recognizing that connectivity is a function of individual species’ perceptions of barriers in the landscape, we employed focal species as the basis for linkage identification. We reviewed dispersal, home range, and habitat requirements of numerous native species to select a comprehensive set of 28 focal species that captured the range of connectivity needs. Maintaining our focus on a suite of focal species allowed us to concentrate our efforts while ensuring that the linkages are appropriate for the species for which they are intended. These focal species guided linkage identification in both the workshop and modeling tracks.

The goal of the workshop track in the two-pronged approach was to compile existing information and knowledge about habitat and linkages for the selected focal species via a series of regional workshops. This track is analogous to the first three steps outlined by Beier et al. (2005) for the SCML project (building a coalition; selecting core habitat patches and prioritizing linkages; and selecting focal species), although we pursued a somewhat modified approach.

Rather than one statewide expert workshop, we elected to hold five daylong workshops at locations across the state (Alamosa, Fort Collins, Meeker, Montrose and Pueblo). The intent was to encourage greater local participation and allow more people the opportunity to contribute to the process. In addition, we used these occasions to host additional information sessions to which local officials, planners and interested community members were invited. Each of the workshops followed the same format, focusing on the primary goal of identifying linkage areas for the focal species based on the expertise of the workshop participants, and compiling information about the functionality of each linkage and its role in the landscape to prioritize the linkages. The information from these workshops was compiled and scored, based on a prioritization scheme that evaluated conservation significance, opportunity and threat.

The second track (or ‘modeling track’) was incorporated as a parallel process designed to complement the expert workshop track outlined in the scope of work. These analyses integrated layers of spatial data about the physical characteristics of the landscape (e.g., topography, vegetation, roads, development etc.) with information about wild-life-habitat preferences and movement patterns to model areas of the landscape that are key to wildlife movement. Through this modeling, habitat patches and the multiple linkages between them were identified for gray wolf, Canada lynx, and pronghorn.

Finally, we overlaid the highest-priority linkages identified by each track for large carnivores and ungulates. This comparison provided the foundation for determining the location of the most critical wildlife linkages that are the focus of the Phase II linkage assessments. In selecting high-priority linkages, the Executive Committee considered the priority ranks from the two biological prioritization processes as well as several other factors: the presence of local partners that are prepared to engage in these efforts and other feasibility considerations; stretches of roadway with frequent animal-vehicle collisions; the location of planned transportation projects projected by CDOT through 2030; the complementary contributions that each linkage offers to network connectivity across the greater landscape; and the distribution of linkages across the state. All of these factors guided the selection of the final suite of 12 high-priority linkages.

**Phase II**

The primary objective of Phase II is to provide in-depth analyses of each high-priority linkage, analogous to steps 4-7 as described by Beier et al (2001), i.e. developing linkage design, providing management recommendations, and creating implementation and monitoring plans. Linkage assessments identify additional species that utilize the linkage; identify specific crossing locations; assess land ownership and management within the linkage; and evaluate existing features that facilitate or impair movement. Based on this compilation of site-specific information, we can develop recommendations for possible crossing structures, management alternatives, and other measures to improve permeability in these linkage areas. The resulting linkage-assessment packages and recommendations will serve as a guide for CDOT and other local and regional transportation planners, community leaders, and conservationists working to develop more wildlife-friendly landscapes and transportation networks.

Within each site, we characterize the roadway on its permeability (or lack thereof) relative to the suite of focal wildlife species identified for each linkage in Phase I. These linkage assessments are not designed to provide long-term analyses of wildlife movements through the linkage area. Instead, they are detailed snapshots that can act to define future mitigation and monitoring priorities.

Site visits were conducted between June and August 2005. These roadway assessments were conducted along nearly 200 miles of highway in the identified high-priority linkage areas. Highway interference zones were identified where each linkage intersected with a highway or interstate. For each linkage, the highway interference zone was defined by easily-identifiable physical locations such that landscape-level wildlife movements across the roadways were captured. We then characterized potential roadway barriers through the following variables: number of lanes, shoulder barriers, median barriers, and other features. We also identified unique situations that could potentially serve as a wildlife crossing locale. These situations were categorized into three types: 1) structures, 2) fill slopes, and 3) at-grade...
crossing areas. Finally, we took note of all road-stream crossings and recorded the condition of the inlet and outlet, the substrate type, and vegetation cover.

Detailed information was collected for each situation type that was encountered. Structures were defined as any bridge or culvert that could provide a safe passage for wildlife species underneath the roadway. We also recorded locations of structures along each roadway designed to allow animals to escape the highway right-of-way such as one-way deer gates and ramps. Fill slopes were defined as any location where the roadway was elevated above the surrounding land. These locations typically occurred where the roadway bisected drainages, but were also common along topographic depressions lacking a hydrological component. While it was not uncommon to have some sort of drainage structure under the roadway to allow for water flow, these structures (typically corrugated pipes) are almost always under 1 m in diameter, thus forcing wildlife up the fill slope to attempt a surface crossing of the roadway. All other potential wildlife-crossing locations were designated as at-grade crossings. Unlike structure and fill slope locations, at-grade locations are not specific points along the roadway. Rather, they incorporate longer stretches of the roadway (typically 0.5–2 miles in length). These locations typically include stretches of roads that run parallel to drainages, places where a particular vegetation type comes up to the shoulder of the roadway, or choke points. These areas are also typically stretches of the road where there have been a high level of animal-vehicle collisions. For each situation, we measured a suite of variables unique to the situation type. We also recorded any incidental sign of species activity at each situation location. This included species use of structures, tracks and scat, game trails, and roadkill.

The information collected during these site visits provides the basis for understanding the current level of permeability through these linkages. Additional information about the landscape context is also essential to developing a comprehensive understanding of the linkage situation and opportunities for mitigation at specific crossing points within the linkage. For each linkage, the following information was compiled in the linkage assessment reports: vegetation, topography and landscape context; habitat and dispersal needs for each of the focal species; animal-vehicle collisions per half-mile (from Colorado State Patrol records); land ownership and management, zoning and lot sizes adjacent to the roadway; current and projected traffic volumes; speed limits; and general demographics of the nearby communities.

Following the site evaluation and information compilation, we developed preliminary recommendations to maintain and/or enhance wildlife movement across the roadway. Recommendations were based on the functionality and feasibility of implementation and were grouped into zones, highlighting stretches of highway within that larger linkage that provide clear opportunities and offer the greatest benefit to improved permeability. Recommendations were categorized into several categories: structural, fill slope, vegetation, barriers, aquatic, traffic awareness, and monitoring.

The next step in this process involves review of the linkage assessments by agency biologists and the development of specific recommendations for the key highway segments highlighted within each linkage. To facilitate these discussions, we will host a one-day workshop with a select group of CDOW biologists and engineers for the state and federal transportation agencies. The workshop has two goals: 1) review the key findings of the linkage assessments to further define the focal highway segments, and 2) for commonly found situations, facilitate collaboration between the biologists and engineers to discuss potential solutions that are both feasible from a design standpoint and ecological functional so as to adequately provide for species-movement needs.

The workshop will then be followed up with a series of site visits with regional engineers and biologists from CDOT, FHWA, and CDOW to evaluate the site-specific considerations at each crossing location. These recommendations will complete the final linkage reports (Spring 2006).

**Implementation**

Linking Colorado’s Landscapes does not end with the completion of Phase II. This is an on-going project, in which our focus narrows at every step until permeability is restored at the most critical crossing points. The Phase II linkage assessments provide important guidelines for achieving this goal. Based on the preliminary recommendations and other information compiled in the linkage assessments thus far, it is clear that there are numerous mitigation opportunities at existing structure locations. Such situations range from minor restoration and management to large-scale reconstruction of structure and include actions such as, the removal of sediment in a culvert; revegetation at the entrances to a structure; fence maintenance; excavation to enlarge clearance area through a structure; or enlarging existing structures to facilitate movement for a greater variety of wildlife species.

However, some situations will require the construction of new structures to overcome the fragmentation presented by highways. One such project is the proposed vegetated wildlife overpass at west Vail Pass in Eagle County, Colorado (Fig. 1). This pilot project would provide a safe passage for wildlife and help to reconnect populations for a variety of native wildlife including elk, moose, deer, mountain lion, black bear, and the recently reintroduced Canada lynx. In addition, the overpass would connect via eight-foot high fencing to existing span bridges, creating multiple crossing opportunities at more frequent intervals. This pilot wildlife overpass will have tremendous visibility on this heavily traveled route, giving the public an opportunity to experience its safety, visual appeal, and utility.
An overpass is proposed as the structure of choice in this area because of the type of animals that will be using the structure, as well as the cost effectiveness in engineering an overpass. Constructing an underpass or span bridge would be prohibitively expensive at this location and would cause unacceptable traffic delays. The proposed overpass, on the other hand, would complement the already existing wildlife underpasses in this area, ensuring that wildlife have multiple options for crossing I-70.

Four independent studies have identified this location as a high priority for restoring connectivity through the spine of the Rockies. Additional site-specific monitoring will determine the exact location of the structure.

**Education and Outreach**

Animal vehicle collisions present a major safety hazard for both people and wildlife. Improving driver awareness is an essential component of any comprehensive efforts to reduce these types of collisions and improve landscape permeability. Because crossing structures are not feasible in many locations and wildlife will continue to be at risk of being hit by a vehicle, driver education and awareness is a major tool in preventing collisions with animals on all types of roads and in all locations.

To address these safety issues, SREP spearheaded Colorado Wildlife on the Move, an on-going driver education and outreach campaign which urges drivers to watch for wildlife on Colorado highways, particularly during migration seasons. A broad array of partners (including state and federal transportation agencies, as well as rental car companies, insurance companies and a non-profit insurance information organization) have come together in support of this campaign, highlighting the diverse community that is struck by the issue of animal-vehicle collisions. By capitalizing on the widespread concern about these issues, we can catalyze support for other restoration and protection measures that will help not only to create safer roadways, but also to improve the permeability of the landscape for our native wildlife.

In an effort to educate motorists about how to avoid dangerous and costly collisions, the campaign prepared a safety-awareness poster and driver-safety tip sheet that includes suggestions for how to avoid hitting animals. These posters and tip sheets have been distributed to rental-car offices, tourist-information centers, highway rest stops, motor-vehicle offices, Forest Service visitor centers and State Patrol offices.

**Biographical Sketch:** Julia Kintsch is the Program Director for the Southern Rockies Ecosystem Project and has been leading the Linking Colorado’s Landscapes project for two years. Julia holds bachelor’s degrees in environmental science and German from the University of Colorado at Boulder and a master’s degree in landscape ecology from Duke University. Prior to joining SREP, Julia worked as a conservation planner for the Michigan Chapter of The Nature Conservancy and was a Peace Corps volunteer in Senegal, West Africa. The Southern Rockies Ecosystem Project is a nonprofit conservation-science organization working to protect, restore, and connect ecosystems in the Southern Rockies of Colorado, Wyoming, and New Mexico.

**References**


