Planning-Support for Mitigation of Wildlife-Vehicle Collisions and Highway Impacts on Migration Routes in Wyoming

WYDOT Sponsor
Thomas Hart
Wildlife Specialist
5300 Bishop Blvd.
Cheyenne, WY 82009
Phone: 307-777-4495

Co-Principal Investigators
Corinna Riginos, Research Ecologist
Morgan Graham, GIS Manager
Teton Research Institute, Teton Science Schools
700 Coyote Canyon Road
Jackson, WY 83001

Holly Copeland, Spatial Ecologist
The Nature Conservancy
258 Main Street
Lander, WY 82520

Partners
Wyoming Migration Initiative:
Matt Kauffman, Unit Director, Wyoming Cooperative Fish and Wildlife Research Unit
Bill Rudd, Project Manager, WMI
Kevin Monteith, Research Faculty, University of Wyoming
Hall Sawyer, Research Ecologist, WEST, Inc.

Submitted to
Wyoming Department of Transportation
Programming Research Unit
5300 Bishop Blvd.
Cheyenne, WY 82009

Date
September 22, 2014

Table of Contents

Table of Figures

Problem Statement

Collisions between vehicles and large wild mammals pose a serious threat both to highway safety and to wildlife populations. Across the United States, an estimated 1-2 million wildlife-vehicle collisions (WVC) occur every year (1). Predicting and mitigating the occurrence of wildlife-vehicle collisions are high priorities both for the Federal Highway Administration (FHWA) and for State Departments of Transportation (1). In Wyoming, 2,487 WVCs were reported in 2012 and 2,096 in 2013, accounting for 18 and 14 percent of all reported collisions, respectively (2,3). In both years, deer-vehicle collisions (mostly mule deer) made up greater than 85 percent of all wildlife-vehicle collisions, with pronghorn and elk collisions making up an additional 5-10% each of reported collisions. However, our analysis of Wyoming Department of Transportation (WYDOT) collision and carcass data (the latter of which is not included in collision statistics) revealed that an average of more than 5,000 deer-vehicle collisions have occurred annually over the last three years. This number further underestimates actual collisions, as many animals leave the road right-of-way before dying.

These collisions pose a safety hazard and are costly; they often result in significant damage to vehicles, injury to their occupants, and are almost always lethal to the animal. Collisions may occur when a vehicle strikes an animal or when a vehicle swerves to avoid an animal and instead drives off the road or into the oncoming lane. In some cases, wildlife-vehicle collisions are fatal to human occupants of the vehicle. WYDOT's estimated costs per reported collision are $11,600 in injury and property damage costs and $4,000 in the unclaimed restitution value of each mule deer that is killed. As mentioned above, fewer than half of deer-vehicle collisions are reported; those that are not reported likely result in lesser damage to vehicles but almost always kill the animal. Taken together, deer-vehicle collisions total approximately $24-29 million per year in Wyoming in injury and damage costs and an additional $20-23 million per year in wildlife costs.

Highways and vehicle collisions also have a significant negative impact on wildlife populations – reducing their numbers and impeding their movements through their seasonal ranges and along their migratory corridors (4,5). Where highways create a partial or complete barrier to wildlife movements, they threaten populations by impairing their ability to access the resources they need (5). In Wyoming, mule deer home ranges and migration routes crisscross much of the state, intersecting with many of the major highways (Figure 1). Mule deer populations in the state are in decline, as they are across most of the West (6), and conserving their populations is an extremely high priority for the Wyoming Game and Fish Department (WGFD) (7). Mule deer are an important economic and cultural player in Wyoming. In response to recent declines in mule deer populations, WGFD has placed particular emphasis on mule deer conservation through the Mule Deer Initiative (7) and Mule Deer Working Group. [NB: Although wildlife-vehicle collisions are locally problematic for pronghorn, elk, and moose, we will focus our work on mule deer since they are widespread across the state, the most common cause of wildlife-vehicle collisions, and a species of conservation concern].

The Wyoming Department of Transportation continues to work extensively to mitigate wildlife-vehicle collisions. Wildlife crossing structures have been installed in a number of locations, and priority locations for more crossing structures have been designated using expert knowledge from WGFD. WYDOT continues to seek funds to implement these priorities. New data and understanding of mule deer movement patterns, however, can be used to improve our knowledge of where WVC mitigations can best be located and thus improve the cost-effectiveness of these mitigations. In particular, Teton Research Institute biologists have worked extensively with WYDOT Highway Safety and Maintenance staff to create a comprehensive roadkill database that was not previously available for geo-spatial analysis. There is much information from this database that can be leveraged to:

a) Improve our understanding of the spatial patterns and causes of deer-vehicle collisions;
b) Update and verify assessments of where existing and planned future collision mitigation measures should be located; and
c) Predict where future increases in collisions (and decreases in crossing ability) are most likely to occur in order to plan future actions and funds necessary to mitigate these effects.

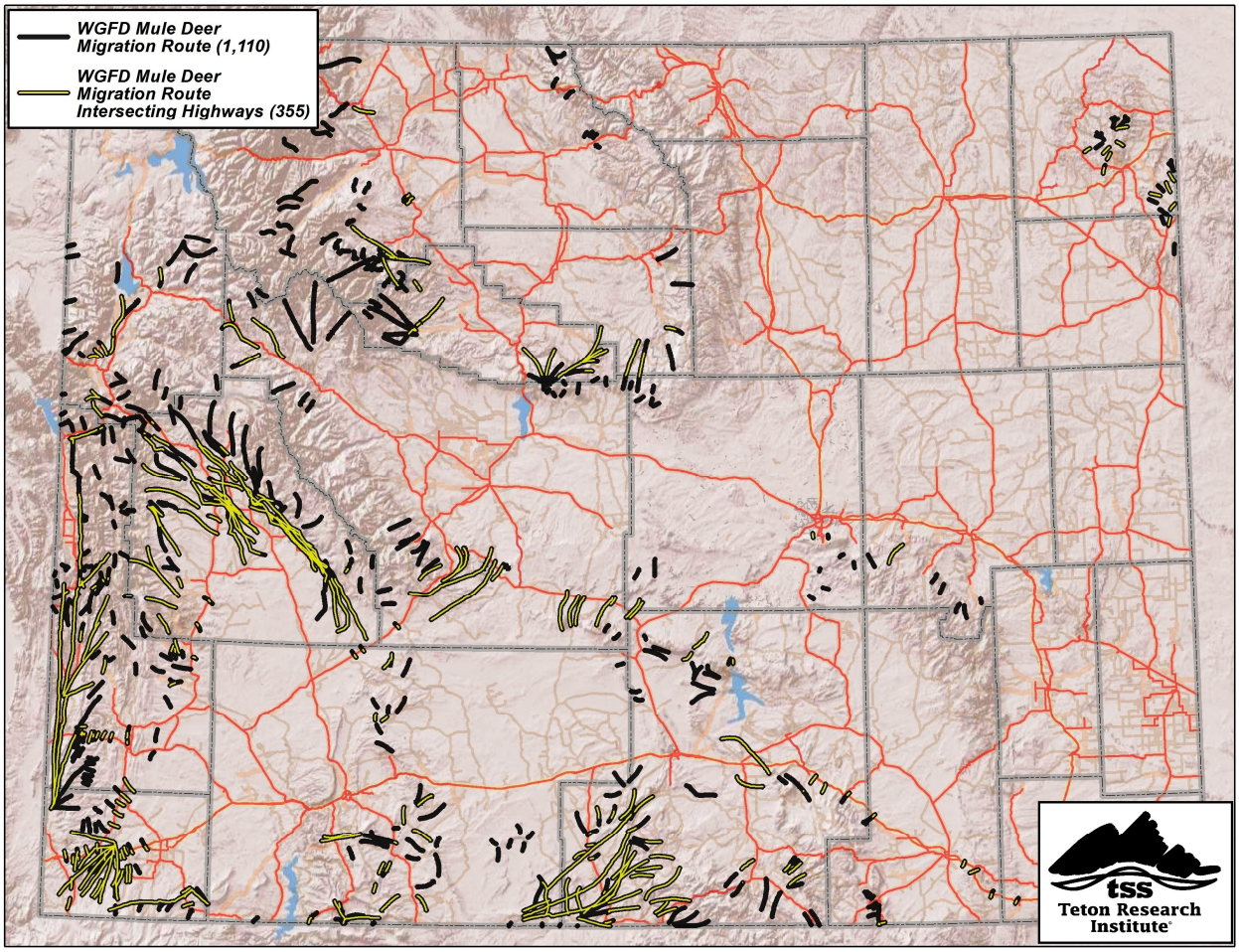

Figure 1. Mule deer migration routes in Wyoming, based on expert knowledge

Problem Background

Teton Research Institute has been working to analyze the spatial patterns of deer-vehicle collisions in Wyoming under WYDOT Project Number RS05212. WYDOT has maintained wildlife-vehicle collision and carcass records since 1987 in two separate tabular databases. We have removed duplication within and between databases, cleaned up ambiguous location references, and converted the data into geospatial records that can be analyzed in a GIS framework. We are currently assembling geospatial data on habitat and road variables to facilitate analysis of the locations of deer-vehicle collisions across the state. These basic analyses are supported under the current project.

We propose to build upon and leverage this current work to inform optimal placement of current and future vehicle collision mitigation measures. WYDOT's mitigation measures range from relatively low-cost and frequently-used measures, such as roadside signage, to high-cost, infrequently-used (but highly effective (8-10)) measures, such as highway crossing structures. Placement of such mitigation measures is intended to optimize cost-effectiveness. Although much effort has already been put into assessing WVC mitigation needs, our work will add value to prior efforts through including several new analyses.

Current Conditions

Currently, WYDOT maintains over 450 wildlife crossing signs across the state. These signs are intended to alert drivers in areas where wildlife frequently cross roads. Such "driver awareness" mitigation methods are relatively inexpensive but, unfortunately, have been found to have low effectiveness at reducing wildlife-vehicle collisions in other parts of the country (9,10). One potential reason for this is the "dilution" effect – where signs are used too frequently and/or in locations where wildlife rarely cross the highway, leading drivers to ignore the warning signs. The effectiveness and placement of WYDOT's crossing signs have not been evaluated in any comprehensive way. We will conduct this evaluation using spatially explicit data on both crossing sign location and wildlife-vehicle collision locations. Specifically, we will answer the following questions:

1. Where are signs located relative to high collision areas?
2. Are there places where signs are present but not needed?
3. Are there places not currently signed where signs are warranted?

Spatial data on wildlife-vehicle collision locations can also be overlapped with data on animal movement or migration routes to determine where roads are threatening habitat connectivity and inform suitable mitigation measures. Mule deer, for example, cross roadways in very different ways depending on whether they are migrating (long distance spring and fall movements, necessitating one road crossing per season) or using both sides of the road as part of their winter or year-round range (crossing roads frequently)(11). For migrating animals, collision mitigation might include very fine-scale and specific measures such as temporary signage, making roadside fencing more wildlife-friendly to encourage animals to cross in higher driver visibility locations, vegetation modification, or installing deer-proof fencing along with highway under- or over-passes. Collision mitigation for wintering or resident animals is more challenging and may require a multi-faceted approach due to high crossing frequency and dispersed crossing locations (11).

Previous analyses, such as those performed by WYDOT and WGFD in preparation for WYDOT's TIGER II proposal for federal highway funding, have relied largely on expert knowledge of deer and pronghorn migration corridors (e.g. Figure 1) to prioritize locations for crossing structures. However, over the last decade, much has been learned about the migration corridors of Wyoming's mule deer herds. Most of this work has been conducted using GPS collars and has been led by biologists at WEST, Inc. (Hall Sawyer) and the Wyoming Cooperative Fish and Wildlife Research Unit (Matt Kauffman and Kevin Monteith). These and other data sets are currently being assembled under the Wyoming Migration Initiative (WMI; www.migrationinitiative.org). This migration database has largely been funded by WYDOT through a grant to Bill Rudd (WMI Project Coordinator) and Matt Kauffman. Further, WMI researchers have been partnering with Holly Copeland of The Nature Conservancy to develop the means to map expected migration routes for herds in western WY for which migration route data are limited or do not currently exist. They will also incorporate mule deer population estimates so that planners can better understand the level of use of different migration routes. These two projects can inform – and be informed by – analysis of the spatial patterns of wildlife-vehicle collisions. We propose to:

1. Identify, where possible, areas where high collision rates are caused by migrating versus wintering or resident deer;
2. Identify areas where collision rates are high because of a road intersecting a migration route and suggest possible mitigation measures;
3. Identify areas where collision rates are low, despite a road intersecting a migration route, and potentially learn whether conditions are facilitating safe deer crossings – thereby informing low-cost mitigation measures for other locations; and
4. Assess whether vehicle collision data can be used to validate and further the development of predictive migration mapping.

Predictive Modeling for Rising Traffic Volume

Traffic volume has consistently been a strong predictor of wildlife-vehicle collisions across multiple studies in other locations (e.g. 12-14, reviewed in 15). Our work from southern Teton County (under a previously-funded study for WYDOT) also indicates that mule deer habitat variables and traffic volume explain most of the spatial distribution of mule deer-vehicle collisions in this area. We anticipate similar findings across all of Wyoming.

Although traffic volumes in Wyoming are relatively low, they have more than tripled over the last two decades in some parts of the state (16). Given past trends, traffic volume can be expected to continue to increase, particularly in areas where development is occurring relatively rapidly (e.g. due to energy development). In places where traffic volumes are expected to increase and in which roads intersect with mule deer habitat and/or migration routes, we thus expect to see an increase in deer-vehicle collision rates and decrease in landscape connectivity for mule deer over the coming years. Our current understanding of spatial patterns of wildlife-vehicle collisions may not be sufficient to predict where future WVC rates will be high unless we consider the effects of (often locally) elevated traffic volumes.

Patterns of wildlife-vehicle collisions can be used to predict vehicle collisions in new spatial locations or under new conditions, such as changes in traffic volume. Under our current grant (WYDOT Project Number RS05212) we are assembling geospatial data on habitat and road variables to parameterize a statewide model of mule deer-vehicle collisions. Habitat variables include land cover or vegetation types and road characteristics include factors such as speed limit, traffic volume, and divided versus undivided highway. This statistical approach has been used by others successfully (reviewed in 15). Once a robust model has been developed, it can be applied to predict vehicle collision patterns in different locations and according to a range of WYDOT generated traffic forecasts.

In order to help WYDOT to plan and budget for future conditions and wildlife-vehicle collision management, we propose to further develop and test our predictive model. This will enable WYDOT engineers to answer questions such as:

1. Given expected traffic volume increases, where are vehicle collisions most likely to increase?; and
2. Where might future mitigation measures be necessary and cost-effective?

Study Objectives

Our overarching objective is to provide transportation planners, conservation planners, and wildlife managers with statewide information that will help them to evaluate the placement of current and future wildlife-vehicle mitigation measures. Doing so will increase the cost-effectiveness of mitigation measures and will be vital to reducing the rising problem of wildlife-vehicle collisions while maintaining and enhancing landscape connectivity for wildlife in Wyoming.

Specifically, we propose to:

- Provide decision-support for planners and managers by:
  - Evaluating the placement of existing wildlife crossing signage
  - Differentiating between migration crossings and (winter/summer) home range crossings (and implications for mitigation options)
  - Assessing where mule deer migration routes and landscape connectivity are most threatened by highways, in light of new data on migration routes, and where mitigation measures may be best situated
  - Identifying areas where additional migration information may be warranted
  - Predicting where future increases in collision rates are likely to pose the greatest threats to highway safety and wildlife populations
- Provide planners with predictions of future deer-vehicle mitigation needs, enabling them to better prioritize and forecast budget needs
- Provide spatially-explicit baseline analysis of past and current deer-vehicle collision patterns against which to compare future trends and success of recent mitigation efforts (e.g. crossing structures recently installed at several locations)

Goals

1. Cost Benefit: Reduce costs and improve performance for Highway Safety and Planning programs by informing WVC mitigation planning
2. Improving Safety: Reduce transportation related injuries by reducing WVC

Study Benefits

This project aims to provide transportation and wildlife managers in Wyoming with updated information, using new information about mule deer migrations and new modeling of WVC patterns, to improve the cost-effectiveness of current WVC mitigation measures, to improve mitigation of the effects of roadways on mule deer movement pathways, and to proactively plan future actions necessary to mitigate rising WVC rates in areas where traffic volume is rising.

Output and Outcome Measures

Output measures support WYDOT's Strategic Goals (17) of:

1. Keeping people safe on the state transportation system, and
2. Exercising good stewardship of our resources

Outcome measures include:

1. Cost Benefit: This project will provide valuable information to inform analyses of the environmental and monetary costs and benefits of various wildlife-vehicle collision mitigation options; by doing so, this project will provide significant WVC mitigation performance improvements and cost savings for WYDOT.
2. This project will provide valuable information to inform highway safety planning towards reducing WVC. In doing so, this project will improve safety by avoiding harm, injury, loss, and risk to members of the public using Wyoming's highways.

Applicable Questions

1. Are there any potential barriers to implementation? *None*
2. Are there strategies to mitigate each potential barrier? *N/A*
3. What is the expected time frame for implementation? *One year, beginning in January 2015 (see below)*
4. Does the project involve action on Federal lands or other conditions that will require NEPA documentation? *No*
5. What are the major uncontrollable factors and/or unknowns in the project? *The only unknown is the degree to which migration route predictions can be made, since this is a novel technique. However, Copeland and colleagues are making significant progress on predicting migration routes and expect to finish this work (a pre-requisite for Phase 2 of our proposed work) by mid-2015.*
6. Are there contingencies to address these uncontrollable factors and unknowns in the proposal and are there additional costs if there are delays due to uncontrollable variables? *There are no additional costs associated with any challenges or delays in developing migration route models.*
7. Should the project be segmented into phases with go/no-go decision points based on known unknowns? *We do not anticipate this need. However if only a portion of the study can be funded, it could be segmented based on the below phases (see "Statement of Work").*
8. If the project involves evolution of one or more technologies, is a technology roadmap provided showing how these technologies fit together? *N/A*
9. Will a Buy American Waiver be necessary? *N/A*

Statement of Work

Work Plan/Scope

This work will leverage and build upon several existing projects. We will assemble data from three core projects: (1) our currently WYDOT-funded project to model predictors of current wildlife-vehicle collision patterns in Wyoming (led by Corinna Riginos and Morgan Graham, Teton Research Institute); (2) the Wyoming Migration Initiative (partially funded by WYDOT and led by Matt Kauffman, UW/Coop Unit), under which existing GPS-derived data about large mammal migrations in Wyoming are being assembled and mapped; and (3) a project connected with the Wyoming Migration Initiative, in which WMI researchers are developing predictive mule deer migration maps. Our work will extend across four phases.

Phase 1: Assess efficacy of placement of wildlife crossing signage

WYDOT maintains data on the location of over 450 wildlife crossing signs. We will analyze the placement of these signs relative to WVC frequency per mile over the past 10 years. Each one-mile segment of highway (the spatial resolution of most WVC data) will be categorized as "low", "medium" or "high" occurrence of WVC. By overlaying wildlife sign locations on WVC categorizations, we will be able to identify road segments where (a) WVC rates are high and signs are present, (b) WVC rates are high and signs are not present, and (c) WVC rates are low and signs are present. Based on this analysis, we will be able to point to specific signs that are not necessary or specific areas where new signs are warranted.

Phase 2: Identify vulnerable migration and movement routes

We will overlay WVC spatial data with known and model-derived mule deer migration routes. Known migration routes, derived from GPS collar studies and Brownian bridge

movement modeling, have already been assembled under the Wyoming Migration Initiative. These datasets are mostly concentrated in western Wyoming, but the predictive migration model may allow predictions for herd units in other parts of the state where no migration data exists. By overlaying all known and modeled migration routes with WVC data, we will be able to assess which migration routes are most threatened by roadways. Based on this analysis, we will be able to recommend locations suitable for migration-oriented WVC mitigation efforts. This will also suggest where more simple measures, such as making roadside fences more wildlife-friendly or removing roadside vegetation, will facilitate wildlife movements across highways.

Phase 3: Refine and test state-wide vehicle-collision model

Under current funding, we are developing and parameterizing a model of the predictors of vehicle collisions in Wyoming for mule deer. Specifically, we are relating a suite of candidate variables to deer-vehicle collision data from the past three years (2010-2013) and using a model selection approach using information theoretic criteria to select the best model.

Under this proposed grant, we will further test this model using a time-series of past (pre-2010) traffic volume and wildlife collision data from several stretches of highway that have seen rapid increases in traffic volume (e.g. WY-191 in Sublette County, using WVC data from before over- and under-passes were installed). WYDOT maintains detailed traffic volume data for 2,142 individual highway segments (16). By comparing model-predicted collision rates with real (past) collision rates, we will test the models' ability to accurately predict collision rates in response to varying future traffic volumes. We will work closely with WYDOT staff, including Sherm Wiseman, to ensure we are incorporating the most current and accurate Average Annual Daily Traffic counts.

Phase 4: Generate predictions under future traffic scenarios

Once parameterized and tested, we will use our model of wildlife-vehicle collisions to generate future WVC predictions for key areas of the state. We will work with WYDOT engineers to identify areas of greatest concern and/or areas where traffic volume is expected to increase most. We will work collaboratively to identify three scenarios (low, medium, high traffic) of predicted future traffic volume for each area. We will then use our predictive model to generate spatially-explicit predictions of future WVC rates under each scenario. Further, we will overlay these predicted WVC surfaces with migration route data (see above) to identify which migration routes are under greatest threat from future traffic volume increases. These predictions will provide valuable information for WYDOT to plan future WVC mitigation needs and will provide an early warning of places where WVC rates are likely to pose an increased threat to human safety and wildlife populations.

Work Schedule

All work will take place between January and December 2015.

	J	F	M	A	M	J	J	A	S	O	N	D
Signage analysis												
Migration and WVC analysis												
Predictive modeling: testing												
Predictive modeling: scenario development												
Report writing												
Outreach and tech transfer												

Cost Estimate

	WYDOT REQUEST	Match (TSS)	Match (TNC)	Comments
DIRECT COSTS				
Personnel				
PI, Corinna Riginos	$ 7,713.60	$ 2,571.20		6 weeks (WYDOT); 2 weeks (TSS match)
TNC Ecologist, Holly Copeland	$ 7,000.00		$2,747.00	3 weeks (WYDOT); 1 week (TNC match)
Benefits	$ 1,744.80	$ 581.60		Full-time ~22.5%
Personnel Total	$16,458.40	$ 3,152.80	$2,747.00	
Travel	$ -	$ -		
Mileage		$ 1,764.00		Partner Trips: Lander (2), Laramie (1), Cheyenne (2)
Travel Total	$ -	$ 1,764.00	$ -	
Data Analysis, Management and Reporting				
Technical Support (GIS analysis)	$ 4,216.80	$ 4,216.80		3 weeks, includes benefits (WYDOT); 3 weeks (TSS match)
Metadata, Data Management, Tech Transfer	$ 4,216.80	$ 4,216.80		3 weeks, includes benefits (WYDOT); 3 weeks (TSS match)
Printing/Publications		$ 250.00		Publications, reports, maps
Analysis, Mgmt, Reporting Total	$ 8,433.60	$ 8,683.60	$ -	
Outreach, Education & Dissemination				
Presentations/Meetings	$ 500.00	$ 500.00		Mileage, room rental fees, food/lodging, etc.
Education Material Development/Implementation	$ -	$ 2,144.80		2 weeks, includes benefits, Research/Stewardship Coordinator
Outreach Total	$ 500.00	$ 2,644.80	$ -	
Subtotal before Overhead:	$25,392.00	$16,245.20	$2,747.00	
INDIRECT COSTS				
Overhead	$ 3,808.80	$ 1,269.60		15% (WYDOT); 5% (TSS match)
TOTAL REQUEST	$29,200.80	$17,514.80	$2,747.00	
TOTAL MATCH	$20,261.80			

Change Order Information and Agreements

We understand that any changes in the duration of the contract, in the work plan / scope, work schedule, or costs must be in writing and approved by the RAC.

Deliverables

1. Geospatial data:
    a. Quality-controlled and quality-assessed WVC geodatabase
    b. Federal Geographic Data Committee-compliant metadata detailing model parameters and quality control procedures
2. Decision-support maps: digital and print map products showing:
    a. Locations of wildlife crossing signs relative to areas of low, medium, and high WVC rate; specific identification of signed areas with low WVC rates and unsigned areas with high WVC rates
    b. Locations of deer migration routes relative to areas of high collision rate; specific identification high collision areas associated with migration routes and vulnerable migration routes
    c. Verification of the areas that have already been identified as priorities for crossing structures
    d. Updated and enhanced information necessary to set priorities for crossing structures and other, less costly, mitigation measures
    e. Locations for focused examination of traffic volume scenarios
    f. Predicted WVC rates under different traffic volume scenarios for each area or transportation corridor
3. Quarterly and final reports to WYDOT detailing specific methodologies and findings
4. Presentations of major findings and decision-support maps to WYDOT engineers
5. Summary data and maps that can be used by Highway Safety Program for internal and external education materials.
6. Presentations to interested members of the general public
7. Curriculum material and integration into Teton Science Schools educational programming, which reaches >13,000 participants annually
8. Scientific journal articles and conference presentations

We will share all final GIS products with state agencies including WYDOT, WGFD, and WYGISC for inclusion in online decision support tools such as the Wyoming Interagency Spatial Database & Online Management System (WISDOM). By working with our WMI partners, we will facilitate the inclusion of statewide layers of mortality risk and vehicle collisions as base layers in the WMI Migration Database and Viewer (http://migrationinitiative.org/content/migration-viewer). All deliverables except scientific journal articles will be completed by December 2015.

Performance Measures

a. (Cost Benefit) – Improve wildlife-vehicle collision mitigation performance to as much as 80% (the effectiveness of well-sited WVC mitigations such as crossing structures) over a time period of five decades by using the best available data, such as will be generated by this proposal, to prioritize and set the location of mitigations.
b. (Safety) – Reduce roadway collisions to <1 per thousand people per year by reducing WVC by 80%.

Performance measures are presented assuming continued improvement of our understanding of wildlife movements and WVC mitigation options where crossing structures are not feasible. Further, we assume that implementation of mitigations is feasible and can be funded. The timeline over which mitigations such as crossing structures can be implemented is not within our control.

Implementation Process

We will work closely with our WYDOT partners and project partners through all phases of the project to ensure that our findings are relevant and actionable. Some of our deliverables (e.g. evaluation of wildlife crossing signage) will provide directly implementable recommendations. Other deliverables (e.g. location of WVC hotspots relative to migration routes) will provide necessary information for future analyses that lead to implementable recommendations (e.g. costs and benefits of different mitigation measures on specific transportation corridors).

Technology Transfer

Technologies and results from this project will be shared with WYDOT staff in several ways. WYDOT staff from Planning, Programming, Environmental Services, and Highway Safety will be key partners in identifying specific questions and developing future traffic scenarios for which deer-vehicle collision predictions would be valuable. WYDOT will receive written or verbal (in-person presentations) quarterly reports over the course of the project. We will also discuss the project's progress regularly with WYDOT Wildlife Specialist, Tom Hart.

At the end of the project, we will provide a comprehensive final report, including research results and map products, conclusions and recommendations, and raw data and metadata. Our deliverables (see above) will provide specific map and GIS products that can be used directly by WYDOT, WGFD, and other state and federal agencies. We will be available to assist WYDOT staff with data interpretation and integration of results into transportation planning. We will also be available to assist county government and wildlife managers with interpretation of our results.

Education, Outreach, and Scientific Products

1. Presentations to interested members of the general public and targeted interest groups:
   We will create an interactive presentation that emphasizes how WYDOT uses data to help mitigate WVC, showcasing project maps and models. The program will emphasize steps that drivers and other citizens can take to reduce WVC.

2. Curriculum material and integration into Teton Science Schools' educational programming, which reaches >13,000 participants annually:
   Using project maps and models as examples, we will design inquiry-based curriculum material focused on the nature of science, problem-solving, the design cycle, GIS and/ or animal migrations.

3. Scientific journal articles and conference presentations:
   We will prepare and submit at least one manuscript detailing the results of the study to a peer-reviewed scientific journal. We will present findings at two regional scientific conferences.

4. Distribution of information to roadway users:
   We will distribute maps of deer migration routes and high collision areas to rental car companies, driver's education classes and DMV offices across the state.

5. Project Evaluation:
   We will evaluate the outputs of the education phase to ensure that project outcomes were achieved.

Personnel

Dr. Corinna Riginos is a Research Ecologist with 14 years of experience in wild herbivore-habitat interactions and more than 20 peer-reviewed publications. She led all analyses, final reporting, and outreach for a previously-funded WYDOT grant to the Teton Research Institute (RS03210: Understanding mule deer movement and habitat use patterns in relation to roadways in NW Wyoming) and is Co-Investigator with Morgan Graham on a currently-funded WYDOT grant (RS05212: Evaluating the effects of deer delineators on wildlife-vehicle collisions in NW Wyoming). She has broad expertise on the issue of wildlife-vehicle collisions and the statistical tools necessary to carry out this proposed work. She holds degrees in ecology from the University of California, Davis and Brown University.

Morgan Graham is the GIS Manager at Teton Research Institute (TRI). Over the past 11 years he has successfully lead GIS projects for the Minnesota Department of Natural Resources Natural Heritage and Nongame Research Program, University of Michigan, The Nature Conservancy, Hawaii Division of Forestry and Wildlife, Wyoming Game and Fish Department, Bureau of Land Management, United States Forest Service, and Teton County, WY. At TRI he manages geographic information systems work, overseeing the acquisition, organization, analysis and documentation of geospatial data for contractual and research projects. He is a Co-Investigator on the currently-funded WYDOT project RS05212: Evaluating the effects of deer delineators on wildlife-vehicle collisions in NW Wyoming. He holds a degree in biology and GIS/Cartography from Macalester College.

Holly Copeland has worked as a Spatial/Landscape Ecologist with the Wyoming Chapter of the Nature Conservancy for the past 15 years, where her research focuses on sustainable energy development through the use of GIS and modeling tools for mitigation planning and forecasting future impacts of energy development on wildlife. She holds degrees in geography from the University of Wyoming and the University of California, Davis.

References

1 Huijser, M.P., McGowen, P., Fuller, J., Hardy, A., Kociolek, A., Clevenger, A.P., Smith, D. and Ament, R. (2008a). Wildlife-Vehicle Collision Reduction Study: Report to Congress. U.S. Department of Transportation, Federal Highway Administration. FHWYA-HRT-08-034 254 pp.

2 Wyoming's 2012 Report on Traffic Crashes, Wyoming Department of Transportation, Cheyenne, WY.

3 Wyoming's 2013 Report on Traffic Crashes, Wyoming Department of Transportation, Cheyenne, WY.

4 Forman, R. T., & Alexander, L. E. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics*, 207–C2.

5 Beckman, J.P. and Hilty, J.A. 2010. Connecting wildlife populations in fractured landscapes. In Safe Passages: Highways, Wildlife, and Habitat Connectivity. Beckman, J.P., Clevenger, A.P, Huijser, M.P., and Hilty, J.A. eds. Island Press: Washington, DC.

6 de Vos, Jr. J. C., M. R. Conover, and N. E. Headrick. 2003. Mule deer conservation: issues and management strategies. Berryman Institute Press, Utah State University, Logan, USA.

7 Mule Deer Working Group. 2009. The Wyoming Mule Deer Initiative. Wyoming Game and Fish Department.

8 Sawyer, H., Lebeau, C., & Hart, T. 2012. Mitigating roadway impacts to migratory mule deer-A case study with underpasses and continuous fencing. *Wildlife Society Bulletin* 36: 492-498.

9 Huijser, M.P. and McGowen, P.T. 2010. Reducing wildlife-vehicle collisions. In Safe Passages: Highways, Wildlife, and Habitat Connectivity. Beckman, J.P., Clevenger, A.P, Huijser, M.P., and Hilty, J.A. eds. Island Press: Washington, DC.

10 Huijser, M. P., Duffield, J. W., Clevenger, A. P., Ament, R. J., & McGowen, P. T. 2009. Cost–benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada: a decision support tool. *Ecology and Society* 14: 15.

11 Riginos, C., Krasnow, K., Hall, L.E., Graham, M.W., Sundaresan, S., Brimeyer, D., Fralick, G., and Wachob, D. 2013. Mule deer (*Odocoileus hemionus)* movement and habitat use patterns in relation to roadways in Northwest Wyoming. Federal Highway Administration. FHWA-WY-13/08F.

12 Seiler, A. 2005. Predicting locations of moose-vehicle collisions in Sweden. *Journal of Applied Ecology* 42: 371-382.

13 van Langeveld, F. and Jaarsma, C.F. 2004. Using traffic flow theory to model traffic mortality in mammals. *Landscape Ecology* 19: 895-907.

14 Danks, Z.D. and Porter, W.F. 2010. Temporal, spatial, and landscape habitat characteristics of moose–vehicle collisions in Western Maine. *Journal of Wildlife Management* 74: 1229-1241.

15 Gunson, K. E., Mountrakis, G., & Quackenbush, L. J. 2011. Spatial wildlife-vehicle collision models: a review of current work and its application to transportation mitigation projects. *Journal of Environmental Management* 92: 1074-1082.

16 Wyoming Department of Transportation, Vehicle Miles Book.

17 Wyoming Department of Transportation Strategic Plan 2012-2015.