Traffic Thresholds in Deer Road-Crossing Behavior

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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). In Wyoming, an average of 2,248 WVCs were reported over the last three years, accounting for 16 percent of all reported collisions (2,3,4). 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 (5). Deer-vehicle collisions (mostly mule deer) make up greater than 85 percent of all wildlife-vehicle collisions in Wyoming.

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 (6,7). Where highways create a partial or complete barrier to wildlife movements, they threaten populations by impairing their ability to access the resources they need (7). Mule deer populations in the state are in decline, as they are across most of the West (8), and conserving their populations is an extremely high priority for the Wyoming Game and Fish Department (WGFD) (9). 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 (9) and Mule Deer Working Group.

The Wyoming Department of Transportation continues to work extensively to mitigate wildlife-vehicle collisions. Mitigation measures include a variety of tools, each of which may be suited to different conditions. Mitigation measures broadly fall into two categories: those that enable at-grade crossings, and those that allow animals to cross over or under the roadway (crossing structures). The former are generally much less costly but can only work if traffic is sparse enough for deer to actually be able to cross the road. In cases where traffic volume is high, crossing structures are the best option to ensure habitat connectivity and safe road crossings for deer. However, the threshold of traffic volume above which deer are unable to cross roads is not known.

Using existing video footage of deer road crossing attempts, collected under a previous WYDOT-funded project, we will determine:

a) The threshold of traffic volume above which deer are unable to cross the road; and
b) The threshold of traffic volume above which deer are able to cross the road but with considerable risk, and below which deer are able to cross the road safely.

Problem Background

It is generally known that roads can create barriers for large mammal movements (6). Whether roads act as partial or complete barriers is thought to depend on traffic volume; above some threshold of traffic volume, the theory is, animals are no longer able to cross roads. However, our understanding of where this threshold lies is poor. A handful of studies have addressed this question using carcass counts and annual average daily traffic (AADT) numbers (10,11). In these studies, carcass counts are seen to increase with rising AADT, up to some point, above which carcass counts decrease; the assumption is that fewer carcasses are observed at high AADT because animals rarely attempt to cross the road above some threshold of AADT. This approach, while valid, paints only a crude picture of the relationship between traffic volume and animal road crossing behavior – first because carcass counts do not tell us anything about the fraction of animals that attempted to cross, succeeded in crossing, or failed to cross, and second because ADDT estimates do not tell us anything about the traffic volume at the time when the deer attempted to cross. Further, AADT estimates can be heavily skewed by episodically high traffic volumes (for example, if traffic volumes peak seasonally – potentially during a season when deer are rarely present).

An understanding of the effect of traffic volume on wildlife (largely deer, in Wyoming) road crossing behavior is vital to successful mitigation of the problems of wildlife-vehicle collisions and roads acting as barriers to animal movements. Optimizing the cost-benefit ratio of mitigations also depends on this information. Wildlife-vehicle collision mitigation strategies vary widely in cost and in methodology. They include signage, modifying roadside vegetation, warning deer (e.g. with wildlife warning reflectors), animal-detection systems, and crossing structures. Of these, only crossing structures separate the animals from the road; all other mitigation measures assume that deer are able to make at-grade crossings and aim to improve the safety of those crossings by making drivers and wildlife more aware of each other's presence. These at-grade mitigation measures are most suitable for locations where deer are able to cross most of the time (potentially excepting peak rush hour times). They will not be successful or worth the cost in places where deer are unable to cross. Conversely, crossing structures are most necessary where deer struggle to cross the road due to high traffic at most times.

Understanding deer crossing behavior in relation to traffic volume is thus central to decisions about which mitigation strategy to employ at a given location, whether it is likely to be successful, and whether it is worth the expense.

We have collected more than 800 observations of deer crossing or attempting to cross highways in District 5. These observations were recorded as video footage using a FLIR (Forward-Looking Infra-Red) camera under a previous WYDOT-funded research project (5). Observations were collected on US 20 north and south of Thermopolis, on US 16/20 between Basin and Greybull, and on US 26 near Kinnear. Observations were collected between 5 PM and 7 AM and collectively encompass a wide range of traffic conditions. From reviewing the footage, it is clear that deer often struggle to cross the road due to high traffic volume and, as a consequence, take considerable risks or abort their attempt to cross. At other times, deer cross easily and safely.

These video observations were collected and analyzed for the purpose of examining deer behavior in response to deer wildlife warning reflectors, but without regard to traffic volume. They were collected thanks to new FLIR technology and provide a unique opportunity to learn more about deer road-crossing behavior; to our knowledge, no other study has collected such a large number of observations under real-world high-speed traffic conditions (one other study was conducted on a road with 30 mph speed limit [12], and others have examined deer behavior

on a handful of animals in real-time). Our footage was collected over two autumns and winters and required considerable amounts of time spent in the field and reviewing footage to identify times when a deer approached or crossed the roadway. However, there is more that can be learned from this footage about how traffic volume influences deer road crossing behavior. We propose to add considerable value and new information to our previous study by leveraging existing video data.

Study Objectives

Our overarching objective is to provide transportation planners with information that will help them to evaluate the placement of 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:

1. Identify the threshold of traffic volume above which deer must make numerous attempts to cross the road and/or abort their attempt to cross.
2. Identify the threshold of traffic volume above which deer make more risky crossings (e.g. in front of an oncoming vehicle) versus safe crossings.
3. Use this information to provide guidelines about the traffic volume conditions under which at-grade crossings versus crossing structures are appropriate for collision mitigation.
4. Couple the above with a cost-benefit analysis for four mitigation methods for each mile of the WYDOT road network. Further, we will indicate the expected post-mitigation WVC rates for each mile under each of the four mitigation methods.

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

The results of this study will help to:

- Reduce costs and increase success of WVC collision mitigation measures by providing guidelines about which mitigations are most effective and have benefits exceeding costs for specific geographic locations in Wyoming.
- Improve safety by reducing collisions with wildlife.

Output and Outcome Measures

Output measures support WYDOT's Strategic Goals (13) 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 support planning for WVC mitigation measures; by doing so, this project will provide significant WVC mitigation performance improvements and cost savings for WYDOT.
2. By improving WYDOT's efforts to reduce WVC, this project will improve safety by avoiding harm, injury, loss, and risk to members of the public using Wyoming's highways.

Performance Measures

a. (Cost Benefit) – This project aims to improve wildlife-vehicle collision mitigation performance by as much as 80% (the effectiveness of well-sited WVC mitigations such as crossing structures) over a time period of 20 years by using the best available data, such as will be generated by this proposal.
b. (Safety) – Reduce roadway collisions to <1 per thousand people per year by reducing WVC by 80%.

Performance measures are presented assuming that implementation of mitigations is feasible and can be funded. The timeline over which mitigations can be implemented is not within our control.

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 2016 (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? *None – all field data collection is complete.*
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? *N/A*
7. Should the project be segmented into phases with go/no-go decision points based on known unknowns? *This is not necessary.*
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 existing video footage already collected with WYDOT support and Federal Highway Administration funding. This project will consist of re-viewing the footage and collecting new data on traffic volume and deer behavior not previously collected.

Previous analysis of this video footage focused on assessing the vigilance and road crossing behavior of the lead deer in each group. For the purposes of examining the effect of

traffic volume on crossing behavior, there are several different or additional pieces of data we will obtain:

- Traffic counts in the five minutes preceding the attempted crossing(s) and during attempted crossing(s), which will be converted to vehicles per hour
- Number of attempts to cross by each deer (not just group leader)
- Whether the deer eventually did cross or not
- From the above two, we calculate a success to failure ratio
- Total time spent by each deer attempting to cross (time from when they show intent to cross until they complete a crossing or abort efforts to cross)
- Whether the deer ran into the road directly in front of an oncoming vehicle or not (this data already exists for group leaders but will be collected for all deer)

We will analyze data using linear modeling techniques to examine the relationship between traffic volume and difficulty of crossing (success to failure ratio and total time spent attempting to cross) and safe versus risky road crossing behavior. By examining the shape of the response, we will be able to identify thresholds of traffic volume associated with changes in ability to cross and riskiness of crossing behavior.

Because video footage was collected under several experimental treatments (in the presence of wildlife warning reflectors, reflectors covered with white bags, and no reflectors), we will group observations by treatment to ascertain whether these experimental treatments influenced deer crossing rates. Data we have already collected indicate that deer exhibit safer road crossing behavior (less likely to run into the road) in the presence of white bags and red reflectors, but that crossing success rate is not influenced by these treatments. By including the effects of these treatments, we will be able to evaluate their effectiveness under different traffic volume conditions – something we were not able to do in previous work (i.e. we will be able to determine at what traffic volume white bags and reflectors stop facilitating safe deer road crossings).

This will allow us to develop recommendations about which prevailing traffic volume conditions lend themselves to at-grade crossing mitigations versus separated crossing structures. Operationally, we will define a road whose traffic volume exceeds this threshold for more than three hours of the peak deer road-crossing time (5 PM – 7 AM) during fall and winter months (peak deer road-crossing season) as an “impermeable” road for deer. This is a conservative definition, since deer are expected to be able to cross during other hours, but since traffic volumes are generally rising across the state, a conservative definition is necessary for long-term mitigation planning. We will use WYDOT’s traffic data to classify as “permeable” and “impermeable” the 20 worst hotspots of WVC in the state (identified in previous and current WYDOT-funded projects to PI Riginos). We will analyze any other locations by request from WYDOT; since the analysis has to be done for each road segment, it is impractical to do this analysis for the entire state.

We will combine this with a cost-benefit analyses of several mitigation options for these 20 hotspots: signage, wildlife warning devices, animal detection systems, and crossing structures. We will use the approach of Huisjer (14) and our existing analysis of WVC rates (annual number of collisions per mile) across Wyoming’s road network to determine which miles meet or exceed the threshold for each mitigation to be cost-effective. Benefits will be calculated as dollar cost per WVC x number of WVC per mile per year x percent reduction documented from each mitigation (using published studies). Costs will be calculated as the cost per mile of the mitigation (using published studies and WYDOT’s actual costs, where applicable) with a 3% discount rate for 50 years. From this analysis we will produce a map and data table for each

mitigation measure indicating where the benefits exceed the costs and the expected number of WVC per mile per year after mitigation.

Finally, using the "permeable" versus "impermeable" designations, we will modify recommendations for the 20 worst hotspots. For example, an at-grade mitigation might have benefits that exceed its costs for a particular hotspot, but if traffic volume is high enough for the road to be classified as "impermeable" then a separated crossing would be recommended for that hotspot.

Together, the results of this study and our current work will provide valuable decision-support information for WVC mitigations, based on best available data about deer behavior in Wyoming.

Deliverables

1. One-page summary document providing recommendations about which prevailing traffic volume conditions lend themselves to at-grade crossing mitigations versus separated crossing structures.
2. Maps and tabular data showing which miles in the WYDOT road network exceed threshold cost-benefit values (benefits outweigh costs) for four WVC mitigation measures.
3. Maps showing expected post-mitigation WVC rates for each of the four potential mitigation measures.
4. Added information for the 20 worst WVC hotspots as to whether an at-grade or separated crossing is recommended.
5. Quarterly and final reports to WYDOT detailing specific methodologies and findings.
6. Presentations of major findings and decision-support information to WYDOT engineers.
7. Presentations to interested members of the general public.
8. Collection of video clips with high education value – illustrating the highway safety and ecological challenges, examples of collisions, and how driver behavior matters.
9. Scientific journal articles and conference presentations.

We will share all final products with WYDOT and the Wyoming Game and Fish Department. All deliverables except scientific journal articles will be completed by December 2016.

Work Schedule

All work will take place between January and December 2016.

	J	F	M	A	M	J	J	A	S	O	N	D
Review of video footage												
Data analysis												
Report writing												
Outreach and tech transfer												

Budget

	Projected Project Costs	Percent of Total
DIRECT COSTS	**$31,900.00**	**86%**
Total personnel costs	**$30,000.00**	**82%**
Principal investigator	$16,000.00	43%
GIS analyst	$6,000.00	16%
Technician	$8,000.00	22%
Research travel	$400.00	1%
Equipment	$1,500.00	4%
TECH TRANSFER	**$1,700.00**	**5%**
Travel for meetings and presentations	$400.00	1%
Conference attendance	$300.00	1%
Publication costs	$1000.00	3%
INDIRECT COSTS	**$3,360.00**	**9%**
Overhead	$3,360.00	9%
TOTAL	**$36,960.00**	

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.

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. Our deliverables will provide valuable implementation recommendations about the benefits of different mitigation measures under different prevailing traffic conditions, which can be tied to specific transportation corridors.

Technology Transfer

Technologies and results from this project will be shared with WYDOT staff in several ways. WYDOT District 5 Maintenance Engineer Pete Hallsten and Wildlife Specialist Tom Hart will be consulted throughout the project to ensure that the project meets their needs and expectations and to solicit their ideas for improvements to the project. WYDOT will receive written or verbal (in-person presentations) quarterly reports over the course of the project.

At the end of the project, we will provide a comprehensive final report, including research results, conclusions and recommendations, and raw data and metadata. Our deliverables (see

above) will provide specific guidelines. 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 a presentation that highlights study findings and emphasizes how WYDOT uses data to help mitigate WVC.

2. Video footage for driver education: Video footage of deer-vehicle interactions is a very powerful tool to communicate with diverse audiences. We will compile a set of video clips illustrating the challenges that deer and drivers face when they meet on roadways and how driver behavior matters to the outcome of this interaction. We will work with WYDOT public relations staff to suggest how they might use this footage to create an educational video that raises driver awareness.

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 a regional scientific conference.

4. 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 15 years of experience in wild herbivore-habitat interactions and more than 20 peer-reviewed publications. She led all analyses, final reporting, and outreach for two previously-funded WYDOT grants (RS03210: Understanding mule deer movement and habitat use patterns in relation to roadways in NW Wyoming, and RS05212: Evaluating the effects of deer delineators on wildlife-vehicle collisions in NW Wyoming) and is leading a currently-funded WYDOT grant (RS03215: Planning Support for Mitigation of Wildlife-Vehicle Collisions and Highway Impacts on Migration Routes in Wyoming). Together, these projects are beginning to yield a more comprehensive picture of wildlife-vehicle collisions, their causes, and their mitigations across Wyoming. Dr. Riginos 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 (Ph.D.) and Brown University (B.S.).

References

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Data Management Plan

Data type and storage:

- Observational data on deer behaviors and traffic counts, to be stored as .csv spreadsheets
- Derived data on costs and benefits of four mitigations, by mile of road network, to be stored as .csv spreadsheets
- Derived data on reduction in WVC by mile of road network for four mitigations, to stored as .csv spreadsheets
- Data will be regularly backed up on hard drives and in the cloud over the duration of the project
- All data are reproducible

Data organization, documentation, and meta-data:

- All data will be organized and a meta-data file will be generated explaining:
    - the purpose of the project
    - how the data were generated
    - structure and organization of the files
    - quality assurance
    - transformations of the data from the raw data through analyses
    - variable names and descriptions
    - explanations of any codes or classification schemes
- Directories will be named with the project title as the main directory and with subtopics (e.g. deer_behavioral_observations) as folders within that directory. Individual files will be named descriptively and with yyyy.mm.dd added to the name.

Data access and intellectual property:

- There are no access concerns
- All data will be handed over to WYDOT on completion of the project
- Copies of the data will remain with the PI and with the Northern Rockies Conservation Cooperative. The PI retains the right to publish data in peer-reviewed journals and to post on open-access websites such as DataDryad
- No embargo periods other than those imposed during the research period

Data sharing and re-use:

- There are no restrictions on re-use. Anybody wishing to re-use the data should submit a request in writing to the PI with a clear explanation of what the data will be used for an agreement to acknowledge the PI appropriately and not to share the data with any third party.
- Potential audience for re-use are researchers wishing to perform a meta-analysis of similar studies
- Data will be published within a year of project completion in a journal such as *Journal of Wildlife Management*

Data preservation and archiving:

- Data will be archived as .csv files
- Data will be uploaded to www.DataDryad.org upon acceptance for publication
- Dryad is a non-profit that provides free, long-term access to data

Disclosures

A long-term data preservation plan will be used to store the data beyond the life of the project. The data will be deposited into the Dryad Digital Repository. The Dryad Digital Repository is an open access platform that provides free access to data and long-term preservation of data. The data will be vetted by data curation experts to ensure that the preserved data are accompanied by the appropriate documentation, metadata and codes to facilitate reuse and provide the potential for interoperability with similar data sets.