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Wildlife Vehicle Collisions Improved Information to Monitor and Mitigate Collision Risks and Enhance Conservation Management

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WILDLIFE VEHCILE COLLISIONS: IMPROVED INFORMATION TO MONITOR AND MITIGATE COLLISION RISKS AND ENHANCE CONSERVATION MANAGEMENT

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ABSTRACT OF THE THESIS

WILDLIFE VEHCILE COLLISIONS

IMPROVED INFORMATION TO MONITOR AND MITIGATE COLLISION RISKS

AND

ENHANCE CONSERVATION MANAGEMENT

by

Laura Lee Clark

American Public University System, June 7, 2015

Charles Town, West Virginia

Dr. Elizabeth D'Andrea, Thesis Professor

In 2008, collisions were estimated to be between one and two million per year. In 2012, over 1.2 million insurable claims were filed for automobile damages resulting from wildlife vehicle collisions with ungulates. The wildlife collision problem continues on our highways. Collision data does not include uninsured claims, medium or small vertebrae, birds, amphibians or reptiles.

Mitigation programs to reduce collisions are difficult to develop and assess with existing collision data, and collisions have increased since 2008. Eco-logical transportation planning and adaptive conservation management disciplines both require comprehensive information for improved decision making. This paper developed strategies for measuring quantitative losses as well as defining qualitative consequences of wildlife vehicle collisions. Pearson product moment analysis demonstrated a high correlation between hunting harvest takes and wildlife vehicle collision rates. A historical trend index, or C-Value, was developed for analysis of collision and harvest rates for each state. The index values demonstrated states where collision and harvest rates increased, decreased, or stabilized from 2007 to 2012. Examples from selected states whose index showed collision rate improvements provided insights for harvest management as a mitigation strategy. This analysis also demonstrated the need for additional data on collision occurrences, specifically for road and highway collision locations. Geospatial tools with enhanced collision location data points will facilitate essential collaborative conservation management and transportation planning mitigation efforts. Enhanced data will provide the means for targeted mitigation programs to increase compatibility of automobile transportation within our ecological system, ultimately, increasing public welfare and safety.

Keywords: wildlife vehicle collisions, deer harvest, mitigation, roadkill, Eco-logical transportation planning, adaptive resource management

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AND

ENHANCE CONSERVATION MANAGEMENT

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Charlestown, West Virginia

DEDICATION

I dedicate this thesis to the deer hunters who contribute to resource management and environmental health in an ethical and sustainable manner.

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I wish to thank the faculty at American Public University System for their support and guidance throughout the graduate program. I would also like to acknowledge the transportation and resource managers who provided information on their respective state wildlife vehicle collision programs, and special thanks to Dick Luedka, who retired from State Farm Insurance Industry on June 1, 2015, for his steadfast contributions over the years to provide public information and awareness on the risks of wildlife vehicle collisions.

I have found my course work throughout the Environmental Policy and Management Program to be inspiring, providing me with the skills to explore our dynamic and ever-changing environment, and would like to acknowledge my fellow students and professors who enriched the program experience with their diversity of skills and experiences.

TABLE OF CONTENTS

TABLES

FIGURES

I. INTRODUCTION

Comprehensive information on the occurrence rates of wildlife vehicle collisions is not available for risk mitigation and conservation strategies. For wildlife conservation management, the question is: what is wildlife's greatest predator: vehicles or hunting? For public well-being, health and safety, the question is: what economic losses and losses of life are attributable to wildlife vehicle collisions? And, the overriding research question is: what extent do wildlife vehicle collisions indicate incompatibility within our ecological system? Without comprehensive data defining the problem, these three questions remain unknown and mitigation is not prioritized. The purpose of this research is to evaluate the quantitative and qualitative consequences that wildlife vehicle collisions have on public health, productivity, and social and economic welfare, and to justify mitigation. To facilitate the mitigation of wildlife vehicle collisions, and determine the ecological impact, an index of historical collision rates by state is developed to provide a baseline of collision rates for future monitoring and targeting of mitigation strategy.

Wildlife vehicle collisions are witnessed throughout North America with regularity. Insurance industry losses exceed $4.8 billion a year (State Farm Insurance Agency, 2015). Ungulate collisions alone number over 1.2 million per year (State Farm Insurance Agency, 2015), and the roadside carnage is immeasurable for medium and smaller vertebrates, birds, amphibians and reptiles. Fortunately, the loss of human lives from wildlife vehicle collisions is less than 200 per year, although the fatality rate is higher for collisions with larger ungulates such as elk or moose (Insurance Institute for Highway Safety, Highway Data Loss Institute, 2015). These losses of life and property need to be mitigated, and in order to address mitigation, comprehensive data must exist to answer the first two research questions and define the extent of the problem. This paper demonstrates there is a current lack of policy priorities and comprehensive national and local highway data on wildlife vehicle collisions The current Department of Transportation bill, Moving Ahead for Progress in the 21st Century Act (MAP-21), deemphasizes environmental protection by streamlining the National Environmental Policy Act with accelerated decision making for environmental reviews (U.S. Department of Transportation, 2012). The Safe, Accountable, Flexible, Efficient Transportation Equity Act of 2005 (SAFETEA-LU) provided national policy for addressing environmental stewardship and had provisions specifically addressing wildlife vehicle collisions (United States Department of Transportation [USDOT], 2009). However, the policy shifted with economic conditions and less emphasis is placed on wildlife vehicle collision mitigation.

There are a multitude of diverse stakeholders including the insurance industry, and the conservation management and transportation industry professionals who have encountered challenges in obtaining comprehensive information on the behavior of wildlife on our highway system (U.S. Department of Transportation, 2012). Research has identified key indicator risk variables including type of highway, time of year, time of day and driving speeds (Brown, 2006). However, a multitude of challenges exist in predicting and quantifying collision occurrence rates. To answer to the research question, and quantify wildlife predation by vehicles, is challenging. Not only are there a multitude of species with varying behavioral attributes and population density complexities, the efforts to collect and summarize collision occurrences are time intensive and costly. Transportation planners need collision data to justify mitigation strategies, and wildlife managers need collision data to monitor population trends for conservation planning. Without data on the rate of collisions, the collision problem continues on our highways. This research will focus on ungulates, because they represent the greatest risk to drivers and historical conservation data is comprehensive for these species.

Recent collision rate data from State Farm Insurance Agency (2015) indicates a rise in claims since 2007. Prior works have noted the relationship between collision and harvest rates are closely correlated (Normandeau Associates, 2011), and (Hothorn, Brandl & Muller, 2012). Research efforts included summarizing ungulate harvest data as an indicator of population trends. While a number of factors contribute to the collision increase, harvest data demonstrates a decrease in harvest or ungulate population levels, and yet highway collisions increased. The cause and effect variables are not quantifiable, but the analysis demonstrates the available data, while not absolute, is comprehensive from state wildlife resource divisions and from the insurance industry to identify regional and state changes. A data correlation and a trend analysis is developed by state to provide a basis for determining the extent of the collision problem.

Recent technological advances for mitigation are promising and systems for automobiles are in development to modify human behavior (Zhou, 2012). The purpose of this paper is to provide strategies for measuring the quantitative losses, and to define the qualitative consequences. It demonstrates analysis, based on historical trends for collision rates and harvest data, can be developed to define the extent of the collision rates. The results of this paper do not provide data for highway managers to locate specific mitigation “hotspots” needed under the Eco-logical methods for transportation planning. Geospatial tools enhanced with collision location data points will facilitate essential collaborative conservation management and transportation planning mitigation efforts. A C-Value index developed from collision and harvest data provides transportation planners and resource management collision trends by state, as well as justification, based on the economic and ecological costs, for development of added mitigation strategies for automobile safety on a regional basis. The purpose of this paper is to provide information on wildlife vehicle collision occurrence rates for conservation adaptive management strategies and help meet Eco-logical transportation goals. It does this by providing data and comprehensive information to support mitigation, ultimately increasing public welfare, safety, and ecological compatibility of human transportation and natural resources.

II. LITERATURE REVIEW

The literature review is organized by research topics applicable to the purpose of this research. The first organization topic is research on national transportation policy from 2005 to the present in order to illustrate policy direction regarding environmental protection, specifically wildlife vehicle collisions. The second literature review topic is research from 2007 through 2009 encompassing work resulting from the transportation bill of 2005, including wildlife collision prevention, to the newest transportation legislation that lessons environmental reporting requirements to expedite needed transportation infrastructure and provide cost savings. The third topic is current research on vehicle collision predictive modeling and existing data resources. And, the final topic is a selection of research on new mitigation developments focusing on technological developments.

National Policy: Wildlife Vehicle Collisions

United States Department of Transportation. Federal Highway Administration, Office of Legislation and Intergovernmental Affairs, (2009). Program Analysis Team. A summary of highway provisions in SAFETEA-LU. See 23 USC 135(d). Retrieved from http://www.fhwa.dot.gov/safetealu/summary.htm on March 7, 2015

From 2005 to 2008, The Safe, Accountable, Flexible, Efficient Transportation Equity Act of 2005 (SAFETEA-LU) provided the national policy for addressing environmental stewardship and had provisions specifically addressing wildlife vehicle collisions. Funding was provided for research on mitigation of collisions, with a report to Congress on the causes, impacts and mitigation strategy with transportation training included in the provisions. A clear emphasis on collision mitigation was promulgated and was a national priority. The SAFETEA-LU Act of 2005 was amended in 2009 to: "protect and enhance the environment, promote energy conservation, improve the quality of life, and promote consistency between transportation improvements and State and local planned growth and economic development patterns." This bill did not make it through Congress (U.S. Department of Transportation. Federal Highway Administration, Office of Legislation and Intergovernmental Affairs, 2009).

United States Department of Transportation, (2012). Moving Ahead for Progress in the 21st Century Act (MAP-21) Retrieved from http://www.dot.gov/map21 on March 8, 2015

The current emphasis is on transportation infrastructure funding and less extensive reporting compliance requirements for the National Environmental Protection Act (NEPA). The current Department of Transportation bill, Moving Ahead for Progress in the 21st Century Act (MAP-21), deemphasizes environmental protection by streamlining the NEPA with accelerated decision making for environmental reviews (U.S. Department of Transportation, 2012). Public policy has now shifted from environmental reporting and analysis, and is focused on streamlining and cost saving measures for transportation planning.

Significant Research Addressing National Policy

United States Department of Transportation, Federal Highway Administration, (2008). Report to congress. Wildlife vehicle collision study. Retrieved from http://www.fhwa.dot.gov/publications/research/safety/08034/08034.pdf on March 7, 2015

This comprehensive study for Congress was completed and published to comply with the requirement of the SAFETEA-LU Act of 2005, which legislated this report on wildlife vehicle collisions. This is a comprehensive study of existing conditions as of 2008, with a complete research reference list on wildlife-vehicle collisions. At the time of this report, estimates on the extent of the problem are from one to two million collisions per year. This amount is based on several national data bases. The report includes mortality rates on threatened and endangered species. The majority of the report is dedicated to 34 methods of mitigation with cost benefit analysis and mitigation assessment for the methods, either in use, or in development. A group of seven experts contributed to this study with mitigation strategy recommendations.

The report states the greatest challenge to mitigation of collisions is the lack of reliable information to justify cost and effectiveness. Lack of standardized reporting and under reported collisions are noted as a particular shortcoming. The report points out a relationship between deer population density and collision rates with examples from Virginia, Wisconsin and Iowa and states a correlation has not been analyzed at a national level (p.45). The report continues the density discussion with the challenges in reducing deer populations, and historical data are cited to describe the long term challenges associated with deer population reduction management strategies (p. 125).

They concluded the data on the rate of occurrences was an obstacle for planners and safety engineers because of underreporting and lack of standardization. Three sources of data are noted in the report to assess the occurrence rate of collisions: carcass counts, police reports and insurance data. The report described the differing expertise and perspectives of highway professionals and wildlife resource managers.

Brown, J., (2006). Eco-logical: an ecosystem approach to developing infrastructure projects. U.S. Department of Transportation, Federal Highway Administration. Retrieved from http://www.environment.fhwa.dot.gov/ecological/ on March 9, 2015

In 2006, this comprehensive study, an Eco-logical Guide, was published addressing the ecological impact of roads and infrastructure on wildlife. This interagency effort took three years to complete. It provided a comprehensive guide to the ecological impact of road infrastructure. The report recognized the need to coordinate the various agencies in addressing wildlife and disruptive infrastructure including habitat fragmentation, public safety, and environmental health. The project outlined the legislative requirements for compliance with National Environmental Protection Act (NEPA) to improve our conservation goals with an Eco-logical approach. This study is widely cited today by transportation planners. It provided the historical basis for continuing efforts to monitor and mitigate vehicle wildlife collisions, and provided the numerous federal agencies contributions to addresses the collision problems.

Huijser, M.P., Fuller, J., Wagner, M.E., Hardy, A., Clevenger, A.P., (2007). Animal vehicle collision data collection. A synthesis of highway practice. NCHRP Synthesis 370. Project 20-05/Topic 37-12. Transportation Research Board of the National Academies, Washington DC. Retrieved from http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_370.pdf on March 9 2015

This report was a comprehensive analysis of the collision reporting and data collection processes for all fifty states Transportation and Natural Resource Departments. The study found

65% of transportation departments and 36% of resource divisions collect crash data. The challenges in reporting consistency, data summary and analysis were noted as difficult for states to compile. The information needed for mitigation planning, including specific highway locations, type of animal, and resulting damage, were found to have data gaps. A major obstacle in data collection is underreporting of collisions, especially for smaller species and collisions with less than a minimum threshold for damage costs. The report summarized the collection data for birds, reptiles and amphibians, and found the emphasis on reporting was on larger mammals. The recommendations included standardized collision data collection and reporting. Time and cost of this effort is a major consideration for implementation by the states. The study surveyed transportation and resource management for the reason or motivation for data collection, and found responses varied by responsibility between public safety and wildlife resource management. The work is integrated into this paper to demonstrate the differing perspectives of the resource and transportation professionals and their corresponding contributions to collaborative mitigation strategies.

White, P., Michalak, J. L., Lerner, J. (2007). Linking conservation and transportation. Using the state wildlife action plans to protect wildlife from road impacts. Defenders of Wildlife. Retrieved from http://www.defenders.org/publications/linking_conservation_and_transportation.pdf?ht= on March 9, 2015

In 2005, every state completed wildlife action plans for risk assessment of at risk species. This report summarized the action plans for each of the fifty states in response to the SAFETEA-LU legislation of 2005. The work covered impacts to wildlife and transportation planning integration to determine if states are addressing key impacts to wildlife from transportation including habitat loss and fragmentation. It also evaluated proactive needs in the transportation planning process. The results indicated that resource management departments should be involved in the transportation planning processes to adequately address wildlife needs and infrastructure impact. The report emphasized the resources available under the SAFETEA-LU act for lessoning the impact on wildlife from transportation systems. At the time, all fifty states considered roads a threat to wildlife, and eleven states considered wildlife conservation and transportation systems a priority.

Collision Data and Modeling

Insurance Institute for Highway Safety. Highway Data Loss Institute. (2015). Web resource. Retrieved from http://www.iihs.org/iihs/sr/statusreport/article/49/9/3 on March 8, 2015.

This organization provides public information on highway safety research and includes current articles on wildlife vehicle collisions, particularly for ungulates, which have the highest risk for losses. The site has current articles on loss rates and details and focuses the research on vehicle type, regional risks, and insurance claims. The four published articles in 2014 demonstrated the Institute is addressing vehicle wildlife collisions as a substantial risk for automobile drivers and the insurance industry. They maintain records on loss of life, and particular emphasis is placed on driver behavior and automobile testing and safety. This organization is significant for the development of emerging automobile technologies for driver behavior and automobile responsiveness.

State Farm Insurance Agency, (2015). Deer collision data reported. Retrieved from https://www.statefarm.com/about-us/newsroom/2012/10/23/deer-vehicle-confrontations/ and conversation with Dick Luedka on data compilation techniques and historical data sources.

State Farm Insurance Agency, in cooperation with the National Transportation Safety Board, has taken the insurance industry initiative to compile data, by state, on wildlife vehicle collisions. The organization has maintained records that assess the losses to the insurance industry on collisions for over six years. They are the only private organization to take the initiative to monitor the losses. The data is not specific for targeting exact locations for transportation managers to focus mitigation strategies, and losses reported are limited to those resulting in insurance claims; however, the data maintained is invaluable for assessing overall collision rate trends and provides public awareness and education incentive for increased driver safety. The collision data is based on reported collisions for insurance claims and is calculated to estimate national total collision rates, by state, based on market share.

The Deer-Vehicle Crash Information and Research Center, Deer Vehicle Crash Information Clearinghouse, (2015). State deer collision data: Connecticut, Iowa, Illinois, Michigan, Maryland, Minnesota, New Hampshire, New York, Ohio, Texas and Wisconsin 2008 to 2013. Retrieved from http://www.deercrash.org/Current_Research.htm on March 22, 2015

Eleven states are reporting to and participating in the Information Clearinghouse. This site includes significant research and data contributed by the participating states on collision rates and mitigation strategies. The data collection techniques vary by state from police reports to carcass collection and reported losses from $400 to $1,000 floor thresholds. While there are data collection differences, the methods, and trends for each of the contributing states are consistent and provide meaningful information on the rate of collisions for their respective states. The reported amounts are found to be significantly lower, than the state totals provided by the insurance industry, in all cases. This discrepancy highlights the data collection challenges attributable to wildlife behavior and the resources available to those reporting. Email correspondence from a Connecticut state wildlife biologist described the amounts reported are as low as one in five collisions from a study in 2005 (Labonte, 2015). Administrative divisions within the states collecting data include law enforcement, resource management, and highway departments. The states participating in the Clearinghouse demonstrate they are taking the initiative to monitor and mitigate the collision risks. The data reported by these states is a significant contribution to this paper in the analysis of data collection means and methods, and for the essential collision trend information complied by the participating states. As of December 31, 2014 the organization lost funding (Knapp, 2015).

Divisions of Natural Resources, (2015). Harvest data summary reports for fifty states 2008 – 2015.

State Natural Resource Divisions have the primary responsibilities for wildlife management strategies. They were established in the early part of the last century after eradication of many species including the white tailed deer. The state department programs are primarily funded by participating hunters and anglers. The data maintained on species population trends is historically significant given that the records have been consistently maintained for decades, and changes in modeling techniques are reported.

The data on ungulates, or those animals large enough to cause reported collisions, is found in the state Annual Harvest Reports. The harvest totals are an indication of population density of ungulates. The information is comprehensive based on reported harvests, and unreported animal using consistent modeling techniques by state. The Natural Resource Divisions use harvest trends to monitor population, and this paper is following their precedent to use harvest data for population density trends.

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 92(4). *Journal of Environmental Management*. Retrieved from http://www.sciencedirect.com/science/article/pii/S0301479710004305 on March 9, 2015

This is a significant contributory work on mitigation strategy modeling. The paper compiled twenty-four studies on a multitude of species and roadside characteristics for predictive modeling to facilitate highway mitigation projects. The report validates the transportation planning needs for specific highway "hotspot" location data and risk assessment for mitigation projects. The studies reviewed demonstrate significant indicators for road design, and provide modeling variables by species that incorporate the work of numerous researchers. This compilation of modeling variables is a significant contribution for future transportation planning.

Hothorn, T., Brandl, R., Muller, J., (2012). Large-scale model-based assessment of deer-vehicle collision risk. U.S. National Library of Medicine. National Institutes of Health. PLoS One. 2012; 7(2) Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3281017/#pone.0029510-Schwabe1 on March 22, 2015

This study was conducted in Germany on roe deer populations and vehicle collisions. The data resulting from this study indicated a very high correlation between the hunting harvest and collision data. The researchers note biases exist with harvest data, and yet they demonstrated a "surprisingly large" correlation between the data. The research is significant to assess the development of collision risk assessment regionally for the United States. As previously discussed, the harvest data is comprehensive in the United States, and corresponding data for the collisions resulting in reported losses also exists. Correlated values are compiled in this paper to determine if the harvest and collision values provide information to identify trends for developing predictive modeling.

Normandeau Associates, (2011). Methods to identify and prioritize deer-vehicle crash locations. Prepared for Federal Highway Administration. Retrieved from http://www.deercrash.org/DVC%20locations.pdf on March 23, 2015

This work was initiated by The Deer-Vehicle Crash Information and Research Center, and the Federal Highway Administration, to assess the current practices of transportation planners who provide information on highway collision risk for mitigation planning. The study reviewed and presented new models for predictive analysis, and provided a comprehensive analysis of current practices for a multitude of state transportation planners. The work cited current practices being used, including expert analysis and visual analysis as predictive determinates, and also provided an analysis of statistical methods including density characteristics. Normandeau (2011) additionally offers new modeling strategies to be tested for effectiveness in determining mitigation strategies for transportation planners and resource managers using spatial statistical analysis. The developments in Global Information System (GIS) landscape modeling present tremendous opportunity to analyze landscape features contributing to wildlife behavior in proximity to roads. This is a contributory work for mitigation planning, and it provides developmental opportunities for risk assessment. Overall, the research concludes, local expertise is essential and a variety of modeling applications are appropriate. The work also includes a contributory list of modeling variables to be considered in development of this analysis.

For the purposes of this paper, the discussion of density characteristics were of particular interest because of the inherent data limitations and opportunities for a broad scale analysis to answer the fundamental research question on the extent of predation on wildlife by vehicles. The scope of this analysis is a broad perspective to determine the overall trends in collision risks over the last six years. The Normandeau (2011) paper offers significant contributions for data analysis presented here.

Collision Mitigation Developments

Olson, D.D., Bissonette, J.A., Cramer, P.C., Green, A. D., Davis, S.T., Jackson, P.J., Coster, D.C., (2014). Monitoring wildlife-vehicle collisions in the information age: How smart phones can improve data collection. PLoS ONE 9(6). Retrieved from https://www.plos.org/wp-content/uploads/2013/05/pone-9-6-olson.pdf on March 8, 2015

This work describes the development of smart phone technologies and software development to assist in the arduous task of data collection on the highways. The data collection is subject to the strength of the organizational communication and coordination of the multitude of state agencies who have responsibility for the safety of our roads.

United States Department of Transportation, (2012a). Researchers develop handheld tool to collect and map wildlife-vehicle collision data UTC(s): Montana State University. Retrieved from http://www.rita.dot.gov/utc/publications/spotlight/2011_10/html/spotlight_1203.html on March 4, 2015

This work offers additional technological tools to provide needed regional collision data.

Zhou, D., (2012). Infrared Thermal Camera-Based Real-Time Identification and Tracking of Large Animals to Prevent Animal-Vehicle Collisions (AVCs) on Roadways. Intelligent Transportation Systems Institute, Center for Transportation Studies, University of Minnesota. Retrieved from the University of Minnesota Digital Conservancy. Retrieved from http://purl.umn.edu/125297 on April 2, 2015

The hunting community has embraced camera based wildlife observation tools for area assessment and increased hunt success. Logically, the development of this technology for preventing wildlife vehicle collisions has promising applications. A mitigation strategy to modify human behavior on the roadways offers a potential cost savings for highway planners, insurers, and for the public who are at risk.

Summary

The purpose of this paper is to provide strategies for measuring the quantitative losses and defining the qualitative consequences of wildlife vehicle collisions, based on historical collision rates and harvest data, to demonstrate the ecological incompatibility of our highway systems. Data can be developed to define the extent of the collision rates and justify mitigation of wildlife vehicle collisions. The purpose is not to provide transportation planners with species specific or road characteristic analysis that is warranted regionally. This literature review identifies key constraints under the current national transportation policy, and includes the tremendous research contributions resulting from the SAFETEA-LU Act, including Eco-logical transportation planning as a basis to describe the comprehensive and collective contributions to wildlife vehicle collision issues. Modeling tools are included to discuss the application and limitations of developed correlated data herein. New mitigation and data collection technologies are included in this literature review with Global Information System (GIS) technologies offer potential cost saving and expedited mitigation strategies required for current national transportation policies. Not only do GIS spatial analysis tools have promising applications, but new technological devises for data collection and driver safety in development, offer great promise to lessen the ecological impact of wildlife vehicle collisions.

III. THEORETICAL FRAMEWORK

The research following the SAFETEA-LU Act of 2005, from 2006 through 2009 provides an exceptional research base for public policy initiatives to mitigate vehicle wildlife collisions. This research will demonstrate changes in collision occurrences since the SAFETEA-LU Act of 2005. The current transportation bill reflects public opinion on economic efficiencies with a focus on new infrastructure and governmental budgetary spending caps. Specifically, the reduction of NEPA reporting requirements, and the lack of policy regarding wildlife vehicle collisions in the new bill, has placed the issue of wildlife vehicle collisions as a lower priority (USDOT, 2015). In concurrence with the current policy agenda, this paper compiles available comprehensive data on the existing rate of collisions and hunting harvest data to demonstrate that data on ungulate wildlife populations are at record levels and necessitate expedited, cost-effective, collision mitigation strategies applying Eco-logical planning practices. A data analysis and summary on a national level is developed to demonstrate wildlife collisions have not decreased significantly since 2008, and it justifies a commitment to reduce losses to life and property, while increasing our compatibility with the environment. States who have improved the collision rate since 2007, despite the national trend of increasing collisions, provide insights for successful mitigation strategies.

Research has found data over an adequate period to develop time series correlations for wildlife collisions: Wildlife harvest rates are reported by all fifty states in their respective annual harvest reports (Division of Natural Resources, 2015). The Insurance Institute for Highway Safety, Highway Data Loss Institute (2015) reported fatalities from wildlife vehicle collisions. The insurance industry reported losses by state based on actual insurance claims adjusted by market share by state from 2008 to 2012 (State Farm Insurance Agency, 2015). Eleven states report comprehensive data to the Deer Vehicle Crash Information Clearinghouse (2015) with various data collection methodology.

Previous work has indicated correlations between deer density and collision risk (Normandeau Associates, 2011), and the Report to Congress (USDOT, 2008 p.125). DeNicola, VerCauteren, Curtis & Hygnstrom, (2000) cite earlier papers where deer abundance is positively correlated with deer density by Blouch (1984), and Etter et al. They also describe the study by Hygnstrom and VerCauteren (1999) from Sarpy County Nebraska, where they found, from 1984 to 1994, as the deer population increased, the corresponding number of deer-vehicle collisions in that county increased 325 percent (DeNicola, VerCauteren, Curtis & Hygnstrom, 2000). A recent study on roe deer in Germany found a “surprisingly large correlation” between collisions and harvest rates, and the study proposed a development of an index for harvest and collision rates (Hothorn, Brandl, & Muller, 2012). This provides a basis to develop information needed to identify key risk regions, or states, with collision rate decreases or increases are above or below expected values. Based on historical indices, states will have information to justify changes in human and wildlife behavior, and population density for collision mitigation.

IV. METHODOLOGY

Research Design

The question, what is wildlife's top predator, can be addressed, but the answer is not absolute or complete, because the cost and tremendous efforts involved from law enforcement, transportation and wildlife resource divisions to compile the collision data. The collision data obtained from State Farm Insurance Agency does not include unreported claims for drivers who lack full coverage, or damages below the deductible, and the collision data is based on market share (State Farm Insurance Agency, 2015).

The key independent variables include deer density and road miles and driver population trends. Prior studies have demonstrated the variable of road type is a significant factor for collision rates. Illinois researchers found 83% and 77% of collisions occurred on rural roadways for 2012 and 2011 respectively (Deer Vehicle Crash Information Clearing House, 2015). Miles driven on high risk roads is an optimum independent variable. This analysis demonstrates a base line of collision and deer harvest rates nationally. Wildlife density and collisions are demonstrated to have statistical relationships. The close correlation of harvest data and collisions may account for road type and usage. Hunting is traditionally conducted in rural areas, with rural two lane roads, and a close correlation of harvest data and collisions may account for density, harvest areas, road type, and usage.

A preliminary study of the data from the eleven states currently reporting to the Deer Vehicle Crash Information Clearing House, (2015) was done to evaluate the correlated values between harvest and vehicle collisions to develop the national research design. This preliminary development of a harvest collision index by state found highly correlated values over the time series. Each state has different collection and data input values based on law enforcement reports, carcass pickups and different loss reporting thresholds. The collision rates on these reports were below those reported by the insurance industry. These states have contributed data for over ten years. The analysis relies on their expertise and data reported.

Mississippi states in their Annual Harvest Report, that the trends from state collected data demonstrate an increase in collisions while the insurance data shows a decrease for a two year comparison including number of drivers. However, overall they state both information sources demonstrate an increased number of collisions over the seven years of their study (Mississippi Department of Wildlife Fisheries and Parks, Mississippi Annual Deer Report, 2011). The data collection for collisions by states varies significantly from the data compiled by the insurance industry and is indicative of the continuing challenges in data collection. The insurance data is based on claims including those accidents not filed with law enforcement. It represents an actual transfer of funds based on a comprehensive and consistent reporting methodology and resulting data to measure collision risks.

The insurance industry data is based on actual collision claims reported to State Farm Insurance Agency (2015) adjusted for market share. Those collisions below the deductible threshold are not reported, in addition to drivers not reporting collisions, because they lack full coverage. States where State Farm is not the majority market share holder will have data which is not representative of actual collision rates. However, the data available exists for major collisions, over comprehensive time periods, and it is based on actual transactions with monetary exchanges. The periods, from July 1, 2007 - June 30, 2008 to July 1, 2012 - June 30, 2013 are used for a trend analysis based on consistent collision data collection for all states.

Nationally, the state resource divisions all have harvest reports that are extremely comprehensive for population modeling, with harvest records and detailed management strategies by management districts. This data is historically significant. The justification to index harvest rather than population data was based on the most comprehensive data source for a comparative trend analysis. Harvest management records are based on hunter surveys and compliance with strategized hunting management regulations. Harvest levels and trend data is used for population modeling for most states with high ungulate populations. In some regions, the ungulate population densities are in open ranges and aircraft surveys or GIS systems are used. But, since most population estimates are derived from harvest data, the information for correlation is based on occurrence harvest data rather than modeled population estimates. Population information is removed statistically from the base data because of the varying state wildlife population data reporting techniques.

The national harvest data includes ungulates: white tailed deer, roe deer, mule deer, pronghorn antelope, elk, moose, big horn sheep, and caribou, for all fifty states. Collisions and harvest data for bear were not included, although it was noted during the review of state harvest reports collisions with bear is occurring and does result in insurance claims. (Maryland Division of Natural Resources, 2012). The index is developed for ungulates only.

The period under review is subsequent to the SAFETEA-LU Act of 2005, from 2007 to 2012. The insurance collision occurrence data is assembled from July 1, to June 30th each year. The harvest data is reported in the spring at the end of the hunt season. The data for collisions was matched with the fall harvest season reports. For the 2013 hunt period, the corresponding collision data July 1, 2013 to June 30, 2014 will not be available until fall of 2015 (State Farm Insurance Agency, 2015).

Statistical Analysis

The correlation coefficients of harvest and collisions totals for each year 2007 to 2012 were calculated to determine the value of the association of the harvest and collision data by year for all fifty states. Scatterplot diagrams were developed for each year with all states to identify association and state data statistically variant from the clusters. Pearson product moment correlation of state harvest totals for ungulates and collision totals was used to determine how closely the relationship between harvest and collision data was associated. Excel 2013 embedded statistical formulas were used, and the formula is as follows:

The formula for the Pearson product moment correlation coefficient, r, is:

$$r = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

(Source: Microsoft Office: http://support.office.microsoft.com/en-US/article/PEARSON-function-22f752ac-ad5a-4f1f-a2cf-1ef7ed96e1af)

Where x and y are the sample means AVERAGE (array1) and AVERAGE (array2), where (array 1) is annual harvest total, and (array 2) is annual collisions.

Once the correlations between collisions and harvest totals was established, a graphic presentation was developed for the change in collisions from 2007 and 2012 stacked against the change in harvest from 2007 and 2012 to represent, by state, which states are ideally having an increase in harvests and a corresponding decrease in collisions for collision mitigation. Interpretation of the data results includes variables such as increased population densities, both human drivers and ungulates causing an increase in both collisions and harvest, or reverse decrease in population densities. The interpretation of this data is subject to limited collision variables included in this analysis. Cause and effect relationships are not quantified by this analysis.

Collision Harvest Index Ratio Time Series by State

The index was developed by state for the statistical analysis and provides a benchmark for state trends. The index value by state is calculated as a ratio of collisions to harvest from 2007 to 2012. The relative value demonstrates if harvest and population density measures are positivity or negatively changing with comparative analysis. If positive, the management strategies for collision mitigation, including harvest management, are effective, and/or wildlife population and human density has decreased.

Road Miles, Changes in Collisions, Harvest and Number of Drivers

Wildlife vehicle collisions rates are based on wildlife and human population densities. A final analysis compares road miles, collisions, and harvests by state for 2012. The Pearson's product moment correlation between road miles and harvest is computed. A summary by state is conducted using road miles obtained from the U.S. Department of Transportation, (USDOT, 2013). A ratio of collisions per road mile and harvest per road mile was computed, and presented with the C-Value by state.

The number of drivers per state was obtained from U.S. Department of Transportation (USDOT, 2012a). The percentage change in number of drivers, harvest and collisions from 2007 to 2012 is compiled by state to determine if human population changes have impacted the collision rates.

This analysis compares these two significant attributes to collision rates to demonstrate the changes in response to increases or decreases in human and wildlife densities since 2007. The data sorted to determine the high deer-human density states with the most challenging mitigation circumstances.

Quantitative Collision Cost Analysis

To address the question, what economic losses and losses of life are attributable to wildlife vehicle collisions, a quantitative analysis on the historical collision loss data gathered will define the parameters. A summary of the cost of collisions is developed from the insurance industry data.

Qualitative Analysis on Ecological Compatibility and Consequences of Collisions

Wildlife vehicle collisions demonstrate our incompatibility within our natural environment. Roadways result in habitat fragmentation and automobiles cause untold unnatural losses of life. Our environment is providing abundant sustainable resources which lay to waste on our roadsides as demonstrated by the collision data. The analysis of ecological compatibility will emphasize the motivation for development of mitigation strategies from an ethical and ecological perspective. Behavioral modification is necessitated for both wildlife and humans, and each has challenges that must be addressed. Wildlife behavior is complex, and additional research is warranted for understanding the lack of behavioral adaptation for collision avoidance. Human response, behavior and motivation for mitigation is emphasized since it is understandable and controllable to some degree.

V. RESULTS

National Trends: Ungulate Harvests and Collisions 2007 to 2012

Compilation of data from the Annual Harvest Reports from all fifty states on ungulates (Appendix 1), represents the total national annual harvest data, and the total collisions (Appendix 2) from the insurance industry data are summarized as follows:

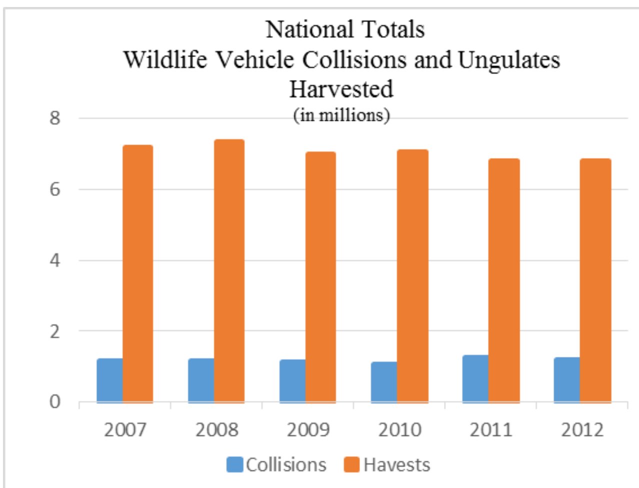

Figure 1
National Collisions and Harvests 2007 to 2012

In answer to the first research question, what is wildlife's top predator, vehicles or hunters? The data summarizing the collisions and harvests suggests hunter harvesting is the greater predator.

Year	Number of Collisions	Ungulates Harvest	Collision Change	Harvest Change	C-Value Ratio Index
2007	1,168,117	7,204,347			
2008	1,160,979	7,407,093	-0.6%	-2.8%	15.7%
2009	1,141,166	7,012,912	-1.7%	5.3%	16.3%
2010	1,063,731	7,121,374	-6.8%	-1.5%	14.9%
2011	1,261,034	6,815,773	18.5%	4.3%	18.5%
2012	1,217,463	6,808,763	-3.5%	0.1%	17.9%

Table 1
National Totals Wildlife Vehicle Collisions and Ungulates Harvested

The data on the number of collisions represents insurance reported claims only for ungulates, and does not represent total wildlife collisions for birds, small and medium mammals, etc. The collision data obtained from State Farm Insurance Agency represents claims above the deductible amount for full coverage drivers, adjusted for market share, and does not include unreported claims (State Farm Insurance Agency, 2015). The number of actual collisions is immeasurable based on actual data collection methods. While states are conducting actual studies based on law enforcement reports and carcass collections to target mitigation strategies, it is impractical and cost prohibitive to monitor every state road and highway in the United States for actual collision data. The collision data only includes ungulates, white-tailed deer, roe deer, moose and elk, or those animals large enough to cause reported collisions.

The harvest totals are an indication of population density of ungulates. The information is comprehensive, based on reported harvests and consistent modeling techniques by state to include unreported animal harvests. The state resource departments were established in the early part of the last century after eradication of many species, including the white tailed deer in some regions, and the data maintained on species population trends is historically significant. The records have been consistently maintained for decades, and changes in modeling techniques are reported.

The national harvest totals are remarkable. They indicate an unprecedented population of ungulates and the popularity of deer hunting in the United States. The harvests have declined nationally since the peak of 7.4 million in 2008 by 9.4% compared to 2013. These hunting efforts are significantly impacting the rate of collisions. Without managed harvesting over the years, the deer populations would have increased exponentially, and wildlife vehicle collisions rates would be higher without successful hunting strategies and population management.

Indices presented in Table 1 are simply a ratio of collisions to harvest. The significance of the index will be discussed after the correlation of data is demonstrated following the statistical analysis.

Statistical Analysis

A positive linear correlation was determined from the state collision and harvest data. This indicates the viability of the comparative analysis of harvests and collisions by state and by year. All years were consistent, and 2012 and 2008 result examples are as follows:

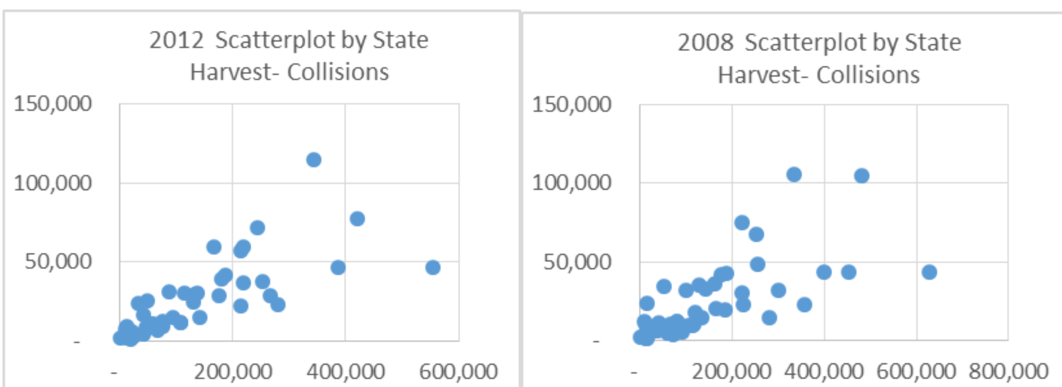

Figure 2
Annual Scatterplot Analysis

The data represents a positive linear correlation for each of the states by year, with the x axis as harvest and y as collisions. Washington, D.C. and Hawaii did not have harvest reported totals, and these data points were excluded from the correlation. The Pearson correlation coefficient or product moment demonstrated relatively high correlations between harvest and collisions by year: (.764, 47, $p<001$) for 2012, (.747, 47, $p<001$) for 2011, (.647, 47, $p<001$) for 2010, (.701, 47, $p<001$) for 2009, (.694, 47, $p<001$) for 2008, and (.689, 47, $p<001$) for 2007.

This correlation indicates the data is related; however, the cause and effect of the relationships cannot be quantified. The harvest totals used for this analysis are an indicator of ungulate density. Population densities are modeled from harvest data, and are not absolute. The population variables are dependent on, and vary by, each state's management strategy for hunting and targeted population levels. Hunter harvest success has been suggested as a refinement variable for the analysis (Normandeau Associates, 2011). If the purpose of this work was to direct mitigation strategies by wildlife management district or state, using population, the variable of hunter success rates and hunting regulations would have significant applications for targeting harvest efforts in the high wildlife density areas. Many state wildlife management plans do this, and during the review of state harvest reports, the information is available to direct the hunting community to targeted regions, with limits placed accordingly by management district.

Hunting is traditionally conducted in rural areas, in proximity to rural roads. Previous studies have found the incidence rate for collisions is high on rural roads. A 2012 study in Wisconsin showed 90.3% of deer crashes occurred on rural roads. In Illinois, 83% were on rural roadways in 2012, and 77.2% in 2011 (Deer Vehicle Crash Information Clearinghouse, 2015). The cause and effect relationships between the highly correlated data suggest the harvest pressures are occurring in rural areas with rural roads, but this cannot be quantified without collision location data.

Transportation planners need comprehensive data for "hotspot location" to justify the cost of mitigation projects and to adequately design transportation plans that incorporate wildlife conservation. Unfortunately, the data and results presented here, do not provide this information. The insurance industry collision data is compiled by state only without the needed collision locations for mitigation projects. GIS landscape analysis technology offers tremendous opportunity for resource managers and transportation planners to develop information for conservation planning including urban development trends. Habitat fragmentation and wildlife habitat landscape desirability features provide predictive analysis indicators. Iowa has identified the significance of these variables, and presents an excellent example of geospatial analysis tools (Iowa Department of Natural Resources, 2015). In summary, the correlated values indicate trends in collision and density only. It is a density based trend analysis by state. There are significant variable attributes to collision rates as determined by previous analyses (Normandeau Associates, 2011) that are not included in the index, such as landscape features, road type, collision location, and corresponding wildlife management district, human wildlife densities, and changes in hunting harvest goals.

State Analysis: Comparison of 2007 and 2012 Collision and Harvest Data

Nationally, the increase in collisions between the years of 2007 and 2012 was 4.2%, while harvests declined by 5.5% as shown in Figure 1. But, the comparative analysis of the change in collisions and change in harvest between 2007 and 2012 for the individual states as shown in Figure 3 indicate a variety of changes in harvests and collisions.

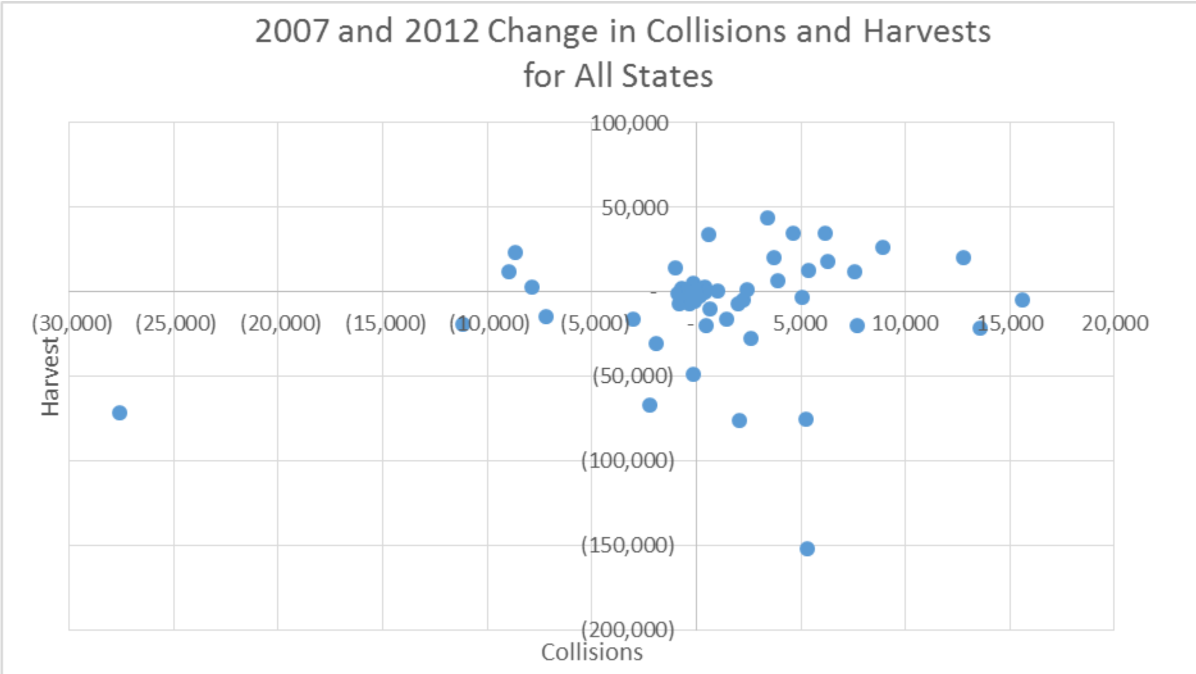

Figure 3
Collision Harvest Comparison 2007 and 2012

Figure 3 represents a change in collisions and change in harvest by state with harvest change in the center axis. Most states fall in the upper right quadrant with an increase in both collisions and harvests. States with increased collisions, and decreased harvests include Wisconsin, Montana, Alabama, Louisiana, and North Dakota in the lower right quadrant. This information is based on the insurance industry data. Wisconsin tracks accidents reported to law enforcement in excess of $1,000, and they contract for carcass collection (Deer Vehicle Crash Information Clearing House, 2015). Using harvest strategy to reduce ungulate population as collision mitigation strategy, the states in the upper left quadrant are demonstrating the highest success. These states are New Jersey, New York, Indiana, and Connecticut.

Further research found Connecticut is collecting data on the frequency of roadkill by management district. This state reported a five year trend analysis in their Annual Summary Report to identify those districts with deer collisions that require additional hunting pressure (Connecticut Department of Energy and Environmental Protection, 2013). Connecticut's report states the rates of road kill are significant factors for deer management strategies. This is true for many states, as demonstrated by the overall collision harvest rate of 17%. This is discussed further on the C-Value or collision value index on page 36. Connecticut completed a study in 2001 on the number of deer killed on the roads versus those reported to the wildlife department. The ratio of reported collisions to actual was found to be 1 in 5 (Connecticut Department of Energy and Environmental Protection, 2013). Based on this statistic, Connecticut reported 1,177 collisions in 2012 by wildlife management district. The insurance data, for purposes of this analysis, estimated Connecticut's actual collisions to be 9,349 from July 1, 2012 to June 30, 2013, a significantly higher number than Connecticut's wildlife division used for management strategies (State Farm Insurance Agency, 2015). The collision data, both incident rate and collision locations continues to represent one of the greatest challenges for mitigation implementation. The use of the insurance data for the purposes of this report, is based on the availability and reporting consistency over the years. This available data facilitates a trend analysis, and is based on actual number of insured claims from wildlife vehicle collisions.

The Connecticut Annual Deer Summary report estimated wildlife vehicle collisions by district and determined the districts that had a significantly higher percentage of deer collisions. Hunting quotas were increased, an extended archery season was introduced, and baiting practices were implemented to increase the hunt success rates. After these changes, the districts had a decrease in road kill occurrences. This state's example presents an interesting observation question: is the reduction of collisions based on targeted hunting strategies, particularly for urban deer and increased human populations? Connecticut summarized in their 2013 report, "with increased opportunities and incentives to harvest deer in urban deer management zones 11 and 12, the harvest has more than doubled, while roadkills have been exhibiting a steady downward trend" (Connecticut Department of Energy and Environmental Protection, 2013 p. 20). Connecticut's collection of collision occurrence data to target harvesting as a collision mitigation strategy proved worthwhile.

Michigan, the outlier in the lower left quadrant, experienced the highest decrease in both harvest and collisions. Other states are having a decline in both harvest and collisions. This indicates a reduction in population and a corresponding decrease in collisions.

Figure 4, shown in the following two graphs for ease of reading, uses stacked bars for change in collisions and harvests for all states.

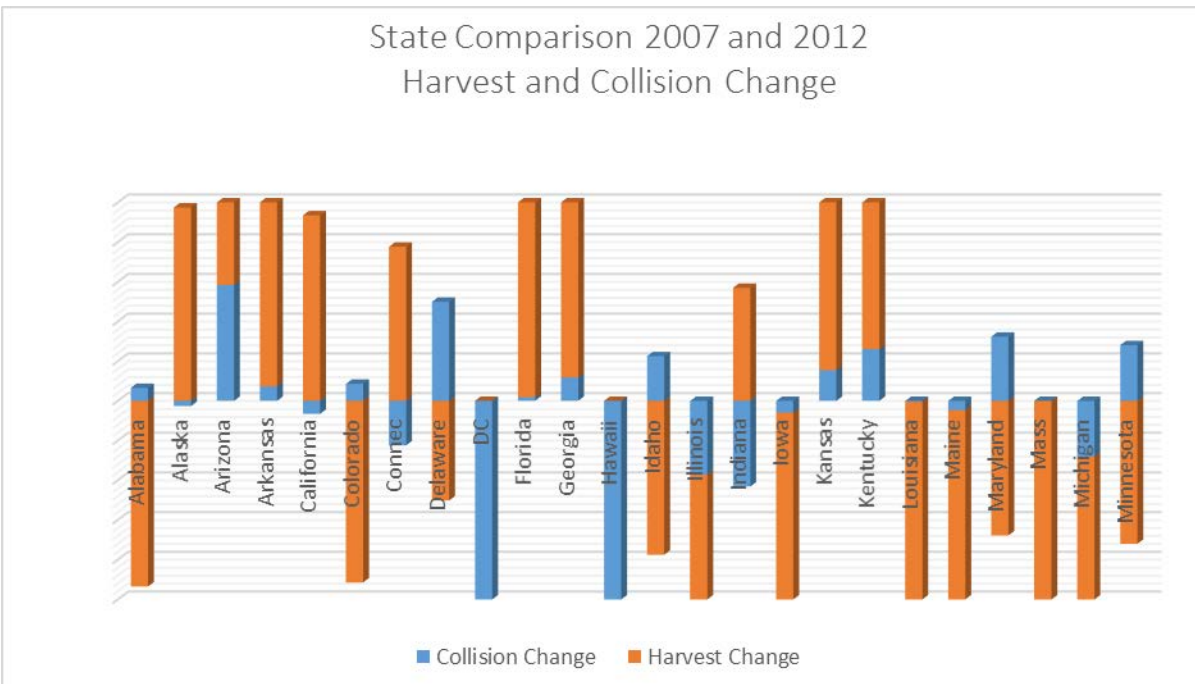

Figure 4.1
Collision and Harvest Change 2007 and 2012

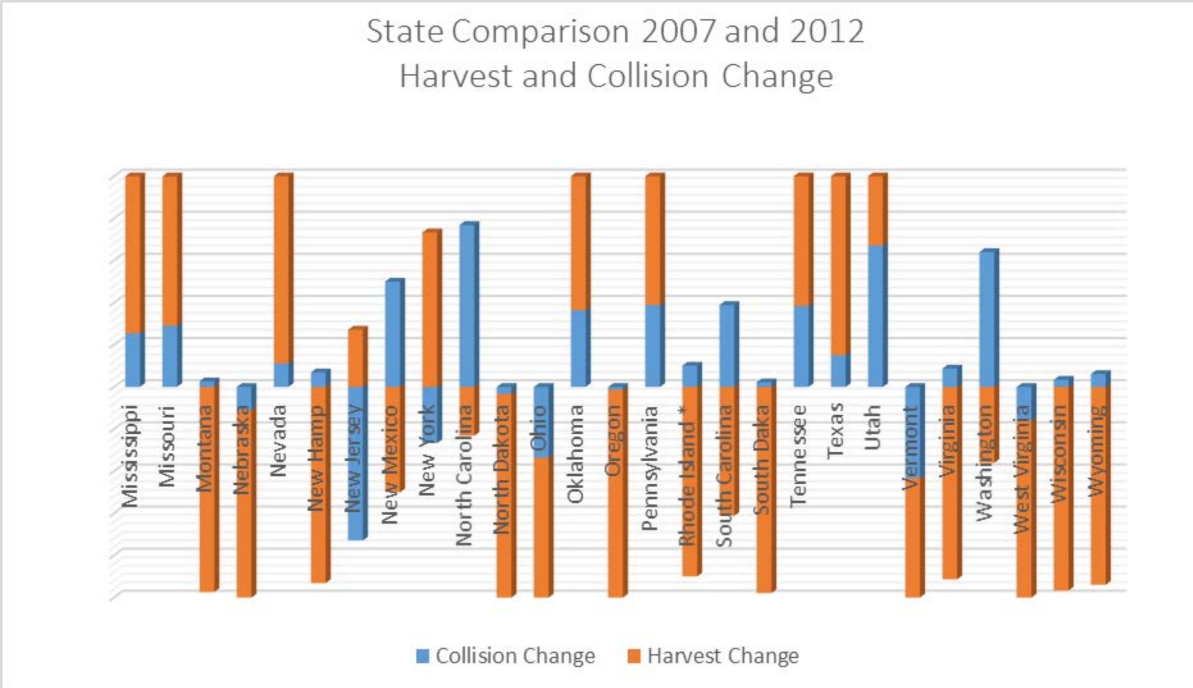

Figure 4.2
Collision and Harvest Change 2007 and 2012

Collision Index –Trends in Population and Collisions

Predictive strategies are challenged by the adaptive nature of wildlife. The movement of wildlife into urban areas is a historically unpredictable event. Who, in 1970, would have predicted the dramatic increase in urban white-tailed deer populations, for example? The correlation of the data between harvest and collisions may provide limited and broad indicators if harvest and other mitigation efforts are matched with wildlife density. Predictive models and location collision data are required for specific transportation project planning. The C-Value index, developed here, is based on historical harvest or population data and collisions to determine the degree of the change in the risk of occurrence.

The C-Value index is computed based on the ratio of collisions to harvests from 2007 to 2012. Collision changes for all states are shown in Table 2. For 2012 and 2007 comparison, Pennsylvania, Michigan, New York, North Carolina, Ohio and Virginia had the highest collision occurrences, yet Michigan and New York, actually experienced a decrease in collisions. Pennsylvania had a negative value in their index change as demonstrated by the collision index in Table 2. The best states were Michigan, New York, Indiana, and New Jersey, with collision reductions and a positive C-Value change. While not all of the variables accounting for the collision increase are known, deer density as measured by harvest data is an indicator.

State	Collisions 2012	Collisions 2007	Change	Mean C-Value	C-Value 2012-Mean
Pennsylvania	114,933	102,166	12,767	0.329	(0.006)
Michigan	77,103	104,676	(27,573)	0.206	0.021
New York	71,368	80,022	(8,654)	0.328	0.034
North Carolina	59,270	43,658	15,612	0.285	(0.069)
Ohio	59,154	66,353	(7,199)	0.268	(0.002)
Virginia	56,759	54,135	2,624	0.224	(0.040)
Wisconsin	50,341	45,008	5,333	0.121	(0.016)
Texas	46,537	40,378	6,159	0.074	(0.010)
Georgia	46,512	41,874	4,638	0.109	(0.012)
Minnesota	41,522	33,799	7,723	0.179	(0.043)
Illinois	39,218	50,380	(11,162)	0.220	0.003
Missouri	37,042	31,667	5,375	0.111	(0.007)
South Carolina	36,738	23,174	13,564	0.118	(0.051)
Maryland	31,300	29,075	2,225	0.332	(0.025)
Indiana	30,114	39,066	(8,952)	0.260	0.039
Iowa	29,843	31,737	(1,894)	0.234	(0.024)
West Virginia	28,968	31,967	(2,999)	0.222	0.003
Alabama	28,862	23,605	5,257	0.084	(0.024)
Tennessee	28,158	20,612	7,546	0.136	(0.023)
New Jersey	25,488	33,342	(7,854)	0.598	0.087
Kentucky	24,517	18,214	6,303	0.170	(0.017)
California	23,699	24,716	(1,017)	0.864	0.150
Mississippi	22,850	13,954	8,896	0.062	(0.022)
Arkansas	21,913	18,498	3,415	0.105	0.003
Washington	16,088	11,036	5,052	0.294	(0.079)
Kansas	15,035	11,306	3,729	0.148	(0.012)
Florida	14,284	13,665	619	0.097	(0.004)
Colorado	11,940	10,480	1,460	0.117	(0.021)
Montana	11,549	9,498	2,051	0.068	(0.029)
Oklahoma	11,444	7,518	3,926	0.089	(0.017)
Nebraska	10,333	11,180	(847)	0.154	(0.013)
Oregon	10,218	10,285	(67)	0.174	(0.008)
Connec	9,349	10,029	(680)	0.746	0.049
Louisiana	9,256	9,391	(135)	0.062	0.001
Utah	8,488	6,074	2,414	0.162	(0.017)
South Dakar	8,083	7,647	436	0.093	(0.023)
Mass	7,500	7,500	-	0.875	0.194
Idaho	6,657	4,667	1,990	0.076	(0.022)
Maine	5,429	5,752	(323)	0.206	(0.018)
Wyoming	4,358	3,730	628	0.031	(0.006)
Delaware	4,267	3,882	385	0.317	(0.004)
North Dakota	3,980	6,204	(2,224)	0.074	(0.022)
New Hamp	3,617	3,472	145	0.299	(0.009)
Arizona	3,434	2,413	1,021	0.132	(0.033)
Vermont	2,714	3,586	(872)	0.199	0.004
New Mexico	2,559	2,422	137	0.112	0.001
Nevada	1,613	1,197	416	0.108	0.001
Rhode Island	1,500	1,429	71	0.695	0.020
Alaska	1,029	1,174	(145)	0.067	0.013
DC	395	412	(17)	-	-
Hawaii	135	92	43	-	-

Table 2
C-Value Change 2012 from Mean
With 2012 and 2007 Collision change

State Farm Insurance Agency (2015) uses a measure for the top states where you are likely to get into a deer crash each year. Their data based on actual collisions adjusted by market share against number of insured drivers. West Virginia has been the highest collision state per driver with about a 1 and 41 chance over the last few years, while California is the lowest (State Farm Insurance Agency, 2015). California has the highest numbers of drivers in the nation. This measure is a relative indicator of the number of insured drivers by state.

On the other hand, the chances of an ungulate being hit by a car are extremely high in Massachusetts, California, Rhode Island and Connecticut where the collision rate approaches the harvest rate at 87.5%, 86.4%, 69.5%, and 74.6% respectively. Collision rates are a significant conservation management variable for these states. West Virginia is holding the C-Value steady with very little change, despite the risk to drivers, while white tailed deer population densities declined from 2008 to 2012. The southern states such as North and South Carolina demonstrate both a highest increase in collisions and harvests with the greatest mitigation challenges using harvest management and other strategies.

As seen in Table 2, New Jersey had a decrease in collisions and high C-Value change from 2012 compared to the index. New Jersey has evaluated collisions, on a county and regional basis, based on collisions reported to law enforcement since 2008 (New Jersey Division of Fish and Wildlife, and Transportation Planning Authority, 2015). The number of collisions reported to the local law enforcement is noted as less than half of the actual collisions, and once again the insurance industry data is significantly higher than those collisions reported to state authorities. Interestingly, New Jersey has a state Deer Vehicle Crash Coalition to coordinate the efforts between the Natural Resource and Transportation Divisions. Their natural resource division harvest data defines bow hunting as the highest means for hunting, and they have eliminated antlerless limits for both rifle and bow in selected districts. The resulting C-Value of 059.8% is higher than average. The coordinated efforts between the state divisions, and the prioritization of deer vehicle collision reduction, demonstrates they have effectively reduced the number of collisions from 2007 to 2012, while most states are experiencing an increase. The corresponding index value reflected a positive value for 2012 compared to the index.

The national deer harvest levels have decreased by 5.5% from 7.2 million animals in 2007 to 6.8 million in 2012. In the Report to Congress, a study by Knapp, Putnam and others cited suggests a reduction in population results in decreased collisions (USDOT, 2008 p. 125). In the study by Urbanek, Allen, and Nielsen, (2011), they state, “Urban and suburban deer populations were increasing in most states (75.8%); accordingly, most biologists (97%) believed that urban and suburban deer were a problem in their state,” which indicates a strong consensus for targeting hunting pressure in urban areas.

Hunting efforts are a long term strategy. A New York study by Weckel & Rockwell (2012) found bow hunting less effective than sharpshooting in reducing white-tailed deer to established population density guidelines for forest regeneration because of the movement of white-tailed deer into available habitat. While sharpshooting was more efficient in the short term, the process has to be repeated every few years because of deer migration (Weckel & Rockwell, 2012). The study concludes it may take over 20 years to reach targeted population densities. Long term strategies are necessitated to manage white-tailed deer populations. Sharpshooting may provide temporary reductions for targeted goals, but risks to public safety are minimized with bow hunting.

Hunting as a mitigation method necessitates a long term strategy, but the data suggests from those states with a decreased number of collisions and an increased C-Value for 2012 such as

Michigan, New York, Illinois, Indiana, and New Jersey that targeted hunting pressure reduces deer density and collisions. The C-Value is a broad measure of collision and harvest data, and does not include urban density of human and ungulates variables.

Road Miles, Changes in Collisions, Harvest and Number of Drivers

The analysis is incomplete without the inclusion of the number of road miles per state correlated by deer harvest or density and the resulting collision rate. The Pearson product moment correlated value for number of road miles and deer harvest was high at (.710, 47, p<001) for 2012. Table 3 below is sorted by collisions per mile for each state and demonstrates deer density, collision rates, and includes roadway miles. The top states of Maryland, Pennsylvania and Virginia have particular challenges with both populated roads and deer densities. The C-value distributions for the highest collision per mile states are highest with New Jersey higher than average. The C-value index does not include miles of road, but instead measures the deer density and number of collisions. To include road miles would not isolate the collision variable to harvest and reduction of deer density for mitigation. Collisions per mile is a key characteristic for other mitigation strategies such as fencing.

	Number of Road Miles	Deer Harvest	Harvest/mile	Collisions	Collisions/mi	C-Value (as %)
Maryland	32,321	87,541	2.71	31,300	0.97	33%
Pennsylvania	119,771	343,110	2.86	114,933	0.96	33%
Virginia	74,461	215,240	2.89	56,759	0.76	22%
West Virginia	38,646	132,261	3.42	28,968	0.75	22%
Delaware	6,358	13,302	2.09	4,267	0.67	32%
New Jersey	39,213	49,942	1.27	25,488	0.65	60%
Michigan	122,086	418,012	3.42	77,103	0.63	21%
New York	114,592	242,957	2.12	71,368	0.62	33%
North Carolina	105,869	167,249	1.58	59,270	0.56	29%
South Carolina	65,997	217,854	3.30	36,738	0.56	12%
Ohio	123,247	218,910	1.78	59,154	0.48	27%
Wisconsin	115,018	366,747	3.19	50,341	0.44	12%
Connecticut	21,445	13,421	0.63	9,349	0.44	75%
Georgia	123,546	385,410	3.12	46,512	0.38	11%
Indiana	97,066	136,248	1.40	30,114	0.31	26%
Kentucky	79,220	131,395	1.66	24,517	0.31	17%
Mississippi	75,119	273,126	3.64	22,850	0.30	6%
Minnesota	138,702	186,634	1.35	41,522	0.30	18%
Tennessee	95,492	176,962	1.85	28,158	0.29	14%
Alabama	101,668	266,725	2.62	28,862	0.28	8%
Missouri	131,667	313,254	2.38	37,042	0.28	11%
Illinois	139,498	180,811	1.30	39,218	0.28	22%
District of Colu	1,501	-		395	0.26	0%
Iowa	114,387	115,608	1.01	29,843	0.26	23%
Maine	22,874	24,249	1.06	5,429	0.24	21%
Rhode Island	6,485	2,221	0.34	1,500	0.23	70%
New Hampshire	16,076	11,740	0.73	3,617	0.22	30%
Arkansas	100,082	213,487	2.13	21,913	0.22	11%
Massachusetts	36,303	11,022	0.30	7,500	0.21	87%
Washington	83,743	43,079	0.51	16,088	0.19	29%
Vermont	14,290	13,962	0.98	2,714	0.19	20%
Utah	45,635	47,312	1.04	8,488	0.19	16%
Oregon	59,148	56,370	0.95	10,218	0.17	17%
Wyoming	28,253	120,816	4.28	4,358	0.15	3%
Montana	74,880	119,150	1.59	11,549	0.15	7%
Louisiana	61,635	152,700	2.48	9,256	0.15	6%
Texas	312,911	556,621	1.78	46,537	0.15	7%
California	172,202	33,198	0.19	23,699	0.14	86%
Idaho	48,553	67,950	1.40	6,657	0.14	8%
Colorado	88,415	87,044	0.98	11,940	0.14	12%
Florida	121,759	142,325	1.17	14,284	0.12	10%
Nebraska	93,600	61,723	0.66	10,333	0.11	15%
Kansas	140,513	94,070	0.67	15,035	0.11	15%
Oklahoma	112,808	107,848	0.96	11,444	0.10	9%
South Dakota	82,459	69,797	0.85	8,083	0.10	9%
Alaska	16,675	19,040	1.14	1,029	0.06	7%
Arizona	65,092	20,847	0.32	3,434	0.05	13%
North Dakota	86,851	41,240	0.47	3,980	0.05	7%
Nevada	36,839	15,092	0.41	1,613	0.04	11%
New Mexico	68,384	23,141	0.34	2,559	0.04	11%
Hawaii	4,405	-		135	0.03	0%

Table 3
Collisions, Harvest and Road Miles 2012

The analysis thus far has analyzed trends in ungulate populations and the rates of collisions. To complete the discussion, the final and important variable for wildlife vehicle collision risk analysis is the number of drivers. Figure 5 shows the percentage change in number of drivers, harvest and collisions from 2007 to 2012 by state. The corresponding data for Figure 5 is found on page 45 in Table 4. Most states show an increase in collisions and drivers from 2007 to 2012, but harvest strategies are varied.

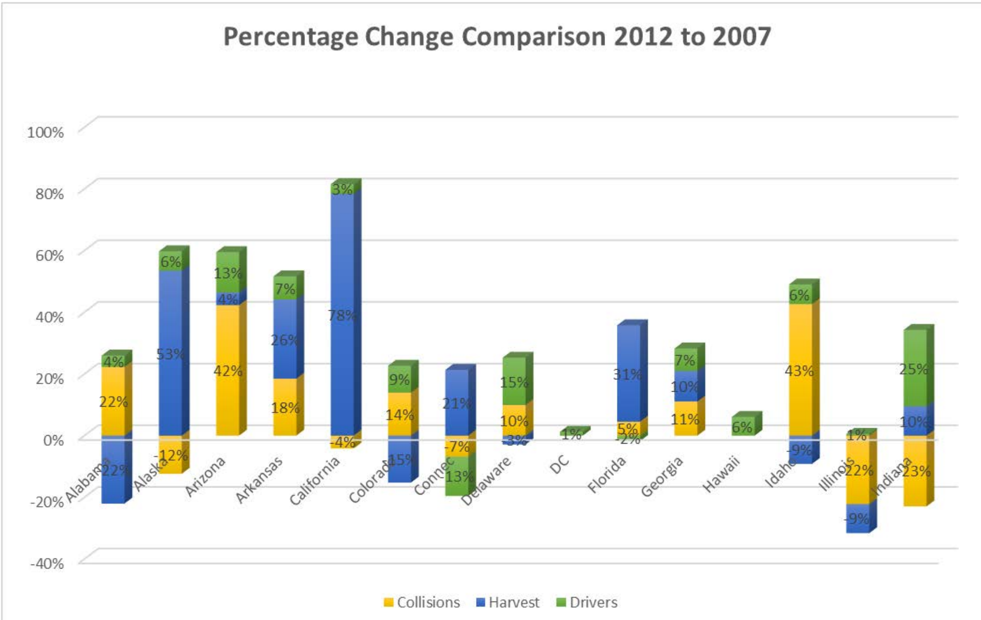

Figure 5.1
Changes in Collisions, Harvest and Number of Drivers

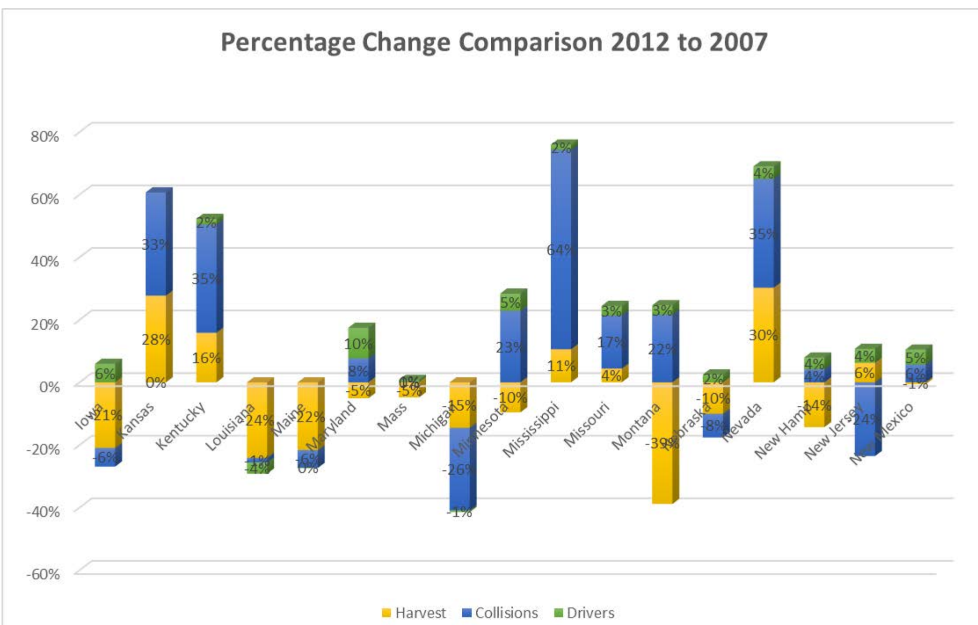

Figure 5.2
Changes in Collisions, Harvest and Number of Drivers

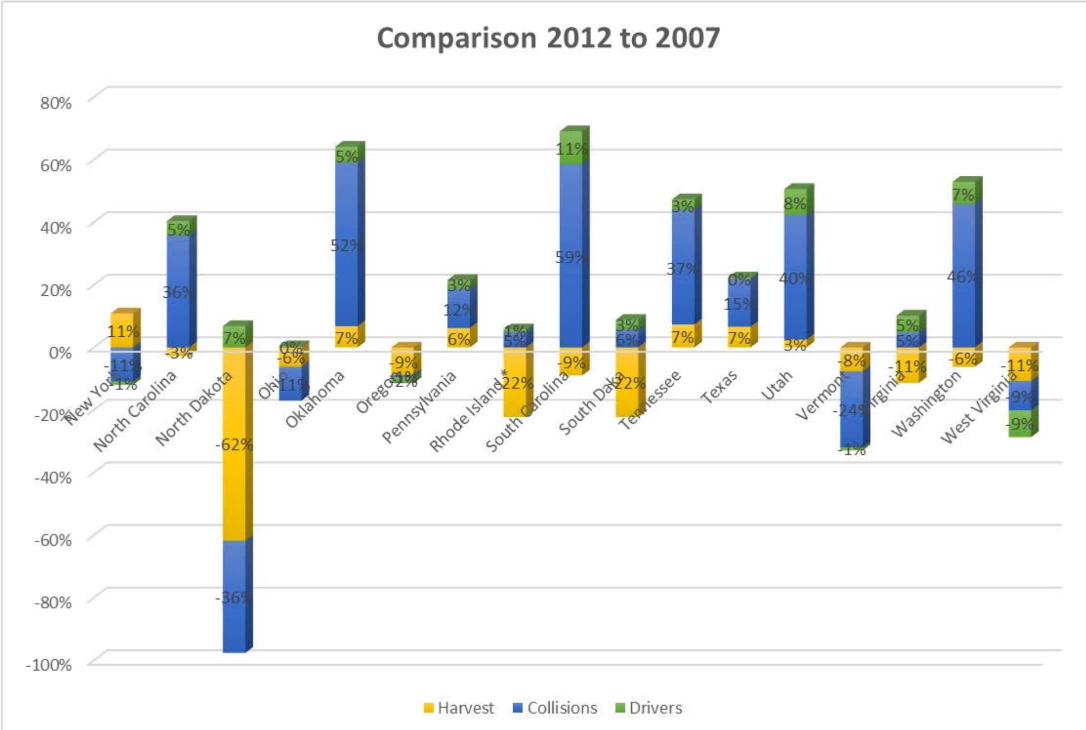

Figure 5.3
Changes in Collisions, Harvest and Number of Drivers

Indiana had the largest increase in drivers at 25% while decreasing collisions by 23% over the five year period. Indiana harvests increased by10%, and their C-Value demonstrated hunting pressure for collisions at 25%. Indiana Department of Natural Resources collects collision data and sets harvest targets by collisions per miles driven. They have a bonus antlerless permit system, and they target hunting by collision occurrences in addition to hunter harvest history, and crop damage reports (Indiana Department of Natural Resources, 2013). Subsequent to the 2012 hunting season, Indiana is seeing a decline in the harvest.

New Jersey, Alaska and Iowa also have an increase in drivers, and declines in collisions. New Jersey has a higher than average C-value, and their state has a collaborative group, the Deer Vehicle Crash Coalition, to coordinate the efforts between the Natural Resource and Transportation Divisions. Alaska's harvest numbers increased, yet their C-value remains low, and their collision per road mile is one of the lowest in the United States. Iowa has a reduction in collisions, and a decrease in harvest totals. Their C-Value is slightly higher than average, and despite an increase in number of drivers, Iowa has decreased collisions, in part by a reduction in deer population, but they also collect data on collision location, install deer crossing signs, and fence along fully controlled access roadways (Iowa Department of Transportation, 2015).

Illinois has a reduction in collisions. In 2008, the Illinois General Assembly enacted a joint task force for deer population control to specifically reduce the number of deer vehicle collisions. The state has monitored the collision rate by vehicle miles driven, and they use a Deer/Vehicle Accident (DVA) rate to set target collision reduction goals on a county basis (Illinois Department of Natural Resources, 2015). This has proven successful with a reduction in collisions. Connecticut's number of drivers decreased significantly, and the C-Value of 74.6% and the harvest increase of 21.3%, all have the combined effect of reducing collisions by 6.8%.

North Dakota and California both have harvest level changes which are significant for resource management. North Dakota has a significant decline in white-tailed and mule deer populations (North Dakota Department of Natural Resources, 2015). California is harvesting at an increasing rate, and seeing a slight decrease in collisions. Both states have an increase in number of drivers.

The states with increased collisions and increased drivers from 2007 to 2012 include South Carolina, Arizona, Delaware and Maryland. Delaware and Maryland have higher than average C-values and collisions have increased, but the collision rate is slightly less than the increase in number of drivers. These two states have high collisions per mile at .97 and .67 respectively.

Mississippi states in their annual deer report, the collision numbers collected from their state reporting systems and State Farm Insurance are both indicating record numbers of collisions.

Their state reporting system is based on observed roadkill by the resource management personnel. Prior to 2012 this data was assembled by district; however, they are now assembling the data statewide. They attribute the collision increase entirely to the record deer density levels (Mississippi Department of Wildlife Fisheries and Parks, 2012). The harvest levels continue to increase in Mississippi, yet their C-Value is lower than most states. Pennsylvania and Michigan are cited by Mississippi as comparable states with high deer densities and collision rates. Pennsylvania's harvest and collision levels continue to increase, while Michigan's are decreasing with the corresponding decrease in collisions.

State	Collisions Change	Harvest Change	Drivers Change	C-Value (as %)
Mississippi	64%	11%	2%	6%
South Carolina	59%	-9%	11%	12%
Oklahoma	52%	7%	5%	9%
Hawaii	47%		6%	0%
Washington	46%	-6%	7%	31%
Idaho	43%	-9%	6%	8%
Arizona	42%	4%	13%	13%
Utah	40%	3%	8%	17%
Tennessee	37%	7%	3%	14%
North Carolina	36%	-3%	5%	29%
Nevada	35%	30%	4%	11%
Kentucky	35%	16%	2%	17%
Kansas	33%	28%	0%	15%
Minnesota	23%	-10%	5%	18%
Alabama	22%	-22%	4%	9%
Montana	22%	-39%	3%	7%
Arkansas	18%	26%	7%	10%
Missouri	17%	4%	3%	11%
Wyoming	17%	-7%	6%	3%
Texas	15%	7%	0%	7%
Colorado	14%	-15%	9%	12%
Pennsylvania	12%	6%	3%	33%
Wisconsin	12%	-29%	0%	13%
Georgia	11%	10%	7%	11%
Delaware	10%	-3%	15%	32%
Maryland	8%	-5%	10%	34%
South Daka	6%	-22%	3%	9%
New Mexico	6%	-1%	5%	11%
Rhode Island *	5%	-22%	1%	73%
Virginia	5%	-11%	5%	22%
Florida	5%	31%	-2%	9%
New Hamp	4%	-14%	4%	31%
Mass	0%	-5%	1%	92%
Oregon	-1%	-9%	-2%	18%
Louisiana	-1%	-24%	-4%	7%
California	-4%	78%	3%	77%
DC	-4%		1%	0%
Maine	-6%	-22%	0%	21%
Iowa	-6%	-21%	6%	24%
Connec	-7%	21%	-13%	71%
Nebraska	-8%	-10%	2%	15%
West Virginia	-9%	-11%	-9%	22%
New York	-11%	11%	-1%	32%
Ohio	-11%	-6%	0%	27%
Alaska	-12%	53%	6%	6%
Illinois	-22%	-9%	1%	21%
Indiana	-23%	10%	25%	25%
New Jersey	-24%	6%	4%	58%
Vermont	-24%	-8%	-1%	19%
Michigan	-26%	-15%	-1%	20%
North Dakota	-36%	-62%	7%	8%

Table 4
Combined Analysis
Comparative 2007 and 2012. Sorted by Change in Collisions

Quantifiable Analysis of Data and Cause and Effect Relationships and Limitations

This density based trend analysis has limitations for needed mitigation projects on a localized basis. It does not account for the significant variables to be incorporated into transportation and conservation management such as occurrence location and landscape use characteristics. A regional study in Clark County of Northern Virginia over a two year period demonstrated landscape characteristics of open fields for pasture and agriculture, and traffic volume, demonstrated a higher correlated value of collisions than harvest data. While the harvest rate was low, this exurban - urban county example demonstrates the need for localized collision location data to determine the appropriate mitigation strategy (McShea, Stewart, Kearns, Liccioli & Kocka, 2008). The urbanization of deer over the last thirty years is discussed as a significant factor for collision rates based on the high consensus of wildlife biologists (Urbanek, Allen, & Nielsen, 2011). Nationally, the urban deer problem is addressed as a significant variable (Urbanek, Allen, & Nielsen, 2011). This paper demonstrates state collision trends since the SAFELU Act of 2005, provides state examples for targeted hunting pressures, and subsequent research and mitigation strategies for wildlife vehicle collisions. As demonstrated by this analysis, with less than a 10% decrease in harvests from 2007 to 2012, harvesting and hunting pressures will be a long term effort for mitigation and collision location data is needed.

The data limitations using the insurance industry data, which is significantly higher than the amounts reported by the states, is indicative of the collision data collection challenges for the states. Many collisions are simply not reported to the local law enforcement agencies, or the deer moves away from the road side, and the carcass is not collected. The insurance data is comprehensive and based on actual collision transactions; however, the market share adjustments may have a significant effect on analysis results for those states where State Farm Insurance is not the majority shareholder.

The use of harvest data as a density indicator has limitations. It eliminates extra variables and assumptions for the analysis, and is once again based on actual harvest occurrences adjusted for reporting variances for many states. Two states reported increases in harvest, and decreases in collisions. This may not be indicative of regional deer population densities, or collisions, if rates are based on a low market share, but both states have targeted the high collision areas with hunting pressures. The collision location data is collected by these states, and the harvest efforts may be impacting densities disproportionately within the states. Indiana is showing a state wide decline in deer population for years subsequent to this analysis (Indiana Department of Natural Resources, 2015).

Cost of Collisions

The loss of life in wildlife vehicle collisions has resulted in 1,173 human lives lost from 2008 to 2013 or an average of 195 per year (Insurance Institute for Highway Safety, Highway Data Loss Institute, 2015). The highest deer density states: Texas, Wisconsin, Michigan, Pennsylvania, Minnesota and Georgia, account for approximately one third of these deaths. Wisconsin Department of Transportation, (2012) reported that 69.9% of the crashes involving wildlife and motorcycle drivers reported injuries, and in 2012, 13 of the 14 fatalities were deer collisions with motorcycle drivers.

During the period reviewed, financial losses are increasing disproportionally to other insured claims. The wildlife collision claims have increased over the last four years by 7.9%, while similar claims have decreased by 8.5% (State Farm Insurance Agency, 2015). From an actuarial perspective, a sudden increase in collisions for 2010-2011 presents financial and managerial challenges for the industry. This trend is exacerbated by the total cost to drivers and the insurance companies. The average cost of a collision with an ungulate is $3,805, ($3,305 plus a $500 deductible) (State Farm Insurance Agency, 2015). In 2012, this equated to over $4.8 billion in losses, and does not include uninsured losses.

Schwabe, Schumann, & Tonkovich (2002), in their paper on mitigation and hunting, make a very interesting point on the cost benefit analysis of deer collisions. The opportunity cost of foregone revenues for state wildlife conservation programs in lost licensing and harvest fees is a considerable variable for the economic losses for white-tailed deer lost to collisions that could have been ethically harvested for economic benefit for state programs and sustainable sustenance. Hunting efforts targeted at high density and collision rate areas will increase the hunter success rates with a corresponding increase in revenues.

The cost of monitoring collisions regionally is an important part of the discussion. This research has demonstrated the challenges for localized regional data collection strategies for identifying not only collision data for targeted hunting, but also for “hotspot” identification for transportation projects. The costs include man hours to collect carcasses, file reports, and observation hours. The cost of data collection could be in part offset with better hunting success rates. Just a 20% reduction in collisions would result in over $1 billion dollars of savings or $20 million per state. The transportation departments will have continued challenges for “hotspot” identification, but collaboration between transportation departments and wildlife expertise within the natural resource departments will facilitate mitigation strategies. The insurance industry has opportunities for increased profitability and decreased risk by expanding the collision data to include highway location data in claims reports. Because the insurance data is transaction based data, this means of collision data is very reliable if all major insurers participate to generate actual collision occurrences including species type and highway location information.

VI. DISCUSSION

Ecological Compatibility

Clearly, the high collision rates, quantified losses, and lack of efficiencies in resource use demonstrate the extent of ecological compatibility. Mitigation is not prioritized by financial incentives. The Report to Congress in 2008 recognized the need for improved data on collisions and collaboration between conservation and transportation disciplines at both the state and national level (USDOT, 2008). The study by Patricia White, Julia Michalak and Jeff Lerner in 2007, *Linking Conservation and Transportation*, evaluated existing collaborative relationships, and determined a need for increased collaboration between the various stakeholders. This trend analysis demonstrates states such as New Jersey are successfully mitigating wildlife vehicle collisions with a collaborative effort between state conservation and transportation divisions. Nationally, the collision rate has increased from 2008 to 2012, and millions of animals are killed and wasted on our highways.

Ethical and Motivational Considerations for Mitigation

During the review of the state harvest reports, Indiana's (2013) Deer Season Summary report quoted a hunter's perspective on ecological compatibility and an ethical basis in coexisting with wildlife:

> "I do not hunt for the joy of killing but for the joy of living, and the inexpressible pleasure of mingling my life, however briefly, with that of a wild creature that I respect, admire, and value." John Madson, *Out Home,* 1979

Madson expresses the joy of living so well, yet, the mingling of life necessitates taking of life, but it is done with respect, admiration and value. The cultural carrying capacity of the white tailed deer is at low levels. In a public survey conducted by this author for establishment of an urban deer management program, community members commented, "I like the deer, just not so many." We have to question if the abundance of deer is devaluing the resource? The collision rate indicates our incompatibility within our natural world by our lack of value for this abundant resource. This is evident with continued high collision rates, public attitudes of intolerance, and a low cultural carrying capacity. We have the cost justification for mitigation, but not the attitude and will expressed by Mr. Madson in this quote to coexist with wildlife in a respectful and sustainable manner.

Albert Schweitzer (1875-1965), a theologian, physician, philosopher, and Nobel Peace Prize winner developed an ethical argument for the reverence of life. This reverence for life discussion compels us to consider the conflict of destroying the will to live and the suffering of other life for our own existence. Schweitzer's discussion states, "The ethic of reverence for life recognizes no such thing as a relative ethic. The maintenance and enhancement of life are the only things it counts as being good in themselves" (Schweitzer, 1923). Our reckless automobile use is an excellent example of our lack of reverence for life. Efforts to educate the public on collision avoidance exist nationally by state transportation departments and with State Farm's press release on the annual collision rate do demonstrate efforts to improve our coexistence and moral obligations.

For purposes of this discussion, the automobile is referred to as a predator, but it is recognized the human is the actual predator. The lack of an adaptive response for wildlife to instinctively avoid roadways and responding to the human-automobile as a predator is tragic phenomena. Why is there not a learned response for wildlife to avoid roadways and automobiles? In conversations with urban hunters, they describe driving in close proximity of repeatedly used hunt stand locations, and the white tailed deer respond and run at the sight of the automobile. The collision rate increase during the rutting period in October, November and December is yet another unknown response of white tailed deer to automobiles. A study by the Texas Parks and Wildlife Department, conducted throughout the state over a three year period, found the bucks lost their sense of caution during the rut. The information was presented for hunters to increase their success rates for hunting during the rut (Traweek, Wardroup, Williams & Young, 1996).

The combined effect of the deer movement changes during the fall and the effect on drivers with shortened daylight hours and Day Light Savings Time change occurring concurrently represents challenges for both humans and white tailed deer. The combined deer and human behavior responses to changing environmental conditions and stresses contribute to collision risks.

Adaptive Management: Changes and Responses

Wildlife may not be demonstrating adaptive responses, but our response to the “Eco-logical” approach presented by the United States Department of Transportation and Janice Brown (2006) continues to be a significant cultural approach for integrated transportation and natural resource planning. The Eco-logical approach emphasizes a feedback loop from planning, to mitigation and measurement. The program incorporates the discipline of adaptive management to revise our strategies with changing conditions and information (USDOT, 2015). It follows the adaptive management principals of integrated planning, mitigation, and performance measurement for revised strategies with changing conditions (Johnson, 1999).

The information presented here describes trends in wildlife vehicle collisions since the Eco-logical approach was introduced in 2006. From 2008 to 2012, the collision rates have increased, while the harvest as population indicator has decreased nationally. The number of drivers has also increased from 211 to 241 million and the losses from wildlife collisions are disproportionately higher than other claims (State Farm Insurance Agency, 2015). There are states that are preforming better with decreased collisions with various ungulate densities. Another significant change since the introduction of the Eco-logical report is the continued increase in urban wildlife. Reports on the 2014 deer harvest are reporting a continuing decline in hunter success rates and harvests, and state resource departments are responding to this information with hunt limit adjustments for population management strategies (Deerfriendly.com, 2015). The balance of abundant wildlife populations and acceptable cultural carrying capacity is difficult to manage.

New technological advances now in development have tremendous opportunities for cost effective mitigation and data collection improvements. These are timely developments because of the increased budgetary constraints under the current transportation legislation, Moving Ahead for Progress in the 21st Century Act (MAP-21), (USDOT, 2015). These developments include: geospatial tools for data sharing and increased collaboration (USDOT, 2014), handheld smartphone technology for collision collection data recording and reporting (Olsen, et al, 2014), and infrared thermal camera sensors for automobiles to alter driver behavior for wildlife in or around roadways (Zhou, 2012).

Summary

The public needs quantitative and qualitative justification for mitigation implementation in high collision risk regions. The information provided here demonstrates significant quantitative and qualitative consequences and ecological incompatibility that wildlife vehicle collisions have on public health, productivity, and social and economic welfare. This paper provided state trend analysis for collisions from existing information. The existing information, while broad, is consistently reported and provides a comprehensive base for trends in wildlife vehicle collisions. Enhanced data and informational improvements are necessitated for targeted hunting in high collision risk regions, and for "hotspot" collision location for transportation planning. The analysis identified states whose collision rates decreased while national rates increased. While not all of the cause and effect variables contributing to the changes are quantified, targeted harvesting for high density wildlife areas was demonstrated successful for selected states.

Mitigation of collisions using harvesting strategy will be a long term endeavor based on historical trends. The cost of collisions to the insured and the insurers will be lessened if collisions are reduced with targeted hunting. Opportunities for economic benefit exist for state wildlife resource departments with increased hunt success rates and corresponding revenues. New driver and automobile safety improvements, and highway design offer promising means to drastically reduce wildlife vehicle collisions, and have tremendous potential to mitigate collisions faster than harvesting alone (Zhou, 2012). The development of mitigation strategies using fencing are also warranted for implementation (Nichols, Huijser, Ament, Dayan, &

Unnikrishnan, 2014). Wildlife bridges and automobile tunnels are demonstrated as effective mitigation means, and improve habitat connectivity (ARC, 2015). And, finally and most importantly, collaborative efforts by conservation and transportation professionals to address this continuing problem will result in development of the best conservation and mitigation strategies.

Recommendations

This collision data issue has been discussed as a road block for adequate mitigation from research from 2005 to the present and in this paper. A federally funded program for improved collision data based on insurance claim data is needed. In a presentation to the State Association of Transportation Professionals, for development of Eco-logical transportation plans, the presenter cites four basic requirements for Eco-logical transportation planning: “predictability, connectivity, conservation and transparency” (Williams, 2014). Without collision data, predictability is impossible to determine. Transportation planners currently select targeted roadways for collision risk studies. Expanded collision data is needed for collision locations for all roadways. State Farm Insurance has provided an excellent basis for the type of data available, and because it is transaction based, it has merit. This analysis provided information for trends in collisions; however, there is a continued need for collision data for transportation planners to identify specific high risk roadways from actual collision location data to target roadway improvements, and for natural resource managers to target hunting efforts as a mitigation strategy and for conservation. A national program would require insurance claimants to include species, road and mile marker data at a minimum. Ideally, it would be a voluntary compliance program for insurer participation. This would insure the transportation planners and natural resource managers have the necessary data for collision rates and locations needed to for mitigation and conservation strategies.

States that demonstrated an improvement in the wildlife vehicle collision rates were all found to collect collision occurrence data, including locations, in order to mitigate primarily using targeted hunting strategies. This data underestimates the collision occurrences, because of unreported collisions. National data from the insurance industry is needed by the states to enhance the local expertise in their efforts to reduce collision rates. A collision reduction was found with reduced ungulate densities. Without local collision occurrence location data, the strategy to reduce collisions through targeted harvesting is not available. This is occurring in many states. The national data from the insurance industry needs to evaluated further and expanded to eliminate market share adjustments. Collisions are underreported, and part of the underreporting is because many collisions are not reported to local law enforcement. This is further justification for comprehensive insurance data to be disseminated to the states.

Secondly, increased collaboration between wildlife biologists, natural resource departments and transportation planners is essential because of the complexities of the problems and the diverse skills and expertise needed to mitigate collisions. Geospatial tools offer an excellent medium for information sharing across the diverse disciplines; however, the tools are only as good as the information inputs, and clearly, this is the road block for mitigation strategy development.

A trend analysis, such as this, should be further developed for program assessment for adaptive management and Eco-logical approaches for program analysis. The trend analysis calls for additional data, on both temporal and spatial scales, to be expanded to quantify cause and effect variables and relationships. Specifically, the index benchmark values could be based on an extended historical period, and be calculated with a moving average for each year added. The number of drivers per mile and collision location data would provide the needed density characteristics for correlating both the ungulate densities and human population movements. Illinois has provided an example of using collision index to set goals and targets regionally for reducing collisions (Illinois Department of Natural Resources, 2008, p. 15).

Harvesting and hunting data presented here demonstrates the high levels of ungulate populations and the long term trends and efforts to reduce the white tailed deer population levels. Hunting as a mitigation strategy was demonstrated to be effective in some states by this analysis in just five years. The technological developments discussed have the potential to reduce collision risks over a shorter period, but public support is needed to reduce white-tailed deer densities in high collision areas.

Finally, the public needs comprehensive information on the occurrence rates of wildlife vehicle collisions, for both increased public safety and for increased mitigation program support. The purpose of this paper is to address the three research questions to qualitatively and quantitatively define the overall extent of wildlife vehicle collisions. The data and trend analysis presented provide information for public awareness for increased mitigation programs and improved public safety. The questions of economic loss and loss of life that are attributable to wildlife vehicle collisions, and the level of predation, are qualitatively defined. Our current transportation systems are not ecologically compatible with our natural world, and wildlife vehicle collisions are a clear indication of this incompatibility. Continued mitigation efforts resulting from enhanced data will increase our ability to live sustainably within our natural world while enjoying all the benefits of our current transportation means.

Concept design for the winning entry in the 2010 ARC International Wildlife Crossing Infrastructure Design Competition by HNTB with Michael Van Valkenburgh & Associates.
(Source: Arc.org)

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APPENDIX 1

Harvest Report Summary 2007 to 2013

	2007	2008	2009	2010	2011	2012	2013
Alabama	342,000	356,000	289,000	337,658	254,800	266,725	269,960
Alaska	13,505	16,876	17,158	18,837	25,030	19,040	18,888
Arizona	20,120	19,952	23,100	17,217	21,367	20,847	21,536
Arkansas	169,853	184,991	187,074	186,166	192,511	213,487	213,215
California	18,607	28,999	28,106	27,077	29,280	33,198	31,429
Colorado	102,647	90,605	92,556	95,223	88,557	87,044	83,513
Connec	11,062	12,682	11,774	12,183	12,897	13,421	12,579
Delaware	13,689	13,926	12,400	14,883	13,559	13,302	14,263
DC	-	-	-	-	-	-	-
Florida	108,437	180,000	151,679	176,791	136,189	142,325	102,626
Georgia	350,715	398,917	398,668	464,003	411,481	385,410	453,952
Hawaii	-	-	-	-	-	-	-
Idaho	74,801	68,112	59,686	63,675	61,514	67,950	67,578
Illinios	199,610	188,901	189,634	182,270	181,451	180,811	148,614
Indiana	124,427	129,748	132,752	134,004	129,018	136,248	125,635
Iowa	146,215	142,194	136,504	127,094	121,407	115,608	99,400
Kansas	73,681	80,490	87,047	89,038	97,938	94,070	89,664
Kentucky	113,436	120,610	113,585	110,376	119,653	131,395	144,404
Louisianna	201,200	158,300	144,300	153,500	133,000	152,700	166,200
Maine	30,936	23,302	20,440	22,456	21,421	24,249	27,703
Maryland	92,208	100,436	100,663	98,663	98,029	87,541	95,863
Mass	11,576	11,217	10,381	10,699	11,081	11,022	11,566
Michigan	488,984	489,922	444,231	417,850	422,014	418,012	385,302
Minnesota	206,434	221,837	194,186	207,313	192,331	186,634	172,781
Missisippi	247,024	249,993	285,644	322,287	272,275	273,126	263,705
Missouri	300,150	283,470	301,187	276,650	293,527	313,254	252,574
Montana	195,190	171,818	159,275	145,708	122,768	119,150	107,021
Nebraska	68,601	80,694	78,884	89,065	87,788	61,723	49,517
Nevada	11,782	10,170	10,286	10,795	10,059	15,092	14,872
New Hamp	13,701	11,046	10,514	9,905	11,251	11,740	12,668
New Jersey	47,017	53,260	52,784	55,404	50,109	49,942	51,595
New Mexico	23,278	21,948	23,205	18,083	19,170	23,141	22,752
New York	219,141	222,979	222,798	230,100	228,359	242,957	243,567
North Carolina	171,956	176,297	169,273	175,157	173,553	167,249	188,130
North Dakato	107,739	91,873	75,205	73,339	50,001	41,240	28,566
Ohio	233,212	252,017	261,260	239,475	219,748	218,910	191,503
Oklahoma	101,000	111,427	116,175	109,314	112,862	107,848	88,009
Oregon	61,739	60,832	56,867	54,309	57,244	56,370	58,221
Pennslyvania	323,070	335,850	308,920	316,420	336,200	343,110	352,920
Rhode Island	2,856	2,937	2,422	2,569	2,413	2,221	2,502
South Carlolina	239,193	248,778	231,319	222,696	226,458	217,854	225,806
South Dakato	89,735	92,582	90,453	88,021	95,276	69,797	54,064
Tennessee	164,856	164,414	161,765	162,827	167,705	176,962	168,524
Texas	521,993	628,976	571,103	654,084	582,854	556,621	633,963
Utah	46,134	39,506	43,937	41,871	33,502	47,312	47,910
Vermont	15,108	17,635	15,838	16,011	12,368	13,962	14,305
Virginia	242,792	256,382	259,147	222,074	233,104	215,240	244,440
Washington	45,916	41,944	41,874	40,451	36,390	43,079	40,903
West Virginia	148,000	163,600	155,214	106,499	135,696	132,261	150,266
Wisconsin	518,573	451,885	329,103	336,871	347,711	366,747	342,631
Wyoming	130,448	126,763	133,536	134,413	122,854	120,816	106,722
Totals	7,204,347	7,407,093	7,012,912	7,121,374	6,815,773	6,808,763	6,714,327

For: white tailed deer, roe deer, mule Deer, sitka deer, pronghorn antelope, elk, moose, big horn sheep, caribou
(Source: Respective State Harvest Reports and deerfriendly.com)

APPENDIX 2

Wildlife Vehicle Collisions by State

July 1 to June 30	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013
ALABAMA	23,605	22,783	24,971	23,153	27,043	28,862
ALASKA	1,174	1,152	1,306	1,227	1,345	1,029
ARIZONA	2,413	2,311	2,413	2,134	3,497	3,434
ARKANSAS	18,498	18,974	20,710	16,961	22,271	21,913
CALIFORNIA	24,716	23,434	22,664	21,219	21,694	23,699
COLORADO	10,480	10,502	9,859	9,826	11,897	11,940
CONNECTICUT	10,029	10,256	9,000	7,023	9,333	9,349
DELAWARE	3,882	4,294	4,350	4,230	4,767	4,267
DC	412	416	500	357	492	395
FLORIDA	13,665	14,361	14,446	13,135	14,335	14,284
GEORGIA	41,874	43,673	41,749	41,009	46,096	46,512
HAWAII	92	100	68	142	134	135
IDAHO	4,667	4,202	4,167	4,352	5,873	6,657
ILLINOIS	50,380	42,844	37,816	33,218	43,810	39,218
INDIANA	39,066	35,522	34,776	31,108	33,014	30,114
IOWA	31,737	32,427	29,657	27,773	32,313	29,843
KANSAS	11,306	11,902	11,747	10,618	17,010	15,035
KENTUCKY	18,214	17,814	18,202	18,090	23,995	24,517
LOUISIANA	9,391	10,000	10,394	8,437	9,943	9,256
MAINE	5,752	4,258	4,669	4,103	4,924	5,429
MARYLAND	29,075	31,936	31,888	32,675	34,819	31,300
MASSACHUSETTS	7,500	12,052	10,333	11,333	8,750	7,500
MICHIGAN	104,676	104,561	101,174	78,304	87,277	77,103
MINNESOTA	33,799	30,479	32,059	33,218	43,565	41,522
MISSISSIPPI	13,954	14,327	14,738	13,489	21,859	22,850
MISSOURI	31,667	31,774	31,347	28,096	37,292	37,042
MONTANA	9,498	9,103	8,963	7,959	12,183	11,549
NEBRASKA	11,180	12,261	12,174	12,283	13,254	10,333
NEVADA	1,197	976	1,128	984	1,406	1,613
NEW HAMPSHIRE	3,472	3,140	3,443	2,894	3,705	3,617
NEW JERSEY	33,342	34,388	31,639	30,866	28,291	25,488
NEW MEXICO	2,422	2,189	2,250	2,144	2,694	2,559
NEW YORK	80,022	74,958	77,582	72,307	70,658	71,368
NORTH CAROLINA	43,658	42,126	43,844	46,652	58,585	59,270
NORTH DAKOTA	6,204	5,215	5,192	4,440	5,294	3,980
OHIO	66,353	67,331	65,753	60,200	62,711	59,154
OKLAHOMA	7,518	9,333	9,382	8,459	12,880	11,444
OREGON	10,285	10,300	9,968	8,809	10,729	10,218
PENNSYLVANIA	102,166	105,843	102,165	101,299	119,511	114,933
RHODE ISLAND	1,429	1,833	2,167	1,667	2,000	1,500
SOUTH CAROLINA	23,174	23,035	23,215	23,337	32,585	36,738
SOUTH DAKOTA	7,647	8,056	7,879	7,420	9,248	8,083
TENNESSEE	20,612	19,891	20,432	20,039	26,990	28,158
TEXAS	40,378	43,432	38,438	38,067	49,984	46,537
UTAH	6,074	5,729	6,333	6,190	7,490	8,488
VERMONT	3,586	3,380	3,183	2,414	2,686	2,714
VIRGINIA	54,135	48,303	51,990	48,658	58,354	56,759
WASHINGTON	11,036	10,773	10,441	10,181	14,373	16,088
WEST VIRGINIA	31,967	36,089	32,472	25,175	31,588	28,968
WISCONSIN	45,008	43,392	42,597	42,261	52,091	50,341
WYOMING	3,730	3,549	3,533	3,796	4,396	4,358

(Source: State Farm Insurance Agency, 2015)

APPENDIX 3

Collision Value (C-Value) Index by State

	2007	2008	2009	2010	2011	2012	Mean	2012 Change from Mean
Alabama	0.069	0.064	0.086	0.069	0.106	0.108	0.084	-0.024
Alaska	0.087	0.068	0.076	0.065	0.054	0.054	0.067	0.013
Arizona	0.120	0.116	0.104	0.124	0.164	0.165	0.132	-0.033
Arkansas	0.109	0.103	0.111	0.091	0.116	0.103	0.105	0.003
California	1.328	0.808	0.806	0.784	0.741	0.714	0.864	0.150
Colorado	0.102	0.116	0.107	0.103	0.134	0.137	0.117	-0.021
Connec	0.907	0.809	0.764	0.576	0.724	0.697	0.746	0.049
Delaware	0.284	0.308	0.351	0.284	0.352	0.321	0.317	-0.004
DC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Florida	0.126	0.080	0.095	0.074	0.105	0.100	0.097	-0.004
Georgia	0.119	0.109	0.105	0.088	0.112	0.121	0.109	-0.012
Hawaii	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Idaho	0.062	0.062	0.070	0.068	0.095	0.098	0.076	-0.022
Illinios	0.252	0.227	0.199	0.182	0.241	0.217	0.220	0.003
Indiana	0.314	0.274	0.262	0.232	0.256	0.221	0.260	0.039
Iowa	0.217	0.228	0.217	0.219	0.266	0.258	0.234	-0.024
Kansas	0.153	0.148	0.135	0.119	0.174	0.160	0.148	-0.012
Kentucky	0.161	0.148	0.160	0.164	0.201	0.187	0.170	-0.017
Louisianna	0.047	0.063	0.072	0.055	0.075	0.061	0.062	0.001
Maine	0.186	0.183	0.228	0.183	0.230	0.224	0.206	-0.018
Maryland	0.315	0.318	0.317	0.331	0.355	0.358	0.332	-0.025
Mass	0.648	1.074	0.995	1.059	0.790	0.680	0.875	0.194
Michigan	0.214	0.213	0.228	0.187	0.207	0.184	0.206	0.021
Minnesota	0.164	0.137	0.165	0.160	0.227	0.222	0.179	-0.043
Missisippi	0.056	0.057	0.052	0.042	0.080	0.084	0.062	-0.022
Missouri	0.106	0.112	0.104	0.102	0.127	0.118	0.111	-0.007
Montana	0.049	0.053	0.056	0.055	0.099	0.097	0.068	-0.029
Nebraska	0.163	0.152	0.154	0.138	0.151	0.167	0.154	-0.013
Nevada	0.102	0.096	0.110	0.091	0.140	0.107	0.108	0.001
New Hamp	0.253	0.284	0.327	0.292	0.329	0.308	0.299	-0.009
New Jersey	0.709	0.646	0.599	0.557	0.565	0.510	0.598	0.087
New Mexico	0.104	0.100	0.097	0.119	0.141	0.111	0.112	0.001
New York	0.365	0.336	0.348	0.314	0.309	0.294	0.328	0.034
North Carolina	0.254	0.239	0.259	0.266	0.338	0.354	0.285	-0.069
North Dakato	0.058	0.057	0.069	0.061	0.106	0.097	0.074	-0.022
Ohio	0.285	0.267	0.252	0.251	0.285	0.270	0.268	-0.002
Oklahoma	0.074	0.084	0.081	0.077	0.114	0.106	0.089	-0.017
Oregon	0.167	0.169	0.175	0.162	0.187	0.181	0.174	-0.008
Pennslyvania	0.316	0.315	0.331	0.320	0.355	0.335	0.329	-0.006
Rhode Island *	0.500	0.624	0.895	0.649	0.829	0.675	0.695	0.020
South Carlolina	0.097	0.093	0.100	0.105	0.144	0.169	0.118	-0.051
South Daka	0.085	0.087	0.087	0.084	0.097	0.116	0.093	-0.023
Tennessee	0.125	0.121	0.126	0.123	0.161	0.159	0.136	-0.023
Texas	0.077	0.069	0.067	0.058	0.086	0.084	0.074	-0.010
Utah	0.132	0.145	0.144	0.148	0.224	0.179	0.162	-0.017
Vermont	0.237	0.192	0.201	0.151	0.217	0.194	0.199	0.004
Virginia	0.223	0.188	0.201	0.219	0.250	0.264	0.224	-0.040
Washington	0.240	0.257	0.249	0.252	0.395	0.373	0.294	-0.079
West Virginia	0.216	0.221	0.209	0.236	0.233	0.219	0.222	0.003
Wisconsin	0.087	0.096	0.129	0.125	0.150	0.137	0.121	-0.016
Wyoming	0.029	0.028	0.026	0.028	0.036	0.036	0.031	-0.006