Report No. FHWA-ICT-25-006

Understanding Wildlife-Vehicle Collisions in Illinois

Kirk W. Stodola
Noah I. Finney
Peg A. Gronemeyer
Lauren C. Scopel

ICT Project R27-SP70

June 2025

ISSN: 0197-9191
ICT Series Report No. 25-006
https://doi.org/10.36501/0197-9191/25-006

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA-ICT-25-006	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle Understanding Wildlife-Vehicle Collisions in Illinois		**5. Report Date** June 2025 **6. Performing Organization Code** N/A
7. Authors Kirk W. Stodola, Noah I. Finney, Peg A. Gronemeyer, and Lauren C. Scopel (https://orcid.org/0000-0002-1292-7335)		**8. Performing Organization Report No.** ICT-25-006 UILU-2025-2006
9. Performing Organization Name and Address Illinois Center for Transportation Department of Civil and Environmental Engineering University of Illinois Urbana-Champaign 205 North Mathews Avenue, MC-250 Urbana, IL 61801		**10. Work Unit No.** N/A **11. Contract or Grant No.** R27-SP70
12. Sponsoring Agency Name and Address Illinois Department of Transportation (SPR) Bureau of Research 126 East Ash Street Springfield, IL 62704		**13. Type of Report and Period Covered** Final Report 10/1/24–6/30/25 **14. Sponsoring Agency Code**
15. Supplementary Notes Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. https://doi.org/10.36501/0197-9191/25-006		

16. Abstract

Wildlife-vehicle collisions (WVCs), particularly those involving deer, pose significant risks to public safety, economic stability, and biodiversity. This review and analysis highlight key contributing factors, including habitat fragmentation, road design, vehicle speed, and environmental conditions, which collectively increase the likelihood of WVCs. This review identifies specific locations in Illinois where WVCs are most common and the landscape features that are attributed to them. The review also identifies a range of mitigation strategies that have been implemented with varying degrees of success. Engineering solutions, such as wildlife fencing, overpasses, and underpasses, have proven effective in reducing collisions by guiding animal movement. Additionally, driver-focused interventions, including improved signage, road lighting, and public awareness campaigns, can play a crucial role in reducing WVC risks. Emerging technologies, such as real-time vehicle-based detection systems and road-integrated warning mechanisms, offer promising advancements in collision prevention. To further reduce WVCs, this review recommends integrating wildlife conservation efforts into transportation planning, ensuring that mitigation strategies are proactively incorporated into infrastructure development. Public education and driver awareness programs could be expanded, particularly in high-risk areas, to encourage safer driving behaviors. Finally, this review recommends developing a standardized approach for collecting data on WVCs for non-deer species. Roadways may pose a significant threat to the population health of many species of conservation concern, yet little information exists on the locations and factors influencing their occurrence. By adopting a proactive, interdisciplinary approach, stakeholders can enhance both human safety and wildlife conservation while addressing the increasing challenges posed by WVCs.

17. Key Words	**18. Distribution Statement**
Wildlife-Vehicle Collisions, Wildlife Crossings, Deer, Animals, Collision Mitigation, Accident Analysis, Accident Data, Accident Locations	No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified	37	N/A

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

ACKNOWLEDGMENT, DISCLAIMER, MANUFACTURERS' NAMES

This publication is based on the results of **ICT-R27-SP70: Understanding Wildlife-Vehicle Collisions in Illinois**. ICT-R27-SP70 was conducted in cooperation with the Illinois Center for Transportation; the Illinois Department of Transportation; and the U.S. Department of Transportation, Federal Highway Administration.

Members of the Technical Review Panel (TRP) were the following:

- Bradley Daugherty, TRP Chair, Illinois Department of Transportation
- Greg Larson, Illinois Department of Transportation
- Anna Lopez, U.S. Fish and Wildlife Service
- John Senger, Illinois Department of Transportation
- Darien Siddall, Federal Highway Administration

EXECUTIVE SUMMARY

Wildlife-vehicle collisions (WVCs) are a public safety, economic, and ecological concern. These incidents, particularly those involving deer, constitute a significant percentage of total vehicle collisions and have increased in recent decades. Various factors contribute to the growing prevalence of WVCs, including expanding road networks, rising traffic volumes, and growing wildlife populations. Seasonal and temporal patterns indicate that collisions peak during autumn and are more likely to occur between dusk and dawn, aligning with wildlife movement behaviors and reduced driver visibility.

Several contributing factors heighten the risk of WVCs. Habitat fragmentation and land-use changes force wildlife to navigate across roadways, increasing their exposure to vehicle traffic. Additionally, road design, vehicle speed, and driver behavior play pivotal roles in collision likelihood, with areas with limited visibility being particularly prone to accidents. Environmental conditions such as adverse weather, poor lighting, and dense roadside vegetation further exacerbate the risks by reducing reaction times and obscuring animal crossings.

The economic and ecological impacts of WVCs are profound. Deer-vehicle collisions alone account for billions of dollars in damages annually, including costs associated with vehicle repairs, medical expenses, insurance claims, and lost productivity. Beyond financial burdens, these collisions harm wildlife populations—contributing to mortality rates, genetic isolation, and broader ecosystem disruptions. The increasing frequency of such incidents highlights the urgency of implementing effective mitigation strategies.

A range of mitigation strategies have been explored and implemented to address the growing problem of WVCs. Engineering solutions such as wildlife fencing, overpasses, and underpasses have proven effective in directing wildlife away from roadways and reducing collisions. Driver-focused interventions—including improved signage, increased road lighting, and public awareness campaigns—have also helped enhance driver alertness and response times. Emerging technologies such as vehicle-based detection systems and road-integrated warning mechanisms offer additional promising avenues for reducing collision risks by providing real-time alerts and enhancing driver decision-making.

Despite these advancements, several research gaps remain. Improved data collection, especially for non-ungulate species, is needed to refine WVC reporting and analysis. Further studies on the long-term efficiency and cost-effectiveness of mitigation measures would help ensure optimal allocation of resources. Finally, the integration of artificial intelligence and real-time monitoring systems holds significant potential for predictive and preventive strategies, yet further research is required to optimize their implementation.

Addressing WVCs—particularly those involving deer—necessitates a collaborative, multidisciplinary approach involving transportation planners, ecologists, policymakers, and the public. By leveraging scientific research, technological innovations, and policy-driven initiatives, it is possible to reduce the frequency and severity of WVCs, enhancing both human safety and wildlife conservation. This

literature review and analysis underscores the pressing need for ongoing research, strategic investments in mitigation efforts, and a concerted effort to balance transportation infrastructure development with ecological preservation. Policymakers should consider integrating wildlife conservation into transportation planning to ensure mitigation strategies are not only reactive but also proactively incorporated into infrastructure development. Additionally, fostering partnerships between government agencies, private industries, and academic institutions is necessary to ensure that mitigation efforts lead to positive outcomes for all stakeholders.

We investigated wildlife-vehicle collisions in Illinois to identify high-risk areas and potential mitigation strategies. Using the IDOT GIS portal, we analyzed over 220,000 records of deer-vehicle crashes from 2009 to 2023. No other species were commonly represented in the database or in other georeferenced sources (e.g., iNaturalist, Illinois Department of Natural Resources Roadkill database). We identified deer collision hotspots and examined the influence of landcover types. As expected, collision risk is higher near metropolitan areas. However, while total collisions increase with traffic volume, the likelihood of any individual vehicle being involved in a collision decreases as traffic volume rises.

We recommend targeted mitigation strategies and improvements in data collection to better understand wildlife-vehicle collisions in Illinois. We identify 18 high-risk road segments where mitigation efforts would yield the greatest benefit. Physical barriers are the most effective solution but combining them with additional deterrents—such as rumble strips, painted medians, or automated crossing signs—could improve effectiveness. Additionally, we advocate for a standardized data collection system to document collisions involving non-deer species. Many states have successfully implemented web-based or stand-alone applications, which could be adapted for Illinois. A better understanding of these collisions will help to inform targeted strategies that will reduce their frequency and impact.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

Wildlife-vehicle collisions (WVCs) are a widespread and costly problem on American roads, with an estimated one million vertebrates killed daily (Forman and Alexander, 1998). These collisions result in significant financial burdens, as evidenced by the 1.8 million insurance claims filed in 2023 due to wildlife-related crashes (State Farm, 2024). In Illinois, most reported WVCs involve white-tailed deer (*Odocoileus virginianus*), with each collision averaging $1,577 in damages. While official reports suggest a 0.6% annual risk for drivers, underreporting means the actual rate is likely closer to 1.2% (Conover, 2019). In addition to the economic costs, WVCs pose serious safety risks, injuring nearly 60,000 people and causing approximately 440 fatalities nationwide each year (Conover, 2019).

Beyond the direct financial and human safety costs, WVCs pose a significant threat to wildlife populations, particularly species of conservation concern. Roads and highways fragment habitats, disrupt migration patterns, and create mortality sinks that can contribute to population declines (Huijser et al., 2008). Species with low reproductive rates, high site fidelity, or specific habitat requirements are especially vulnerable to road mortality (Gibbs and Shriver, 2002, 2005). Turtles, snakes, and amphibians experience some of the highest rates of road-induced mortality due to their slow movement, poor avoidance behaviors, and frequent use of roads for thermoregulation (Gibbs and Shriver, 2002, 2005; Row et al., 2007). Insects, particularly butterflies, are also heavily impacted by vehicle collisions, with road mortality contributing to declines in pollinator populations (Kantola et al., 2019). Even small increases in mortality can have dramatic population-level consequences. For example, Row et al. (2007) found that a road-induced mortality rate of only 2.6% was sufficient to elevate the extinction probability of black rat snakes (*Elaphe obsoleta*) from 7.3% to 99%. These findings highlight how even seemingly minor WVC rates can lead to severe ecological consequences, particularly for species with limited distributions or already declining populations.

Understanding when and where WVCs occur is essential for effective mitigation efforts. While some species, such as white-tailed deer, have been extensively studied due to their significant impacts on human safety and the economy, collision patterns for most wildlife remain poorly understood. For deer, WVCs exhibit strong temporal trends, peaking during the fall breeding season when movement and activity levels increase (Finder et al., 1999; Pagany, 2020). These collisions are also spatially concentrated in areas where forests and agricultural lands intersect, as these landscapes provide both cover and forage for deer (Finder et al., 1999; Pagany, 2020). Similar research has been conducted on kangaroo-vehicle collisions in Australia, where road mortality is influenced by seasonal changes in food availability, drought conditions, and the proximity of roads to high-density kangaroo populations (Reeves et al., 2022; Candy et al., 2024; Lester, 2015). However, for most North American species—particularly those that do not pose a direct threat to human life or economic interests—there remains a significant gap in knowledge regarding collision hotspots, seasonal patterns, and environmental risk factors. Without a comprehensive understanding of WVC trends across a wide range of species, mitigation efforts risk being ineffective or misapplied, failing to protect both motorists and wildlife.

One of the most significant challenges in WVC research is the high rate of underreporting, which obscures the true scale of the problem and limits the development of targeted mitigation strategies

(DeGregorio et al., 2011; Snow et al., 2015). While large ungulates such as deer and elk are typically well-documented due to the damage they cause to vehicles, underreporting can still exceed 70% in some regions (Snow et al., 2015). The issue is even more pronounced for smaller species, which are less likely to be noticed or reported by drivers. Many motorists do not stop for collisions involving small-bodied wildlife, especially when no vehicle damage occurs. This leads to major detection biases, particularly for species that are scavenged rapidly or decompose quickly, further complicating efforts to collect reliable data (Rosen and Lowe, 1994; DeGregorio et al., 2011). The reliance on opportunistic or volunteer-based roadkill surveys introduces additional inconsistencies, as observer effort varies across locations and time periods (Valerio et al., 2021). These challenges make it difficult to assess the full ecological impact of WVCs and emphasize the need for more systematic monitoring efforts.

This study examines WVC patterns in Illinois to improve understanding of collision data and inform potential mitigation strategies. We focus primarily on white-tailed deer because of the abundance of data on collisions with deer, the disproportionate impact of deer-vehicle collisions on human health and property, and the limited information available for other wildlife species. Our objectives were fourfold: (1) assess the extent of existing data on WVCs in the state, (2) analyze spatial and temporal patterns of WVCs in Illinois, (3) collate and evaluate the effectiveness of various mitigation strategies, and (4) provide recommendations to enhance road safety in Illinois while minimizing wildlife impacts. By addressing these objectives, we aim to provide support for both traffic safety and wildlife conservation in Illinois.

CHAPTER 2: METHODS

DATA EXTENT AND PATTERNS

We gathered data on white-tailed deer vehicle collisions using the IDOT GIS portal (IDOT 2025). We utilized location and timing data collected across the entire state of Illinois from 2009 to 2023 to assess patterns in deer-vehicle collisions. We summarized the number of collisions per year, hour of day, and month. Chi-square tests were used to evaluate differences between years, hours, and months. We then examined patterns in collisions relative to sunrise and sunset times throughout the year to evaluate the influence of dawn and dusk. To assess long-term trends, we fit a general linear model (Collisions ~ Year) to the annual collision data from 2009 to 2023. All analyses were conducted in RStudio using R Version 4.4.3 (R Core Team, 2025).

CORRELATES AND SPATIAL PATTERNS OF DEER-VEHICLE COLLISIONS

We investigated the influence of traffic volume on collision counts using average annual daily traffic data from the IDOT GIS portal (IDOT 2025). Using the Spatial Join tool in ArcGIS Pro version 3.4.0 (ESRI, 2024), we calculated the number of collisions on each road segment used for traffic data and examined its relationship to the traffic volume at that location. The Spatial Join tool joins attributes from one feature to another based on their spatial relationship.

To further analyze the relationship between traffic volume and collisions, we grouped traffic volume into 10 categories and plotted the number of collisions per million vehicles in each bin. The bins were unequal because traffic volume was not normally distributed.

We also analyzed collision patterns and functional road class data using the IDOT GIS portal. Functional road class represents a combination of traffic volume, speed limit, road width, and area served (FHWA, 2017). There are seven road classes: interstates, freeways and expressways, other primary arterials, minor arterials, major collectors, minor collectors, and local roads (FHWA, 2017). We used the Spatial Join tool to calculate the annual number of collisions in each road class. We performed a one-way ANOVA to test for significant differences in the annual number of collisions per kilometer for each road class. To ensure assumptions of the test were met, we visually assessed the residuals and conducted Levene’s test for homogeneity of variance. When the ANOVA identified significant differences, we conducted Tukey post-hoc tests to determine which functional classes contributed to any differences.

We further examined spatial patterns in deer-vehicle collisions using ArcGIS Pro. After plotting all recorded deer-vehicle collisions statewide, we applied the Hot Spot Analysis tool to determine hot spots of deer-vehicle collisions in Illinois. The Hot Spot Analysis tool calculates the Getis-Ord Gi* statistic for each observed deer collision to determine where features with either high or low values cluster spatially. A statistically significant hot spot is identified when a collision has a high Getis-Ord Gi* value and is surrounded by other collisions with similarly high values. The local sum for a collision and its neighbors is compared proportionally to the sum of all collisions across the state. When this local sum is substantially different from what is expected—and the difference is unlikely to be due to random variation—the location is classified as a hot spot.

Finally, we investigated the influence of land cover on deer-vehicle collisions using maximum entropy modeling in ArcGIS Pro. This method uses presence-only data to generate predictions of where land cover characteristics suggest a high probability of future collisions. We used land cover data gathered from the NLCD 2007 dataset (USDA–NASS, 2007). We created buffers around each collision point with radii of 0.4 km, 0.6 km, and 1.6 km, representing three categories of home range size in white-tailed deer (Quinn et al., 2013). All points were snapped to the nearest road segment to maintain consistency between collision points and randomly generated points. We used one-tailed t-tests assuming unequal variances to determine significant differences between collision and random sites. Land cover types were aggregated into seven broad categories: cropland, woodland, wetland, open water, developed land, grassland, and pasture. We assumed that the general presence of certain land cover types—such as wetlands—was more relevant to collision risk than specific land cover subtypes.

WILDLIFE-VEHICLE COLLISION MITIGATION STRATEGY LITERATURE REVIEW

We searched Web of Science using the query developed by Pagany (2020), which returned 1,736 results. We manually screened the articles for relevance and inclusion in our review. Only English-language articles addressing factors that influence collision frequency were retained. We excluded studies focused on species (e.g., large predators, anteaters, marsupials, or primates) or environments (e.g., tropical, coastal, or desert) not found in Illinois. After narrowing the search, we conducted snowball searches (finding additional studies from the literature cited in saved articles) to capture additional relevant studies.

CHAPTER 3: RESULTS

DATA EXTENT AND PATTERNS

Information on wildlife-vehicle collisions in Illinois is almost entirely limited to deer-vehicle collisions. Between 2009 and 2023 there were 236,188 deer-vehicle collisions recorded in the IDOT GIS portal (IDOT, 2025). By comparison, raccoon (*Procyon lotor*) was noted 286 times, coyote (*Canis latrans*) 216, and wild turkey (*Meleagris gallopavo*) 74. All other species had fewer than five observations in any year. There was no obvious spatial pattern to wildlife-vehicle collisions, other than being ubiquitous throughout the state (Figure 1).

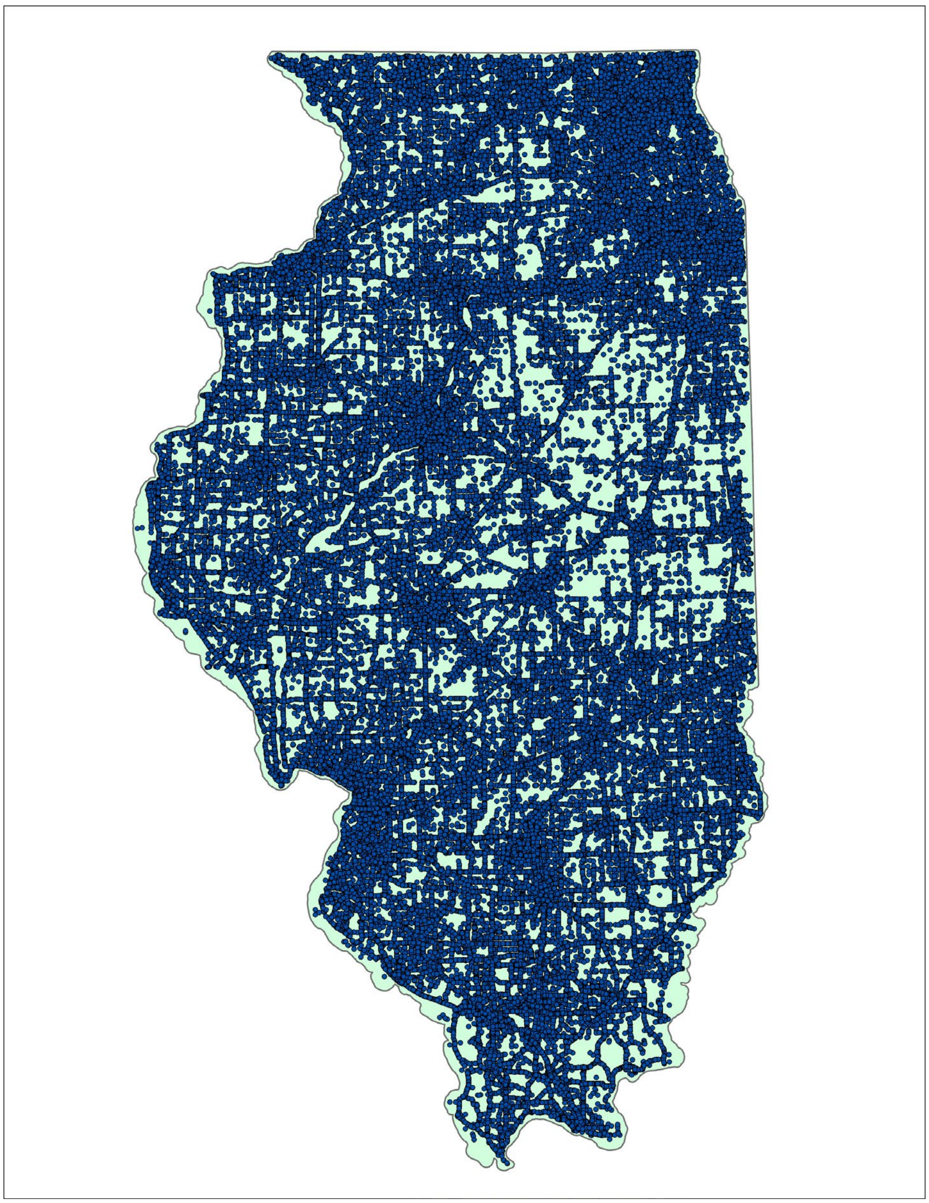

Figure 1. Map. Location of reported deer-vehicle collisions in Illinois between 2009 and 2023. Blue dots represent a single deer-vehicle collision event.

One-third of all deer-vehicle collisions occurred in October and November (Figure 2). August and September had the lowest collision rates, potentially because of increased visibility from longer daylight hours. Differences among months were statistically significant (X^2: 59549, df: 11, p-value < 0.001).

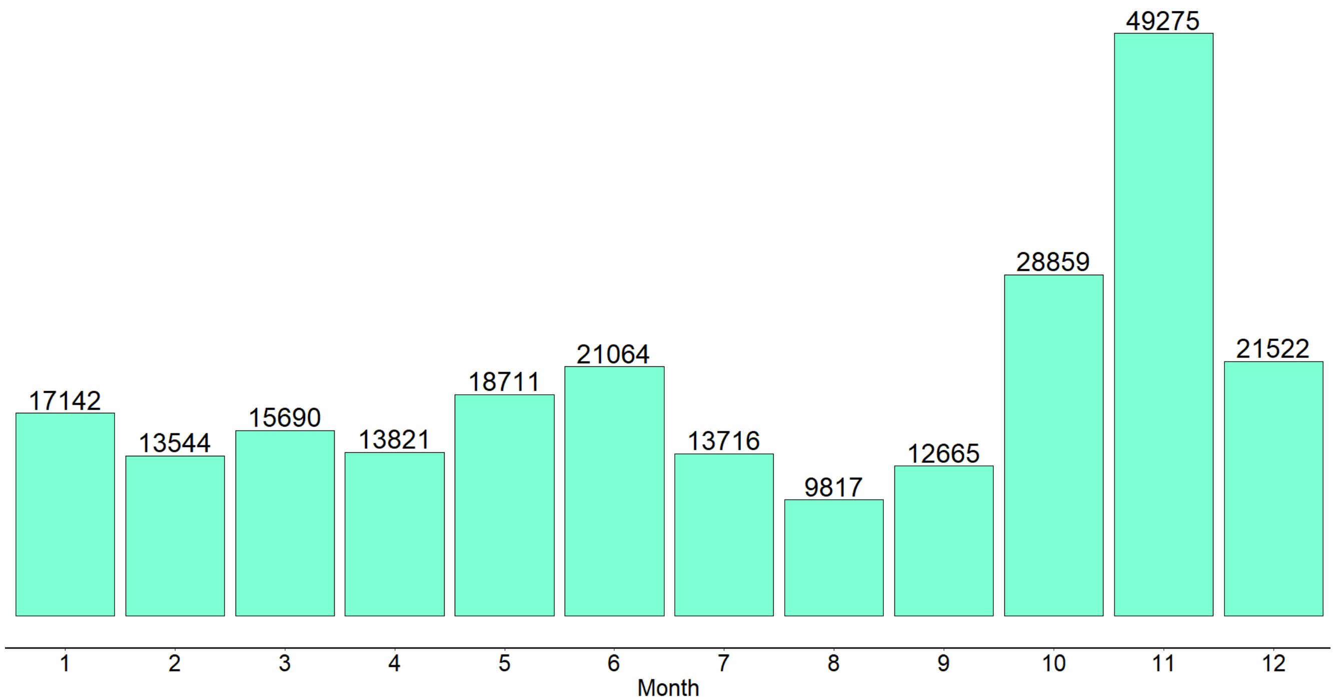

Figure 2. Chart. Total deer-vehicle collisions in Illinois by month from 2009 to 2023.

Deer-vehicle collisions exhibited a bimodal distribution with peaks between 0500–0700 and 1700–2100 (Figure 3). These times correspond to dawn and dusk, when deer are most active. Collisions were more common during nighttime hours than during the day (X^2: 116180, df: 23, p-value < 0.001).

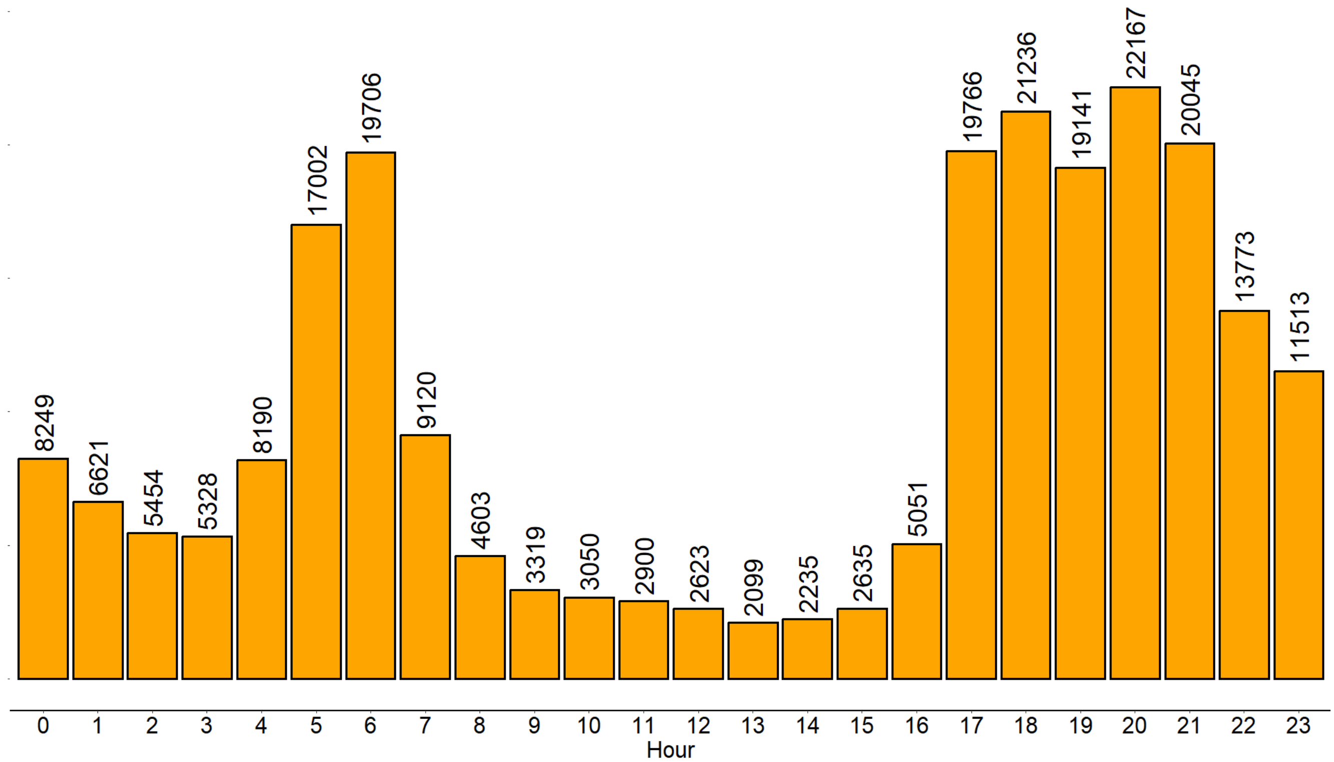

Figure 3. Chart. Total deer-vehicle collisions by hour of day from 2009 to 2023.

The peak hour of collisions typically occurred after sunset, although the specific timing varies slightly by month—most often falling one or two hours after sunset. Collision frequency also increased in most months during or shortly after sunrise, but there was some variation.

The highest number of collisions occurred in 2009 and 2010. However, a linear model of collisions by year was not significant (p-value: 0.07, R^2: 0.24). A model that included a quadratic term was significant (p-value: 0.02, R^2: 0.51; Figure 4), showing that the number of collisions decreased from 2009 to 2012, then remained stable after 2012.

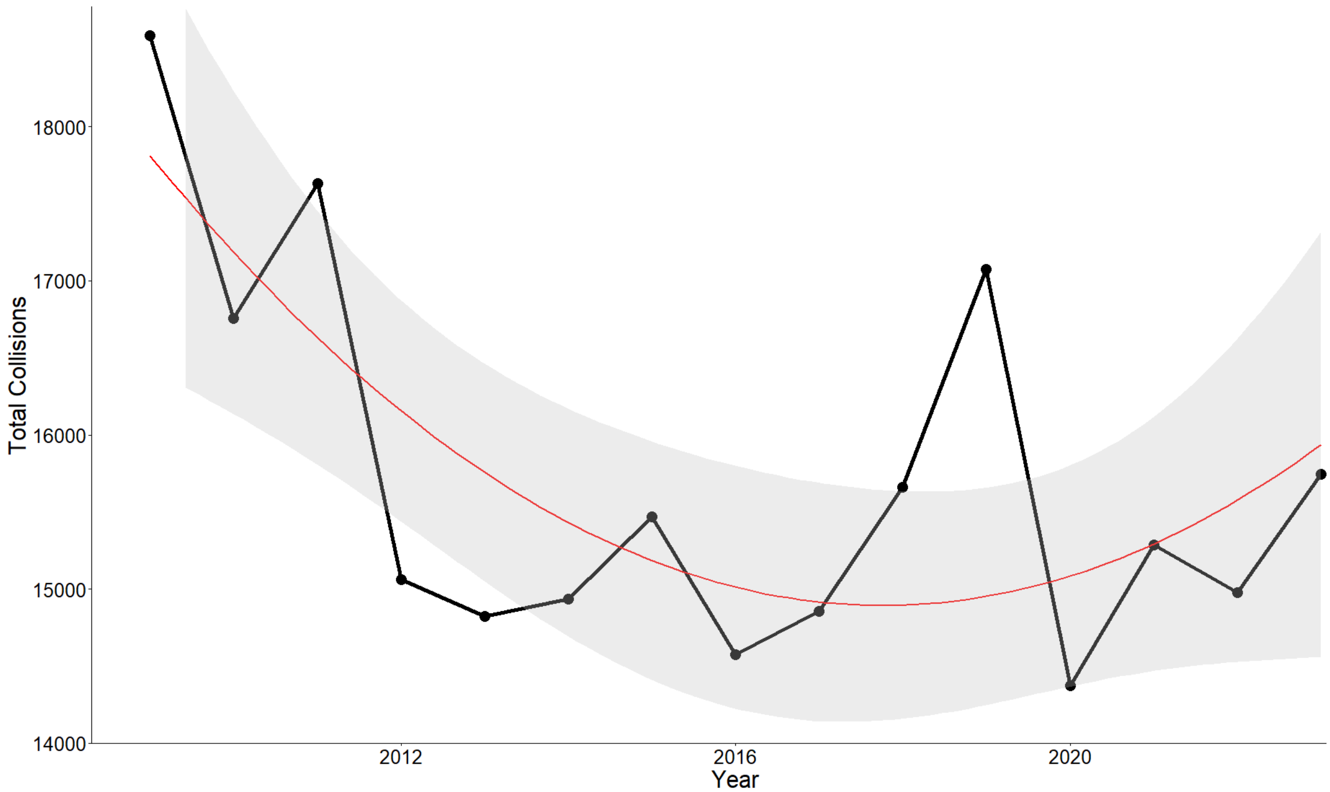

Figure 4. Graph. Deer-vehicle collisions by year with quadratic best fit line (red). Shaded area represents a 95% confidence interval.

CORRELATES AND SPATIAL PATTERNS OF DEER-VEHICLE COLLISIONS

Average annual daily traffic (AADT) was significantly related to the number of deer-vehicle collisions (p-value = 0.04), with collisions increasing with decreasing traffic volume. However, the effect size was extremely small and not very meaningful (< −0.001). In contrast, collision rate plots (collisions per million vehicles) for bins of AADT values revealed that areas with low traffic volume were much more likely to encounter deer-vehicle collisions (Figure 5).

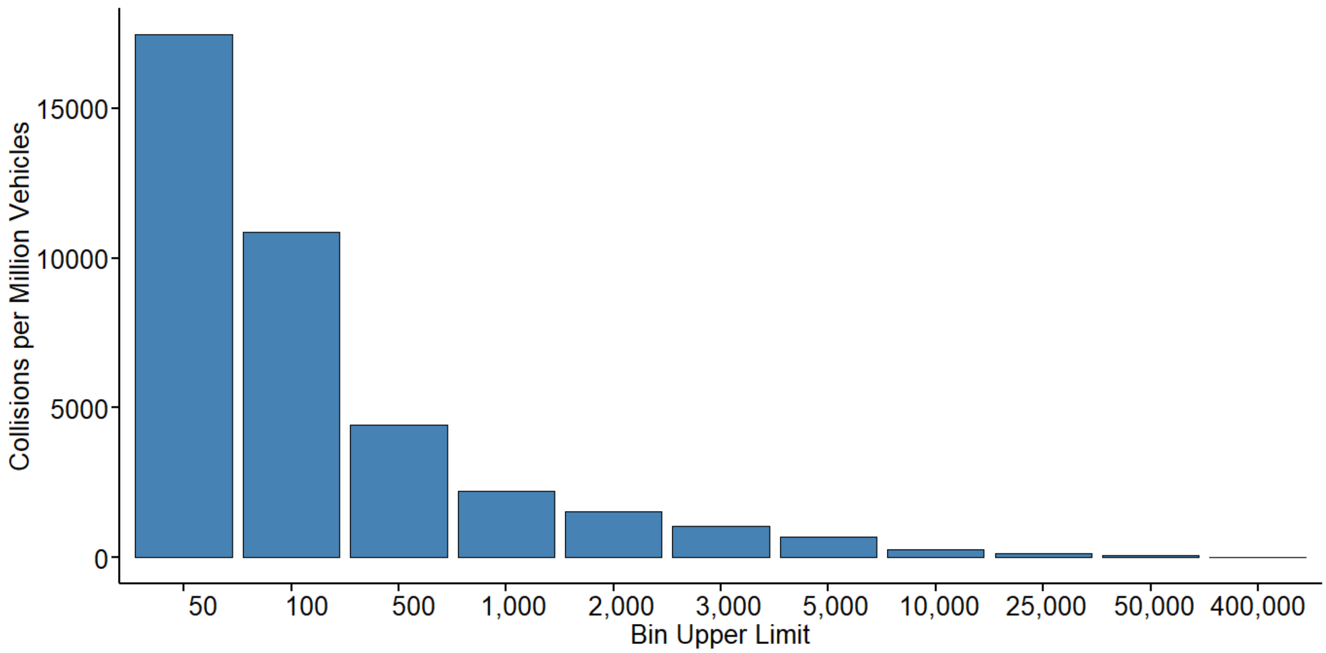

Figure 5. Chart. Deer-vehicle collision rates (per million vehicles) relative to traffic volume.

We found significant differences in collisions per kilometer among the seven functional road classes ($F(6,91)$: 364.3, p-value: < 0.001). Tukey post-hoc tests showed that all road classes differed significantly from each other (p-value < 0.05). The highest collision rates occurred on mid-level road classes, including non-interstate freeways and major arterials. The smallest difference was between minor collectors and local roads.

Hot spot analysis indicated that deer-vehicle collisions were most frequent near urban areas (Figure 6). However, the individual road segments with the highest collision counts were scattered across the state and did not appear strongly associated with any specific land cover type. Road segment hot spots were affected by numerous factors that had complex interactions, including peak traffic times, land cover, road conditions, visibility, traffic volume, and deer movement patterns. Unfortunately, collisions are so common and widespread that specific areas of greatest risk are not possible to identify.

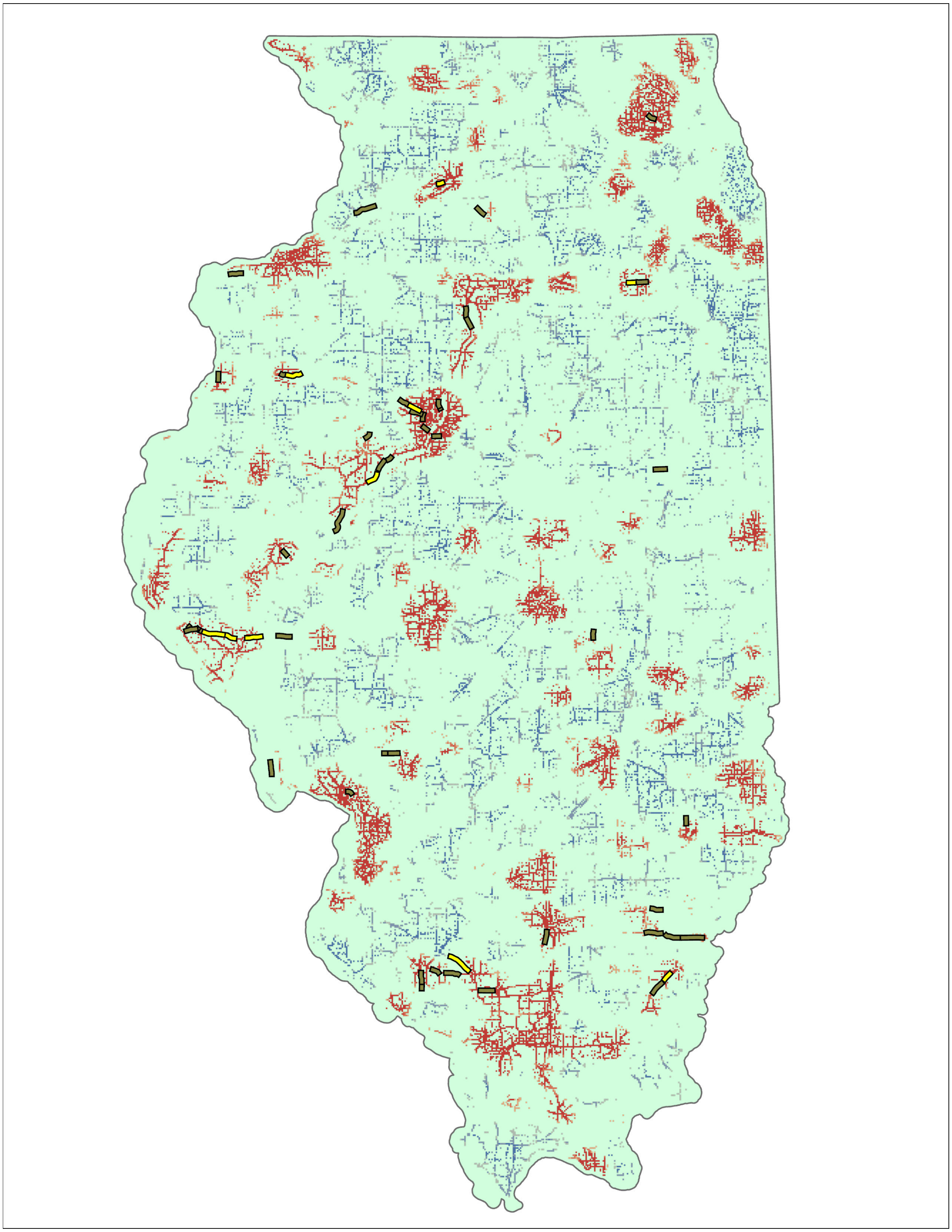

Figure 6. Map. Deer-vehicle collision hot spots in Illinois. Blue areas represent cold spots, and red areas represent hot spots. Yellow segments show the 10 road segments with over 120 collisions from 2009 to 2023. Green segments had less than 120 but 75 or more collisions over the same period.

Collision sites were associated with lower agricultural and developed land cover compared to random points, but showed higher proportions of woodland, open water, pasture, grassland, and wetland cover (Table 1).

Table 1. Land Cover Characteristics at Deer-Vehicle Collision Points Versus Random Points in Illinois (2009–2023)

Land Cover	Buffer Radius	Collision mean	Random mean	t-statistic	Degrees of freedom	p-value (One-tailed t-test)	Collision mean difference
Cropland	0.4 km	42.5	51.68	−22.9	10667	< 0.0001	Lower
	0.6 km	42.93	52	−23.6	10634	< 0.0001	Lower
	1.6 km	43.82	52.71	−25.8	10593	< 0.0001	Lower
Woodland	0.4 km	26.06	13.27	56.3	11346	< 0.0001	Higher
	0.6 km	26.43	14.13	18.8	12235	< 0.0001	Higher
	1.6 km	26.13	15.96	55.0	10970	< 0.0001	Higher
Wetland	0.4 km	1.11	0.5	16.4	12174	< 0.0001	Higher
	0.6 km	1.23	0.56	18.8	12235	< 0.0001	Higher
	1.6 km	1.43	0.76	21.2	12080	< 0.0001	Higher
Open Water	0.4 km	1.54	1.03	9.5	11168	< 0.0001	Higher
	0.6 km	1.79	1.16	12.7	11273	< 0.0001	Higher
	1.6 km	2.32	1.43	20.4	11425	< 0.0001	Higher
Developed	0.4 km	11.16	20.55	−25.2	10401	< 0.0001	Lower
	0.6 km	10.74	19.71	−25.3	10376	< 0.0001	Lower
	1.6 km	10.76	17.18	−20.8	10380	< 0.0001	Lower
Grassland	0.4 km	0.0116	0.0089	1.2	11048	0.2212	Higher
	0.6 km	0.0134	0.0088	2.6	11193	0.0084	Higher
	1.6 km	0.0122	0.0086	3.7	11331	0.0002	Higher
Pasture	0.4 km	17.58	12.84	25.5	11040	< 0.0001	Higher
	0.6 km	16.81	12.27	28.2	10998	< 0.0001	Higher
	1.6 km	15.29	11.56	30.5	10923	< 0.0001	Higher

Note: Means and standard deviations are reported for land cover at three buffer sizes, along with t-statistics, degrees of freedom, and p-values.

Our maximum entropy model provided a more detailed analysis of associations between land cover and collision hotspots (Figure 7). Woodland and developed land within 1.6 km of collision sites had the greatest positive influence on collision likelihood (Table 2).

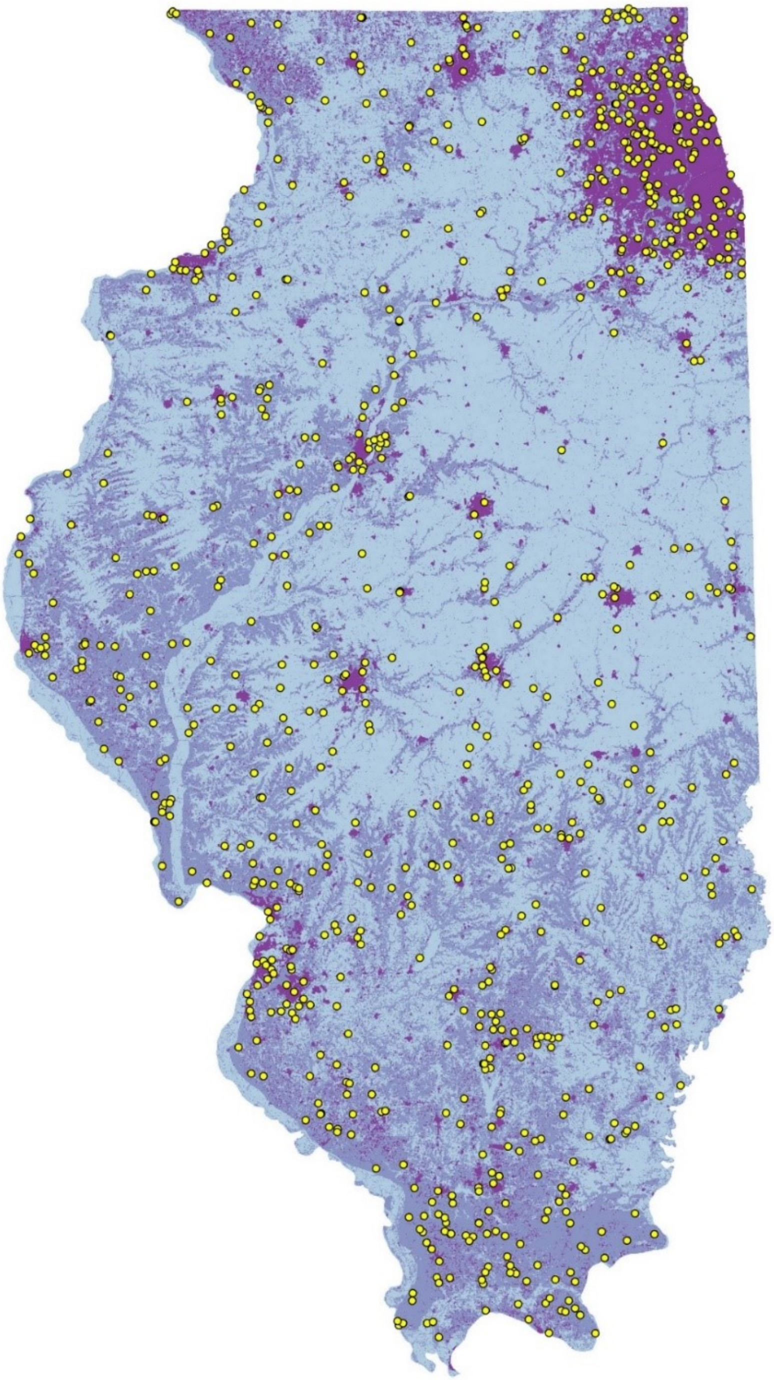

Figure 7. Map. Predicted likelihood of deer-vehicle collisions in Illinois based on a maximum entropy model of land cover characteristics. Darker areas indicate higher collision likelihood. Yellow points are random locations that were predicted by the model to have greater than 90% likelihood of collisions.

Table 2. Proportions of Land Cover Groups Within 1.6 km Buffers around Random Points and Predicted Presence Points from Maximum Entropy Modeling

LC Class	MaxEnt Proportion	Random Point Proportion	Difference
Beans	0.09	0.15	−0.06
Corn	0.15	0.29	−0.14
Developed	0.30	0.20	0.10
Grains	0.02	0.04	−0.02
Pasture	0.09	0.10	−0.01
Woodland	0.30	0.19	0.11
Wildflowers	0.01	0.01	0.00
Open Water	0.02	0.01	0.01
Wetland	0.01	0.01	0.00
Fallow Cropland	0.01	0.00	0.01
Misc. Crops	0.00	0.00	0.00
Barren	0.00	0.00	0.00
Shrubland	0.00	0.00	0.00

WILDLIFE-VEHICLE COLLISION MITIGATION STRATEGY LITERATURE REVIEW

After refining the initial 1,736 literature results, we retained 318 articles, 129 of which focused on the design and effectiveness of different mitigation strategies. We found an additional 22 articles by searching specifically for proposed mitigation measures, and performed snowball searches, resulting in 148 papers on collision mitigation. Of the 337 retained articles, 227 focused on deer or other large ungulates. Only 33% addressed non-ungulate animals.

CHAPTER 4: DISCUSSION

From 2009–2023, there were 220,454 deer-vehicle collisions reported by IDOT. Deer-vehicle collisions peaked in November, probably due to a combination of factors, including rut, hunting season, and overlap between deer activity and peak traffic times. Since deer are crepuscular (Cunningham et al., 2022), most collisions occur around sunset or sunrise (Figure 3), although traffic volume and timing also contribute to collision frequency.

Deer-vehicle collisions are concentrated around cities, although the segments with the most collisions are not especially clustered (Figure 6). Collision rates—measured as collisions per million vehicle miles—were inversely related to daily traffic volume, meaning that the probability of a collision decreased as the number of vehicle miles increased (Figure 5). Functional road class, a simplified indicator of speed, volume, and road function (FHWA, 2017), showed that mid-level classes—particularly non-interstate freeways and major arterials (primarily state highways)—had the highest collision rates per kilometer.

Woodlands were associated with increased rates of collisions using multiple methods (Tables 1–2). Developed land was associated with greater probabilities of collisions using maximum entropy modeling (Table 2) but was less abundant within buffers around collision sites than random sites (Table 1). This likely reflects a more complex, nuanced effect of urbanization on the location of deer-vehicle collisions. Buffer analysis showed that wetland and grassland were present in greater proportions near collision points (Table 1). Agricultural cover was associated with lower collision rates (Tables 1–2). Therefore, deer collisions will be most common around natural areas (grassland, wetland, or woodland) or pastures that are near cities.

We sought to examine collision patterns involving other species, not just white-tailed deer, but there was a lack of available georeferenced data on collisions with species other than deer. The IDOT Wildlife Collisions Database included only about 600 records for all other species combined. Two additional data sources we found pertaining to wildlife-vehicle collisions in Illinois: the Illinois Department of Natural Resources roadkill dataset and the iNaturalist citizen-science database (iNaturalist, 2024). The IDNR roadkill dataset has collected annual data on vehicle collisions with upland game (rabbit, ring-necked pheasant) and furbearers (raccoon, skunk, opossum, armadillo, woodchuck) since 1986. However, IDNR collects roadkill data based on northern and southern zones, using State Highway 36 and Interstate 72 as a boundary. Therefore, the data are not spatially referenced and have limited use. The iNaturalist dataset contained 322 observations of roadkill animals that were georeferenced. However, we found that the spatial extent of the data was greatly limited due to the number of observers contributing observations. Specifically, three observers contributed 59% of all observations, reducing the utility of the data for our purposes.

MITIGATION STRATEGIES

Mitigation measures can be implemented more effectively once the spatial and temporal patterns of wildlife-vehicle collisions are documented. Identifying high-risk locations and peak times for collisions allows for targeted interventions that maximize efficiency and cost-effectiveness. Most mitigation strategies have been designed for large ungulates, such as deer and elk, because these species pose the greatest risk to motorists due to their size and population densities (Conover et al., 1995; Conover, 2019). However, some measures, particularly those involving fencing, crossing structures, and modified road designs, can also provide benefits for smaller-bodied wildlife, including amphibians, reptiles, and small mammals (Huijser & McGowen, 2010). Regardless of the species being targeted, mitigation strategies generally fall into three primary categories: preventing wildlife from crossing roadways, influencing driver behavior to reduce collision risk, and modifying animal behavior to deter road use. A comprehensive approach that integrates multiple strategies is often the most effective, as no single measure is universally applicable across all species and road conditions. By addressing both human and animal factors contributing to wildlife-vehicle collisions, mitigation efforts can enhance road safety while also supporting biodiversity conservation and ecosystem connectivity. We provide a comprehensive list of mitigation strategies that have been proposed along with their potential benefits and drawbacks (Table 3). We discuss the most salient measures below.

Table 3. Benefits and Detriments of Proposed Mitigation Strategies

Mitigation Type	Mitigation Measure	Studies	Effectiveness	Positives	Negatives	Costs	Recommendation
Environment	Permanent daylight savings time	Cunningham et al., 2022	Theoretically would prevent 36,550 collisions nationwide.	Effective and with no direct costs.	Permanent daylight savings has much broader effects than just deer collisions.	$0	Unknown. Only theoretically effective, and laboratory or field studies are not possible.
Driver Behavior	Public information and education	Vanlaar et al., 2019	Unknown	Iowa's "Don't Veer for Deer" campaign was related to a reduction in human fatalities from 10 in 2003 to 4 in 2005.	There are no studies linking education to actual reductions in collisions.	Variable, depending on the strategy.	Possibly recommended. Inexpensive, but unsubstantiated. Could reduce severity, but not frequency, of collisions.
Driver Behavior	Standard warning signs	Meyer, 2006	0% reduction	Inexpensive and easy to install. Initially effective in urban areas, but effectiveness decreases quickly.	Drivers quickly habituate to warning signs. Standard warning signs have no statistical impact on frequency of collisions in most studies.	$50–100 depending on size.	Not recommended. Inexpensive, but not effective beyond the first year of installation.
Driver Behavior	Enhanced warning signs	Huijser et al., 2015	Unknown	Double-sized signs were significantly more effective than regular warning signs.	Even large warning signs only affected driver speed in a 1 km band centered on the warning sign.	$2,000 per sign	Not recommended. More expensive and more effective than standard warning signs. Effect is limited to a 1 km area centered on the sign.
Driver Behavior	Seasonal warning signs	Sullivan et al., 2004	51% reduction in collision frequency, 50% reduction in speeding during first season of operation.	Effective in reducing wildlife-vehicle collisions and in reducing driver speeds during the first year of use.	May lose effectiveness after the first season of use. Need to be installed and taken down annually. May be more frequently vandalized or stolen than standard signs.	$50–400 per sign depending on size and message	Slightly recommended. Effective, but may lose effectiveness over multiple years.

Mitigation Type	Mitigation Measure	Studies	Effectiveness	Positives	Negatives	Costs	Recommendation
Driver Behavior	Animal detection systems (ADS)	Gagnon et al., 2019; Huijser et al., 2009	82% reduction in collision frequency.	Infrared area-cover detection systems reduced collision frequency by 82% in Switzerland. They do not restrict animal movement.	Can create a hazard for vehicles that run off the road.	$40,000–$96,000 per km	Recommended. Expensive, but effective. Less ecologically impactful than barriers. Most useful for roads with frequent deer crossings and low enough speeds for drivers to react.
Driver Behavior	Vehicular animal detection systems	Sharma and Shah, 2017	Unknown	Highly accurate.	Detection distance was too short to allow drivers to avoid a collision at speeds greater than 32 kph.	$2,250 per vehicle	Unknown. This concept is still being developed and is not yet an effective method.
Driver Behavior	Reflective collars	Huijser and McGowen, 2010	Unknown	May make animals more visible.	Requires a lot of effort and may harm the animals.	Unknown	Has been proposed in review papers but not studied.
Roadway Changes	Changing pavement color	Lester, 2015	59% reduction in combination with other measures.	Seems to be effective in Tasmania with dark-colored animals.	Deer are light-colored, so they already should stand out on dark pavement.	$625,000 per km	Not recommended. Likely not effective with white-tailed deer and very costly.
Roadway Changes	Increasing roadway lighting	McDonald, 1991	65% reduction in collision frequency in the lighted area.	Reduction in collision frequency, even without other measures. Most collisions take place when visibility is reduced. May also reduce other types of collisions at night.	Reduction may be due to animal avoidance of lighted areas. May temporarily blind nocturnal animals and reduce driver reaction time after leaving the lighted area. Nighttime light has negative ecological effects.	$250,000 per km	Possibly recommended. Lighting is expensive but seems to reduce collision frequency. Could be useful when traffic volume on one road segment is higher than nearby segments of the same road.
Roadway Changes	Vegetation removal in right-of-way	Meisingset et al., 2014	53% reduction during winter only.	May increase visibility for both drivers and wildlife. May also keep deer from approaching roads.	Removal of brush may result in fresh growth of attractive food for deer, drawing them to the road.	$9,000 per year	Possibly effective. May have mixed effects that result in no net change in collision frequency. Probably more expensive than it is worth.

Mitigation Type	Mitigation Measure	Studies	Effectiveness	Positives	Negatives	Costs	Recommendation
Roadway Changes	Wider striping	Huijser and McGowen, 2010	Unknown	May make animals crossing the road more visible. It might also give drivers a perception of a narrower roadway, leading to reduced speeds.	Unknown	Unknown	Has been proposed in review papers but has not been studied or implemented. Theoretically beneficial, but no supporting data.
Roadway Changes	Reducing traffic volume	Abraham and Mumma, 2021	Depends on how much traffic volume decreases.	Collision rate has not changed, but traffic volume has been increasing, so a reduction in traffic will probably reduce the total number of collisions.	May increase collision rate because of increased animal use of roadways (2020 data seems to support this hypothesis)	Unknown	May be helpful but would be difficult to implement.
Roadway Changes	Reducing posted speed limit	Meisingset et al., 2014; Riginos et al., 2022	At best, 37% reduction.	Collisions are less frequent on roads with lower speed limits.	Reducing speed limits without changing road design may increase speed dispersion, which increases crash rates between cars.	Unknown	Not recommended. Increases collisions between vehicles and is only minorly effective. If the speed design of the road were changed, it could be effective, but that is expensive and impractical.
Roadway Changes	Reducing road design speed	Riginos et al., 2022	Inconclusive	Depends on the method and the location.	Traffic will be slower, which may have economic effects.	Unknown	Unknown. These measures have not been widely implemented since they are expensive and there is no conclusive data about their effects on wildlife collisions.
Roadway Changes	Increasing median width	Huijser and McGowen, 2010	Unknown	Allow animals to cross one direction of traffic at a time. May be more aesthetically pleasing to drivers and allows for high beam headlights to be on for longer periods.	May attract grazers to the increased vegetation in the median.	Unknown	Unknown. It has not been implemented widely yet or studied empirically.

Mitigation Type	Mitigation Measure	Studies	Effectiveness	Positives	Negatives	Costs	Recommendation
Deer Behavior	Deer reflectors/ mirrors	Benten et al., 2018	Ineffective	May elicit minor flight response in deer.	Reflectors may not elicit avoidance responses.	$4,400–$6,200 per km	Not recommended. Ineffective in reducing wildlife collisions, even when paired with sound.
Deer Behavior	Deer whistles attached to vehicles	Terrade et al., 2024; Valitzski et al., 2007	Ineffective	Unknown	Not effective in reducing wildlife collisions. Mule deer did not respond, even to ultrasonic frequencies.	$23.50 each	Not recommended. Inexpensive, but not effective.
Deer Behavior	Olfactory repellents	Keken et al., 2024	Inconclusive	Predator-based repellents may be effective at deterring deer from roads and/or increasing vigilance.	May attract predators or cause panic instead of avoidance. Deer may become habituated to the repellents.	Variable, depending on the product	Unknown. Some products (mostly derived from predators) seem to be slightly effective. Habituation is a problem that is still debated by researchers.
Deer Behavior	Deer flagging models	Graves et al., 1978	Ineffective	Unknown	Unknown	Unknown	Experimental. Only one study has ever been done on these models, and the models were ineffective in the study.
Deer Behavior	Hazing (frightening with lights, noises, water sprays, chasing, etc.).	Romin and Bissonette, 1996	Probably ineffective	Some methods might be effective in reducing collisions.	Noise and bright lights are as annoying for people as they are for deer.	Variable, depending on the method	Not recommended. Most studies found that hazing was ineffective in deterring deer from crossing roads.
Deer Behavior	Alternative deicers	Huijser and McGowen, 2010	Unknown	Could potentially reduce the attractiveness of the road to deer. Road salt increases the salinity of nearby water bodies.	Most alternative deicers are toxic to wildlife.	Unknown	Experimental. Work is still being done to find non-toxic alternatives to typical road salt.

Mitigation Type	Mitigation Measure	Studies	Effectiveness	Positives	Negatives	Costs	Recommendation
Deer Behavior	Intercept feeding	Huijser and McGowen, 2010	Unknown	May work for short-term reductions or in combination with other mitigation measures	May create a dependency on the supplemental food and might increase population size. Very labor intensive.	Inexpensive	Experimental. Probably ineffective and may have serious adverse effects in the long-term.
Deer Behavior	Virtual fencing	Candy et al., 2024; Coulson and Bender, 2022; Reeves et al., 2022	Ineffective in Australia	Inexpensive and easy to install. Does not form a barrier to wildlife dispersal.	Depends on behavioral modification strategies that do not work in other contexts.	$5,000 per km	Not recommended. Ineffective and depends on deterrent methods that are also ineffective.
Animal Population Reduction	Population culling	DeNicola and Williams, 2008	Variable	Can reduce deer population sizes, especially if populations are small.	Deer fertility is density-dependent, so culling needs to be maintained. Culling may not be accepted by the public.	$150 per deer	Not recommended. More difficult and costly than it is worth. Culling for wildlife collision reduction would require intensive effort and high cost.
Animal Population Reduction	Targeted recreational hunting	Deslisle et al., 2024	21% reduction in Indiana	Expanding hunting season and bag limit near collision hotspots is effective and may increase hunting license revenues.	Shifting hunter demographics could make this method obsolete.	$0	Recommended. Targeted hunting near collision hotspots can be effective.
Animal Population Reduction	Anti-fertility treatment	Warren, 2011	Unclear	Unknown	Labor intensive. Removing randomly selected individuals from breeding could have serious long-term effects on population genetic health.	$33,833 for 30 deer for 2 years	Not recommended. Very expensive and only slightly effective. It is unknown how much population reduction would be needed to reduce WVCs.

Mitigation Type	Mitigation Measure	Studies	Effectiveness	Positives	Negatives	Costs	Recommendation
Physical Barrier	Wildlife fencing	Clevenger et al., 2001; Huijser et al., 2016	75%–90% reduction in deer collisions	Highly effective in nearly all studies. It has a lower effect on the health of wildlife populations than road mortality does.	If fencing is not paired with some crossing structure, effectiveness decreases because wildlife will break through the fences. Completely blocks animal movements across roads. Many people think fences look ugly.	$4,400 per km	Effective. Would recommend with crossing structures and maintenance. Would be most effective on interstates or other busy roads that already pose a nearly impermeable barrier to deer movement. Long fences are more effective than shorter fences.
Physical Barrier	Boulders	Sperry et al., 2023	Unknown	May form an effective barrier to ungulate access to roads.	Some locations have used boulders as a means of excluding off-road vehicles from structures intended for wildlife, so boulders may not prevent ungulates from crossing.	$197,000 per km	Experimental. Has only been implemented in a few case studies. May be effective and is more aesthetically pleasing than fencing.
Physical Barrier	Long tunnels and long bridges	Denneboom et al., 2021	100%	Long tunnels or bridges allow for free animal movement and ecosystem processes. They physically separate animals and vehicles and remove any need for animals to use the roadway.	Long tunnels and bridges are very expensive.	200 m tunnel was $16,600,000. 200 m bridge was $9,000,000.	Not recommended. Even though long tunnels and bridges are very effective in reducing collisions, they are by far the most expensive option. They are only ever built in cases where they are needed for reasons other than wildlife collision mitigation.

Note: White = environmental changes; green = driver behavior modification; tan = roadway changes; blue = deer behavior modification; purple = animal population reduction; gray = physical barriers.

Prevention

Preventing animals from accessing roadways is the most effective mitigation strategy. Fences that restrict movement across roads are widely recognized as the best method for reducing wildlife-vehicle collisions and can decrease collisions by over 80% when properly implemented (Huijser et al., 2008). Fences are also the most cost-effective mitigation strategy when considered on a cost-percent-reduction basis (Huijser et al., 2008); on average, they save $32,728 per km per year. If landscape aesthetics are important, some managers have planted trees in front of the fences (or installed the fences behind already present trees), replaced fences with boulders, or painted the fences brown or green to make them blend into the landscape.

There are several ways to increase the effectiveness of wildlife fences (Table 4). Fences can be made more effective when paired with overpasses or underpasses that provide a safe and effective corridor for an animal to travel in its desired direction (Huijser and McGowen, 2010). Without these crossing structures, the ends of the fence will become hotspots for collisions (Huijser and McGowen, 2010). These types of intensive mitigation efforts are effective for both large mammals and small-bodied animals. If safe crossing structures are impractical, animal detection systems at fence endings can mitigate potential increases in collisions (Huijser and McGowen, 2010) (Table 4). However, no fence is completely impermeable, so additional features such as jump-outs—one-way escape ramps that allow animals to exit but not re-enter fenced areas—are recommended to further enhance safety (Bissonette and Hammer, 2000) (Table 4).

Table 4. Means of Improving Effectiveness of Road Fencing for Deer Collision Mitigation

Mitigation Type	Description	Studies	Effectiveness	Positives	Negatives	Estimated Costs	Recommendations
Driver Behavior	Safe crossing: Gaps in fence	Gagnon et al., 2019	36%–42% reduction over unaltered roads	Can reduce barrier effects of fences.	Reduces effectiveness of fences from 80% to 40% by allowing wildlife onto the grade of the road inside the fence.	There is no cost to creating gaps	Not recommended. Significantly reduces fence effectiveness.
Driver Behavior	Safe crossing: Underpasses and overpasses	McCollister and Van Manen, 2010	87% reduction in collision frequency	Enhance effectiveness of fencing, provides safe crossing for animals. Provides safe crossing for small and endangered animals.	Need to be carefully designed, or else wildlife will breach the fence.	Underpasses: $30,000 to $1,350,000. Overpasses: $1,500,000 to $2,500,000.	Most effective mitigation strategy. More expensive than some other measures.
Roadway Changes	Escape: Jump-outs and escape ramps	Bissonette and Hammer, 2000	8 to 11 times more effective than other escape measures	Escape opportunities are necessary.	If jump-outs are not high enough, animals may be able to jump in, but if they are too high, animals will not use them to jump out.	$6,000 to $11,000.	Will reduce collisions even further than fences alone. If they reduce mortality by even 2%, they would be cost effective within 1 to 2 years.
Roadway Changes	Escape: One-way gates	Bissonette and Hammer, 2000	Unknown	Escape opportunities are necessary.	Only 17% of deer that approach one-way gates use them.	$8,000	Not recommended. Do not provide effective escape opportunities and can allow deer to enter the roadway.
Deer Behavior	Fence ends: Boulders	Huijser et al., 2008	Unknown	Boulders at fence ends can reduce deer-vehicle collisions.	May create an additional safety hazard for drivers in the right of way.	$60,000	Possibly useful. Has not been implemented widely enough or studied thoroughly enough for confident recommendations one way or the other.
Deer Behavior	Fence ends: Animal detection systems	Gagnon et al., 2019; Huijser et al., 2009	Alone, reduced collisions by 82%. Not studied in conjunction with fences.	Animal detection systems are effective in reducing collisions.	Animal detection systems may provide a minor hazard in the right of way.	$40,000—$96,000 per km estimated, not including labor cost for installation.	Probably useful. Best way to reduce hotspot effect of fence ends.

Note: Green = driver behavior modification; tan = roadway changes; blue = deer behavior modification.

Driver Behavior

Efforts to modify driver behavior have been explored as an alternative or complementary strategy to infrastructure-based mitigation, though the effectiveness of these measures varies widely (Table 3). Traditional static deer crossing signs, though inexpensive and easy to install, have limited impact on driver awareness and speed reduction (Meyer, 2006). More advanced warning systems, such as roadside animal detection systems, use sensors to detect wildlife presence and activate flashing lights to alert drivers. These systems have shown potential in reducing WVCs (Bhardwaj et al., 2022; Huijser et al., 2009), but their reliability depends on their ability to accurately detect large animals without generating excessive false alarms, which could lead to driver desensitization (Huijser et al., 2009). Dark roads increase road mortality in deer (Frank et al., 2023), so enhancing nighttime visibility by increasing roadway lighting has been proposed. However, this measure has shown mixed results, as it may shift the location of collision hot spots rather than reducing overall incidents (Huijser and McGowen, 2010) because deer prefer to move on darker roads (Frank et al., 2023). Additionally, excessive artificial lighting can disrupt nocturnal wildlife behavior and ecological processes, creating unintended consequences. Speed limit reductions in high-risk areas are another potential strategy because lower speeds generally correlate with fewer WVCs (Meisingset et al., 2014). However, simply lowering posted speed limits without enforcement or roadway design changes is often ineffective (Riginos et al., 2022), as many drivers fail to comply. This can lead to speed dispersion—variability in vehicle speeds—which has been associated with an increased risk of vehicle-on-vehicle collisions (Huijser and McGowen, 2010; Riginos et al., 2022). In some cases, structural interventions are necessary to ensure speed reductions are followed. In Tasmania, a combination of concrete barriers and lane reductions successfully lowered median vehicle speeds by 19 km/h and led to a reduction in WVCs (Jones, 2000). However, the additional infrastructure costs may limit the widespread adoption of this approach.

Another emerging driver-focused strategy is the use of red LED lighting to improve nighttime visibility while minimizing ecological disruptions. Many animals have low sensitivity to red light (Cohen et al., 2014), making it a less intrusive alternative to traditional white or yellow lighting, though no research has directly examined its impact on WVC rates. If effective, red lighting could also reduce collisions involving pedestrians, cyclists, or other motorists by improving overall nighttime visibility. However, research specifically examining the impact of red light on collision rates is currently lacking. Potential ecological drawbacks also need to be considered, as even low-intensity lighting can alter animal behavior, migration patterns, and predator-prey dynamics (Durmus et al., 2024). Moreover, red lighting may have psychological effects on human drivers, potentially influencing reaction times or inducing fatigue, though these effects have not been thoroughly studied in the context of traffic safety (Durmus et al., 2024). While red LED lighting presents an intriguing possibility for collision mitigation, further research is needed to evaluate its effectiveness and any unintended consequences before widespread implementation.

Beyond infrastructure-based and behavioral solutions, policy changes such as the implementation of permanent daylight savings time could help mitigate wildlife-vehicle collisions. Most deer-vehicle collisions occur in November during dusk, when peak traffic hours coincide with high deer activity levels (Cunningham et al., 2022). By shifting daylight hours via permanent daylight savings time, peak traffic in November would occur just before sunset rather than immediately after, potentially reducing evening collisions. While this change might lead to an increase in morning collisions, the overall net effect could result in a significant reduction in total WVCs (Cunningham et al., 2022). However, the feasibility of such a policy change depends on broader legislative decisions and may be beyond the control of individual transportation agencies.

Animal Behavior

Attempts to influence animal behavior without the use of physical barriers have generally had limited success. Various deterrents—including reflectors, whistles, olfactory repellents, and hazing techniques—have been tested, but most have proven ineffective or suffer from rapid habituation by wildlife (Table 3). Reflectors and whistles, which aim to deter deer by reflecting vehicle headlights or emitting high-frequency sounds, have little to no effect on deer behavior (Benten et al., 2018; Terrade et al., 2024; Valitzski et al., 2007). Hazing techniques, which involve startling or harassing animals to discourage road crossings, may provide short-term deterrence, but wildlife quickly becomes accustomed to these disturbances, rendering them ineffective over time. Olfactory repellents, which use scents to deter animals from roadways, have shown some promise (Balciauskas and Jasiulionis, 2012), though concerns remain about their long-term effectiveness due to potential habituation (Keken et al., 2024).

Reducing deer populations through culling has been suggested to decrease WVCs by lowering overall wildlife density near roadways. However, this method is challenging to implement due to public opposition, ethical concerns, and the density-dependent nature of deer reproduction, which can result in increased birth rates when populations decline (Swihart et al., 1998). Delisle et al. (2024) increased the bag limit and hunting season duration near known hot spot road segments in Indiana. This method was effective in reducing collisions at those segments. Other road modifications, such as wider medians and alternative deicers, have been proposed as potential mitigation strategies, but their effectiveness remains largely unsubstantiated (Huijser and McGowen, 2010).

Another proposed solution is virtual fencing, which consists of small devices mounted along roadways that detect vehicle headlights at night and emit flashing lights and high-pitched sounds to deter animals from crossing (Reeves et al., 2022). While virtual fences are cheaper and require less maintenance than physical barriers (Reeves, 2018), they are not effective. Other deterrent methods that rely on light or sound to repel deer, such as reflectors and ultrasonic whistles, are also ineffective (Valitzski et al., 2007; Benten et al., 2018), suggesting that virtual fences may face similar limitations. Some research suggests they may increase vigilance in kangaroos (Reeves et al., 2022), but other studies found no significant reduction in roadkill (Coulson and Bender, 2021; Candy et al., 2024).

Non-Deer Species

Most research on mitigation strategies focuses on deer and/or other large herbivores, which creates a major gap in road ecology because roadkill has more significant impacts on populations of smaller species than on deer (Gibbs and Shriver, 2002, 2005; Row et al., 2007). For instance, mesocarnivore, reptile, and amphibian populations are more significantly affected by roadkill than large ungulate populations (Gibbs and Shriver, 2002, 2005; Denneboom et al., 2021). While this imbalance persists, some mitigation measures designed for deer may still benefit a broader range of wildlife and should be evaluated for multi-species effectiveness.

For example, collision hotspots tend to cluster similarly across major taxonomic groups, suggesting that deer could serve as a spatial proxy for identifying areas in need of mitigation (Morelli et al., 2024). Because deer collisions are often well-documented, their data can help prioritize locations for broader wildlife mitigation. However, the assumption that strategies effective for deer will benefit other species remains largely untested. Differences in size, behavior, and habitat needs mean that smaller species may respond differently to the same mitigation measures. For instance, while a large underpass may be suitable for deer, it may not meet the microhabitat requirements of amphibians or reptiles. Similarly, fences designed for deer may have gaps that allow smaller animals through. Therefore, while deer data offer a useful starting point, more research is needed to evaluate whether mitigation strategies provide cross-species benefits and to identify adjustments needed for smaller, more vulnerable species.

Solid physical barriers designed for deer can also prevent roadkill among smaller species—provided the gaps are small enough to exclude them (Conan et al., 2023). However, some barriers, like chain-link fences, have holes large enough for small animals to pass through, making them less effective at reducing roadkill in those species (Conan et al., 2023, Hamer et al., 2023). Mitigation strategies should be tailored to the goal of mitigation, whether that is to exclude all species or to exclude deer while allowing small species to move freely. If the goal is to exclude both deer and small animals from the road, a fence on top of a one-foot-tall concrete barrier with a small overhang should be sufficient to prevent access of amphibians and similarly sized animals from the road (Conan et al., 2023). However, if the barrier is not maintained, amphibians will still be able to access the road (Conan et al., 2023).

Some methods have been attempted to target species other than deer. Ultrasonic devices were found to be ineffective at deterring rodents from roadways (Sousa-Guedes et al., 2020), similar to deer. Poles spaced one foot apart, with colored flags on top, formed an effective barrier to hawks, waterbirds, and vultures (Zuberogoitia et al., 2015). However, because of the in-air agility of birds, they could still access the road without going through the pole barrier (Zuberogoitia et al., 2015). Educational campaigns may be effective in reducing snake collisions, since snakes are often killed intentionally by drivers (Secco et al., 2014).

Cost-Benefit Analyses

Wildlife-vehicle collisions are costly. For instance, mean cost per collision in Utah from 1996 to 2001, adjusted for inflation, was $7,057 (Bissonette et al., 2008). This includes human fatality cost assessed at $49,000,000, total vehicle damage worth $37,000,000 and loss of deer worth $5,500,000, all adjusted for inflation. Mitigation strategies can also be costly (Table 5). However, there is great variability in the benefits of implementing various strategies (Table 5), While some strategies like seasonal wildlife warning signs are not effective, their cost benefits may be greater than highly effective road tunnels and elevated roadways (Table 6).

Table 5. Cost-Benefit Analysis of Mitigation Strategies

Mitigation Measure	Cost ($/km/yr)	%DVC Reduction	Benefit ($/km/yr)	Balance ($/km/yr)
Standard warning signs	$18	0%	$0	**($18)**
Enhanced wildlife warning signs	$249	?	?	?
Seasonal wildlife warning signs	$27	26%	$10,904	$10,878
Animal detection systems (ADS)	$31,300	82%	$34,391	$3,091
ADS linked to on-board computer	?*	82%	$34,391	?
On-board animal detectors	$2,225*	?	?	?
Vegetation removal	$500	38%	$15,937	$15,437
Deer reflectors and mirrors	$495	0%	$0	**($495)**
Deer whistles	$23.5*	0%	$0	**($23.5)**
Carcass removal	$250*	?	?	?
Population culling	$2,508	50%	$20,970	$18,462
Relocation	$10,260	50%	$20,970	$10,710
Anti-fertility treatment	$61,702	50%	$20,970	**($40,732)**
Fence (including dig barrier)	$3,760	87%	$36,488	$32,728
Boulders in right of way	$2,461	?	?	?
Long bridges	$781,250	100%	$41,940	**($739,310)**
Long tunnels	$1,500,000	100%	$41,940	**($1,458,060)**
Fence with gap and warning signs	$3,772	0%	$0	**($3,772)**
Fence with gap and crosswalk	$5,585	40%	$16,776	$11,191
Fence with gap and ADS	$9,930	82%	$34,391	$24,461
Fence with underpasses	$5,860	87%	$36,488	$30,628
Fence with overpasses	$26,485	87%	$36,488	$10,003
Fence with under- and overpasses	$7,510	87%	$36,488	$28,978

Note: Adapted from Huijser et al. (2008), based on a national analysis. Costs marked with an asterisk are per unit, not per kilometer. DVC = deer-vehicle collision. Bold text indicates a cost deficit. Question marks indicate unknown values.

Table 6. Cost per Percent Reduction

Mitigation Measure	Effectiveness	Crossing Opportunity	Present Value Costs	Costs per % Reduction
Seasonal wildlife warning sign	26%	Yes	$3728	$143
Vegetation removal	38%	Yes	$16,272	$428
Fence, gap, crosswalk	40%	Yes	$300,468	$7,512
Population culling	50%	Yes	$94,809	$1,896
Relocation	50%	Yes	$391,870	$7,837
Anti-fertility treatment	50%	Yes	$2,183,207	$43,664
Fence (incl. dig barrier)	86%	No	$187,246	$2,177
Fence, underpass, jump-out	86%	Yes	$538,273	$6,259
Fence, under- and overpass, jump-out	86%	Yes	$719,667	$8,368
Animal detection system (ADS)	87%	Yes	$1,099,370	$12,636
Fence, gap, ADS	87%	Yes	$836,113	$9,610
Elevated roadway	100%	Yes	$92,355,498	$923,555
Road tunnel	100%	Yes	$147,954,696	$1,479,547

Adapted from Huijser et al. (2009). Note: Effectiveness is the estimated percentage reduction in collisions. Crossing opportunity refers to deer mobility. Costs are adjusted to 2025 dollars.

Mitigation Conclusions

In conclusion, the most effective strategy for reducing WVCs remains the prevention of wildlife from crossing roadways via the use of fencing and safe crossing structures. While driver-focused measures like enhanced visibility and speed management can provide some benefits, their effectiveness is often limited without additional enforcement or infrastructure support. Attempts to influence animal behavior through non-physical deterrents have largely failed due to habituation and inconsistent results. A comprehensive, multi-faceted approach that integrates infrastructure improvements, driver awareness, and ecological considerations offers the best chance of significantly reducing WVCs while maintaining habitat connectivity and minimizing negative impacts on wildlife populations.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

NON-DEER WILDLIFE-VEHICLE COLLISIONS

There is a clear lack of information pertaining to non-deer wildlife-vehicle collisions. A few species are occasionally recorded in the IDOT GIS portal (IDOT 2025), including raccoon, coyote, and wild turkey. However, data recording is largely opportunistic and unsystematic, resulting in limited usable data due to a lack of standardization. For instance, we recorded 10 different ways raccoon (e.g., raccoon, racoon, racon, one racoon, etc.) were entered into the IDOT GIS portal database (IDOT 2025). We found more anecdotal evidence through citizen-science projects, like iNaturalist; however, these data are too sparse and inconsistent to be of widespread use. The Illinois Department of Natural Resources also collects data on roadkill animals, although these observations are not georeferenced. Consequently, we believe there is great need to collect information pertaining to vehicle collisions for non-ungulate species. We believe there are two plausible approaches to addressing this paucity of information: (1) engage with the public to promote participatory science, or (2) implement more formalized data collection on non-ungulate roadkill species through partnerships.

Many states have taken steps to encourage the public to report collision or roadkill data. Although many states, including Illinois, focus only on large ungulates, other states have explicitly requested data on other species, and set up websites or mobile apps to support data collection and reporting. In California, The Road Ecology Center at the University of California-Davis developed a publicly accessible database and website to upload pictures of roadkill along California roads, the California Roadkill Observation System (https://www.wildlifecrossing.net/california/). Massachusetts has a similar program (https://www.linkinglandscapes.info/wildlife-roadkill-database.html), and the Florida Fish and Wildlife Commission is developing a statewide program. Several states have websites built through Survey123 for the public to report sick, injured, or dead wildlife, managed by state agencies; many include fields for the data to be specifically georeferenced, but are not limited to roadkill or collisions. Other states have built apps that record only roadkill, notably Utah and Wyoming (https://roadkill-reporter.utah.gov/). The Oregon Department of Fish and Wildlife created their own iNaturalist project, with instructions for the public who are interested in contributing (https://myodfw.com/articles/roadkills-oregon). States with no formal roadkill reporting programs also have informal iNaturalist projects created by interested members of the public (https://www.inaturalist.org/projects/roadkills-of-texas). Of these existing programs, the ones most likely to yield useful data are those that provide users with detailed technical instructions on how to download apps and provide structure on the specific data requested from the user, including georeferencing information. This guidance allows interested citizens to contribute to data collection but also allows for a method to vet and verify observations consistently. Participatory science is frequently beset with biases, especially based on observer patterns and frequency of participation (Sauermann and Franzoni, 2015; Boakes et al., 2016), so incorporating a set data structure can help mitigate biases analytically.

To counteract potential biases from unstructured data collection, a more formalized roadkill and wildlife-vehicle collision monitoring system may be an additional way to collect meaningful data. Illinois DNR currently has a long-term roadkill monitoring survey; however, these data are not georeferenced and were not usable for this study. If a mobile app were developed for the public that could easily and expediently record roadkill encounters, IDNR could continue collecting its existing roadkill data while also gaining the added benefit of georeferenced observations—without creating additional work for contributors. Other jurisdictions have also developed app-based survey procedures and protocols that may be transferable to Illinois. The U.S. Fish and Wildlife Service, National Park Service, and Montana State University developed the Roadkill Observation and Data System (ROaDS), a survey framework hosted in Survey123 for assessing roadkill on refuge lands (Fleming, 2022). Vermont and other states also use the ROaDS framework for their roadkill observations, so creating an Illinois-specific branch would likely be straightforward and interface with a large-scale existing database.

Beyond public participation, the app could be distributed to municipal, county, and state roadway maintenance crews, as well as forest preserve staff and other personnel working in areas with high concentrations of species of conservation concern. Similar targeted approaches have been successful elsewhere. For instance, Maine Audubon coordinated a three-year turtle road mortality survey with trained volunteers using a systematic sampling design (Maine Audubon, 2021). Likewise, the nonprofit Tortoise Group used the ROaDS framework to monitor vehicle collisions involving Mojave desert tortoises (*Gopherus agassizii*) and related threats such as predation by Common Ravens (*Corvus corax*). Targeted surveys using the ROaDS platform—or similar tools—could help identify collision dynamics and mitigation needs for vulnerable species or known hotspots in Illinois. Collaborations with IDNR, academic institutions, and conservation nonprofits would likely enhance the effectiveness and reach of these efforts.

DEER WILDLIFE-VEHICLE COLLISIONS

The 12 road segments in Table 7 had the greatest number of collisions. We propose prioritizing these segments for mitigation measures. Segments on I-72, I-74, US 34, and I-64—interstates, freeways, and expressways with high speeds and heavy traffic volumes—would benefit most from the installation of wildlife exclusion fencing. Lesser-used roads, like US 24, SR 100, SR 13, and SR 152, may be better suited for alternative mitigation methods, including animal detection systems. Some road segments (Pine Bluff Rd, SR 1) have a moderate traffic load and other factors, such as speed limit and road design, which need to be considered when deciding on mitigation. Some evidence suggests that animal detection systems will also help with moderately used roads (Bhardwaj et al., 2022).

Table 7. Road Segments with More Than 100 Deer-Vehicle Collisions (2009–2023)

Road Name	County	Segment Start X	Segment Start Y	Segment End X	Segment End Y	AADT	Collisions	Length (km)	Mitigation
I-72	Pike	-91.0226	39.6997	-90.9096	39.6889	8,850	211	9.86	Fences
US 34	Warren	-90.5176	40.9200	-90.4412	40.9243	8,950	180	6.73	Fences
I-74	Peoria	-89.7530	40.7741	-89.6990	40.7525	21,100	160	5.15	Fences
Pine Bluff Rd	Grundy	-88.3771	41.3440	-88.3443	41.3446	4,600	139	2.76	ADS
US 24	Fulton	-90.0119	40.4168	-89.9621	40.4509	2,100	136	6.09	ADS
SR 2	Lee	-89.5661	41.8250	-89.5435	41.8298	50	136	1.99	ADS
SR 13	Perry	-89.5262	38.1643	-89.4227	38.0991	1,900	135	11.78	ADS
I-72	Pike	-90.9096	39.6889	-90.8381	39.6714	8,850	132	6.56	Fences
SR 1	White	-88.2132	38.0681	-88.2443	38.0422	3,700	132	3.96	ADS
I-72	Pike	-90.7607	39.6740	-90.6774	39.6809	9,900	124	7.23	Fences
SR 2	Lee	-89.5646	41.8240	-89.5467	41.8281	11,500	118	1.55	Fences
SR 152	Perry	-89.3487	38.0029	-89.2753	38.0018	2,300	116	6.45	ADS
I-474	Peoria	-89.6696	40.6729	-89.6489	40.6606	23,100	116	2.22	Fences
SR 100	Fulton	-90.1748	40.2753	-90.2171	40.1843	550	113	11.47	ADS
I-64	Wayne	-88.3478	38.2659	-88.2610	38.2606	12,000	109	7.73	Fences
I-64	White	-88.1313	38.2377	-88.0136	38.2359	12,200	109	10.32	Fences
SR 29	Peoria	-89.5772	40.7937	-89.5740	40.7726	11,200	105	2.39	Fences
SR 1	White	-88.2642	38.0235	-88.3144	37.9812	3,250	103	6.49	ADS

Note: Segment lengths and traffic volumes are also reported. See Figure 6 for mapped locations.

Animal detection systems and wildlife fencing have consistently proven to be among the most effective mitigation measures for reducing wildlife-vehicle collisions. However, their effectiveness is highly context-dependent, making strategic implementation essential. Animal detection systems are best suited for roads with lower speed limits, where drivers have enough time to react after being alerted to the presence of wildlife. These roads also tend to have lower traffic volumes than interstates, making them ideal candidates for mitigation strategies that preserve habitat connectivity while reducing collision risk. Because detection systems allow animals to cross safely, they help maintain landscape permeability without creating rigid barriers. In contrast, wildlife fencing is most effective along high-speed roads such as interstates and major state highways, where the combination of high traffic volumes and fast-moving vehicles leaves little opportunity for drivers to avoid collisions. These roads already function as near-impassable barriers to wildlife movement, so the additional restriction imposed by fencing does not significantly alter landscape connectivity. Instead, its primary function is to prevent animals from entering the roadway altogether, thereby reducing collision risks. However, fencing alone is not a sufficient long-term solution. Without the support of crossing structures such as underpasses or overpasses, deer and other wildlife will attempt to breach fences. The breaching of fences will lead to structural damage, crossings at fence ends, and reduced effectiveness over time. Pairing exclusionary fencing with well-placed crossing structures is therefore critical to both safety and long-term maintenance.

The primary drawback of both animal detection systems and wildlife fencing is the initial cost of installation. However, both approaches have long lifespans and relatively low maintenance costs. This means that they eventually pay for themselves by reducing the frequency and severity of wildlife-vehicle collisions, which carry significant financial and human safety costs. Our recommendation is thus to prioritize the installation of exclusionary fencing along highways, particularly in segments with historically high collision rates. Highways account for the greatest number of wildlife-vehicle collisions, so the economic return in terms of reduced collisions and associated damages would be substantial. To maximize effectiveness, fences should be paired with cost-efficient underpasses and jump-outs, ensuring that wildlife can still move safely across the landscape without testing or breaching the fencing.

For lower-traffic roads where fencing may not be practical or necessary, targeted animal detection systems could be a potential, albeit expensive, alternative. Targeted animal detection systems could be placed on road segments with a high likelihood of deer presence, much like standard warning signs are implemented currently. These segments would likely be near woodlands or other natural areas. Unlike warning signs, animal detection systems are effective in reducing collision frequency and severity. If cost is a prohibitive factor, olfactory repellents—particularly those derived from human or natural predator scents—could serve as a lower-cost mitigation strategy. However, because deer quickly habituate to olfactory repellents, their use should be limited to specific high-risk periods, such as peak deer movement seasons, to maintain effectiveness.

Increased street lighting may offer localized benefits in small areas with high traffic volumes, such as small towns and highway entrance and exit ramps. While research suggests that street lighting can reduce wildlife-vehicle collisions within illuminated zones, it may also displace collisions to darker surrounding areas as deer attempt to avoid the lit sections of road. As a result, lighting should be used strategically and selectively to balance the potential benefits of increased visibility with the risks of displacement effects. When implemented thoughtfully, a combination of fencing, crossing structures, detection systems, and targeted deterrents can significantly reduce wildlife-vehicle collisions while maintaining ecological connectivity and minimizing costs.

In conclusion, effectively mitigating wildlife-vehicle collisions requires a multi-faceted approach that balances road safety with ecological connectivity. While no single strategy can eliminate collisions entirely, the most effective solutions demonstrate significant potential for reducing both human and wildlife fatalities. Targeted measures, including olfactory repellents and selective street lighting, may provide supplementary benefits in specific contexts, though their effectiveness varies. The financial investment in these mitigation strategies is substantial, but the long-term benefits—fewer collisions, reduced infrastructure damage, lower insurance costs, and improved wildlife conservation—justify the expense. By integrating data-driven mitigation planning with adaptive management strategies, transportation agencies can develop solutions that enhance motorist safety and wildlife movement, creating a more sustainable coexistence between human infrastructure and natural ecosystems.

REFERENCES

Abraham, J. O., and Mumma, M. A. (2021). Elevated Wildlife-Vehicle Collision Rates During the COVID-19 Pandemic. *Scientific Reports*, 11: 20391.

Balciauskas, L., and Jasiulionis, M. (2012). Reducing the Incidence of Mammals on Public Highways Using Chemical Repellent. *Baltic Journal of Road and Bridge Engineering*, 7(2): 92–97.

Benten, A., Hothorn, T., Vor, T., and Ammer, C. (2018). Wildlife Warning Reflectors Do Not Mitigate Wildlife-Vehicle Collisions on Roads. *Accident Analysis and Prevention*, 120: 64–73.

Bhardwaj, M., Erixon, F., Holmberg, I., Seiler, A., Hakansson, E., Elfstrom, M., and Olsson, M. (2022). Ungulate Use of an At-Grade Fauna Passage and Roadside Animal Detection System: A Pilot Study from Southern Sweden. *Frontiers in Environmental Science,* 10: 991551.

Bissonette, J. A., and Hammer, M. (2000). Effectiveness of Earthen Return Ramps in Reducing Big Game Highway Mortality in Utah. *UTCFWRU Report Series*, 2000(1): 1–29.

Bissonette, J. A., Kassar, C. A., and Cook, L. J. (2008). Assessment of Costs Associated with Deer-Vehicle Collisions: Human Death and Injury, Vehicle Damage, and Deer Loss. *Human-Wildlife Conflicts,* 2(1): 17–27.

Boakes, E. H., Gliozzo, G., Seymour, V., Harvey, M., Smith, C., Roy, D. B., and Haklay, M. (2016). Patterns of contribution to citizen science biodiversity projects increase understanding of volunteers' recording behavior. *Scientific Reports* 6: 33051.

Candy, S. G., Bunker, J. A., and Englefield, B. (2024). A Trial of a Virtual Fence to Mitigate Roadkill on an Unsealed Rural Road in Tasmania, Australia. *Animals,* 2024(14): 1641. https://doi.org/10.3390/ani14111641

Clevenger, A. P., Chruszcz, B., and Gunson, K. E. (2001). Highway Mitigation Fencing Reduces Wildlife-Vehicle Collisions. *Wildlife Society Bulletin*, 29(2): 646–653.

Cohen, B. S., Osborn, D. A., Gallagher, G. R., Warren, R. J., and Miller, K. V. (2014). Behavioral Measure of the Light-Adapted Visual Sensitivity of White-Tailed Deer. *Wildlife Society Bulletin*, 38(3): 480–485.10.

Conan, A., Le Brishoual, M., Garnier, L., Fleitz, J., Dehaut, N., Enstipp, M., Jumeau, J., and Handrich, Y. (2023). Efficacy of Permanent Wildlife Fences as Barriers to Amphibian Movement. *Frontiers in Ecology and Evolution,* 11: 1074072.

Conover, M. R., Pitt, W. C., Kessler, K. K., DuBow, T. J., and Sanborn, W. A. (1995). Review of Human Injuries, Illnesses, and Economic Losses Caused by Wildlife in the United States. *Wildlife Society Bulletin,* 23(3): 407–414.

Conover, M. R. (2019). Numbers of Human Fatalities, Injuries, and Illnesses in the United States Due to Wildlife. *Human-Wildlife Interactions,* 13(2): 264–276.

Coulson, G., and Bender, H. (2022). Wombat Roadkill Was Not Reduced by a Virtual Fence. Comment on Stannard et al. Can Virtual Fences Reduce Wombat Road Mortalities? *Ecol. Eng.* 2021, 172, 106414. *Animals,* 12: 1323.

Cunningham, C. X., Nunez, T. A., Hentati, Y., Sullender, B., Breen, C., Ganz, T. R., Kreling, S. E. S., Shively, K. A., Reese, E., Miles, J., and Prugh, L. R. (2022). Permanent Daylight-Saving Time Would Reduce Deer-Vehicle Collisions. *Current Biology*, 32: 4982–4988.

DeGregorio, B. A., Hancock, T. E., Kurz, D. J., and Yue, S. (2011). How Quickly are Road-Killed Snakes Scavenged? Implications for Underestimates of Road Mortality. *Journal of the North Carolina Academy of Science*, 127(2): 184–188.

Delisle, Z. J., Reeling, C. J., Caudell, J. N., McCallen, E. B., and Swihart, R. K. (2024). Targeted Recreational Hunting Can Reduce Animal-Vehicle Collisions and Generate Substantial Revenue for Wildlife Management Agencies. *Science of the Total Environment,* 935: 173460.

DeNicola, A. J., and Williams, S. C. (2008). Sharpshooting Suburban White-Tailed Deer Reduces Deer-Vehicle Collisions. *Human-Wildlife Conflicts*, 2(1): 28–33.

Denneboom, D., Bar-Massada, A., and Shwartz, A. (2021). Factors Affecting Usage of Crossing Structures by Wildlife – A Systematic Review and Meta-Analysis. *Science of the Total Environment*, 777: 146061.

Durmus, D., Jagerbrand, A. K., and Tengelin, M. N. (2024). Research Note: Red Light to Mitigate Light Pollution: Is it Possible to Balance Functionality and Ecological Impact? *Lighting Research and Technology,* 56: 304–308.

ESRI (2024, Nov. 7). ArcGIS Pro Version 3.4.0.

Federal Highway Administration. (2017, June 28). Highway Functional Classification Concepts, Criteria, and Procedures. Federal Highway Administration: Planning Processes. www.fhwa.dot .gov/planning/processes/statewide/related/highway_functional_classifications/section03.cfm.

Finder, R. A., Roseberry, J. L., and Woolf, A. (1999). Site and Landscape Conditions at White-Tailed Deer/Vehicle Collision Locations in Illinois. *Landscape and Urban Planning,* 44: 77-85.

Fleming, S. Improving safety for wildlife and people on roadways. ESRI blog. Accessed March 28, 2025. https://www.esri.com/about/newsroom/blog/wildlife-vehicle-collision-protection/

Forman, R. T. T., and Alexander, L. E. (1998). Roads and their Major Ecological Effects. *Annual Review of Ecological Systems,* 29: 207–231.

Frank, K. M., Ditmer, M. A., Stoner, D. C., Currie, W. S., Olson, D. D., and Carter, N. H. (2023). Dark Roads Aid Movement but Increase Mortality of a Generalist Herbivore in the American Southwest. *Ecosphere,* 14: e4508.

Gagnon, J. W., Dodd, N. L., Sprague, S. C., Ogren, K. S., Loberger, C. D., and Schweinsburg, R. E. (2019). Animal-Activated Highway Crosswalk: Long-Term Impact on Elk-Vehicle Collisions, Vehicle Speeds, and Motorist Braking Response. *Human Dimensions of Wildlife*, 24(2): 132–147.

Gibbs, J. P., and Shriver, W. G. (2002). Estimating the Effects of Road mortality on Turtle Populations. *Conservation Biology,* 16(6): 1647–1652.

Gibbs, J. P., and Shriver, W. G. (2005). Can Road Mortality Limit Populations of Pool-Breeding Amphibians? *Wetlands Ecology and Management* 13: 281–289.

Graves, H. B., and Bellis, E. D. (1978). *The Effectiveness of Deer Flagging Models as Deterrents to Deer*

Entering Highway Rights-of-Way (Report No. FHWA-PA-78-12). Federal Highway Administration.

Hamer, A. J., Mechura, T., and Puky, M. (2023). Patterns in Usage of Under-Road Tunnels by an Amphibian Community Highlights the Importance of Tunnel Placement and Design for Mitigation. *Global Ecology and Conservation*, 43: e02420.

Huijser, M. P., McGowen, P., Fuller, J., Hardy, A., Kociolek, A., Clevenger, A. P., Smith, D., and Ament, R. (2008). *Wildlife-Vehicle Collision Reduction Study: Report to Congress* (Report No. FHWA-HRT-08-034). Federal Highway Administration.

Huijser, M. P., Holland, T. D., Blank, M., Greenwood, M. C., McGowen, P. T., Hubbard, B., and Wang, S. (2009). *The Comparison of Animal Detection Systems in a Test-Bed: A Quantitative Comparison of System Reliability and Experiences with Operation and Maintenance* (Report FHWA/MT-09-002/5048). Western Transportation Institute – Montana State University.

Huijser, M. P., and McGowen, P. T. (2010). Reducing Wildlife-Vehicle Collisions. In: Beckmann, J.P., Clevenger, A.P, Huijser, M.P., and Hilty, J.A. (eds). *Safe Passages – Highways, Wildlife, and Habitat Connectivity.* Island Press: Washington, DC.

Huijser, M. P., Mosler-Berger, C., Olsson, M., and Strein, M. (2015). Wildlife Warning Signs and Animal Detection Systems Aimed at Reducing Wildlife-Vehicle Collisions. In: van der Ree, R., Smith, D.J., and Grilo, C. (eds). *Handbook of Road Ecology*. Wiley-Blackwell: West Sussex, UK.

Huijser, M. P., Fairbank, E. R., Camel-Means, W., Graham, J., Watson, V., Basting, P., and Becker, D. (2016). Effectiveness of Short Sections of Wildlife Fencing and Crossing Structures Along Highways in Reducing Wildlife-Vehicle Collisions and Providing Safe Crossing Opportunities for Large Mammals. *Biological Conservation*, 197: 61–68.

Illinois Department of Transportation. (2025). IDOT GIS Portal.

iNaturalist community. Observations of all species from Illinois, United States observed and tagged as roadkill. Exported from https://www.inaturalist.org on 12/1/25.

Jones, M. E. (2000). Road Upgrade, Road Mortality, and Remedial Measures: Impacts on a Population of Eastern Quolls and Tasmanian Devils. *Wildlife Research* 27: 289–296.

Kantola, T., Tracy, J. L., Baum, K. A., Quinn, M. A., and Coulson, R. N. (2019). Spatial Risk Assessment of Eastern Monarch Butterfly Road Mortality During Autumn Migration within the Southern Corridor. *Biological Conservation,* 231: 150–160.

Keken, Z., Wimmerova, L., Solcova, O., Kusta, T., and Dvorakova, P. (2024). Olfactory Repellents in Road Ecology: What We Know and What to Focus on in the Future. *Sustainability*, 16: 5920.

Lester, D. (2015). Effective Wildlife Roadkill Mitigation. *Journal of Traffic and Transportation Engineering*, 3: 42–51.

Maine Audubon. 2021. Maine turtle roadkill survey. Accessed March 28, 2025. https://maineaudubon.org/projects/road-watch/maine-turtle-roadkill-survey/.

McCollister, M. F., and Van Manen, F. T. (2010) Effectiveness of Wildlife Underpasses and Fencing to Reduce Wildlife-Vehicle Collisions. *Journal of Wildlife Management*, 74(8): 1722–1731.

McDonald, M. G. (1991). Moose Movement and Mortality Associated with the Glenn Highway

Expansion, Anchorage, Alaska. *Alces*, 27(1991): 208–219.

Meisingset, E. L., Loe, L. E., Brekkum, O., and Mysterud, A. (2014). Targeting Mitigation Efforts: The Role of Speed Limit and Road Edge Clearance for Deer-Vehicle Collisions. *Journal of Wildlife Management*, 78(4): 679–688.

Meyer, E. (2006). *Assessing the Effectiveness of Deer Warning Signs. Kansas Department of Transportation* (Report KTRAN: KU-03-6). The University of Kansas, Lawrence.

Morelli, F., Benedetti, Y., Kustusch, K., and Wuczynski, A. (2024). Spatio-Temporal Hotspots of Wildlife-Vehicle Collisions in Poland: How Congruent are Mammals, Birds, Reptiles, and Amphibians? *Science of the Total Environment*, 957: 177485.

Pagany, R. (2020). Wildlife-Vehicle Collisions – Influencing Factors, Data Collection and Research Methods. *Biological Conservation,* 251:108758.

Quinn, A. C. D., Williams, D. M., and Porter, W. F. (2013). Landscape Structure Influences Space Use by White-Tailed Deer. *Journal of Mammalogy,* 94(2): 398–407.

R Core Team (2025). _R: A Language and Environment for Statistical Computing_. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Reeves, J. (2018). Road Mitigation Measures for Macropods in the Noosa Shire, Queensland. University of Sun Coast: Sippy Downs, Queensland, Australia.

Reeves, J., Burnett, S., and Brunton, E. (2022). Virtual Fencing as a Wildlife-Vehicle Collision Mitigation Measure: Technical Function, Wildlife Response and Considerations for Installation in an Urban Environment. *Australian Zoologist*, 42(1): 55–70.

Riginos, C., Fairbank, R., Hansen, E., Kolek, J., and Huijser, M.P. (2022). Reduced Speed Limit Is Ineffective for Mitigating the Effects of Roads on Ungulates. *Conservation Science and Practice,* 4: e618.

Romin, L. A., and Bissonette, J. A. (1996). Deer-Vehicle Collisions: Status of State Monitoring Activities and Mitigation Efforts. *Wildlife Society Bulletin*, 24(2): 276–283.

Rosen, P. C., and Lowe, C. H. (1994). Highway Mortality of Snakes in the Sonoran Desert of Southern Arizona. *Biological Conservation,* 68: 143–148.

Row, J. R., Blouin-Demers, G., and Weatherhead, P. J. (2007). Demographic Effects of Road Mortality in Black Rat Snakes (Elaphe obsolete). *Biological Conservation,* 137: 117–124.

Sauermann, H and C. Franzoni. 2015. Crowd Science User Contribution Patterns and Their Implications. Proceedings of the National Academy of Sciences 112(3): 679–684.

Secco, H., Ratton, P., Castro, E., da Silva Lucas, P., and Bager, A. (2014). Intentional Snake Road-Kill: A Case Study Using Fake Snakes on a Brazilian Road. *Tropical Conservation Science*, 7(3): 561–571.

Sharma, S. U., and Shah, D. J. (2017). A Practical Animal Detection and Collision Avoidance System Using Computer Vision Technique. *IEEE Access*, 5: 347–358.

Snow, N. P., Porter, W. F., and Williams, D. M. (2015). Underreporting of Wildlife-Vehicle Collisions Does Not Hinder Predictive Models for Large Ungulates. *Biological Conservation*, 181: 44–53.

Sousa-Guedes, D., Ribeiro, H., Vaz-Freire, M. T., Mira, A., and Sillero, N. (2020). Ultrasonic Device Effectiveness in Keeping Rodents off the Road. *European Journal of Wildlife Research*, 66: 23.

Sperry, B. R., Popescu, V., Wyza, E., Porter, S., Wiley, R., Cottrill, D., and McAvoy, D. S. (2023). Assessment of Deer-Vehicle Crash Mitigation Structures on the US 33 Nelsonville, Ohio, Bypass. *Journal of Transportation Engineering*, 149(8): 05023004.

State Farm. (2024). How Likely Are You to Have An Animal Collision? https://www.statefarm.com /simple-insights/auto-and-vehicles/how-likely-are-you-to-have-an-animal-collision.

Sullivan, T. L., Williams, A. F., Messmer, T. A., Hellinga, L. A., and Kyrychenko, S. Y. (2004). Effectiveness of Temporary Warning Signs in Reducing Deer-Vehicle Collisions During Mule Deer Migrations. *Wildlife Society Bulletin*, 32(3): 907-915.

Swihart, R. K., Weeks, H. P., Easter-Pilcher, A. L, and DeNicola, A. J. (1998). Nutritional Condition and Fertility of White-Tailed Deer from Areas with Contrasting Histories of Hunting. *Canadian Journal of Zoology,* 76(10): 1932–1941.

Terrade, A., Prosnier, L., Vion, C., Locatelli, Y., Mathevon, N., and Reby, D. (2024). High-Frequency Hearing Sensitivity Does Not Systematically Imply Aversion to Ultrasounds in Large Terrestrial Mammals. *Bioacoustics*, 33(5): 448–459.

United States Department of Agriculture. (2007). USDA-NASS Cropland Data Layer Illinois 2007.

Valerio, F., Basile, M., and Balestrieri, R. (2021). The Identification of Wildlife-Vehicle Collision Hotspots: Citizen Science Reveals Spatial and Temporal Patterns. *Ecological Processes,* 10: 6.

Valitzski, S. A., D'Angelo, G. J., Gallagher, G. R., Osborn, D. A., Miller, K. V., and Warren, R. J. (2007). Deer Responses to Sounds from a Vehicle-Mounted Sound-Production System. *Journal of Wildlife Management*, 73(7): 1072–1076.

Vanlaar, W. G. M., Barrett, H., Hing, M. M., Brown, S. W., and Robertson, R. D. (2019). Canadian Wildlife-Vehicle Collisions: An Examination of Knowledge and Behavior for Collision Prevention. *Journal of Safety Research*, 68: 181–186.

Warren, R.J. (2011). Deer Overabundance in the USA: Recent Advances in Population Control. *Animal Production Science*, 51: 259–266.

Zuberogoitia, I., del Real, J., Torres, J. J., Rodriguez, L., Alonso, M., de Alba, V., Azahara, C., and Zabala, J. (2015). Testing Pole Barriers as Feasible Mitigation Measure to Avoid Bird Vehicle Collisions (BVC). *Ecological Engineering*, 83: 144–151.

Illinois Department of Transportation

ILLINOIS