Understanding Wildlife Vehicle Collisions in Northern Minnesota: Ecological Drivers, Mitigation Limits, and Community-Based Behavioral Solutions

Literature Review

Energy and Mineral Engineering Capstone

Pennsylvania State University

Angela Carswell

Abstract

Wildlife vehicle collisions (WVCs) represent a significant threat to global biodiversity and public safety. Globally road networks exceed 64 million kilometers creating a significant intersection with natural habitats (van der Ree, Smith, et al., 2015). While structural mitigation like fencing and underpasses effectively reduce mortality at specific hotspots, they often remain reactive and fail to address the everyday behavioral drivers of collisions. This literature review examines the ecological and infrastructure-based causes of WVCs, with a specific focus on northern Minnesota by synthesizing road ecology data with environmental psychology theories such as place attachment and impact focused behavior change, this research identifies a gap in current public messaging strategies. The finding suggests that traditional "crash avoidance" slogans are less effective than messaging rooted in community identity and shared stewardship. The paper proposes a community-based intervention in partnership with the Wildwoods Wildlife Rehabilitation Center, centered on the slogan: "Keep it clean. Keep it slow. Wildlife lives here." This approach reframes collision prevention as a proactive form of coexistence, turning routine driving habits into durable environmental stewardship.

Introduction

Wildlife vehicle collisions (WVCs) are a growing ecological and public safety concern in the United States. Roads intersect wildlife habitat across nearly every landscape, creating repeated points of conflict between animal movement and motor vehicle traffic. Globally, road networks exceed 64 million kilometers, and road expansion is projected to continue for decades to come (van der Ree, Smith, et al., 2015). As road density increases, so do the ecological impacts associated with linear infrastructure, including habitat fragmentation, direct mortality, altered movement patterns, and long-term disruption of ecosystem processes (van der Ree, Smith Daniel J., et al., 2015).

In the United States alone, between one and a half to two million wildlife vehicle collisions occur annually, and the number is increasing (Huijser et al., 2008). Recent insurance data estimates approximately 1.7 million animal-related collision claims between July 2024 and June 2025, including more than 1.1 million involving deer (State Farm Insurance Newsroom, 2025). These collisions carry significant consequences, resulting in substantial human injuries and fatalities, extensive vehicle and property damage, and measurable negative impacts to wildlife populations (Huijser et al., 2008). From an ecological lens, roads fragment habitat and restrict natural animal movement, while directly causing mortality through vehicle strikes (Frank et al., 2023; van der Ree, Smith, et al., 2015). The “road effect zone” concept further emphasizes that the ecological impacts extend beyond the pavement itself, influencing surrounding habitat quality and wildlife behavior (van der Ree, Smith, et al., 2015).

Minnesota presents a particularly relevant context for this issue. The state contains extensive forest, wetland, lake, suburban, and agricultural landscapes that support a high density of white-tailed deer, as well as numerous other mammals, birds, reptiles, and amphibians vulnerable to vehicle strikes. Although large ungulates like deer are frequently emphasized due to their economic and human safety impacts, wildlife vehicle collisions affect a wide taxonomic range of species. The Federal Highway Administration reports impacts to multiple wildlife groups, including mammals, birds, reptiles, and amphibians, with direct road mortality documented for federally threatened and endangered species (Huijser et al., 2008; Roberts & Sjölund, 2015). More broadly, collision events cluster spatially and are shaped by roadway characteristics and surrounding environmental conditions (Shilling & Waetjen, 2015). These patterns demonstrate that wildlife vehicle collisions are structured interactions between animal movement and transportation structure rather than random events.

Wildwoods Wildlife Rehabilitation Center plays a critical role in the region. As a frontline wildlife rehabilitation organization, Wildwoods directly observes and responds to the consequences of wildlife vehicle collisions through daily intake of injured animals. While rehabilitation centers do not control transportation policy, they serve as trusted community partners with unique firsthand knowledge positioned to uniquely bridge ecological science, public awareness, and public engagement.

The purpose of this literature review is to examine the ecological and infrastructure drivers of wildlife vehicle collisions, evaluate existing mitigation strategies, and identify gaps in current approaches. By grounding proposed community messaging in established road ecology and transportation research, this aims to ensure that any recommended intervention builds upon, rather than duplicates, scientific policy and efforts. This review argues that while structural mitigation and policy interventions have reduced WVCs in targeted locations, current approaches remain largely reactive and insufficiently address the everyday behavioral and environmental conditions that produce these collisions, highlighting the need for community-based stewardship messaging as a complementary strategy.

Why Wildlife Vehicle Collisions Happen (Root Cause Analysis)

WVCs are driven not only by animal movement, but by how movement patterns overlap with transportation infrastructure. Collision frequency increases where animal density, habitat configuration, and road placement come together (Frank et al., 2023; Snow et al., 2018; van der Ree, Smith Daniel J., et al., 2015). Temporal patterns further intensify risk; national crash data show that wildlife collisions peak during early morning and late evening hours (Huijser et al., 2008), overlapping with crepuscular wildlife vehicle activity. Artificial nightlight also influences crossing behavior, with deer selecting darker road segments even though mortality risk increases in those areas (Frank et al., 2023). These ecological drivers demonstrate that collision risk emerges from predictable interactions between animal behavior, environmental conditions, and roadway placement rather than from movement alone.

Driver behaviors play a critical role in both the likelihood and severity of WVCs. Vehicle speed consistently influences collision outcomes, as higher speeds reduce reaction time and limit the animal's ability to successfully crossroads (Frank et al., 2023). Transportation research further demonstrates that posted speed limits, traffic volume, and roadway type significantly shape collision frequency and severity (Huijser et al., 2008). Spatial modeling analyses reinforce this relationship, showing that collision hotspots emerge when high traffic exposure overlaps with wildlife movement corridors (Shilling & Waetjen, 2015). Regional dynamic modeling also indicates that traffic intensity functions as a key predictor of collision risk when combined with wildlife abundance and landscape structure (Snow et al., 2018). Together, these findings demonstrate that WVC risk is not just a function of wildlife presence, but how driver speed, traffic volume, roadway conditions, and timing all account for the probability of WVCs.

The economic and public safety consequences of WVCs extend far beyond vehicle repair and roadside response. The Federal Highway Administration identifies property damage, human injury and fatality, towing, accident investigation, emergency services, and carcass removal are recurring cost components associated with these crashes (Huijser et al., 2008). Severity increases with vehicle speed and animal size, specifically in crashes involving larger ungulates. Broader multidisciplinary reviews emphasize that WVC-related costs accumulate at regional and national scales, affecting insurance systems, transportation budgets, and long-term infrastructure planning (Balčiauskas et al., 2025). From a transportation management perspective, these recurring financial burdens position WVCs as both a conservation issue and a systemic public safety challenge (Evink & Erickson, 2002).

Environmental features along transportation corridors can increase the amount of time wildlife spend near pavement edges, elevating exposure to vehicles. Discarded food waste can function as a predictable anthropogenic food subsidy that increases the fitness and abundance of opportunistic species and alters predator-prey interactions (Oro et al., 2013). When these subsidies occur near transportation corridors they may concentrate prey and scavenger activity at road ecology research demonstrates that WVCs cluster spatially in response to local environmental conditions and habitat features (Shilling, F., & Waetjen, D., 2015) and roadside resources such as vegetation and salt runoff have been shown to attract wildlife to traffic corridors (Frank et al., 2023; Mata et al., 2015; van der Ree, Smith Daniel J., et al., 2015). Together, these findings suggest that food subsidies and roadside attractions can increase wildlife presence within the road-effect zone, thereby elevating the probability of vehicle encounters.

Existing Mitigation

Structural mitigation is the most widely implemented response to WVCs. These include wildlife fencing, crossing structures such as overpasses and underpasses, enlarged culverts, and roadsides vegetation

management designed to guide animals away from traffic corridors. Transportation agencies across the United States have incorporated fencing and crossing systems to reduce direct mortality while restoring landscape connectivity (Evink & Erickson, 2002). Research demonstrates that when fencing is paired with properly designed crossing structures, wildlife collisions can be substantially reduced while maintaining movement across fragmented habitats (Roberts & Sjölund, 2015; van der Ree, Smith, et al., 2015). However, effectiveness depends on species-specific behavior, placement, maintenance, and long-term monitoring remains inconsistent (Balčiauskas et al., 2025). While infrastructure solutions directly address mortality hotspots, they require a financial investment and ongoing management.

Policy-based mitigation efforts have included reduced speed limits in high collision corridors, seasonal warning signage during peak movement periods, and legislatively authorized funding for environmental mitigation. Transportation agencies frequently implement seasonal ungulate warning signs to target speed reductions during migration or rutting periods to reduce collision frequency (Huijser et al., 2008). At the federal level, the Safe, Accountable, Flexible, Efficient, Transportation Equity Act; A legacy for Users (SAFETEA-LU) (Safetea-Lu, 2005) formally expanded eligibility for funding environmental mitigation projects within transportation planning, including wildlife crossings and habitat connectivity measures. By integrating ecological considerations into federal transportation policy, SAFETEA-LU recognized that wildlife impacts are a transportation system issue rather than solely a conservation concern. However, while these policies provide funding and regulatory support, implementation remains uneven across states and often reactive to document collision hotspots rather than preventative at the planning stage (Evink & Erickson, 2002).

Public awareness campaigns have historically focused on driver safety messages primarily around ungulates with slogans like “Don’t Veer for Deer.” These campaigns aim to reduce driver panic and secondary crashes rather than to address broader ecological dynamics (Huijser et al., 2008). Transportation guidance emphasizes modifying driver behavior at the moment of encounter, reflecting an immediate crash prevention objective (Evink & Erickson, 2002). While such messaging has become standardized and widely recognizable across states, it operates within a reactive safety framework and was not developed within a broader sustainability or stewardship context. As a result, communication WVCs remains largely driver centered and incident focused rather than oriented toward long term ecological coexistence or shared environmental responsibility.

Why Community Messaging Matters

Efforts to reduce WVCs must extend beyond infrastructure and moment of impact driver responses to address how communities understand their relationship with wildlife. Research on wildlife tolerance indicates that human responses to wildlife are shaped less by objective risk and more by attitudes, values, and perceived legitimacy of wildlife presence (Kansky et al., 2016). Similarly, social ecological systems research emphasizes that “sense of place” influences how individuals interpret environmental responsibility and engage in stewardship behaviors (Masterson et al., 2017). Environmental psychology further argues that behavior change is more durable when communication focuses on meaningful impacts and shared responsibility rather than reactive slogans (Nielsen et al., 2021). Together, these findings suggest that messaging rooted in place-based identity and coexistence may influence everyday driving behaviors more effectively than campaigns framed solely around crash avoidance.

Despite advances in infrastructure design and legislative support, current approaches to WVC mitigation remain largely reactive and narrowly framed. Structural solutions such as fencing and wildlife crossings reduce mortality at documented hotspots but don’t influence driver behavior outside those targeted corridors (Evink & Erickson, 2002; van der Ree, Smith Daniel J., et al., 2015). Policy measures and

warning signage similarly focus on high-risk areas or peak movement seasons, emphasizing immediate crash reduction rather than long term behavior norms (Huijser et al., 2008). Public messaging campaigns continue to center on individual crash avoidance, often focused on deer, without integrating broader ecological stewardship or multispecies awareness. Research on wildlife tolerance and social ecological systems suggests that coexistence depends on community attitudes and place-based responsibility rather than solely on technical mitigation (Kansky et al., 2016; Masterson et al., 2017). Together, these patterns indicate a gap between collision response strategies and sustained community level behavioral change.

Effective slogans are not only concise and action oriented, but they also resonate because they connect to shared identity and place. Dual processing theory suggests that much everyday decision making, particularly in fast moving environments such as driving relies on rapid intuitive processing rather than deliberate reasoning (Evans, 2008). Messages that are simple fluent and easy to process are more likely to be perceived positively and remembered, increasing their persuasive impact (Schwarz & Winkielman, 2004). At the same time, attachment research demonstrates that individuals form emotional and identity-based bonds with the landscapes they inhabit, which shape their willingness to engage in protective behaviors(Scannell & Gifford, 2010). When slogans reflect local identity and shared responsibility, they connect cognitive efficiency with emotional attachment, making behavioral cues more likely to translate into consistent stewardship.

Gaps in Current Approaches

Although infrastructure improvements, policy adjustments, and public safety campaigns have reduced collision risks in specific locations, current approaches do not fully address the interconnected ecological and behavioral drivers of WVC's. Structural mitigation focuses primarily on documented hotspots rather than broader landscape patterns of habitat fragmentation and wildlife movement (van der Ree, Smith Daniel J., et al., 2015). Policy tools such as seasonal signage and speed advisories concentrate on peak risk periods but do not reshape everyday driving norms (Huijser et al., 2008). Likewise existing messaging strategies emphasize immediate crash avoidance rather than reducing roadside attractants or encouraging long term stewardship behaviors. As a result, ecological factors, human behavior, and environmental attractants are often treated as isolated components rather than as interacting root causes within a shared social ecological system.

Because current strategies prioritize hotspot mitigation and movement of impact response, they leave routine behaviors largely unchanged. Drivers continue to travel at habitual speeds, roadside litter persist and wildlife movement remains concentrated near attractants embedded with everyday infrastructure. Without communication that reframes wildlife presence as a shared responsibility, rather than an isolated collision risk remains tied to recurring human patterns rather than exceptional events addressing WVC's. Therefore, this requires a shift from incidental based mitigation towards sustained behavioral norms that recognize coexistence as part of living in wildlife rich landscapes.

Wildwood wildlife rehabilitation center occupies a unique position within this gap as a nonprofit wildlife rehabilitation organization serving the greater Duluth region in Minnesota. Wildwoods directly treats animals injured by human-related causes, including vehicle collisions, and works to educate community members on reducing human-wildlife conflict (Wildwoods, 2026). This dual role, providing hands-on care while engaging in public outreach, gives the organization both practical insight into the consequences of WVC's and established credibility within the community. Because its mission emphasizes compassion, stewardship, and appreciation for local wildlife, Wildwoods is well-positioned to introduce messaging that connects scientific understanding of collision risk with community identity and

shared responsibility. In doing so, it can help shift public framing from reactive crash avoidance toward protective coexistence.

Proposed Community Message

To address the identified gap between reactive collision mitigation and sustained community stewardship it revised public message should move beyond deer-specific crash avoidance toward broader ecological responsibility. A slogan centered on shared habitat in everyday behavior, such as "*Keep it clean. Keep it slow. Wildlife lives here,"* reframes WVC prevention as a collective stewardship practice rather than an isolated traffic hazard. By emphasizing reduced speed, litter prevention, and recognition of wildlife as co-inhabitants of the landscape, this message integrates ecological awareness with routine driving behavior. Unlike traditional safety slogans that focus narrowly on moment of impact response, this framing aligns with research on place attachment, tolerance, and behavior change by connecting local identity, shared values, and practical action (Kansky et al., 2016; Masterson et al., 2017; Nielsen et al., 2021). Because it applies to multiple species in everyday conditions, not only peak deer seasons, it promotes multi-species awareness and long-term coexistence. The message can be reinforced through driver education programs, community outreach, social media campaigns, and partnerships with local organizations, embedding stewardship into daily habits and strengthening a culture of responsibility in wildlife-rich regions such as northern Minnesota.

Conclusion

Wildlife vehicle collisions are not random events but predictable outcomes of ecological movement patterns intersecting with transportation infrastructure, human driving behavior, and roadside attractants. Habitat fragmentation, landscape configuration, vehicle speed, seasonal wildlife activity, and environmental factors such as salt in food waste all contribute to collision risks across multiple species. While infrastructure improvements, legislative measures such as SAFETEA-LU, and driver-focused safety campaigns have reduced risks in specific contexts, these approaches remain largely reactive. They addressed documented hotspots of impact behavior but did not consistently reshape everyday habits or foster broader ecological stewardship. Research on tolerance place attachment in environmental psychology suggests that long term coexistence depends on community identity, shared responsibility, and durable behavior norms rather than isolated warnings.

In wildlife-rich regions such as northern Minnesota, where natural landscapes are central to community identity and quality of life, reframing WVC prevention as stewardship strengthens both conservation and public safety goals. Protecting wildlife and habitat reduces injuries, financial costs, and infrastructure strain while reinforcing shared values of respect for the natural world. Organizations such as Wildwoods are uniquely positioned to lead this shift by connecting scientific understanding with compassion and local pride. By embedding simple placed base cues into daily routines, slowing down, reducing litter, and recognizing wildlife as neighbors, communities can move from a reactive avoidance towards proactive coexistence. In this way, collision prevention becomes not only a transportation concern but a reflection of how residents choose to live within the landscape they call home.

Keep it clean. Keep it slow. Wildlife lives here.

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