Collisions between wildlife and vehicles can be extremely serious or fatal to people and animals alike, and threaten the survival of various animal species. In Canada, wildlife-vehicle collisions (WVCs) have risen by approximately 9% between 1996 and 2000 (L-P Tardif & Associates Inc. 2003) and continue to pose a risk as traffic volumes increase in Canada (Gunson et al. 2003), in part because road networks and other transportation corridors (e.g., railways) act as barriers to wildlife and ecological systems. While the dangers posed by large animal collisions are more recognized, small wildlife often do not receive the same level of attention in terms of mitigation measures; however, they are an important component to ecosystems, and still pose risks to drivers who attempt to evade them. Of concern many of these small animals include several species at risk.

In response to these concerns, a wide variety of mitigation measures have been studied to increase understanding of their effectiveness, applicability, costs, and versatility among other factors. To highlight the research on mitigation, four studies are briefly discussed below that illustrate several of these research areas. The first two articles were selected to provide a comprehensive overview of some of the research, limitations, and recommendations related to the two most effective mitigation measures in use, exclusion fencing and wildlife crossings. The first by Clevenger et al. (2001) studied the impact of exclusion fencing in Banff National Park before and after installation. The second by van der Ree et al. (2007) involved a meta-analysis of 122 studies on the effectiveness of wildlife crossings and evaluated the methodology used in the studies. The results of both studies confirmed the continued effectiveness of these measures, but also highlighted relevant concerns, such as the high concentration of WVCs at the ends of fences and problematic methodological practices used to evaluate mitigation measures.

The other two studies closely examined animal behaviour and movement in relation to mitigation measures. Determining what paths different animal species prefer to follow and at what times of day or year can help transportation planners position proposed transportation corridors or add species-specific mitigation measures to roadways at optimal points along the route. Both studies highlighted different approaches to modeling animal behaviour and movement in relation to WVCs. The first by Gunson et al. (2011) reviewed 24 studies that used statistical spatial modeling to analyze WVCs. A key finding from this study was the increased occurrence of WVCs along roads that provided desirable food sources. The second study by Patrick et al. (2012) designed and tested a model to predict movement and mortality hotspots for 12 species of amphibians and reptiles. Researchers were able to design a model that could predict small animal movement hotspots and assess the impact roads may have on them and translate this model to larger scales for use by transportation planners.

**Issue and objective.** The authors collected data on WVCs before and after the installation of mitigation fencing and wildlife passages along the TransCanada Highway through Banff National Park, Canada. The objective was to study the impact and effectiveness of mitigation (exclusion) fencing on reducing WVCs along a major highway.

**Methodology.** Data were collected over the course of 18 years, from May 1981 until December 1999 that corresponded to before and after the installation of three phases of mitigation fencing. The authors visited the site of each WVC that occurred during the study and recorded the date, species information, number of wildlife involved in the collision, and plotted the location within ± 100 m on a topographical map at 1:50,000 scale. After the mitigation fencing was in place (between 1997 and 1999), the authors were able to observe and record wildlife entering the transportation right-of-ways (unfenced areas that allow access to the transportation corridor) which were equipped with alternative mitigation measures, such as cattle guards or plastic sheeting along railroads. Observations of wildlife which crossed these areas were labeled as “fence intrusions”.

Using select statistical methods of analysis, the authors mapped the location and frequency of WVCs to determine if changes occurred after the installation of fencing. The species that comprised the majority of the wildlife mortality analyses included big horn sheep, black bears, coyotes, deer, elk, moose, and wolves.

**Findings and conclusions.** One of the primary findings from the study was that the authors were able to conclude that mitigation fencing resulted in a significant decline in the occurrence of WVCs within the Banff National Parkway, despite increased traffic volumes. However, the results varied depending on the species type, where ungulate (e.g., moose or deer) mortality dropped by 80% while carnivore (e.g., wolves or cougars) mortality dropped by only 16% and no difference was recorded for coyotes. The differences were largely attributed to the type of mitigation fencing used which was specifically designed for ungulates. It was also noted that ungulate population size, primarily deer and elk, either experienced insignificant fluctuations or increased over the course of the study, thus this variable could be ruled out as a factor for reduced collisions. Other animals, such as bears, cougars, or coyotes, tended to either climb over or dig under the fencing.

The other major finding showed that the occurrence of WVCs post-fence installation was concentrated in four locations. Three of these high-incident locations corresponded to fence ends (the end point of wildlife fencing) while WVCs in the fourth location were located approximately 430 m away from the fence end near drainage systems. In this latter case, the authors suggested that the presence of the drainage systems, which corresponded to the migration routes of deer and elk, might have accounted for the further distance of WVCs away from the fence end.

A number of other results related to the effectiveness of plastic sheeting, cattle guards, use of wildlife passages, and the occurrence of WVCs around fence intrusions were also discussed. Limitations to the study included the low numbers of carnivores in the analysis, which restricted the conclusions that the authors could make regarding fencing and fence-end effects for non-ungulate species. Overall, the study provided effective long-term analysis of mitigation fencing and highlighted problem areas regarding fence ends.

analyzed and evaluated a broad range of studies on wildlife crossings in order to determine, one, the overall findings concerning use and effectiveness of wildlife crossings; and, two, the scientific rigour and methodology employed by the studies.

**Methodology.** A total of 122 studies which analyzed wildlife crossing structures in 13 countries were reviewed and evaluated. Studies were analyzed across a range of criteria based upon each study's overall findings, whether the study used certain credible scientific methods to conduct the analysis, and, among those studies that employed a particular method, the extent of rigour used with the methodology. For instance, studies were analyzed based upon whether they included a before-after analysis of mitigation structures, the type of survey technique employed by the study, if the study included descriptions of road and traffic conditions, the duration of the study, how the study assessed the presence of other potential influential factors, and other methodologies. Some of the methodologies were then further analyzed to determine their scientific rigour. For example, when surveying animal use of crossings, the authors evaluated the technique used by the study (e.g., video, tracks, observation, scat, or other means), or the authors evaluated the number of structures the study evaluated (e.g., one, two, three, and so on).

**Findings and conclusions.** Using criteria developed by Forman et al. (2002), the authors reported that all of the studies demonstrated that the wildlife crossings they examined produced some level of successful mitigation for the animal type for which the measure was designed. The authors pointed out however that successful mitigation does not translate into equal improvements in wildlife conservation. In other words, not enough research has been undertaken to determine if wildlife crossings, although successful at reducing wildlife-vehicle collisions and improving connectivity, do enough to counter the full effects produced by road corridors.

The authors recognized that there were often trade-offs between research design and implementation feasibility; however, they revealed a number of areas where research methodology related to evaluating effectiveness of crossing structures should be improved. Some of the recommendations included developing a selection of pre- and post-population models for the species’ age, sex, dispersal patterns, or genes. Research could also be improved by determining what different animal species use mitigation structures for (e.g., migration, general movement, or to reach food and water sources). It was suggested that survey methods need to better recognize inherent biases. Furthermore, analyses of structure suitability for one area must take into consideration animals in neighbouring habitats and the effect this may have on crossing use. The authors also noted that knowledge transfer concerning reports and studies, particularly within North America, needed to improve.

Overall, this study provided a comprehensive review of research that analyzed the effectiveness of wildlife crossings in numerous countries. The variety of methodological suggestions offered by the authors can be used as a guideline by researchers to further streamline and focus future research. As a next step, researchers may also consider evaluating the impact of poorly placed or incorrect types of wildlife crossings on wildlife and WVCs.


**Issue and objective.** Increasingly, road ecologists use statistical spatial modeling techniques to determine to what extent landscape-related characteristics (e.g., the presence of wetlands, vegetation, or urban development) and road-related predictors (e.g., slope of roads, visibility along roadway, or traffic volume) have an impact on WVCs. The authors reviewed and categorized various studies that tried to explain the occurrence of WVCs through empirical analyses in an effort to reveal “common and novel” results among the studies. The authors shared these results as a means to improve WVC modelling processes as well as to help improve decision-making among transportation planners related to road design and mitigation measures.

**Methodology.** Gunson et al. selected and reviewed 24 studies that used quantitative analyses (specifically, generalized linear models such as logistic regression) that met certain criteria as defined by the authors, as well as those studies which used standardized methodology, in order to conduct comparative
analyses. The studies were divided into either landscape or road-related studies based upon each study’s primary predictors and were further classified based upon the target species in the study. The results of each study were summarized according to the landscape characteristics or road-related predictors the authors previously identified, and whether there was an associated statistically significant increase or decrease in WVCs. The authors presented their findings in two tables: landscape and road-related factors.

**Findings and conclusions.** The review and analyses revealed a number of important linkages between the occurrence of WVCs and landscape characteristics and road-related predictors. Some of these findings included that risks for WVCs increased alongside roads that provided shrub for wildlife cover, improved foraging, encouraged the presence of prey, were flat and easy to traverse, or followed riparian (i.e., banks alongside water) corridors. Therefore, transportation planners should consider using vegetation undesirable to wildlife, widening of culverts and bridges to improve usage by wildlife, and study migration patterns and routes to determine wildlife crossing points in order to construct better targeted mitigation structures.

The authors noted, however, several issues related to the analyses of mitigation effectiveness among the various studies including the presence of interaction effects between multiple variables, non-linear relationships, or conflicting results. For example, obstructed vision beside roadways was associated with WVCs. Although clearing vegetation improved driver vision, studies noted that driver speed increased in areas with greater visibility and trimmed vegetation attracted certain species of wildlife to the roads, both of which may be counter-productive to reducing WVCs.

The results of this study enabled the authors to suggest ways in which to modify modeling designs. For instance, the authors suggested species-specific modelling that corresponded to the environment surrounding the transportation corridor in order to predict the most appropriate mitigation measure to be used.

The study was limited by the types of studies (e.g., use of generalized linear models) and the smaller number (24) of studies analyzed. However, by applying a set of specific inclusion criteria, the authors were able to analyze specific variables and focus on robust studies. As such, this study offered a first step towards designing effective modelling processes and provided a scientific basis to highlight issues associated with various mitigation efforts for future research.


**Issue and objective.** Roads can have a dramatic impact on herpetofauna (reptiles such as turtles and amphibians such as salamanders of a particular region) who are especially vulnerable to road effects, principally reduced connectivity and increased mortality. However, due to the vast numbers of different species, which range widely in size, level of mobility, patterns of distribution, maturation and reproduction stages (‘life-history’ stages), and environmental needs (e.g., wetlands or forest cover) among other differences, the ability to determine where and what types of mitigation structures are most effective is difficult. Furthermore, variances in herpetofauna across different regions mean that mitigation efforts in one area may not be appropriate for another. In order to provide the most useful and relevant information to road planners in wetland areas of New York state, the authors aimed to:

- design a model that could predict herpetofaunal mortality hotspots at a large-scale level;
- create a method to prioritize the hotspots to assist mitigation planning; and,
- to establish a strong collaborative relationship with transportation management agencies.

**Methodology.** The authors developed a model based on the study of 12 New York counties that encompassed a broad landscape. Within this area, ten animals were chosen that represented a cross-section of the range of various herpetofauna species characteristics mentioned above, and that met other selection requirements such as species that had a conservation concern. The herpetofauna included green frogs, northern leopard frogs, wood frogs, American toads, spotted salamanders, red-spotted newts, common snapping turtles, eastern painted turtles, spotted turtles, and wood turtles.
A combination of a mechanistic/computational model (a model that explains relationships between organisms and their environment in order to predict patterns of species distribution) and knowledge-based approaches (analysis of data from other studies) were used to design the predictive model. The authors designed an adapted habitat-resistance model which analyzed ‘friction costs to movement’ versus ‘distance’. In this model, the habitat (landscape) for each species was assigned a numerical value based on how easy or difficult it would be for that animal to cross it (resistance) versus the distance to reach a desired end point. More difficult terrain (friction/resistance) and further distances increase the cost for animals to travel to a certain point, i.e. “cost-distance”. For instance, the movement of an animal from its breeding pond to a desirable food source may require it to travel through dense brush over a long distance (relative to the species). The authors used populated aquatic habitats as the starting point, i.e., friction point of zero/no resistance and then calculated the cost-distance for each species to move around in their habitats including potential movement in and around roads.

Various sources of literature and data were used to create the basis of the model. The authors then tested the ability of the model to predict the number of occurrences of a species along a road by comparing its hotspot (high occurrence index) results to the actual presence of species recorded through observations along two New York road networks. Details about each animal were recorded at selected high movement periods and time of day relative to the species under study.

Findings and conclusions. The model was able to predict with high probability (e.g., p < 0.001) hotspots (occurrence) for some of the species under study, such as wood frogs and red-spotted newts; however, it was unable to accurately predict hotspots for some other species, such as American toads. The model predicted hotspots for species with limited movement, specific aquatic requirements, and those highly sensitive to changes in the environment. The model therefore could be used to pinpoint specific locations to build mitigation measures for these species. In contrast, the model demonstrated that some species which have low population densities and continuous wandering movement, such as spotted turtles, do not typically produce hotspots in the model because their movement patterns were difficult to predict.

For these species, the authors suggested it may be necessary to use broader mitigation measures, such as seasonally reduced speeds, or public education to raise awareness.

Overall, the authors pointed out that the model met the specific purpose for its design: to provide broad-scale data which transportation planners in New York state could use to determine locations where roads were most likely to have an impact on herpetofauna. In comparison to other models, this model produced similar results, further confirming that the model possesses predictive strengths.

The authors noted several limitations to the study such as the requirement that species’ populations were large enough to accurately study movements or that the observational data used to validate the model was limited in time and locations analyzed. To address these issues, the authors recommended ways the model could be improved as well as ways in which mitigation measures could be employed to counter some of the gaps in information from the model. Despite these limitations, the model provides a starting point regarding smaller species and movement data and ways in which models can attempt to overcome issues associated with large-scale design.

Conclusion

The above studies demonstrate the wide range of activities and research underway to better understand and improve mitigation measures. The articles by Clevenger et al. (2001) and van der Ree et al. (2007) revealed that exclusion fencing and wildlife crossings play an important role in reducing WVCs. However, both studies noted that more research was required to improve the effectiveness of these measures, both in terms of the animal species that they target and in terms of the degree of effectiveness these measures actually have on reducing WVCs and improving habitat connectivity. Equally important, it was revealed that a set of rigorous scientific methodological practices across studies is required in order to analyze the full impact of mitigation measures such as wildlife crossings.

Modelling of animal movement, behaviour, and interaction with their habitat is also an important tool that researchers can provide to transportation planners to guide the design of new transportation routes as seen through the studies by Gunson et al. (2011) and Patrick et al. (2012). Models can help
planners predict where large concentrations of animals are likely to occur so that they can alter routes or incorporate mitigation measures appropriate to the species along the route. Furthermore, building comprehensive models that can predict the behaviour of multiple species in different habitat environments can be very challenging and more data and research in this area is required. It is also important to address the impact of transportation routes on small wildlife and environmental sustainability thus modelling and mitigation efforts can be an important effort to reduce mortality among small and potentially endangered animal species.

Overall, the studies demonstrated the important strides being made in the area of mitigation measures to improve road and wildlife safety. The studies also revealed the need for more data and research on mitigation measures and suggested that a common or more rigorous set of scientific methodological procedures could greatly improve understanding about the effectiveness of mitigation measures.

For more information on wildlife-vehicle collision research, visit www.wildliferoadsharing.tirf.org.

Sources


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**Project Information**

The Wildlife Roadsharing Resource Centre (WRRC) is a centralized source of information, research, education, resources, and many other features to answer any questions you may have regarding wildlife-vehicle collisions. Visit [www.wildliferoadsharing.tirf.org](http://www.wildliferoadsharing.tirf.org) to learn more.

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