Analysis of Ungulate-Vehicle Collisions on Arterial Highways in New Brunswick

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Abstract

Vehicle collisions with moose and deer (ungulates) on New Brunswick highways are an ongoing concern for the traveling public. These ungulate-vehicle collisions often result in injuries and fatalities to vehicle occupants, significant property damage, and animal deaths. This study was undertaken to identify New Brunswick arterial highways with high numbers of ungulate-vehicle collisions and determine which landscape features or site characteristics, if any, make these areas more susceptible to these types of collisions.

The process used to achieve this objective was to: (1) create a database of ungulate-vehicle collisions on arterial highways; (2) identify ungulate-vehicle accident trends; (3) calculate ungulate-related accident rates for each highway and select sample routes for further study; (4) use topographic databases and GIS software to plot accidents, create buffer zones, and identify site characteristics that appear in these buffers; and (5) use statistical methods to determine the significance of selected landscape features. One statistical method used was plotting random accidents equivalent to actual accidents, recording the site characteristics for each group, and then comparing the distribution of site characteristics for random accidents to the distribution of site characteristics for actual accidents, to identify any significance.

Statistical analysis showed that landscape features which significantly contributed to the occurrence of ungulate-vehicle accidents were other major roads, transmission lines, railways, cuts/cut lines, limited-use roads, and buildings for deer, and transmission lines, wetlands, trails, cuts/cut lines, and vegetation for moose.

Keywords: vehicle collisions, deer, moose, arterial highways, site characteristics

1 Introduction

A concern for the traveling public on roads across North America is collisions with wildlife. These accidents can occur on busy arterial highways as well as

seldom used back roads. Studies have been done on accidents involving wildlife ranging from bears to panthers [1,2], but in New Brunswick the animals of interest are white-tailed deer (Odocoileus virginianus) and moose (Alces alces), often referred to collectively as ungulates. Collisions with ungulates are widespread in New Brunswick, since a large proportion of rural highways in the province run through the natural habitat of deer and moose [3].

Ungulate-vehicle collisions are troubling because they often result in injuries or fatalities to vehicle occupants, significant property damage to vehicles, and animal injury or death. Thus, they are seen as a "threat to traffic safety, socio-economics, animal welfare, wildlife management and conservation." [4]

Using accident data collected between 1995 and 2000, the New Brunswick Department of Transportation (NBDOT) identified 4,239 deer-vehicle collisions and 1,482 moose-vehicle collisions on New Brunswick roads for the period [5]. Given that total vehicle accidents for the same time period were 66,279, this means that 8.6% of all accidents involved ungulates. Given this safety issue, the Departments of Public Safety and Transportation have instituted various mitigative measures in an attempt to prevent or at least reduce collisions with ungulates. Some of these measures include additional signing, the cutting of brush along roadsides, and public education and safety awareness campaigns, among others [6].

In addition to the mitigative measures mentioned above, there are a number of other measures that have been attempted in various jurisdictions around the world. Some of the more common ones include animal underpasses or overpasses, highway lighting, reduced speed limits, increased hunt harvest, wildlife reflectors, and chemical and auditory repellents [3,7]. However, a concern raised by some researchers is that the implementation of mitigative measures in some jurisdictions seems arbitrary, is not based on knowledge of accident patterns, and lacks effective follow-up analysis [7,8]. This suggests a requirement for determining the factors that contribute to increased animal-vehicle collisions on particular highways.

1.1 Contributing Factors

There have been a number of studies designed to determine factors that contribute to ungulate-vehicle collisions. For deer, this has included analysis of temporal trends such as time of day and mating season [9,10] and spatial features such as traffic volumes, vehicle speeds, animal populations, and topography [7,9,10,11,12]. For moose, this has included temporal trends associated with mating season, migration, temperature, and time of year, as well as spatial features such as topography, development, roadway features, traffic characteristics, forage, and location of fencing [4]. Efforts have also been made to categorize some of the major contributing factors in one of three groups: Human or Driver Related, Animal Related, or Accident Site Related [7,11,13]. The following are examples of some key features found within these categories.

- **Human or Driver Related:** Traffic Volume, Vehicle Speed, Driver Inattention, Hunting/Animal Harvest, Residential Growth, Industrial Development
- **Animal Related:** Breeding/Mating Activities, Animal Dispersal, Seasonal Migration, Animal Population, Habitat Utilization, Feeding Habits, Animal Characteristics
- **Accident Site Related:** Proximity to Vegetation, Proximity to Water, Proximity to Wetland, Proximity to Development, Proximity to Linear Landscape Features, Infrastructure Density, Forest Cover/Forest Edges, Mitigation Measures, Time of Day, Month of Year, Road Conditions, Weather Conditions

2 Scope of the Work

Given the multitude of contributing factors, it was decided to focus this analysis on landscape features that contribute to ungulate vehicle collisions on arterial highways in New Brunswick. NBDOT identifies Routes 1, 2, 3, 4, 7, 8, 10, 11, 15, 16, 17, 95, and 96 as arterial highways. These highways were selected for study because they represent the province's primary road network, and data related to these routes is more easily obtained. The results of this analysis could then be compared against previous findings to determine their significance.

The objective of this study was to identify New Brunswick arterial highways with high occurrences of ungulate-vehicle collisions and, if possible, determine

which surrounding landscape features make these areas more susceptible to animal collisions. This analysis was done through the use of Geographic Information Systems (GIS) and topographic databases.

The process used to achieve this objective was to: (1) create a database of ungulate-vehicle collisions on arterial highways; (2) identify some interesting ungulate-vehicle accident trends; (3) calculate ungulate-related accident rates for each highway and select sample routes for further study; (4) use topographic databases and GIS software to plot accidents, create buffer zones, and identify site characteristics that appear in these buffers; and (5) analyze data using statistical methods to determine the significance of selected landscape features. One statistical method used was plotting random accidents equivalent to actual accidents, recording the site characteristics for each, and then comparing the distribution of site characteristics for random accidents to the distribution of site characteristics for actual accidents, to identify any significance.

The results could potentially be used by highway designers and planners to avoid potentially hazardous areas in future highway development or new roadway design or, if avoidance is not possible, to identify appropriate mitigative measures. The findings could also potentially be used to identify areas on existing routes that should be the focus of mitigative procedures.

3 Methodology (Data Sources and Preparation)

3.1 Accident Database

Ungulate-vehicle collision data was acquired from the Maintenance and Traffic Branch at NBDOT, which maintains a database based on "Report of Motor Vehicle Accident" forms. Law enforcement officers in New Brunswick complete one of these forms for every collision in the province that involves an injury or fatality, or results in over $1,000 in damages to a vehicle [14]. A data query was made for accident records that identified an ungulate action as a major contributing factor. Initial data was gathered for the years 1993 to 2000, since computerized accident records prior to 1993 were not available, and because the alignment and length of many New Brunswick arterial highways were significantly altered after 2000.

The accident-related information contained in the database included: Accident ID, Year, Month, Day, Route, Control Section, Kilometre (from Control Section), Severity, Injuries, Fatalities, Day of Week, Time of Day, Vehicle Quantity, Speed Limit, Road Name, Light Conditions, Weather Conditions, Type of Vehicle, Road Surface Conditions, and Major Contributing Factors.

3.2 Accident Rate

The next step involved calculating an Accident Rate for each arterial highway, which would represent the average number of deer and moose accidents per

million vehicle kilometers. This rate could then be used, in combination with other factors, to identify key routes for further study. Equation 1 shows the Accident Rate formula.

[1] $R = [A(1{,}000{,}000)] / [365(V)(L)]$

Here, R is the average number of ungulate accidents per million vehicle kilometres, A is the number of ungulate accidents, V is the Average Annual Daily Traffic (AADT) on a given route, and L is the total length of the route in kilometres [15].

3.3 Topographic Database and GIS Software

It was then necessary to obtain a topographic database that would adequately show the landscape features surrounding arterial highways in New Brunswick. Through discussions with the Government Documents group at the University of New Brunswick library, it was decided to use the National Topographic Data Base – Edition 3 (NTDB) [16]. The NTDB contains 112 entities grouped into 13 categories of themes. Table 1 outlines the 19 entities from 9 themes that were selected for their potential influence on ungulate-vehicle collisions. ArcView™ GIS 3.3 [ESRI, Redlands, CA] was then used in order to visualize and analyze the data from NRCan's NTDB for each of the routes.

3.4 Plotting Accident Data and Creating Buffers

The next task was to begin plotting the ungulate-vehicle collision locations. To do this required that the location of NBDOT's Control Sections (CS) be identified on the maps for each of the routes. NBDOT divides highways into reasonable lengths (by CS) in order to simplify the collection and analysis of highway data [14]. All accident locations are recorded in the accident database based on their distance, in kilometres, from the beginning of the CS in which the accident occurred.

The deer- and moose-vehicle accidents were then plotted, in separate files, for each of the routes selected for study, and the year of the accident was added adjacent to the plotted accident point. To ensure that the CS and accident locations were accurate, they were verified against two sources: (1) the New Brunswick Atlas, developed by Service New Brunswick from an Enhanced Topographic Base; and (2) NBDOT CS Manuals from 1993 to 2000. The lengths of some of the routes changed minimally over the study period, so the manuals were consulted to account for any differences when plotting. Then, 500m, 250m, and 50m radial buffers were created around each of the collision points, enabling the determination of the landscape features that fall within these buffers.

4 Data Analysis and Results

4.1 Accident Trends

After finalizing the accident database, a number of categories were analyzed to identify some general trends, such as temporal patterns, regarding ungulate-vehicle collisions on New Brunswick arterial highways.

An analysis of the data on a monthly basis for the study period showed that deer collisions on arterial highways peak in November, which some studies attribute to mating activities and the hunting season [10]. Moose collisions peak in June, and are at their highest levels throughout summer months, which might be partially attributed to availability of roadside vegetation or that the animals attempt to escape the heat and flies found in the forest.

For the study period, collisions with deer caused 154 injuries and 3 fatalities while collisions with moose caused 456 injuries and 24 fatalities. This data supports the view that moose-vehicle accidents are more severe, considering there were 769 fewer moose accidents than deer accidents.

The majority of both deer- and moose-vehicle collisions occurred at night in areas without lighting, during clear weather, and on dry roads. Other studies indicate that the majority of accidents occur on level, straight roads, when drivers are traveling at higher speeds and paying less attention to the road [13].

44.2% of deer-vehicle and 66% of moose-vehicle collisions occurred between the hours of 6 p.m. and midnight.

4.2 Accident Rates and Selection of Study Area

Accident Rate calculations were performed for 12 of the arterial highways (Route 96 had no recorded AADT or collisions) for each of the eight years of the study; these were then averaged to produce an Average Annual Accident Rate. Calculations were done separately for deer and moose. Table 2 outlines the resulting average annual accident rates for deer and moose on New Brunswick arterial highways. The results show that the Accident Rate was highest for deer on Routes 4, 10, and 3 and moose on Routes 4, 95, and 17.

However, two additional criteria were applied to the selection of routes for further study: (1) the removal of any route with less than 75 deer or 25 moose accidents over the eight year period, which included Routes 3, 4, 15, 16, 17, 95, and 96; and (2) the removal of any route that experienced a major change in alignment or length over the period, which included Route 11. A weighting was then applied to each of the remaining routes based on the Average Annual Accident Rate values and the total number of collisions for both deer and moose. The results were that the top three routes of interest were Route 8 (Fredericton to Miramichi City to Bathurst), Route 10 (Fredericton to Young's Cove), and Route 7 (Fredericton to Saint John).

4.3 GIS Database and Landscape Features

The 19 themes of interest were selected from NRCan's NTDB, and separate interactive maps containing this topographic data for Routes 7, 8, and 10 were created. CS locations were then added to the maps for each of the routes, and deer- and moose-vehicle collisions were plotted separately. 500m, 250m, and 50m radial buffers were created around each of the collision points, so the landscape features that fall within these buffers could be identified. Figure 1 shows examples of 500m, 250m, and 50m radial buffers around moose-vehicle accidents on a section of Route 7.

5 Statistical Analysis

The next step was to identify and record the landscape features that appeared within each of these buffers, to help determine any trends suggested by the data as to landscape features that might attract ungulates. The results were broken down by different route/buffer combinations for both deer and moose.

Overall, some general observations were made. For deer and moose collisions, the feature that appeared the most at each buffer distance was Vegetation. This was expected, given that the majority of these routes run through rural areas, with only minimal sections running through urban areas. A drawback was that the NRCan topographic data only segmented the Vegetation attribute into "Generic/Unknown", "Orchard", "Vineyard/Hopfield", "Tree Nursary", and "Wooded Area", and Wooded Areas in the database encompass "an area of at

least 35% covered by trees or shrubs having a minimum height of 2m" [16]. This means that different types of wooded areas are not distinguishable, and their differences could have a significant impact on ungulate behaviour. For instance, deer or moose may be attracted to certain species of trees, shrubs, or browse for feeding or shelter purposes. Future study could involve further defining the forest cover that appears around each of these routes.

Beyond Vegetation, the landscape features that dominate varied for the different routes. Some features consistently appeared in the buffers of the ungulate-vehicle accidents, and warrant further investigation to determine whether a significant relationship exists, while others appear sparingly. Some landscape features that repeatedly appeared in high numbers within both deer and moose collision buffers, regardless of route, include Water, Other Major Roads, Buildings, Limited-Use Roads, and Transmission Lines. Some features that make few appearances include Picnic Areas, Barriers, Parks, and Solids Depots. Still other features appeared regularly for some routes, and sparingly in others, such as Embankments, Cuts/Cut Lines, Built-up Areas, Trails, Bridges, Railways, and Wetlands. Some of these differences are likely accounted for in differences between animals. For instance, Wetlands appear more in buffers around moose accidents than deer accidents, suggesting that Wetlands are more of a contributing factor for moose-vehicle collisions.

5.1 Random Accident Plots and Percent Difference

It was determined that it might be useful to compare landscape features that appear within radial buffers of actual recorded accidents against landscape features that appear within radial buffers of randomly plotted accidents, to identify any significant differences. Three sets of random accidents were plotted for each route/animal/buffer combination, where the number of random accidents for each run was equivalent to the number of recorded accidents. The random location of each of the accidents was determined by generating random numbers based on the length of the route being analyzed. For instance, there were 209 deer-vehicle collisions recorded on Route 8, which is 247.07 km in total length. Therefore, 209 random numbers between 0.00 and 247.07 were generated and plotted.

The landscape features appearing within 500m, 250m, and 50m radial buffers of these random accident sites were recorded for each route. Rather than do comparisons of recorded landscape features against each random run separately however, an average of the three random runs was calculated, and the results compared. Table 3 shows the results for Route 8 as an example. This table outlines the percent difference between the number of times a landscape feature appeared within the radial buffer of actual accidents and the average number of times the feature appeared within the radial buffer of average random accidents, for both deer and moose.

5.2 Regression Analysis

Different statistical methods were considered for analyzing the information being gathered on landscape features surrounding ungulate-vehicle collisions. One method used was simple regression analysis. The purpose for doing this analysis was to identify whether the distribution of landscape features around actual ungulate accident locations is equivalent to the distribution of landscape features around random accident locations. Figure 2 shows the results from one example of regression analysis run on the number of times landscape features appeared within a 500m radial buffer of actual deer accidents on Route 7, and the average number of times the same features appeared within a 500m radial buffer of random accidents on Route 7. The interest in running the regression analysis was to review the results of the analysis at a 90% confidence level. For this analysis, a significance level of 10% was used in order to err on the side of caution, given that the variables being analyzed are accidents that could potentially result in injury or death. In the regression results, if "0" does not fall between the lower and upper 90% confidence limits for the Intercept, then the theoretical and observed distributions are significantly different. Similarly, if "1" does not fall between the lower and upper 90% confidence limits for the slope of the simple linear regression line, then the random and observed distributions are likewise significantly different.

Looking at Figure 2 for the analysis of landscape features within a 500m buffer of deer collisions on Route 7, "0" does not fall between the lower and upper 90% confidence limits for the Intercept (0.8385 and 8.1370), so there is a significant difference between the random and observed distributions.

An analysis of the regression results for the eighteen different route/animal/buffer combinations showed that there were no instances where both the Intercept was significantly different from 0 and the slope of the simple linear regression line was significantly different from 1. However, there were four instances where the Intercept was significantly different from 0, and four where the Slope of the simple linear regression line was significantly different from 1, as shown in Table 4.

5.3 Percent Differences

Given the results of Table 4, it was decided to further investigate the eight route/animal/buffer combinations where some overall significance was found. First, some general observations were made for each combination based on the percent difference calculations, such as the ones that appear in Table 3. This was done by labeling the separate landscape features as "Attract" (where a negative percentage difference denoted more instances where a landscape feature appeared within the buffer of actual accidents versus random accidents) and "Avoid" (where a positive percentage difference denotes fewer landscape features within the buffer of actual accidents versus random accidents). The

inference is that features labeled “Attract” may contribute to the occurrence of ungulate-vehicle collisions, while those features labeled “Avoid” are ones to which ungulates may not be attracted. Some features were not applicable, either because there was little to no difference between the number of actual and random observations, or because there were instances where the feature did not appear. The findings are outlined in Table 5 (for Route 7) and Table 6 (for Route 8).

While this does not address every route/animal/buffer combination, it was useful for identifying some early potential trends. Based on the percent difference calculations, some landscape features would seem to consistently make areas more susceptible to deer collisions, such as Railways, Other Major Roads, and Buildings. Trails and Cuts/Cut Lines would also seem to fall in this category, although in some instances there was not enough data to enable a meaningful observation. There were fewer appearances overall for features such as Solids Depots (Dumps), Barriers, Parks, Picnic Areas, and Wetlands, as related to deer collisions.

There are also some landscape features that appear, it would seem conflictingly, as attractors given their proximity to deer collisions in some route/buffer combinations, but not in others. For instance, the Bridges feature appears in the buffers of more actual deer accidents than random accidents at 50m, but in less at 500m. Perhaps this can be explained by the fact that Bridges within 50m of an

accident may increase collision risks, but Bridges that are further away from an actual accident, but still within a 500m buffer, really do not contribute to attracting the animal. Other features for which there was conflicting data included Transmission Lines, Built-Up Areas, Embankments, and Limited-Use Roads.

There was no one landscape feature that consistently seemed to make an area more susceptible to moose collisions, although Wetlands and Trails came closest. However, there were features that appeared in the buffers of more random accidents than observed moose collisions, suggesting that moose avoid them, including Other Major Roads and Embankments. Railways, Built-Up Areas, Buildings, Barriers, and Bridges would also seem to fall in this category, although in some instances there was not enough data to enable a meaningful observation. As with deer collisions, there were features that in some cases seemed to attract moose, while in others moose seemed to avoid them, such as Transmission Lines, Cuts/Cut Lines, Water, Limited-Use Roads, and Vegetation. Again, perhaps the differences can be explained by the different buffer differences being investigated, or perhaps the differences in the proportion of different landscape features surrounding the separate routes.

5.4 Estimating the Difference between Proportions

While the above analysis is useful for some general trends, it does not adequately address the issue of significance. It was next decided to estimate the difference

between the two population proportions. The objective in doing this was to more confidently identify where the proportion of landscape features appearing within the buffers of actual ungulate accidents exceed the corresponding proportion of landscape features appearing within buffers of random ungulate accidents. This can help to better identify which features significantly attract ungulates.

An estimation of the difference between two proportions was performed for landscape features found in the eighteen route/animal/buffer combinations. Table 7 shows an example of the difference between two proportions calculations for one of the combinations. Analysis for the current study was limited to identifying landscape features that significantly contribute to ungulate-vehicle collisions, but in future this approach could also be used to identify landscape features that ungulates tend to avoid.

Overall, the results of the difference of proportions analysis for the eighteen route/animal/buffer combinations showed that the following features significantly contributed to the occurrence of ungulate-vehicle accidents:

- **For Deer on Route 7** – (1) 500m Buffer: Other Major Roads, Transmission Lines, Railways, and Cuts/Cut Lines; and (2) 250m Buffer: Other Major Roads, Cuts/Cut Lines, Buildings

- **For Deer on Route 8** – (1) 500m Buffer: Buildings; and (2) 250m Buffer: Buildings, Railways

- **For Deer on Route 10** – (1) 500m Buffer: Transmission Lines, Limited-Use Roads; and (2) 250m Buffer: Transmission Lines

- **For Moose on Route 8** – (1) 500m Buffer: Transmission Lines, Wetlands, Trails, and Cuts/Cut Lines; and (2) 50m Buffer: Vegetation

- **For Moose on Route 10** – (1) 500m Buffer: Transmission Lines; and (2) 250m Buffer: Transmission Lines

6 Discussion

The fact that Other Major Roads appear to make areas on Route 7 susceptible to deer collisions could be supported by observations that deer adapt to disturbances in their habitat and will congregate around major roads and highways [17], and frequently traverse secondary roads within their home range [8].

Buildings appear to contribute to deer-vehicle collisions (Routes 7 and 8). Deer have been known to search for food in developed areas, particularly with the existence of gardens and hedges in residential areas that border on deer habitat, which may account for the finding on these routes.

The findings that Transmission Lines (Routes 7 and 10), Railways (Routes 7 and 8), and Limited-Use Roads (Route 10) contribute to the occurrence of deer-vehicle accidents, and that Transmission Lines (Routes 8 and 10) and Trails (Route 8) contribute to moose-vehicle accidents, are supported by findings in the literature which indicate that the risks of accidents involving wildlife increase with the presence of linear landscape features that funnel animals to the side of or across the roadway [4]. Transmission Lines, Railways, Limited-Use Roads, and Trails all offer cleared rights-of-way that are easier for the animals to travel than regular forest lands, and these features often run directly beside the roadway or intersect with it. It may also be possible to include the Other Major Roads feature with this group.

According to the results, a feature that significantly contributes to both moose- and deer-vehicle accidents (Routes 7 and 10) is Cuts/Cut Lines. Various sources support this by identifying that manmade clear cuts support new growth vegetation and provide browse that both deer and moose feed upon and will cross roads to access [4,18].

An additional feature that contributes to moose-vehicle collisions (Route 8) is Wetlands, which is supported by moose physiology and biology. The toes of their hooves and their dew claws support moose in Wetland areas -- which are swamps, bogs, and marshy areas where there is an abundance of ground or

surface water and plant life – and the forage in these areas will draw moose [18]. The findings suggest that if the Wetlands are immediately adjacent to the roadway, the feature may contribute to moose presence in the area, resulting in increased moose-vehicle collisions.

It also makes sense that Vegetation attracts moose to certain areas (Route 8), but the drawback with this variable, as mentioned previously, is that different types of Vegetation are not distinguishable in the data used. Therefore, it is difficult to attribute significance to such a generalized feature. Forest cover maps could be used in the future to identify possible types of Vegetation that contribute to moose-vehicle collisions.

7 Summary

Vehicle collisions with ungulates on New Brunswick highways are an ongoing concern for the traveling public. Mitigative measures in some jurisdictions have been implemented without knowledge of accident patterns, suggesting a need for analysis of accident site characteristics to determine what makes these sites susceptible to ungulate-vehicle collisions. Topographic databases and GIS software were used to create interactive maps of selected arterial highways, plot ungulate-vehicle accidents from 1993 to 2000, and create buffers which enable accident site characteristics to be identified and analyzed. Statistical analysis showed that landscape features which significantly contributed to the occurrence of ungulate-vehicle accidents were other major roads, transmission lines,

railways, cuts/cut lines, limited-use roads, and buildings for deer, and transmission lines, wetlands, trails, cuts/cut lines, and vegetation for moose. Future study might involve better defining the forest cover that surrounds the routes, determining whether the densities of particular landscape features might affect ungulate-vehicle accidents, determining whether there are any interaction effects between features, and identifying features that ungulates may tend to avoid.

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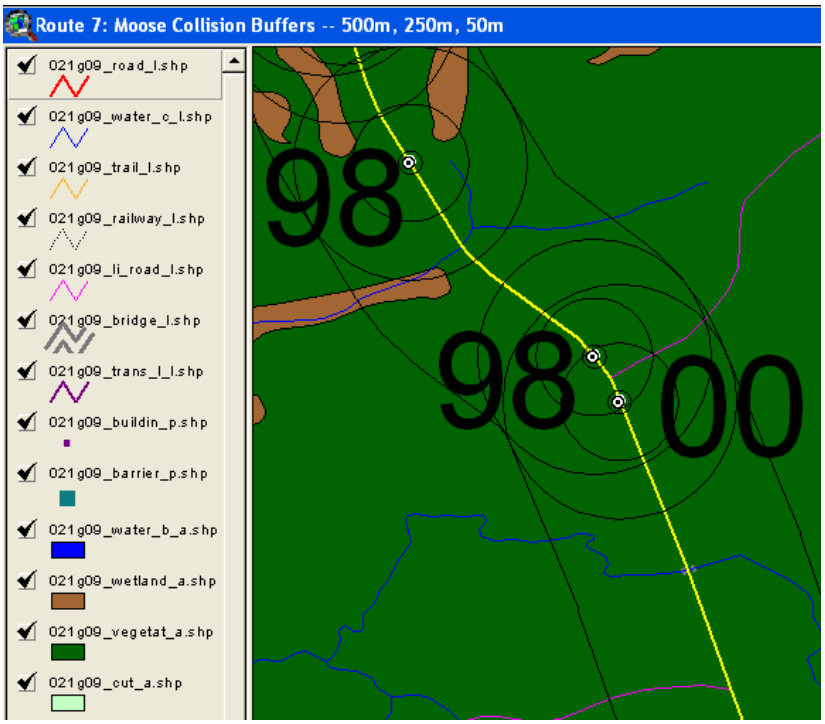

Figure 1. Buffers around Moose-Vehicle Collisions on Route 7.
[Sources: (1) Extract of the data set NTDB at scale 1: 50 000. Her Majesty the Queen in Right of Canada ©. Reproduced with the permission of Natural Resources Canada; (2) ESRI (Redlands, California).]

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.9686							
R Square	0.9382							
Adjusted R Square	0.9341							
Standard Error	6.2390							
Observations	17							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	8863.0563	8863.0563	227.6919	1.78E-10			
Residual	15	583.8849	38.9257					
Total	16	9446.9412						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 90.0%*	*Upper 90.0%*
Intercept	4.4878	2.0817	2.1558	0.0477	0.0508	8.9247	0.8385	8.1370
X Variable 1	0.9650	0.0640	15.0895	0.0000	0.8287	1.1013	0.8529	1.0771

Figure 2. Sample Regression Analysis, Actual and Random Landscape Features for Route 7. [Source: Microsoft Excel 2002 (Microsoft Corporation, Redmond, Washington).]

Table 1: Selected NTDB Themes and Entities

ENTITY	THEME
Designated Areas	• Park/Sports Field • Picnic Site • Solids Depot/Dump
Hydrography[1]	• Waterbody • Watercourse
Manmade Features	• Bridge • Building • Built-up Area (urban areas where buildings are close together) • Cut • Embankment
Power Network	• Transmission Line
Rail Network	• Railway
Road Network[2]	• Road
Roads	• Barrier/Gate • Limited-Use Road (seasonal roads) • Trail (path where motorized vehicles are not permitted)
Vegetation	• Cut Line • Vegetation
Water Saturated Soils	• Wetland
Notes	*[1] These two entities were combined into one entity, labelled "Water", for the purposes of this study.* *[2] The "Raod" entity was named "Other Major Roads" for the purposes of this study, to identify arterial, collector, or local roads that paralleled or intersected with the primary road or route being studied.*

[Source: Natural Resources Canada and Geomatics Canada (1999) National Topographic Data Base – Edition 3: Simplified User's Guide.]

Table 2: Average Annual Accident Rates on NB Arterial Highways

Route	Deer	Moose
1	0.0876	0.0124
2	0.0470	0.0174
3	0.1848	0.0257
4	0.2519	0.2123
7	0.0542	0.0692
8	0.1089	0.0892
10	0.2216	0.0493
11	0.0255	0.0563
15	0.0363	0.0059
16	0.0500	0.0284
17	0.0759	0.1034
95	0.0789	0.1073

Table 3. % Difference between the Number of Actual and Average Random Collisions having Particular Landscape Features within Selected Radial Buffer Distances – Route 8

Landscape Feature	Deer			Landscape Feature	Moose		
	500m	250m	50m		500m	250m	50m
Route 8							
Vegetation	-0.5%	-1.8%	4.7%	**Vegetation**	-0.7%	-1.7%	-8.0%
Buildings	-23.0%	-25.3%	-13.9%	**Water**	39.3%	73.9%	233.3%
Water	4.2%	13.7%	10.5%	**Limited-Use Roads**	12.8%	26.8%	-11.1%
Limited-Use Roads	-7.6%	-6.7%	-36.1%	**Transmission Lines**	-43.9%	-55.6%	-66.7%
Other Major Roads	-2.1%	-3.2%	-10.3%	**Other Major Roads**	75.0%	52.1%	49.0%
Railways	-18.3%	-32.7%	-61.9%	**Wetlands**	-72.3%	-71.1%	-50.0%
Transmission Lines	30.3%	-13.9%	-33.3%	**Buildings**	201.7%	202.2%	553.3%
Trails	94.1%	85.7%	-44.4%	**Trails**	-32.4%	-50.0%	-33.3%
Bridges	15.7%	3.3%	-33.3%	**Cuts/Cut Lines**	-56.4%	-47.6%	-50.0%
Embankments	63.0%	100.0%	83.3%	**Embankments**	25.0%	4.8%	0.0%
Built-Up Area	45.8%	20.8%	13.3%	**Bridges**	77.8%	33.3%	-33.3%
Wetlands	181.0%	500.0%	#N/A	**Railways**	512.5%	352.4%	#N/A
Parks	116.7%	-44.4%	#N/A	**Picnic Areas**	33.3%	-16.7%	#N/A
Solids Depots (Dump)	166.7%	-66.7%	#N/A	**Built-Up Area**	900.0%	566.7%	#N/A
Cuts/Cut Lines	533.3%	#N/A	#N/A	**Barriers**	#N/A	#N/A	#N/A
Picnic Areas	66.7%	-33.3%	#N/A	**Solids Depot (Dump)**	#N/A	#N/A	#N/A
Barriers	#N/A	#N/A	#N/A	**Parks**	#N/A	#N/A	#N/A

Note: Results were also calculated for Routes 7 and 10.

Table 4. Regression Results for 18 Route/Animal/Buffer Combinations.

Route/Buffer	500m	250m	50m
Route 7 Deer	**Significant***	No Significant Difference	Significant*
Route 8 Deer	No Significant Difference	No Significant Difference	Significant*
Route 10 Deer	No Significant Difference	No Significant Difference	Significant
Route 7 Moose	**Significant**	**Significant**	Significant
Route 8 Moose	**Significant**	**Significant**	**No Significant Difference**
Route 10 Moose	No Significant Difference	No Significant Difference	**No Significant Difference**

*** Denotes instances that were also significant at a 95% confidence level.**

Table 5. Effect of Landscape Features on Route 7 Collisions

Route 7	DEER		MOOSE	
	Attract	**Avoid**	**Attract**	**Avoid**
500m	• Solids Depots • Cuts/Cut Lines • Barriers • Railways • Parks • Transmission Lines • Built-up Areas • Other Major Roads • Embankments • Buildings • Trails	• Limited-use Roads • Bridges • Water • Wetlands	• Trails • Wetlands	• Railways • Built-Up Areas • Parks • Transmission Lines • Cuts/Cut Lines • Buildings • Barriers • Embankments • Solids Depots Bridges • Other Major Roads • Water • Limited-Use Roads
250m	*Not Significant*	*Not Significant*	• Trails • Limited-Use Roads • Vegetation	• Transmission Lines • Built-Up Areas • Embankments • Railways • Barriers • Cuts/Cut Lines • Buildings • Other Major Roads • Bridges • Water • Wetlands
50m	• Cuts/Cut Lines • Buildings • Embankments • Other Major Roads • Railways • Bridges	• Limited-use Roads • Water • Transmission Lines • Vegetation.	• Water	• Embankments • Transmission Lines • Other Major Roads • Limited-Use Roads • Trails • Cuts/Cut Lines • Barriers • Vegetation

Table 6. Effect of Landscape Features on Route 8 Collisions

Route 8	DEER		MOOSE	
	Attract	**Avoid**	**Attract**	**Avoid**
500m	*Not Significant*	*Not Significant*	• Wetlands • Cuts/Cut Lines • Transmission Lines • Trails • Vegetation;	• Built-Up Areas • Railways • Buildings • Bridges • Other Major Roads • Water • Picnic Areas • Embankments • Limited-Use Roads
250m	*Not Significant*	*Not Significant*	• Wetlands • Transmission Lines • Trails • Cuts/Cut Lines • Picnic Areas • Vegetation	• Built-Up Areas • Railways • Buildings • Water • Other Major Roads • Bridges • Limited-Use Roads • Embankments
50m	• Railways • Trails • Limited-Use Roads • Bridges • Transmission Lines • Buildings • Other Major Roads	• Embankments • Built-Up Areas • Water • Vegetation.	*Not Significant*	*Not Significant*

Table 7. Sample Results of Differences between Proportions Analysis.

Route 8 Moose, 500m			
Landscape Feature	**Feature Appears in Actual Accident Buffer**	**Feature Appears in Average Random Accident Buffer**	**Difference Between Proportions (90% Confidence Limits)**
Vegetation	196	194.7	N/A
Water	95	132.3	-0.28 to -0.11
Limited-Use Roads	81	91.3	-0.14 to 0.03
Transmission Lines	63	35.3	0.07 to 0.21
Other Major Roads	60	105.0	-0.31 to -0.15
Wetlands	59	16.3	0.16 to 0.28
Buildings	39	117.7	-0.48 to -0.33
Trails	36	24.3	0.00(+) to 0.12
Cuts and Cut Lines	13	5.7	0.00(+) to 0.07
Embankments	12	15.0	-0.06 to 0.02
Bridges	9	16.0	-0.07 to -0.01
Railways	8	49.0	-0.27 to -0.15
Picnic Areas	2	2.7	N/A
Built-Up Area	1	10.0	N/A
Barriers	0	1.7	N/A
Solids Depot (Dump)	0	2.3	N/A
Parks	0	5.7	N/A
LEGEND			
Blue = Ungulates attracted to landscape feature			
Red = Ungulates avoid landscape feature			
Grey = Not Significant (Confidence Limits include "0")			
N/A = Cannot apply approximation for a large-sample confidence interval			
(+) indicates confidence level was positive, but showed 0 due to rounding			