ANALYSIS OF VEHICLE COLLISIONS WITH MOOSE AND DEER ON NEW BRUNSWICK ARTERIAL HIGHWAYS

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Prepared for the 31st Annual Conference of the Canadian Society for Civil Engineering, Moncton, New Brunswick, June 4-7, 2003

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ABSTRACT: Many studies provide sobering statistics on the number of moose- and deer-vehicle collisions that occur annually on North American highways, and the resulting property damage, animal deaths, personal injuries, and human fatalities. Recent accidents involving moose in New Brunswick have again brought the issue to the forefront.

This study was undertaken to identify those sections of various New Brunswick arterial highways with high levels of vehicle-ungulate collisions, and to statistically determine which factors, or combination of factors, make these areas more susceptible to these collisions. The objective was to identify the conditions of the roadways, and their surrounding landscape, which lead to a higher probability of moose- and deer-vehicle accidents. Identifying the influencing environmental and habitat variables helps, in turn, to identify which areas should be the focus of mitigative procedures for existing highways and provides a valuable component and enhancement to the highway planning and design process for proposed highways.

1. INTRODUCTION

A major concern for transportation representatives, wildlife officials, and the driving public worldwide are collisions between animals and vehicles. Wildlife-vehicle accidents can result in significant property damage to vehicles, driver injury or fatality, and animal injury or death. Studies have found, as might be expected, that as traffic volumes, vehicle speeds, and animal populations increase, so does the risk of animal-vehicle collisions (Craighead et al. 2001; Danielson and Hubbard 1998; Puglisi et al. 1974). However, others point out that these animal collision rates "do not relate simply to animal numbers, neither do they relate solely to traffic volume" (Bruinderink and Hazebroek 1996). There have been calls for further research into the patterns or causes behind these collisions, and solutions to the problem.

1.1 Accident Costs

The issue is particularly apparent in North America. In the United States (US), wildlife-vehicle collisions are estimated to kill over 200 motorists and injure thousands more each year, resulting in an annual cost to society in human terms of US$200 million (Craighead et al. 2001). As well, property costs of wildlife-vehicle accidents are estimated at an average of US$2,000 per vehicle (Craighead et al. 2001). With deer-vehicle collisions in the US estimated at 750,000 annually (Danielson et al. undated), this would mean property damages in the range of US$1.5 billion per year for deer alone. In Maine, New Brunswick's closest US neighbor, analysis of data from 1996 to 1998 showed that there were 12,173 deer-vehicle collisions and 2,127 moose-vehicle collisions that resulted in estimated economic losses of

US$97,000,000 for the period, or an average of US$32.3 million annually (Maine Interagency Work Group on Wildlife/Motor Vehicle Collisions 2001).

In the Province of New Brunswick, Canada, attention is particularly focused on deer- and moose-vehicle collisions, sometimes referred to collectively as ungulate-vehicle collisions. The incidence of these types of collisions is common in New Brunswick, given the amount of rural highway in the province that passes through the natural habitat of deer and moose (Hildebrand and Hodgson 1995). The severity of these accidents, particularly for moose, is also a concern. Moose have a high centre of mass, and long, slender legs, so in a collision with a vehicle traveling at a high rate of speed, the animal tends to impact the windshield or roof of the vehicle, where there is less reinforcement (Wilson 2001). This typically kills the animal, and can seriously injure or kill the driver or passengers in the vehicle.

The New Brunswick Department of Transportation (NBDOT) analyzed accident data from 1995 to 2000 and found a total of 4,239 deer-vehicle collisions and 1,482 moose-vehicle collisions over the 6 year period (G. Violette, NBDOT, pers. comm. 2002). This represented 8.6% of the total 66,279 vehicle accidents in the province over those 6 years, and translates to an annual average of 707 deer and 247 moose collisions. According to Statistics Canada (2003), New Brunswick's motor vehicle registrations in 2000 were 562,563, therefore approximately 1 in every 796 New Brunswick drivers will hit a deer and 1 in 2278 drivers will hit a moose.

The costs of ungulate-vehicle accidents in New Brunswick can also be estimated. Using the 1995 to 2000 accident data provided by NBDOT, there were 5,721 combined ungulate-vehicle collisions. At an average cost of CA$3,025 (in Canadian dollars, or the equivalent of US$2,000) per vehicle, this would result in property costs of CA$17,306,025. As well, there were 21 fatalities (20 from moose collisions, 1 from deer collisions) and 955 injuries (550 from moose collisions and 405 from deer collisions) during this period. Transport Canada (1998) estimates that the compensation cost per road vehicle accident for a fatality in Canada is CA$1,560,000 and for an injury is CA$28,000 (1996 dollars). This would result in fatality costs of CA$32,760,000 and injury costs of CA$26,740,000 over the six years. An animal life is also considered by some to be an economic resource, and by others as a valued part of nature that is to be protected. The Michigan Technology Transfer Center identifies the economic cost of a lost deer at between US$700 and US$1,000 (Wilson 2001). Conservatively applying an equivalent of CA$1,050 to the 5,721 ungulate accidents would result in animal costs of CA$6,007,050. In total, this would mean an estimated CA$82,813,075 over the 6 years, or an average of CA$13,802,179 per year for ungulate-vehicle collisions in New Brunswick.

1.2 Mitigative Measures

A number of mitigative measures have been tried by various transportation agencies in an attempt to prevent, or at least decrease, the number of ungulate-vehicle collisions. Some more widely implemented examples include fencing, animal underpasses or overpasses, highway lighting, warning signs, reduced speed limits, public awareness programs, increased hunt harvest, wildlife reflectors, chemical repellents, vegetation management, and animal habitat alteration (Danielson and Hubbard 1998; Hildebrand and Hodgson, 1995). However, an issue raised by Putman (1997) is that the mitigative measures "selected to reduce animal-vehicle collision are often arbitrary, without any follow-up analysis of their effectiveness." Putman (1997) also concludes that the selection of mitigative measures should be based on the knowledge of accident patterns (Danielson and Hubbard 1998). This suggests a need to determine the factors which contribute to increased animal-vehicle collisions on particular highway sections.

1.3 Contributing Factors

The factors that contribute to ungulate-vehicle collisions can typically be placed in one of three categories: Human or Driver Related, Animal Related, or Accident Site Related (Maine Interagency Work Group on Wildlife/Motor Vehicle Collisions 2001). Table 1 identifies examples of contributing factors for each category. These factors are by no means all-inclusive, but are some of the major ones identified in existing literature (Craighead et al. 2001; Danielson and Hubbard 1998; Maine Interagency Work Group on Wildlife/Motor Vehicle Collisions 2001).

Table 1. Factors contributing to ungulate-vehicle collisions.

Human or Driver Related	Animal Related	Accident Site Related
• Vehicle Traffic • Traffic Flow • Vehicle Speed • Driver Inattention • Hunting/Animal Harvest • Residential Growth • Industrial Development	• Breeding Activities • Animal Dispersal • Seasonal Migration • Population • Habitat Utilization • Feeding Habits • Animal Characteristics (e.g., colouring)	• Proximity to Vegetation • Proximity to Water • Proximity to Wetland • Proximity to Development • Proximity to Open Landscapes • Infrastructure Density • Forest Cover/Forest Edges • Mitigation Measures • Time of Day • Road and Weather Conditions

It should be noted that these factors are not independent of each other. For instance, proximity to vegetation is a contributing factor related to the accident site, but it is an animal's feeding habits that make proximity to vegetation so important. There is some debate on how much of an overall effect some of these variables have, which is why there is interest in investigating the impact of site conditions.

1.4 Scope of the Work

The objective of this study is to identify New Brunswick arterial highways with high occurrences of ungulate-vehicle collisions and, if possible, determine which factors, or combination of factors, make these areas more susceptible to these types of collisions. Arterial highways in New Brunswick represent the primary road network in the province, and include Routes 1, 2, 3, 4, 7, 8, 10, 11, 15, 16, 17, 95, and 96. Ungulate-vehicle collisions are typically the result of a combination of human, animal, and accident site factors. The primary focus of this study is an analysis of accident site conditions, as related to roadways and their surrounding landscape, such as water, marshland, vegetation, and development. This analysis is being done through the use of Geographic Information Systems (GIS) and topographic databases.

The process being used to attain this objective is: (1) create a database of deer and moose accidents involving vehicles on New Brunswick arterial highways; (2) identify some useful ungulate-vehicle accident trends from the data; (3) calculate accident rates for each arterial highway for use, in combination with other factors, in selecting sample routes for detailed study; (4) for the selected routes, use topographic databases and GIS software to plot each of the animal accidents, create buffer zones around them, and determine which site characteristics appear in these buffers; and (5) analyze the data using statistical methods, such as regression analysis, to determine the significance, if any, of selected conditions.

The results could potentially be used by highway planners and design engineers to avoid problematic areas in future highway upgrades or new highway designs or, if avoidance is not possible, to plan for appropriate mitigative measures. The findings could also be used to identify areas that should be the focus of mitigative procedures for existing highways. To date, only a portion of this process has been completed, with results to this point discussed below.

2. METHODOLOGY

2.1 Data Sources and Preparation

2.1.1 Accident Database

Deer- and moose-vehicle collision data was obtained from NBDOT. Law enforcement officials in New Brunswick complete a "Report of Motor Vehicle Accident" form for every vehicle collision in the province that results in over $1,000 in damages, or involves an injury or fatality (M. Phillips, NBDOT, pers. comm. 2002). The Maintenance and Traffic Branch at NBDOT maintains a database of this information, a subset of which was accessed for this study. Because the focus of the study is accidents on arterial highways, the data query was for records of all collisions that identified an animal action (deer or moose) as a major contributing factor to the accident. Initial data gathered was for the years 1995 to 2000, as computerized accident records at NBDOT currently go back only to 1995. In addition, an Engineering student at the University of New Brunswick had created an accident database for a report on ungulate-vehicle collisions for the years 1993 to 1996. With some modification and restructuring, the data for the years 1993 and 1994 were made compatible with the results from NBDOT, resulting in eight years of accident data with which to work (1993 to 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. This information was used in the generation of a number of interesting accident trends, as well as for plotting the accidents using GIS.

Two database modifications were necessary. The first was that, while collisions involving wildlife typically involve only one vehicle, occasionally there are multiple vehicles involved. Every entry in the database represents one vehicle, while the Accident ID represents a collision. Therefore, there were instances where two or more entries had the same Accident ID, representing a multiple vehicle collision. It was decided to treat these occurrences as one accident, and the database was revised accordingly. The second modification was to delete incomplete records, particularly ones that were missing Control Section or Kilometre information that would prevent them from being plotted (although these records were included for some general analysis, like total number of accidents on arterial highways).

2.1.2 Accident Rate

The next step involved calculating an Accident Rate for each arterial highway in the province, 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 measures, to select particular routes on which to focus the study. Equation 1 shows how Accident Rate is calculated for each arterial route.

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

In this equation, R is the average number of deer (or moose) accidents per million vehicle kilometres, A is the number of deer (or moose) accidents, V is the Average Annual Daily Traffic (AADT), and L is the total length of the route in kilometres (Wilson 2001).

To do this, information on (1) AADT and (2) highway lengths was required from NBDOT. AADT is defined by NBDOT as "the yearly total volume in both directions of travel divided by the number of days in the year" (M. Phillips, NBDOT, pers. comm. 2002). The department uses vehicle counts from temporary and permanent counters located at various points along arterial highways to calculate AADT at those specific counter locations. A database containing the counts from each of these counters was provided by NBDOT, and a weighted average calculation based on all temporary and permanent counter values, and their locations, was performed to determine an AADT value for each arterial highway for each of the years 1993 through 2000. NBDOT also provided data on the total lengths of each of the arterial highways. These, together with deer and moose accident totals from the accident database, enabled an Accident Rate for each arterial highway for each of the eight years of the study to be determined.

2.1.3 Topographic Database and GIS Software

It was then necessary to access a topographic database that would adequately show the landscape features surrounding arterial highways in the Province of New Brunswick. The Government Documents, Data and Maps group at the University of New Brunswick's Harriet Irving Library was approached about possibilities. Through discussions, it was decided to use the National Topographic Data Base – Edition 3

(NTDB), which is distributed by Natural Resources Canada (NRCan) and Geomatics Canada. The NTDB contains 112 entities such as vegetation, roads, railway, and wetland grouped into 13 categories of themes (Natural Resources Canada and Geomatics Canada 1999). After a review of the entire list, 20 entities from 9 themes were selected for their potential influence on ungulate-vehicle collisions. These were: (1) Designated Areas theme: Park/Sports Field, Picnic Site, Solids Depot/Dump; (2) Roads theme: Barrier/Gate, Limited-Use Road, Trail; (3) Manmade Features theme: Bridge, Building (2 types), Built-Up Area, Cut, and Embankment; (4) Hydrography theme: Waterbody, Watercourse; (5) Power Network theme: Transmission Line; (6) Rail Network theme: Railway; (7) Road Network theme: Road; (9) Water Saturated Soils theme: Wetland; and (9) Vegetation theme: Cut Line, Vegetation. The Government Documents group then provided digital files containing the entities for the routes being investigated.

Subsequently, ArcView™ GIS 3.3 was used in order to visualize and analyze the data from NRCan's NTDB. The NTDB files were opened in the software, and then the themes (entities) identified previously were extracted, so the topographic data could be analyzed in interactive maps. Once the themes were selected, their attributes/legends were organized and formatted to make them consistent and logical, although future study could look at implementing true colour orthophotos to better distinguish some of the themes (Malhotra et al. 2000). A query was then run to select and merge all instances of a route being investigated, so that it became the selected theme and stood out from all other roads.

2.1.4 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 (maximum 20 kilometres) in order to simplify the collection and analysis of highway data (G. Thompson, NBDOT, pers. comm. 2002). There are a number of guidelines for establishing CS locations, but the importance here is that all animal 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. NBDOT provided data on the CS locations and lengths for each of the arterial highways, and these were added to the GIS maps.

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 checked 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 buffers were created around each of the collision points, enabling the determination of the landscape features that fall within these different buffer zones. From this, the impact of these features on the likelihood of deer- or moose-vehicle collisions can be assessed. Distances of 125m, 250m, and 500m were used in a similar study of this nature (Malhotra et al. 2000). Finally, landscape features were selected, and 500m buffers were created around those portions of the feature which appeared within a 500m buffer of the selected route. From this, the portion of the highways that were feature proximal versus not feature proximal (or feature distal) could be measured. The results of these calculations could then be used as part of the statistical analysis of different landscape features.

3. DATA ANALYSIS AND RESULTS

3.1 Accident Trends

After finalizing the accident database, a number of the attributes were analyzed to identify some general trends regarding deer- and moose-vehicle collisions on New Brunswick arterial highways, based on the historical data.

The total number of deer collisions on arterial highways dropped in 1996 after rising since 1993, but have increased since then. Between 1993 and 2000, there was a 60.4% increase in the number of deer-related accidents on arterial highways. The total number of moose-vehicle collisions on arterial highways has fluctuated over this period, rising from 1993 to 1995 and from 1998 to 1999, but decreasing in 1996, 1997, and 2000. Between 1993 and 2000, there was a 6.3% increase in the number of collisions, although the total reached higher numbers in the intermediate years.

An analysis of the data on a per month basis over the study period showed that deer collisions on arterial highways peak in November, which is typically attributed to breeding activities and the hunting season (Puglisi et al. 1974). Moose collisions peak in June, and are at their highest levels throughout the summer months of June, July, and August, which can be at least partially attributed to their feeding on roadside vegetation and escaping the heat and flies found deeper in the woods.

81.9% of all deer-vehicle collisions and 88.7% of all moose-vehicle collisions on arterial highways occur on sections where the posted speed limit of the route is 90 km/hr or above, with the largest percentage of collisions occurring on sections posted at 100 km/hr. This can be attributed to the fact that many sections of the arterial highways in New Brunswick pass through areas with little or no development. Given this, these sections typically have a posted speed limit of 100 km/hr, and drivers increase their speed. As well, deer and moose tend to gravitate to areas with less development, increasing the potential for a collision. Also, vehicles traveling at higher rates of speed are less likely to be able to avoid collisions with animals, so more accidents will be clustered on sections of routes with higher speed limits.

From 1993 to 2000, there were 154 injuries and 3 fatalities caused by deer-vehicle collisions and 456 injuries and 24 fatalities caused by moose-vehicle collisions on New Brunswick's arterial highways. This data supports the view that moose-vehicle accidents are particularly more severe, especially considering that there were 769 fewer moose accidents than deer accidents for the study period.

The majority of both deer- and moose-vehicle collisions occur at night in areas without lighting, when the animals are harder to see, and during clear weather, 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 (Maine Interagency Work Group on Wildlife/Motor Vehicle Collisions 2001). 44.2% of deer-vehicle and 66% of moose-vehicle collisions occur between the hours of 6 p.m. and midnight.

3.2 Accident Rates and Selection of Study Area

Accident Rate calculations were performed for each of the 13 routes in New Brunswick that NBDOT designates as arterial highways. For each route, an Accident Rate was determined for each of the eight years of the study, and then these were averaged to produce an Average Annual Accident Rate for each route. Calculations were done separately for deer and moose. The results are outlined in Table 2.

Table 2. Average annual deer and moose accident rates (R) on NB arterial highways.

Deer	**Route 1**	**Route 2**	**Route 3**	**Route 4**	**Route 7**	**Route 8**
R	0.0876	0.0470	0.1848	0.2519	0.0542	0.1089
	Route 10	**Route 11**	**Route 15**	**Route 16**	**Route 17**	**Route 95**
R	0.2216	0.0255	0.0363	0.0500	0.0759	0.0789
Moose	**Route 1**	**Route 2**	**Route 3**	**Route 4**	**Route 7**	**Route 8**
R	0.0124	0.0174	0.0257	0.2123	0.0692	0.0892
	Route 10	**Route 11**	**Route 15**	**Route 16**	**Route 17**	**Route 95**
R	0.0493	0.0563	0.0059	0.0284	0.1034	0.1073
Note: Route 96 had no recorded AADT or collisions.						

The results show that the Average Annual Accident Rate was highest for deer on Routes 4, 10, and 3 and highest for moose on Routes 4, 95, and 17. However, it was not desirable to base the selection of routes for further study solely on this Accident Rate alone. Two additional criteria were applied to the selection: (1) All routes with a low number of total accidents were removed. In this case, it was decided to remove routes with less than 75 deer accidents or less than 25 moose accidents over the eight year period, which meant removing Routes 3, 4, 15, 16, 17, 95, and 96; (2) Also, any route that had a major change in alignment or length over the period was removed, as this would make it difficult to accurately plot the accidents. This required the removal of Route 11, which had a change in total length of around 15 kilometres. 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, through Miramichi, to Bathurst), Route 10 (Fredericton to Young's Cove), and Route 7 (Fredericton to Saint John).

3.3 GIS Database and Landscape Features

The 20 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. Control Section locations were then added to the maps for each of the routes, and then the deer- and moose-vehicle collisions were plotted separately. 500m, 250m, and 50m buffers were then created around each of the collision points, so the landscape features that fall within these buffers could be identified. Figure 1 shows an example of 500m, 250m, and 50m buffers around moose-vehicle accidents on a section of Route 8.

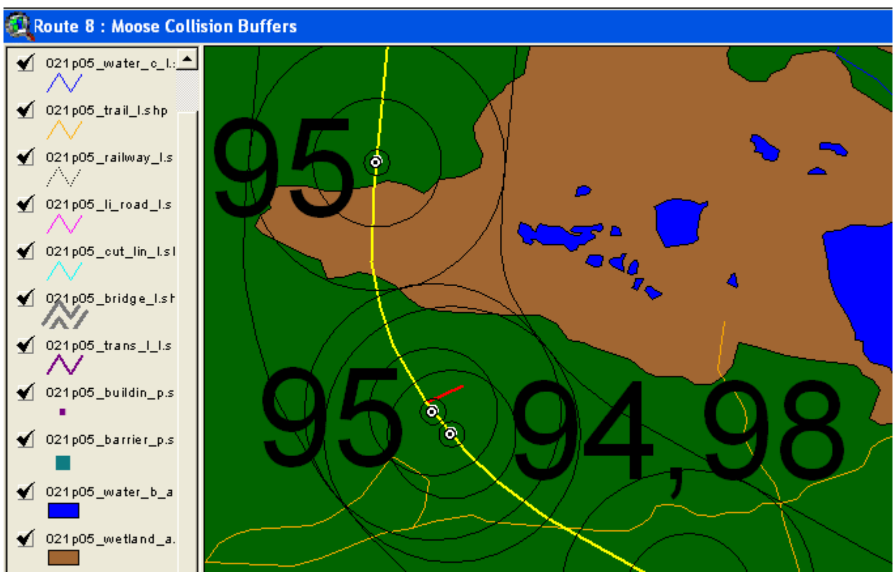

Figure 1. Buffers for Route 8 Moose-vehicle Collisions.
(Sources: (1) Extract of the data set NTDB at scale 1: 50 000. Her Majesty the Queen in Right of Canada ©. Reproduced with the permission of Natural Resources Canada. (2) ESRI, Redlands, California).

To date, analysis has been completed using only the 500m buffer, with the presence of a feature being recorded as a Yes or No event. Future study will investigate differences between the three buffer zones, and may also involve weighting a feature based on the proportion that appears within the buffer. Another task to complete is randomly plotting a number of points equal to the current number of animal accidents on each route, to allow a comparison of the features present for an accident versus a non-accident site.

Table 3 outlines the landscape features that appeared within a 500m buffer of deer- and moose-vehicle accidents on Routes 7, 8, and 10. For both deer and moose collisions, the feature that appeared within every 500m buffer was Vegetation. This is expected, given that only small portions of each of these routes run through urban areas. A drawback that was noted is that the NRCan topographic data only segments the Vegetation attribute into five types: Generic/Unknown, Orchard, Vineyard/Hopfield, Wooded area, and Tree Nursary, and that Wooded Area in the database encompasses “an area of at least 35% covered by trees or shrubs having a minimum height of 2m” (Natural Resources Canada and Geomatics Canada 1999). This means that with current data, the different types of wooded areas are not distinguishable, and their differences could have a significant effect on ungulate behaviour. For instance, deer or moose may be attracted to certain species of trees or shrubs for feeding or shelter purposes. Given this, future study could involve further breaking down and defining the types of vegetation.

Table 3. Landscape features appearing within 500m buffer of deer and moose hits.

Deer						Moose					
Route 7 (92 Hits)		Route 8 (209 Hits)		Route 10 (110 Hits)		Route 7 (112 Hits)		Route 8 (196 Hits)		Route 10 (29 Hits)	
F	%	F	%	F	%	F	%	F	%	F	%
V	100.00	V	100.00	V	100.00	V	100.00	V	100.00	V	100.00
RO	66.30	B	75.60	W	52.73	W	57.14	W	48.47	TL	68.97
W	57.61	W	67.99	TL	51.82	LR	36.61	LR	41.33	W	37.93
TL	47.83	LR	56.94	B	50.91	RO	35.71	TL	32.14	RO	27.59
B	42.39	RO	53.59	RO	50.91	TR	22.32	RO	30.61	WT	24.14
RW	25.00	RW	29.67	LR	33.64	WT	13.39	WT	30.10	B	24.14
LR	25.00	TL	15.79	BR	13.64	B	11.61	B	19.90	LR	24.14
E	20.65	TR	8.13	TR	12.73	BR	9.82	TR	18.37	BR	6.90
CU	20.65	BR	8.13	WT	12.23	TL	8.93	CU	6.63	TR	3.45
BU	15.22	E	4.31	RW	5.45	E	6.25	E	6.12	RW	3.45
TR	14.13	BU	3.83	SD	3.64	CU	3.57	BR	4.59	CU	3.45
BR	13.04	WT	3.35	CU	2.73	RW	2.68	RW	4.08	PA	0.00
SD	9.78	P	1.91	E	0.91	BA	2.68	PA	1.02	BA	0.00
WT	9.78	SD	0.48	P	0.00	BU	2.68	BU	0.51	E	0.00
BA	8.70	CU	0.48	BU	0.00	SD	0.89	BA	0.00	SD	0.00
P	5.43	PA	0.48	PA	0.00	P	0.89	SD	0.00	P	0.00
PA	0.00	BA	0.00	BA	0.00	PA	0.00	P	0.00	BU	0.00

Key to Features (F)

B = Buildings	LR = Limited Roads	TL = Transmission Lines
BA = Barrier/Gate	P = Park	TR = Trail
BR = Bridge	PA = Picnic Area	V = Vegetation
BU = Built-Up Area	RO = Roads	W = Water (Watercourse/body)
CU = Cuts/Cut Lines	RW = Railway	WT = Wetlands
E = Embankments	SD = Solids Depot	

Beyond Vegetation, the landscape features that dominate vary for the different routes. However, there are some features that consistently appear in the buffers of the ungulate-vehicle accidents, and deserve further investigation to determine whether a significant relationship exists. Other features will not necessarily be ruled out, but will have a lower priority. Some features that this analysis suggests should be analyzed include: Water, Development (Buildings), Roads and Limited-Use Roads, Transmission Lines, Cuts and Cut Lines, and Wetland. Given these findings, and taking animal characteristics into consideration, Water and Wetland were selected as the initial features to study.

3.4 Regression Analysis

Different statistical methods will be used to analyze the information being gathered on landscape features surrounding deer- and moose-vehicle collisions. Some methods under consideration include t-tests and regression analysis. Figure 2 shows the results from one example of regression analysis run for Route 7 using SPSS Inc.'s SPSS for Windows 11.5.0, where the dependent variable was the Deer Accident Rate (in collisions per kilometre) for each Control Section, and the independent variables were the AADT of each Control Section and the Wetland Proximal Percentage of the Control Section. The goal was to determine whether AADT and Proximity to Wetland could be useful indicators of deer-vehicle accidents on Route 7. Temporary and permanent counter data provided by NBDOT was used to determine AADT values for each Control Section on Route 7. Wetland-proximal percentages of the roadway were determined using the buffers that had been created around the wetland feature in the GIS software. 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.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.949[a]	.900	.867	.33221

a. Predictors: (Constant), Wetland Proximal Percentage of CS Length, Average Annual Daily Traffic of CS

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.959	2	2.980	27.000	.001[a]
	Residual	.662	6	.110		
	Total	6.622	8			

a. Predictors: (Constant), Wetland Proximal Percentage of CS Length, Average Annual Daily Traffic of CS

b. Dependent Variable: Deer Accident Rate (collisions per km) for CS

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.262	.219		1.195	.277
	Average Annual Daily Traffic of CS	.000	.000	.909	7.039	.000
	Wetland Proximal Percentage of CS Length	-2.621	1.098	-.308	-2.386	.054

a. Dependent Variable: Deer Accident Rate (collisions per km) for CS

Figure 2. Sample Linear Regression on Route 7 Variables.

The R^2 results from the Model Summary table show that 90% of the total variation in the deer accident rate can be explained. The ANOVA table indicates that, because there is approximately a 0.1% probability of exceeding the F value for regression of 27.000, this is an acceptable model for estimating the deer accident rate. The Coefficients table reveals that there is basically no probability of exceeding the t-value of 7.039 for the AADT regression coefficient and a 5.4% probability of exceeding the t-value of -2.386 for the Wetland Proximal regression coefficient, which means that the regression coefficients are significantly different from 0 (10% significance). The AADT findings suggest that deer-vehicle accidents increase as AADT increases, which is somewhat expected; given more vehicles, there are likely to be more accidents. The Wetland findings suggest that deer-vehicle accidents decrease with proximity to Wetland. This might be explained by the fact that wetland areas often contain terrain that is difficult for deer to traverse, so they might favour areas where water and vegetation are easier to access. This provides one example of the analysis under consideration.

4. SUMMARY AND FUTURE STUDY

Deer- and moose-vehicle collisions are a significant concern on New Brunswick's arterial highways. The costs incurred from the resulting damage to vehicles, driver injury or fatality, and animal injury or death are estimated to reach almost CA$14 million annually. Various mitigative measures have been attempted, but often without knowledge of accident patterns. This suggests the need for analysis of accident site conditions, as related to roadways and their surrounding landscape, 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. To date, analysis has been limited to a 500m buffer, but future study will involve investigating differences between buffer zones of varying sizes, and possibly weighting features based on the proportion of the feature in the buffer. It will also be useful to randomly plot a number of points equal to the current number of animal accidents on each route, to allow a comparison of the features present for an accident versus a non-accident site. Initial analysis identified landscape features such as vegetation, water, wetland, and development as key characteristics for study, although further study will be required to distinguish between types of vegetation. Analysis using various statistical methods is just beginning. While this study is limited primarily to site characteristics, future study might involve accounting for various animal-related factors, such as population and migration. The long-term objective is to provide design criteria to be used by highway planners and design engineers to avoid problematic areas in future highway upgrades or new highway designs or, if avoidance is not possible, to plan for appropriate mitigative measures.

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