Title:

Habitat, Highway Features, and Animal-Vehicle Collision Locations ad Indicators or Wildlife Crossing Hotspots

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Abstract:

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HABITAT, HIGHWAY FEATURES, AND ANIMAL-VEHICLE COLLISION LOCATIONS AS INDICATORS OF WILDLIFE CROSSING HOTSPOTS

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Abstract: Tracking techniques were used along US 2 and NH 115 in the towns of Jefferson and Randolph, NH to record geo-referenced wildlife highway-crossing data for GIS-based analysis. Over 7000 track sets from 22 species were recorded from December 2005 through May 2006. Moose, red fox, white-tailed deer, and coyotes left most tracks. A substantial number of fisher and bobcat were also recorded. This data set is unique in size and the number of carnivores recorded. Analyses completed for this report indicate that variations in landscape scale habitat composition in the study area were correlated with variations in wildlife crossing rates at the landscape scale. Different species also showed different affinities for the roadside at this scale. At the local scale, the rate of moose crossing was higher in locations with mixed forest cover types and where guardrails end, but not in locations with high moose/vehicle collision rates. Crossing by predators, excluding red fox, increased with the presence of coniferous cover types, and the rate of deer crossing increased with the presence of open cover types. Additional analyses at the roadside scale will be conducted and results will be available at a later date.

Introduction

Identifying locations where wild animals are most likely to cross highways is key to informing environmentally sensitive highway planning. With this information in hand, highway and conservation planners can collaborate to protect key habitat linkages by guiding highway design. Approaches include reducing the barrier effect of the highway through design or by placing crossing structures, or avoiding construction/upgrade of highways in sensitive locations altogether. Ideally, the characteristics of preferred crossing locations along existing roadways can be modeled from known crossing "hotspots", and the best locations to maintain connectivity can be identified as part of the design process.

Defining the characteristics of preferred crossing locations along existing roadways requires repeated observations of animal presence over large segments of roadway to identify crossing hotspots. Because highway departments have long-term, state-wide accident data that includes animal-vehicle collision (AVC) locations for most public roads, most analyses of hotspot locations to date have used AVCs as indicators of crossing (Allen and McCullough 1976, Finder et al. 1999, Hubbard et al. 2000, Joyce and Mahoney 2001, Nielsen et a. 2003, Malo et al. 2004).

However, using AVC locations to identify crossing hotspots has a number of inherent drawbacks. AVC locations have historically been recorded imprecisely (e.g., to the nearest mile marker), and because AVC are generally only reported when the collision renders the vehicle inoperable, they are heavily biased to deer, elk, and moose. Therefore, analysis based on these data can only identify broad landscape characteristics correlated with the presence of ungulates along the road. Many of the species most in need of adequate landscape scale connectivity are predators (Ruediger 1998). Additionally, animals may be hit and killed in locations where they approach the roadside to use resources, rather then to cross, and/or high AVC/kill locations may simply indicate a particularly dangerous crossing location, as opposed to the preferred place to cross.

Other approaches to identifying hotspot locations included recording the locations of road-killed animals (Bashore et al. 1985, Romain and Bisonette 1996) and roadside tracking studies (Alexander and Waters 2000, Singleton and Lehmkuhl 2000, Barnum 2003). Roadkill studies that rely on "second hand" reports suffer from the same limitations of AVC based studies, and many smaller species (i.e., predators) are also absent form these data sets as they are rapidly removed from the road by scavengers, collectors, or are simply overlooked. Tracking studies have the greatest potential to record a wide range of species, and their behavior, at the roadside.

The Research Approach

This project used tracking techniques to identify locations where wild animals crossed two unfenced highway, at-grade. I divided the track data into three groups moose, deer, and wide-ranging predators (WRP; coyotes, fisher and bobcat). I then used descriptive statistics to examine how crossing varied among groups at the landscape scale, and regression analyses to determine the characteristics of crossing locations at the local scale, and roadside scale, for each species group.

"Local", "landscape", and even "roadside" are relative terms defined by the context of their application. For this study, I considered the immediate roadside to be within 75 m of the pavement, and the local scale to be within 500 m of the roadway. I defined the landscape scale as the area with in 1.5 km of the highway. I did not complete the roadside scale analysis prior to writing this report, and do not address it further in this document.

To determine what factors were associated with crossing rates (dependent variable), I chose variables that described the natural cover type, topography, amount of human activity, and characteristics of the roadway (independent variables). The location of moose/vehicle collisions (MVC) was also considered for association with moose crossing locations. Collision location data for other species was unavailable. The independent variables were chosen as existing research suggests that they influence highway crossing behavior by wildlife. The complete list of variables that I considered for quantitative analysis in the local and landscape scale analyses is given in table 1. The variable list for the landscape scale is comprised of all variables that I measured. For the local scale analysis, some variable categories were collapsed to achieve adequate sample sizes for regression analysis, or when a smaller group of variables adequately addressed the variability of that category.

Table 1: Variables quantitatively evaluated for their association with locations where animals cross a highway at the local (500m) and landscape (1500m) scales

Variable Type	Name* for Regression	Local Scale 500m – Multiple Regression	Landscape Scale 1500m – Chi Squared
Dependent			**Track Records**
	MOOSElog	Number Moose TR	Percent Moose TR
	DEERlog	Number Deer TR	percent crossing v. not crossing
	WPRlog	Number WPR TR	Percent Deer TR
			percent crossing v. not crossing
Independent		**Cover type**	Percent WPR TR
	DECID	Percent deciduous cover type	percent crossing v. not crossing
	MIX	Percent mixed cover type	
	ALCONlog	Percent mixed + coniferous cover	**Cover type**
	OPENlog	Percent open cover type	Percent coniferous cover type
	WETbin	Wetland – present /absent	Percent deciduous cover type
	VEGDI	Diversity of cover at location	Percent mixed cover type
			Percent open cover type
		Topography	Percent wetland cover type
	SLODIlog	Diversity of slope at location	Diversity of cover at location
			Topography
		Human Activity	Percent slope ≤ 5
	PDMNbin	Low parcel density – pres/abs	Percent slope 6 – 10
	PDMXbin	High parcel density – pres/abs	Percent slope 11-15
	PDDIinv	Parcel density diversity	Percent slope > 16
			Diversity of slope at location
		Roadway Feature	**Human Activity**
	GREbin	Guardrail end present	Percent low parcel density
	BRIDbin	Bridge present	Percent moderate parcel density
			Percent high parcel density
	MVCbin	**MVC** – present/absent	Percent very high
			Percent highest
			Roadway Feature
			Average highway width
			Number MVC

* Variables with the postfix “log” were log transformed to meet the assumption of normalcy for regression. Variables with the postfix “inv” were inverted to meet the assumption of normalcy for regression.. Variables with no postfix met normalcy assumptions without transformation. Variables with the postfix “bin” were converted to a binary format (present/absent).

Study Site Description

My study site was located along 31 km (19 miles) of US Route 2 and 10 km (6 miles) of NH 115 in the Towns of Jefferson and Randolph, New Hampshire, USA (Figure 1). These two towns are located in the White Mountain Region of the state, have a substantial wildlife population, and have large areas of protected lands separated by the subject highways and their attendant low-density development. The study area was located along valley bottoms. Many of the surrounding peaks exceed 1225m in elevation, but within the study area elevations ranged from approximately 300m to 500m. The cover type, which is described in greater detail below, is predominantly forested. The study area hosted a substantial population of moose (*Alces alces*) and white-tailed deer (*Odocoilius virginianus*). Other common terrestrial species included red fox (*Vulpes vulpes*), coyote (*Canis latrans*), fisher (*Martes pennanti*), long-tailed and short-tailed weasel (*Mustela frenata, M. erminea*), and snowshoe hare (*Lepus americanus*). Less common species incuded bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), gray fox (*Urocyon cinereoargenteus*), porcupine (*Erethizon dorsatum*), otter (*Lutra candensis*), and American marten (*Martes americana*).

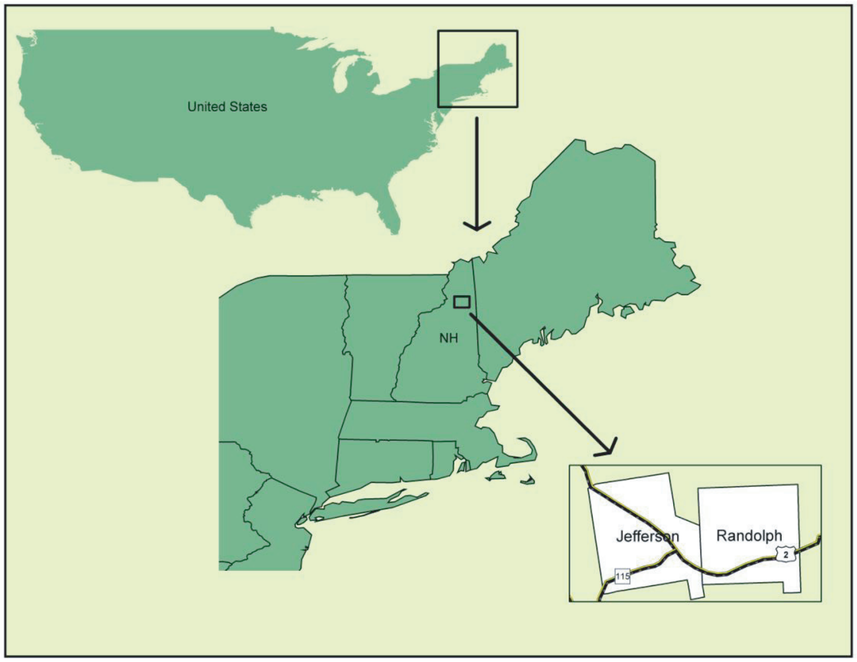

Figure 1. Study site location.

Based on variations in the characteristics of the natural and built environment within the study area, I divided it into three sub-areas, Route 2 east (Rt2E), Route 2 west (Rt2W) and NH 115 (NH115) for descriptive and analysis purposes. Rt2W passes through the Town of Jefferson, and in addition to some sections of forested land, is bordered by low density residential development, a few businesses, a golf course, pasture, and hay fields. Rt2E passes by (as opposed to through) the Town of Randolph, and is bordered by extensive sections of forested land, with very few businesses, some pasture, and a few individual residences. NH115 passes through primarily forested land, with some pasture and a few individual residences. There are no businesses. Additional variations in landscape structure are summarized in table 2. In general, Rt2W has a greater proportion of low angle slopes, more unforested land, and less low-density parcel area then the other two sub-areas. Cover type and parcel density also show greater diversity in Rt2W. Rt2E has the greatest amount of deciduous cover, steepest slopes, and highest slope diversity of the three sub-areas.

Table 2: Comparison of landscape characteristics among the three study area sub-areas

	Rt2W	NH115	Rt2E
Roadway Length	**13.5 km**	**9.8 km**	**17.9 km**
Cover type (%)			
Deciduous	27	42	60
Coniferous	24	14	11
Mixed	14	17	12
Wetland	4	4	2
Open	27	19	12
Diversity Index	4.45	3.81	2.49
Slope Class (%)			
0-5	67	68	39
6-10	24	19	36
11-15	7	6	16
16 +	3	7	9
Diversity Index	1.95	1.97	3.17
Parcel Density Class (%)			
Low	38	54	54
Low-Med	32	26	22
Medium	19	15	14
Med-High	8	5	7
High	2	0	2
Diversity Index	3.45	2.60	2.74
Protected Land (%)			
	6.15	8.65	36.09

The roadway in Rt2W has only two short sections of guardrail over 13.5 km, and is two lanes throughout, with little to no shoulder. Total pavement width is generally between 24 and 30 feet with two small sections that are between 40 and 44 feet in width. The roadway in Rt2E has extensive sections of guardrail, and multiple sections with two lanes, three lanes, no shoulders, and shoulders of varying widths. Total pavement widths vary from 28 to 46 feet. NH115 also has extensive sections of guardrail and both two and three lane sections, but total pavement widths are consistent between 40 and 44 feet. The average annual daily traffic volume on US 2 ranged from 4600 to 5000 vehicles (NHDOT 2005), and just under 3000 on NH 115 in the study area.

Methods

Tracking

A two-person field crew recorded track locations along the study area roadways with a hand-held GPS device\data logger (Geo Explorer III, Trimble). The tracking crew was highly skilled, and able to record an extensive amount of information about each track, in addition to location and date. Recoded information included species, number of animals, activity (cross, enter, exit, turn-away, parallel), age of track, and, in some cases, sex. I downloaded data files from the data logger and converted them to Excel spreadsheet and ArcView shapefile formats for analysis.

While snow was on the ground, the field crew drove slowly (≤10 mph) through the study area searching for and recording track locations. The entire study are could be sampled in one day using this approach. Once the snow melted out, the site was surveyed on foot, and a complete survey of the study area required three days. The bulk of the data was collected while snow was on the ground (Dec, 2005 – March 26, 2006). Snow cover allows the tracks of a wide range of species to be observed, including smaller species such as snowshoe hare, fox, weasel, and marten. Once the snow cover melted out, the field crew depended on impressions left in mud, sand, and short vegetation, were restricted to looking for larger tracks, and focused on finding moose and bear tracks. By mid-May the growth of roadside vegetation rendered most of the study area untrackable in any efficient fashion.

Animal Density Index

To compare the density of a species along the road, as compared to the surrounding habitat, sweep surveys were conducted in habitats adjacent to the road. To conduct a sweep, an observer walked a transect and recorded all tracks encountered. The transect locations and lengths were not pre-determined, and a total of 19 transects were surveyed. No attempt to differentiate between individuals was made, and the same animal may have been recorded multiple times. However, this is also true for the roadside tracking.

Habitat and Highway Measurements

Except for the location of guardrails and bridges within the study area, which were recorded in the field, I made all habitat and highway data measurements from digital data layers, using the ArcView software package. Cover type was derived from National Land Cover Data (NLCD), reclassified into seven categories (developed, deciduous forest, coniferous forest, mixed forest, wetland, open water, unforested) and slopes were derived from Digital Elevation Models (DEMs). Parcel density was derived from parcel maps supplied by Jefferson and Randolph. A point was placed in the center of each parcel and the ArcView extension Spatial Analyst was used to generate a density surface, based on a 500m search radius. Pavement width was derived from NHDOT coverage.

Analysis

To summarize the track data, I summed the total number of species and total number of TRs recorded along the roadside and in the surrounding habitat, and compared the composition of these two groups by species percentages.

To determine if crossing rates varied at a landscape scale, I counted the number of crossers and non-crossers recorded along the roadside in each sub-area, from each species group. I used these counts to describe how crossing varied among groups at the landscape scale, and a chi-squared analysis to detect significant differences in the distribution of the recorded tracks.

To determine which characteristics of the habitat and roadway were most strongly correlated with crossing rates the local scale, I used ArcView to divide the roadway into 700 m segments, then buffered the midpoint of each segment with a 500 m radius. I choose to overlap the buffers to smooth any effects of creating artificial boundaries. Automated ArcView scripts then counted the number of TRs within the buffer and measured the characteristics of the landscape within the buffer. I then used multiple regression to investigate the relationship between number of animals crossing within an area (dependent variable) and the characteristics of that area (independent variables). A backwards stepwise (Systat 11) technique was used. I choose the subset of variables for consideration was by looking at the degree of correlation within each group of independent variables (cover type, topography, human activity, roadway feature). I choose at least one from each group that reflected the variation of that group, and that was correlated (Pearson, $r \geq 0.0300$) to the crossing rate.

Results and Discussion

Tracking Results

Table 3 presents the total number of roadside TRs. Over 7,000 TRs representing 22 species were recorded. Table 4 presents the total number of sweep TRs, and compares the frequencies of each species occurrence in the landscape to its occurrence along the roadside. Because the two types of survey had different levels of effort, the comparison of frequencies should be regarded as index only. However, there is a clear indication that different species have different affinities for the roadside. Even though red fox left many TRs and crossed the roadway often, their occurrence was so disproportionately linked to the roadside I did not include them in further analysis. A visual analysis of the distribution of red fox TRs suggests that this species uses the roadside and directly adjacent areas as their primary habitat. Thus, their crossing does no represent linkage to the surrounding landscape.

Table 3: Counts of all species and their crossing behavior, recorded at the roadside

Species	Cross	Enter	Exit	Parallel	Turn-Away	TOTAL
Moose	1428	413	434	420	14	2709
Red fox	1090	340	300	189	20	1939
White-tailed Deer	900	56	47	62	16	1081
Coyote	336	57	63	29	3	488
Gray fox	142	44	46	12	4	248
Snowshoe Hare	89	10	10	24	6	139
Fisher	104	2	2	7	4	119
Mink	81			9		90
Long-tail weasel	59	3	2	14	1	79
Raccoon	43	2		1	2	48
Black Bear	36		1	3	1	41
Ermine	25			8		33
Bobcat	29				1	30
Turkey	15	1		2	2	20
Striped Skunk	5	2	2	3		12
Squirrel spp.	8			1		9
Dom. cat	6					6
American Marten	6					6
Porcupine	3			1	1	5
Otter	4					4
Dom. dog	3					3
Canada Lynx	1					1
unk weasel spp	1					1
Total	4414	930	907	785	75	7111

Table 4: Counts of all species recorded at the roadside and during sweeps. The percent of each species with a group (roadside or sweep) is given in parentheses

Species	Roadside	(%)	Sweep	(%)
Moose	2709	(38.37)	492	(13.58)
Red fox	1939	(27.46)	261	(7.20)
White-tailed Deer	1081	(15.31)	329	(9.08)
Coyote	488	(6.91)	546	(15.07)
Gray fox	248	(3.51)	27	(0.75)
Snowshoe Hare	139	(1.97)	911	(25.14)
Fisher	119	(1.69)	335	(9.24)
Mink	90	(1.27)	64	(1.77)
Long-tail weasel	79	(1.12)	154	(4.25)
Raccoon	48	(0.68)	18	(0.50)
Black Bear	41	(0.58)	21	(0.58)
Ermine	33	(0.47)	84	(2.32)
Bobcat	30	(0.42)	220	(6.07)
American Marten	6	(0.08)	112	(3.09)
Porcupine	5	(0.07)	47	(1.30)
Otter	4	(0.06)	3	(0.08)
Canada Lynx	1	(0.01)	0	(0.00)
	7060	100%	3624	100%

A simple visual analysis the distribution of TRs revealed variation in their distribution by species across the study area. Additionally, as summarized in table 5, the behavior of each species group at the roadside varied as a whole and between the sub areas. Based on the length of the roadway in each sub-area, no species group was distributed as expected among the sub-areas ($X^2 > 12.75$, p = 0.001, d.f. 2). Moose and WRP were recorded far less often then expected along Rt2W, while deer were recorded far more often. Deer crossed the road the majority of the time they approached it in all sub-areas, while moose crossed the road just over half the time they approached it along NH115 and Rt2E. WRP were also more likely to approach the road, but not cross, along Rt2E.

Table 5: Number of animals recorded at the roadside in each sub area, by species. Percent of animals recorded as crossing is given in parenthesis

Species	Rt2E	NH115	Rt2W
Moose	249 (71%)	1123 (56%)	1212 (51%)
Deer	796 (86%)	207 (82%)	153(69%)
WRP	176 (74%)	230 (78%)	392 (63%)
Coyote	154 (71%)	171 (74%)	326 (59%)
Fisher	10 (90%)	44 (86%)	61(84%)
Bobcat	12 (100%)	15 (93%)	5 (80%)

The landscape scale variation in distribution along the roadside among the three species groups reflects their general habitat preferences. Moose prefer forested cover types with wetlands and softwoods. Deer prefer edges and are more likely to forage in open cover types, as compared to moose. Although coyotes are habitat generalists, bobcat and fisher are forest associated, and all three predators have an affinity of cover. The observed variations in crossing behavior support these patterns.

Along NH115 and Rt2E, which are surrounded by suitable habitat, both moose and coyotes are less likely to cross the roadway when they approach, as compared to Rt2W, which is more open and has a higher intensity of human use. This pattern suggests that the roadside offers resources to these species in certain settings. Local experts and residents concur that moose frequently use wet areas alongside the road, some of which were created as a result of the road's construction. Roadways are also known to provide resources for generalist predators, including road kill, small mammals associated with mowed shoulders, and trash (Spellerberg 1988, Hordequin 2000).

Variables Associated with Crossing at the Local Scale

Moose Associated Variables

For this analysis, the study area was divided into 52 sections, and moose were recorded at 49 of them. The maximum number crossing at one section was 235, and the mean was 36.4 (s.d. = 52.6). After log transformation to achieve normalcy there were 45 non-zero cases with max = 2.37 and mean = 1.20 (s.d. = 0.63). The independent variables I considered in the multiple regression model for moose are listed in Table 6. Although my goal was to include at least one variable from each category, the correlations to the topography variables were so low, I did not include any of them. The most conservative model that explained a substantial amount of the variation in the dependent variable was:

$$\text{MOOSElog} = 0.398 + \text{GREbin}(0.567) + \text{MIXED}(0.044), \quad r = 0.650$$

Both the presence/absence of guardrails ends and the amount of mixed forest cover in the local area around the road had a significant effect (p = 0.000, 0.001, respectively) on the crossing rates of moose. As the amount of mixed cover increased, the number of moose crossing increase, and moose crossing increased with the presences of guardrail ends.

Moose may prefer mixed cover as it provides both foraging and cover opportunities. Locations where guardrails end may show increased rates of crossing because they represent a change in roadside topography. Guardrails are typically situated along steep embankments that moose may avoid. These changes in topography may also coincide with small wetland areas that attract moose. Although wetland presence was not significantly correlated to the rate of moose crossing (table 6), it is important to note that the NLCD data used to quantify wetland cover is relatively coarse, and the small, roadside wetlands within the study area are therefore not well represented.

Table 6: Local-scale variables included for consideration in the multiple regression analysis. The r-value (continuous variables) is the single variable Pearson correlation with the dependent variable. The p-value (dichotomous variables) is for a two-sample t-test, comparing the mean of the dependent variable to locations where the variable is present to locations were it is not

Moose		Deer		WRP	
OPENlog	r = -0.295	OPENlog	r = 0.479	ALLCONlog	r = 0.322
MIXED	r = 0.427	Decid	r = - 0.427	VEGDI	r = 0.488
VEGDI	r = 0.300	SLODIlog	r = - 0.397	SLODIlog	r = 0.209
GREbin	p = 0.000	MNPDbin	p = 0.237	MXPDbin	p = 0.138
MXPDbin	p = 0.010	GREbin	p = 0.008	GREbin	p = 0.602
MNPDbin	p = 0.065				
MVCbin	p = 0.355				

The crossing rate of moose was not significantly related to MVC locations. The MVC location data was not systematically collected. Instead, it is derived from roadkills reported to NH Fish and Game personnel from 1984 through 2004, by a variety of sources. These sources include conservation officers, other law enforcement personnel, highway maintenance workers, and the general public. Most of these MVC locations are reported relative to well-known landmarks (e.g., intersections, business, etc.), and lack the precision of the tracking data. Therefore, the lack of correlation between the two data sets is not surprising.

Deer Associated Variables

Deer were recorded as crossing at 51 of the 52 sections. The maximum number crossing at one section was 175, and the mean was 24.9 (s.d. = 52). After log transformation to achieve normalcy, there were 47 non-zero cases, with max = 2.34 and mean = 0.99 (s.d. = 0.61). The independent variables I considered in the multiple regression model for deer are listed in Table 6. Because my goal was to include at least one variable from each category, I included MNPDbin even though its p-value was non-significant. Conversely, I did not include GREbin despite its highly significant p-value, as it was an artifact related to landscape structure. Most deer were recorded along Rt2W, which provided their preferred habitats, and had very few guardrails. The most conservative model that explained a substantial amount of the variation in the dependent variable included only one independent variable:

DEERlog = -0.421 + 1.032OPENlog r = 0.479

The rate of deer crossing the road is positively correlated with the presence of open cover types. Because the entire study area is predominately forested, the presence of open cover types is an indication of “edge” habitats, for which deer have a well-known affinity. However, it is difficult to interpret this local-scale correlation. More then twice as many deer crossed Rt2W, compared to both the other sub-areas added together, and Rt2W also had the highest proportion of open cover types. Therefore the correlation with crossing rate at the local scale may be driven by a landscape scale habitat preference. Studies that compared the landscape-scale characteristics of areas with many deer/vehicle collision locations to locations with few or none also report a strong correlation with edge habitats (Allen and McCullough 1976, Finder et al. 1999, Hubbard et al. 2000, Nielsen et al. 2003).

WPR Associated Variables

WRP were recorded as crossing at all sections. The maximum number crossing at one section was 61, and the mean was 14.9 (s.d. = 13.1). After log transformation to achieve normalcy, there were 49 non-zero cases, with max = 1.78 and mean = 0.98 (s.d. = 0.46). The independent variables I considered in the multiple regression model for WRP are listed in Table 6. Because my goal was to include at least one variable from each category, I included GREbin, even though the difference in the mean value of WRP was not significantly different for locations with GREs as compared to locations with out GREs. The most conservative model that explained a substantial amount of the variation in the dependent variable included only one independent variable:

WRPlog = 0.177 + VEGDI(0.252),   r = 0.488

The greater the VEGDI in the area surrounding the road, the more WRPs crossed at that location, and this variable was highly influential (p = 0.000). VEGDI at the study site was driven primarily by the presence of coniferous cover types, and secondarily by the presence of open and wetland cover types. In individual tests of correlation between WRP and the independent variables, the number of WRP crossing was highly correlated to coniferous cover types, and weakly correlated to open and wetland cover types, suggesting the positive association to conifers to VEGDI drives the association of WRP with VEGDI.

The next most influential variable was MXPDbin, the presence of the highest parcel density class in area surrounding the road. Although the influence of this variable was not significant (p = 0.232) when included in a model with only VEGDI, including it did improve the fit of the model slightly (r = 0.511) and had a reasonably large coefficient value (-0.142). Additionally, this variable was consistently marginally significant when included in fuller models. Crossing by WRPs was negatively correlated to the presence of the highest parcel density class, and this variable had the strongest relationship with rate of WRP crossing among the non-cover type variables considered.

Summary

Tracking techniques can provide a wealth data related to the presence and behavior of wild animals along the roadside. This information in turn can provide an excellent resource for locating the crossing hotspots that may provide key habitat connectivity benefits. In my study area, the variables that were correlated to the crossing rates for moose and deer were different from each other, and also differed from the variable(s) correlate to WRP crossing rates. These results suggest that if highway and conservation planners wish to maintain or improve connectivity across highways for all suites of species, the needs of each group should be considered separately. However, the needs of multiple species can coincide. A visual analysis of the distribution of TRs across the study area does reveal many locations with substantial crossing by two species groups, and a few that are well used by all three. To maintain adequate habitat linkages across highways, planners should considering crossing areas that are suitable for single species as well as multiple species, to achieve true landscape-scale connectivity.

Biographical Sketches: Ms. Barnum holds a BS from the University of Vermont and an MS from Utah State University in Wildlife Biology. She received her Ph.D. from the University of Colorado at Denver in Conservation Planning, in 2003. Previous job experience includes working as an environmental planner for the Colorado Department of Transportation. Currently Ms. Barnum is the Vice President of Conservation at New Hampshire Audubon.

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