Investigating Wildlife and Roadway Interactions in the Chignecto Isthmus, NS

NOVA SCOTIA HABITAT CONSERVATION FUND

Contributions from Hunters and Trappers

Final Report to the Nova Scotia Habitat Conservation Fund
2019

Introduction

Habitat connectivity is critical for wildlife dispersal, migration, other life-requisites such as finding a mate and reaching diverse food sources, genetic flow between populations, and range shifts in response to climate change (Bennett, 2003). Roads pose major threats to habitat connectivity within wildlife corridors, affecting wildlife movement by creating barriers for some species through direct mortality due to collisions with vehicles and stimulating indirect avoidance behaviours in others (Forman & Alexander, 1998; Robinson et al., 2010). Where roads are constructed, other fragmenting features such as residences, agriculture, businesses, and industry typically follow. As human communities expand, roads are often upgraded to accommodate higher traffic volumes that allow goods, services, residents, and tourists to more quickly and efficiently move from place to place. This ultimately leads to isolated wildlife populations and reduced genetic diversity. Proliferation of roads and increased speed and volume of traffic have led to roadkill becoming a leading source of human-caused mortality for terrestrial vertebrates (Forman & Alexander, 1998). Because reporting of roadkill is not mandatory and only collisions with large mammals are typically reported, there is a lack of quantitative and spatial data on wildlife-vehicle collisions (Fudge et al., 2007).

The Chignecto Isthmus is a narrow (~25 km) strip of land that connects Nova Scotia to continental North America via New Brunswick. Habitat on the isthmus is fragmented by agriculture, urban development, and roads (MacDonald & Clowater, 2005). As a result, it is increasingly difficult for wildlife, in particular wide-ranging species, to find sufficient un-impacted habitat. Therefore, the 25 km that would have been available for seasonal migrations and dispersal has rapidly been reduced through human influence, and any wildlife movement into and out of Nova Scotia must pass through relatively narrow remaining corridors. This creates the potential for a bottleneck effect, also known as a pinch-point, where movements of multiple species are concentrated in close proximity, due to a lack of suitable habitat in the surrounding area (Chiasson, 2016; Nature Conservancy Canada, 2016). Without access to these narrow pinch-points or corridors, some wildlife in Nova Scotia would be isolated from continental populations, with negative implications for viability and persistence (Fahrig, 2003; Woolmer et al., 2008; Beazley et al., 2005), especially in response to climate changes.

As a key example of the importance of connectivity, moose (*Alces alces Americana*) are listed as endangered in Nova Scotia with potentially fewer than 100 individuals remaining (NS DNR, 2007; Timmermann & Rogers, 2015; McGregor, 2019). Currently, although the neighbouring New Brunswick population is robust with over 30,000 individuals (Fowler, 2016), the Nova Scotia population is too small and unstable to support hunting practices; hunting for mainland moose has been closed since 1981 (NS DNR, 2007). While there exist different pressures on moose populations and no one factor can be pinpointed for their decline (Beazley et al., 2006), interactions with roadways, both in terms of avoidance behaviour and vehicle-caused mortality are hypothesized to inhibit movement between Nova Scotia and New Brunswick populations through the isthmus (Snaith & Beazley, 2004a; Snaith et al., 2004). These impediments to movement reduce gene flow and access to habitat, and thereby increase the vulnerability of moose in Nova Scotia to environmental change and other stressors (NS DNR, 2007; Snaith & Beazley, 2004b). Similar effects apply to many other wildlife species in Nova Scotia (Beazley & Cardinal, 2004; Beazley et al. 2004). Identifying and reducing barriers to wildlife movement will have a positive effect on population viability and will support sustainable hunting and trapping practices in the province.

The work we have completed builds upon previous research by the Nature Conservancy Canada (NCC) with funding support from the Nova Scotia Habitat Conservation Fund (NS HCF) in 2016. Through that work, NCC modelled a high-probability wildlife movement corridor of approximately 3-7 km in width, from the northwest to the southeast across the New Brunswick-Nova Scotia border (Fig. 1).

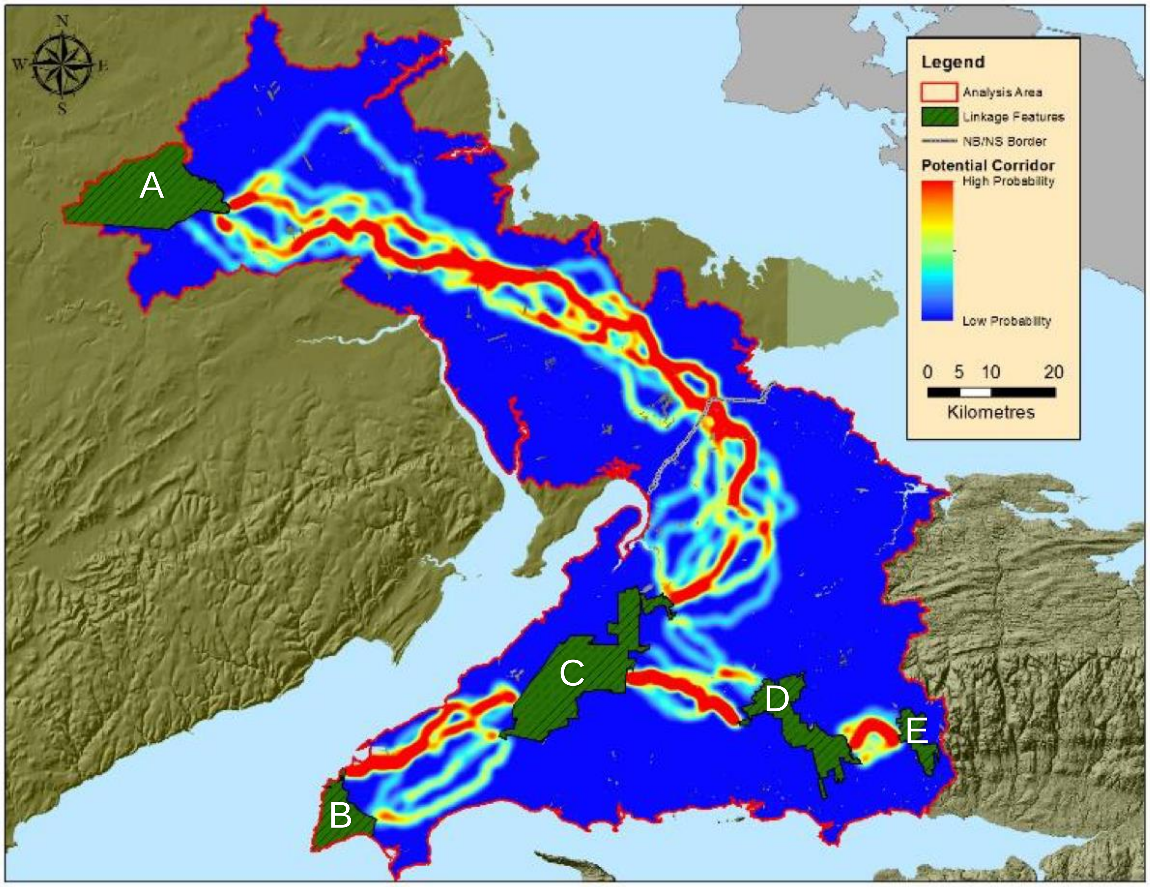

Figure 1. Model of potential corridors across the study area showing a low to high range of probability for wildlife movement. The four protected areas are shown as A) Canaan Bog, B) Cape Chignecto, C) Kelley River, D) Economy River, and E) Portapique. Adapted from "A wildlife connectivity analysis for the Chignecto Isthmus Region" (Nature Conservancy Canada, 2016).

To delineate this corridor, the NCC determined the most-likely movement pathways for twelve representative vertebrate (mammal and bird) species[1] in the Chignecto Isthmus region (NCC, 2016). These 'least-cost paths' were determined by assigning habitat suitability scores to land cover types between wilderness areas located in New Brunswick[2] and Nova Scotia[3]. The resulting combined paths were then used to predict a high-probability wildlife movement corridor, which represents a route that selected wildlife are most likely to take that minimizes resistance to movement from

[1] Focal species used for Chignecto Isthmus wildlife connectivity analysis were: moose (*Alces alces*), black bear (*Ursus americanus*), red fox (*Vulpes vulpes*), bobcat (*Lynx rufus*), snowshoe hare (*Lepus americanus*), fisher (*Martes pennanti*), northern flying squirrel (*Glaucomys sabrinus*), northern goshawk (*Accipiter gentilis*), pileated woodpecker (*Dryocopus pileatus*), brown creeper (*Certhia americana*), boreal chickadee (*Poecile hudsonicus*), blackburnian warbler (*Setophaga fusca*) (NCC, 2016).

[2] Canaan Bog Protected Natural Area

[3] Cape Chignecto Provincial Park, Kelley River Wilderness Area, Economy River Wilderness Area, and Portapique Wilderness Area

perspectives of risk of mortality, difficulty in movement, and energy expenditure (Graves & Wang, 2012; NCC, 2016; Skarin et al., 2015). Several sections of the corridor represent 'pinch-points' where there are likely to be higher rates of animal mortality or barriers to animal movement (Forman & Alexander, 1998; Fudge et al., 2007; Coffin, 2007). Many of these pinch-points intersect with roads, potentially resulting in a heightened barrier or avoidance effect for wildlife.

Such models, however, require ground truth validation. One way to do this is to collect and analyze wildlife road mortality data to verify crossing areas and/or pinch-points using systematic carcass surveys (Gerow et al., 2010). Intersections between wildlife movement pathways and roads result in higher rates of animal mortality due to wildlife-vehicle collisions, barriers to animal movement due to aversion to traffic noise or sudden gap in tree cover, and other negative effects (Forman & Alexander, 1998; Lodé, 2000; Trombulak & Frissell, 2000; Coffin, 2007; Fudge et al., 2007). Roadkill has been shown to be related to the degree of connectivity in the surrounding landscape; roads which intersect through otherwise more connected habitat tend to experience elevated levels of wildlife-vehicle collisions, especially as roads grant access to otherwise protected areas (Gerow et al., 2010; Garriga et al., 2012; Kang et al., 2016). As a consequence, our work aimed to investigate wildlife-road interactions through field surveys along selected roads in the Chignecto Isthmus region. The results were intended to validate, through on-the-ground research, the modelled habitat movement pathways and provide important information on how and where wildlife interacts with roads. This report summarizes the findings from this one-year (June 1, 2018 to May 31, 2019) research project supported by funds from the NS HCF.

Project Goals and Objectives

Our main objectives were to quantify interactions (i.e. successful and unsuccessful crossings and avoidance behaviours) between wildlife and roads in four modelled pinch-point areas associated with roads in the Nova Scotia portion of the isthmus, and to assess the impacts of these roads on wildlife movement. The findings were intended to (1) verify model results on the ground, (2) inform the locations for future camera trap studies, and (3) identify optimal locations for, and provide information relevant to designing mitigation measures to reduce wildlife-roadway conflicts. We hypothesized that there would be significant aggregations of wildlife road mortality where roads intersect with the NCC's modeled wildlife movement corridor. To quantify unsuccessful crossings, we collected primary wildlife roadkill data. We then analyzed and mapped these data to both identify hotspots of roadkill, and to compare these patterns with the locations of the modelled high-probability wildlife movement corridors identified by NCC in their earlier work (NCC, 2016).

The findings are intended to help inform decisions for mitigating vehicle-caused wildlife mortality while enhancing human safety and habitat connectivity to promote robust, genetically diverse populations of wildlife in Nova Scotia. If implemented, mitigation measures should be monitored to verify their effectiveness, providing information and a potential model for similar applications in other regions (Clevenger, 2005; Corlatti, 2008; Slesar, 2017). More broadly, the research will contribute to the much-needed work to restore and maintain ecological connectivity in the Chignecto Isthmus, and thus increase the adaptability and resiliency of wildlife in Nova Scotia and of the larger Northern Appalachian-Acadia ecoregion (NS DNR, 2007; NEGECP, 2016).

Work Completed

Roadkill surveys were conducted over 15 weeks from May to August 2018 to collect quantitative observational data on wildlife road mortality events along the selected road sections in the Chignecto Isthmus region (Fig 2.).

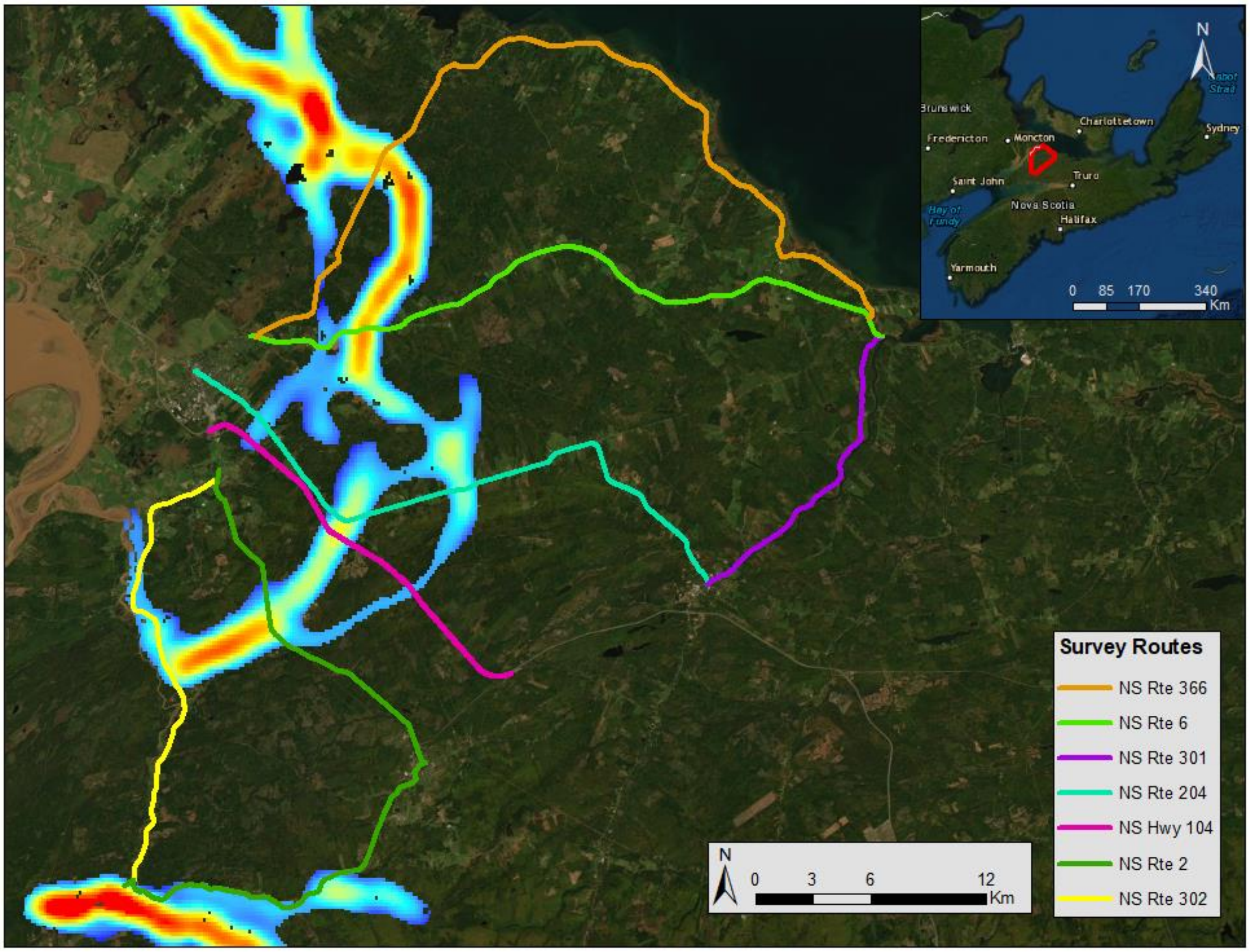

Figure 2. Chignecto Isthmus roadkill carcass survey routes intersecting the NCC's modeled wildlife movement corridor. The modeled corridor uses a cool – warm colour scale to indicate low – high probability of wildlife movement. The darkest red areas represent pinch-points to movement (NCC, 2016). The inset map shows the position of the Chignecto Isthmus as a terrestrial linkage between the peninsular province of Nova Scotia and the province of New Brunswick. Basemaps courtesy of ESRI (ESRI, 2016).

Vertebrate mortalities only were recorded, and domestic species and livestock (e.g. house cats, domestic rabbits, sheep) were excluded from data collection. All roadkill events were recorded regardless of state of decomposition or degradation. When unidentifiable to species, the taxon was recorded. The six roads chosen represented a range of size classes with speed limits of either 70-90 km/h, or 100-110 km/h (Table 1).

Table 1. Roads surveyed for roadkill carcasses in the Chignecto Isthmus region of Nova Scotia from May to August 2018.

Province	Route number	Speed limit range (km/h)	Number of lanes	AADT (vehicles/day)	Length surveyed (km)	Survey frequency	Driving survey speed (km/h)
NS	366	70-90	2	1,180	49.6	Weekly	50
NS	6	70-90	2	1,828	36.4	Twice Weekly	50
NS	301[4]	70-90	2	1,135	17.1	Weekly	50
NS	204	70-90	2	905	31.9	Weekly	50
NS	104	100-110	4	11,400	21.2	Twice Weekly	60-70
NS	2	70-90	2	1,172	40.2	Weekly	50
NS	302	70-90	2	1,665	25.1	Weekly	50

Two roads within the study area (NS Rte 6, and NS Rte 104) were surveyed at a rate of twice weekly, while the remaining roads were surveyed weekly. These two roads of interest were selected for more frequent surveys due to their roles as important transportation corridors linking urban centres in the isthmus. NS Hwy 104 and NS Rte 6 both connect with Amherst, an urban centre located at the border region in Nova Scotia; Hwy 104 is the main highway leading out of Nova Scotia, and Rte 6 represents the secondary road in the Nova Scotia portion of the study area with the highest annual average daily traffic volume (AADT). Although it is suggested that sampling for roadkill should occur at one- or two – day intervals to account for low carcass persistence time of some species, which could lead to false-negative estimation of hotspots (Ratton et al., 2014; Santos et al., 2015), weekly surveys were chosen for the majority of roads due to the time and financial constraints of traveling large distances around the isthmus daily. Similar surveys for a comparable set of roads were carried out simultaneously on the New Brunswick side of the border.

All roadkill surveys began at 6:00 am. Roadkill surveys are most effective when they detect mortalities that occur overnight, close to dawn, before scavengers can remove the carcass or the carcass becomes overly degraded by vehicle traffic (Collinson et al., 2014). Additionally, surveys performed shortly after sunrise will capture

[4] NS Rte 301 did not intersect the modeled corridor but was surveyed weekly because the searchers used it as a connector between NS Rte 204 and NS Rte 6.

the mortality events that occur frequently overnight due to reduced motorist visibility and prevalence of nocturnal wildlife (Ratton et al., 2014). Depending on the length of the road and the number of roads surveyed on that day, surveys generally lasted 3-5 h. Thus, not every road segment was surveyed at the same time of day.

Each survey was conducted by car, traveling at speeds of 50-70 km/h (slower speeds for secondary roads with low traffic volumes and low speed limits, higher speeds for major highways with higher traffic volumes and higher speed limits). A speed of 50 km/h is recommended as the maximum at which reliable roadkill data can be obtained, however it is also not recommended to drive more than 20 km/h slower than the speed limit for safety reasons (Collinson et al., 2014). Although searching by foot is more effective for detecting carcasses in the ditch or verge along the roadside, driving surveys at these speeds are as effective as walking surveys for detecting roadkill on the road surface or shoulder (Guinard et al., 2012), although some small species may still have been missed (Brockie et al., 2009). Thus, a compromise was struck to maximize visibility while searching and for safety on the roads.

When an animal carcass was spotted (by the driver or the passenger), the car was stopped safely on the shoulder. The observers exited the vehicle, and collected photos, GPS coordinates, and information on species identification, size, carcass position and condition, and on the surrounding roadside habitat. When it was safe to do so, the carcasses were removed from the road to 1) reduce the chance of being re-counted during a subsequent survey, 2) prevent further mortality of scavengers, and 3) allow nutrients to cycle back into the ecosystem through decomposition. Large carcasses (e.g. deer, bear) were reported to the appropriate department of transportation for removal. If an animal injured by a collision had been discovered alive, a nearby wildlife rehabilitation centre would have been called to help assess the situation. Live animals seen on the road shoulder or the verge were recorded as evidence for the presence of individual species near the road, the habitat associated with road crossings and whether they attempted to cross.

Key sections (i.e. areas which overlapped with the model directly) were initially chosen as approximately 3-6 km stretches to be walked daily for fine-scale surveys. These sections comprised the sections of the modeled corridor which were predicted to encompass the highest degree of probability of movement, plus buffer sections of 2 km on either side. These fine-scale walking surveys were conducted for 8 weeks in conjunction with the driving surveys to cover longer sections of each road for better comparison between the modeled corridor and the surrounding landscape. When walking, the two observers started at opposite ends of these shorter sections and walked towards each other (each walking against the direction of traffic for increased safety) to perform the searches on foot. As the main observer would remain in the car until reaching the drop-off point, each section of road was searched both in the car and on-foot. Through this process, conducted for a period of 8 weeks, it was determined that walking surveys were not returning different results from the surveys completed while driving at 50 – 70 km/h, and thus, the walking surveys were abandoned in favour of driving surveys.

Road network shapefiles were obtained from Open Data Nova Scotia, for the Nova Scotia Road Network (Open Data Nova Scotia, 2016). All data were projected to a common spatial reference, NAD 1983 UTM Zone 20N, using ArcGIS Desktop V. 10.5 (ESRI, 2016). A spatial analysis to detect hotspots, defined as significant aggregations of mortality as compared to a random distribution of the given mortality events along the surveyed road (Coelho et al., 2014), was conducted using Siriema Road Mortality Software V. 2.0 (2014), and displayed cartographically using ArcGIS Desktop V. 10.5 (ESRI, 2016).

Roadside infrastructure surveys were conducted on the initial 3-6 km stretches initially chosen for walking surveys, excepting Hwy 104; for safety reasons due to the vehicle speed and traffic volume, Hwy 104 was not included in the walking surveys. During these surveys, culverts and other passages under the road were recorded, as well as major obvious barriers to wildlife movement, such as fences. The size and location of each crossing opportunity or barrier was recorded, and a brief description of its condition reported. These data were used to create maps showing crossing opportunities on NS Rtes 6, 204, and 366 along the modeled wildlife movement corridor.

Animal-vehicle collision data were obtained from the Nova Scotia Department of Lands and Forestry (NS LAF). The dataset provided was for Cumberland County, which borders New Brunswick and encompasses the towns of Amherst, Oxford, Springhill, and Parrsboro. Although it was expected that all of the datapoints would be associated with GPS coordinates, many of the records were lacking this information. The report contained not only dead wildlife records, but also any instance of sick, injured, or distressed wildlife, wildlife nuisance complaints, or general wildlife sightings. Once the records were filtered to include only dead wildlife, there were categories for (1) wildlife that were reported dead and (2) incidents that involved a vehicle. Both of these categories were included in the counts in Table 3, as it was possible that the person who reported the dead animal did not cause the collision, and therefore simply reported it as dead without specifying a cause. As these records are all associated with roads, it is reasonable to assume that the mortalities were collision related. As an extended analysis for comparison across the Chignecto Isthmus and for the masters thesis which these data will contribute to, a dataset for New Brunswick was also obtained. The New Brunswick dataset contained only records for three large mammals (American moose, white-tailed deer, and black bear) which died as a result of a collision with a motor vehicle. For consistency, these were the only species counted from the Nova Scotia dataset, although other species, such as coyote, bobcat, and birds of prey were included in the records obtained from the NS LAF. Finally, as the locations were often vaguely described (e.g. some records were listed with the associated road, others with a general location description), the records were sorted by county, rather than by individual roads. This caused the data to be less comparable with the targeted roadkill surveys from this study as those surveys were conducted on selected roads in the Chignecto Isthmus, and the NS LAF dataset covers a larger area and more roads.

Results

Roadkill surveys

A total of 354 vertebrate carcasses were recorded on roads in the study area comprising 15 weeks of surveys (Table 2). Nearly 50 individual species were observed from mammal, bird, and amphibia taxa, with mammals being the most abundant, comprising 60% of the observations. The most frequently observed species during the surveys were common raccoons (*Procyon lotor*) and North American porcupines

(*Erethizon dorsatum*). Both species often forage along disturbed edges of the roadside nocturnally. Together, they constitute over 36% of carcasses collected during surveys. Green frogs were also found in high numbers, however the majority of these records were observed during one roadkill event, while raccoon and porcupine mortalities were recorded daily.

Table 2. Raw data of species (or bird families) collected during the roadkill carcass surveys.

Common name	Scientific name	Count	% of Taxa	% of Total
Mammals	**Class Mammalia**	**212**		**60.0**
Common raccoon	*Procyon lotor*	82	38.7	23.2
North American porcupine	*Erethizon dorsatum*	46	21.7	13.0
American red squirrel	*Tamiasciurus hudsonicus*	19	9.0	5.4
Striped skunk	*Mephitis mephitis*	14	6.6	4.0
Eastern chipmunk	*Tamias striatus*	11	5.2	3.1
Snowshoe hare	*Lepus americanus*	7	3.3	2.0
White-tailed deer	*Odocoileus virginianus*	6	2.8	1.7
Red fox	*Vulpes vulpes*	5	2.4	1.4
Shrew species	*Sorex* spp.	4	1.9	1.1
Black bear	*Ursus americanus*	3	1.4	< 1.0
Canadian beaver	*Castor canadensis*	3	1.4	1.0
Mouse species	Family Muridae	2	< 1.0	< 1.0
Woodchuck	*Marmota monax*	1	< 1.0	< 1.0
Eastern coyote	*Canis latrans*	1	< 1.0	< 1.0
American mink	*Mustela vison*	1	< 1.0	< 1.0
Unknown (due to degradation of carcass)		7	3.3	2.0
Birds (by family)	**Class Aves**	**78**		**22.0**
Crows, jays, and magpies (American crow, blue jay)	Family Corvidae (*Corvus brachyrhynchos, Cyanocitta cristata)*	19	24.4	5.4
New world warblers (northern parula, common yellowthroat, American redstart, yellow-rumped warbler, magnolia warbler, ovenbird)	Family Parulidae (*Setophaga americana, Geothlypis trichas, Setophaga ruticilla, Setophaga coronata, Setophaga magnolia, Seiurus aurocapilla*)	10	12.8	2.8
Starlings (European starling)	Family Sturnidae (*Sturnus vulgaris*)	10	12.8	2.8
Woodpeckers (northern flicker)	Family Picidae (*Colaptes auratus*)	5	6.4	1.4

Thrushes and allies (hermit thrush, American robin)	Family Turdidae (*Catharus guttatus, Turdus migratorius*)	5	6.4	1.4
Troupials and allies (common grackle)	Family Icteridae (*Quiscalus quiscula*)	5	6.4	1.4
Swallows (barn swallow, tree swallow)	Family Hirundinidae (*Hirundo rustica, Tachycineta bicolor*)	4	5.1	1.1
Waxwings (cedar waxwing)	Family Bombycillidae (*Bombycilla cedrorum*)	3	3.8	1.0
New world sparrows (savannah sparrow, song sparrow)	Family Passerellidae (*Passerculus sandwichensis, Melospiza melodia*)	3	3.8	1.0
Vireos (red-eyed vireo)	Family Vireonidae (*Vireo solitarius, Vireo olivaceus*)	1	1.3	< 1.0
Pheasants, grouse, and allies (ruffed grouse)	Family Phasianidae (*Bonasa umbellus*)	1	1.3	< 1.0
Falcons (American kestrel, merlin)	Family Falconidae (*Falco sparverius, Falco columbarius*)	1	1.3	< 1.0
Tits, chickadees, and titmice (black-capped chickadee)	Family Paridae (*Poecile atricapillus*)	1	1.3	< 1.0
Tyrant flycatchers (alder flycatcher)	Family Tyrannidae (*Empidonax alnorum*)	1	1.3	< 1.0
Finches (American goldfinch)	Family Fringillidae (*Spinus tristis*)	1	1.3	< 1.0
Owls (great horned owl)	Family Strigidae (*Bubo virginianus*)	1	1.3	< 1.0
Unknown (due to degradation of carcass)		7	9.0	2.0
Amphibians	**Class Amphibia**	**64**		**18.1**
Green frog	*Lithobates clamitans*	46	71.9	13.0
Northern leopard frog	*Lithobates pipiens*	6	9.4	1.7
Red-spotted newt	*Notophthalmus viridescens*	6	9.4	1.7
Pickerel frog	*Lithobates palustris*	3	4.7	1.0
Wood frog	*Lithobates sylvaticus*	1	1.6	< 1.0
Unknown (due to degradation of carcass)		2	3.1	< 1.0

Only three (i.e., black bear, red fox, and snowshoe hare) of the 12 focal species selected for the NCC's corridor model were observed as roadkill during the field season (Fig. 3). Three mortality instances of black bear (*Ursus americanus*), a wide-ranging habitat generalist, were observed, all on NS Hwy 104. Red fox (*Vulpes vulpes*) was observed as roadkill five times, mainly on secondary roads in Nova Scotia. Snowshoe hare (*Lepus americanus*), a habitat generalist and important prey species, was the sixth most common mammal roadkill observation, with seven instances of mortality distributed across most of the surveyed roads.

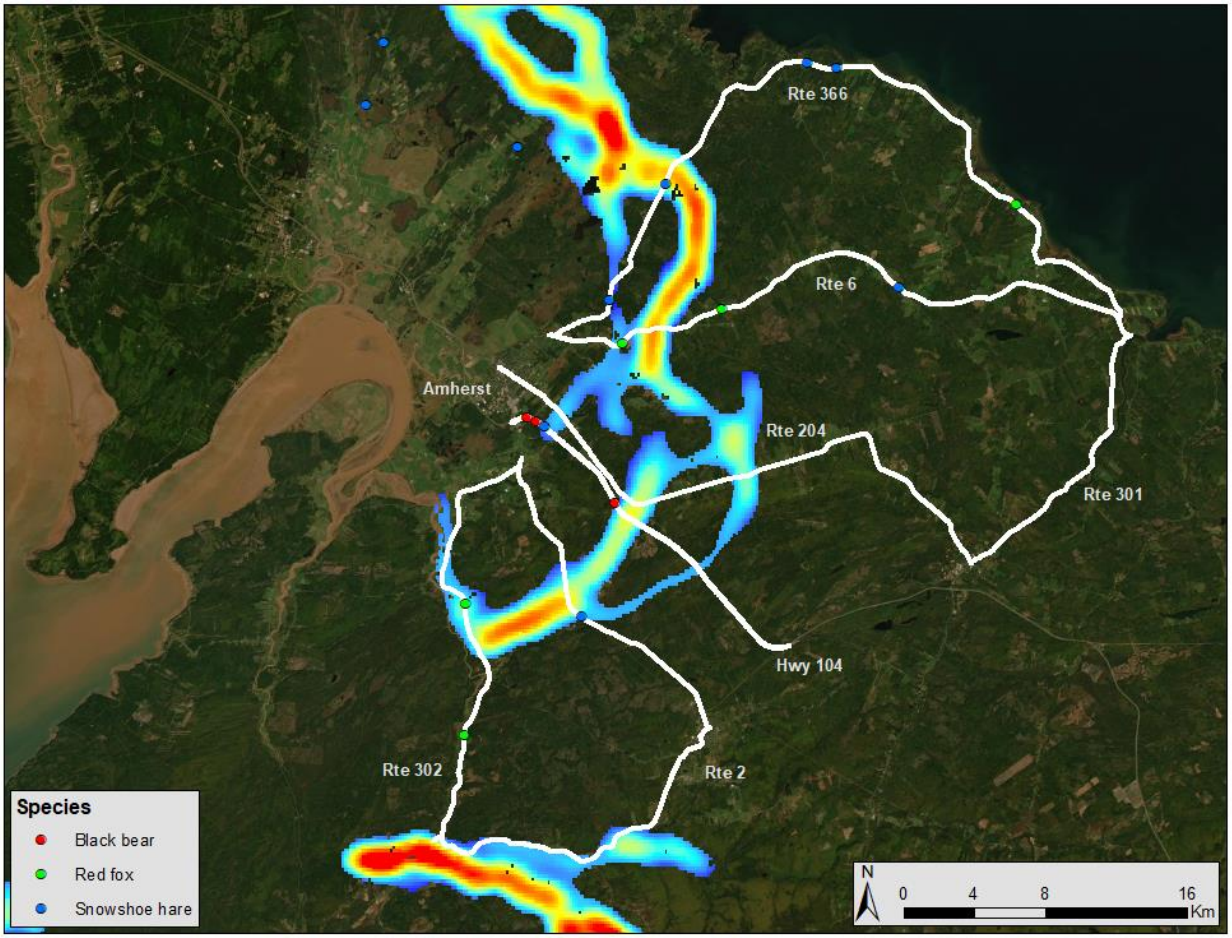

Figure 3. Locations of the roadkill events on NS roads recorded for the three species included in the NCC's modeled connectivity analysis. Basemap courtesy of ESRI (ESRI, 2016).

Aggregations of mortality ("hotspots") were calculated for each road by comparing the actual distribution of the roadkill events with a simulated random distribution of the mortality events along each road. When overlaid on the NCC's modeled corridor, the roadkill hotspots can be compared to the position of the corridor as it passes through the Chignecto Isthmus, showing several locations where significant hotspots correspond with high probability pinch-points (Fig. 4). There are significant sections of road mortality that are roughly found along the NCC's modeled corridor on NS Rte 366, NS Rte 6, NS Rte 204, and NS Hwy 104.

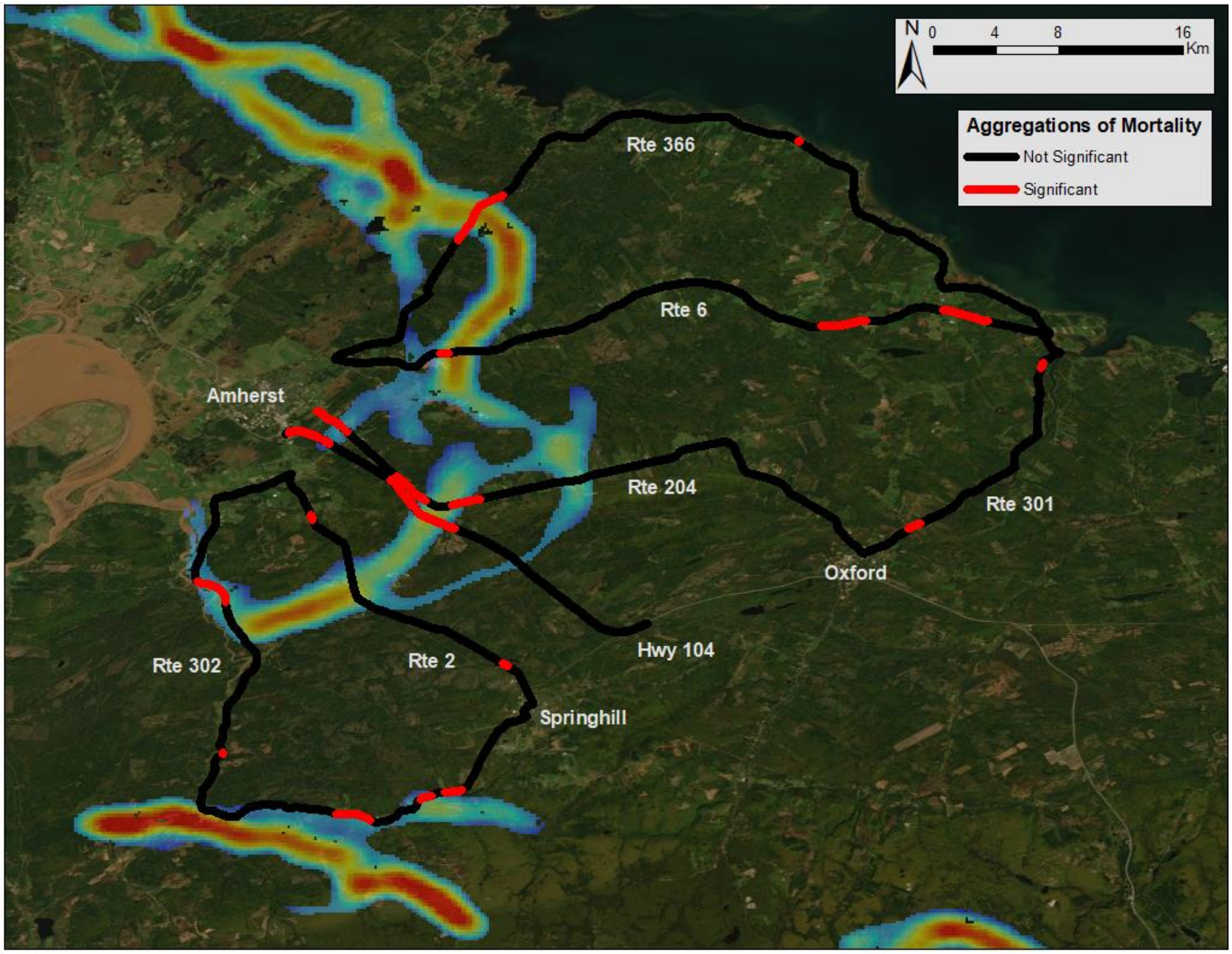

Figure 4. Results of Siriema 2D Hotspot Analysis showing significant aggregations of wildlife mortality in red along the Chignecto Isthmus survey routes, overlaid on the NCC's modeled wildlife movement corridor. Basemap courtesy of ESRI (ESRI, 2016)*.*

For comparison purposes, a second hotspot analysis was conducted with the same parameters, using a subset of the data with birds, amphibians, and reptiles removed. The mammalian roadkill represents approximately 60% of the data collected. As most mitigation decisions, such as large-scale crossing structures, would be targeted to terrestrial mammals, it is logical to determine if the same patterns are seen. Overall, many of the same hotspots are seen as when the entire dataset was used to model the roadkill hotspots (Fig. 5). However, hotspots are less concentrated, and show more diffuse patterns along each road.

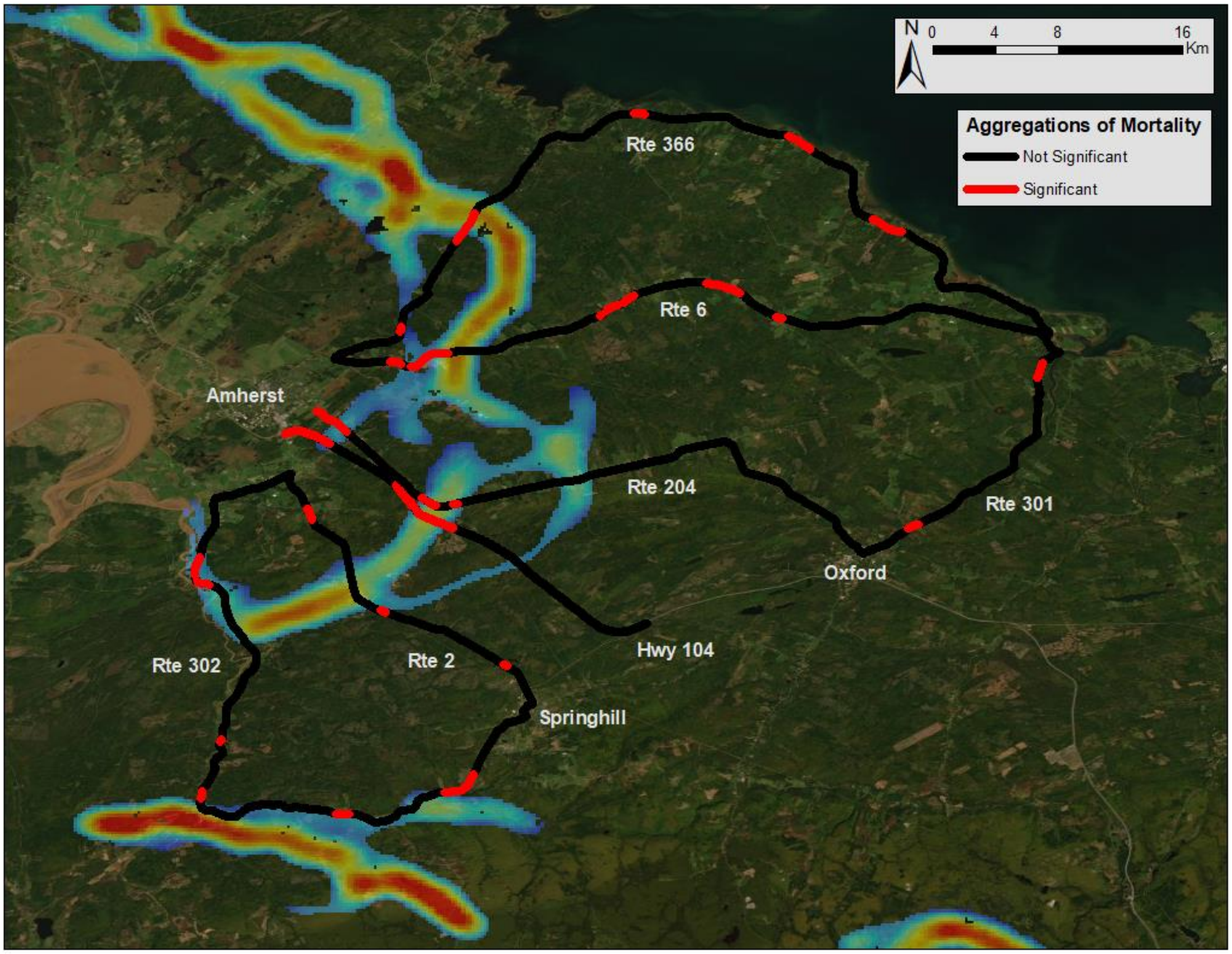

Figure 5. Results of Siriema 2D Hotspot Analysis for mammal roadkill only, showing significant aggregations of wildlife mortality in red along the Chignecto Isthmus survey routes, overlaid on the NCC's modeled wildlife movement corridor. Basemap courtesy of ESRI (ESRI, 2016).

Raccoons are a generalist species which thrives in human dominated landscapes and therefore does not represent a good focal species upon which to base mitigation decisions for wildlife conservation purposes. As raccoons made up nearly 40% of the mammals recorded and over 20% of the entire dataset, it is possible that they influenced the results for locations of road morality hotspots. Although often a difficult sight for motorists, raccoons do not warrant road crossings on the basis of either human safety or wildlife conservation concerns, nor are they a good indicator species for identifying wildlife movement pathways for species of concern. Once removed from the dataset, the 2D hotspot analysis was performed again and the results mapped (Fig. 6). NS Rte 301 was also excluded from this analysis and mapped results, as the sample size after the removal of raccoons was too small (n = 4) to conduct a meaningful analysis[5]. For most of the roads, only the size of the hotspot changed, while most of the general locations remained the same as with the mammal-only analysis.

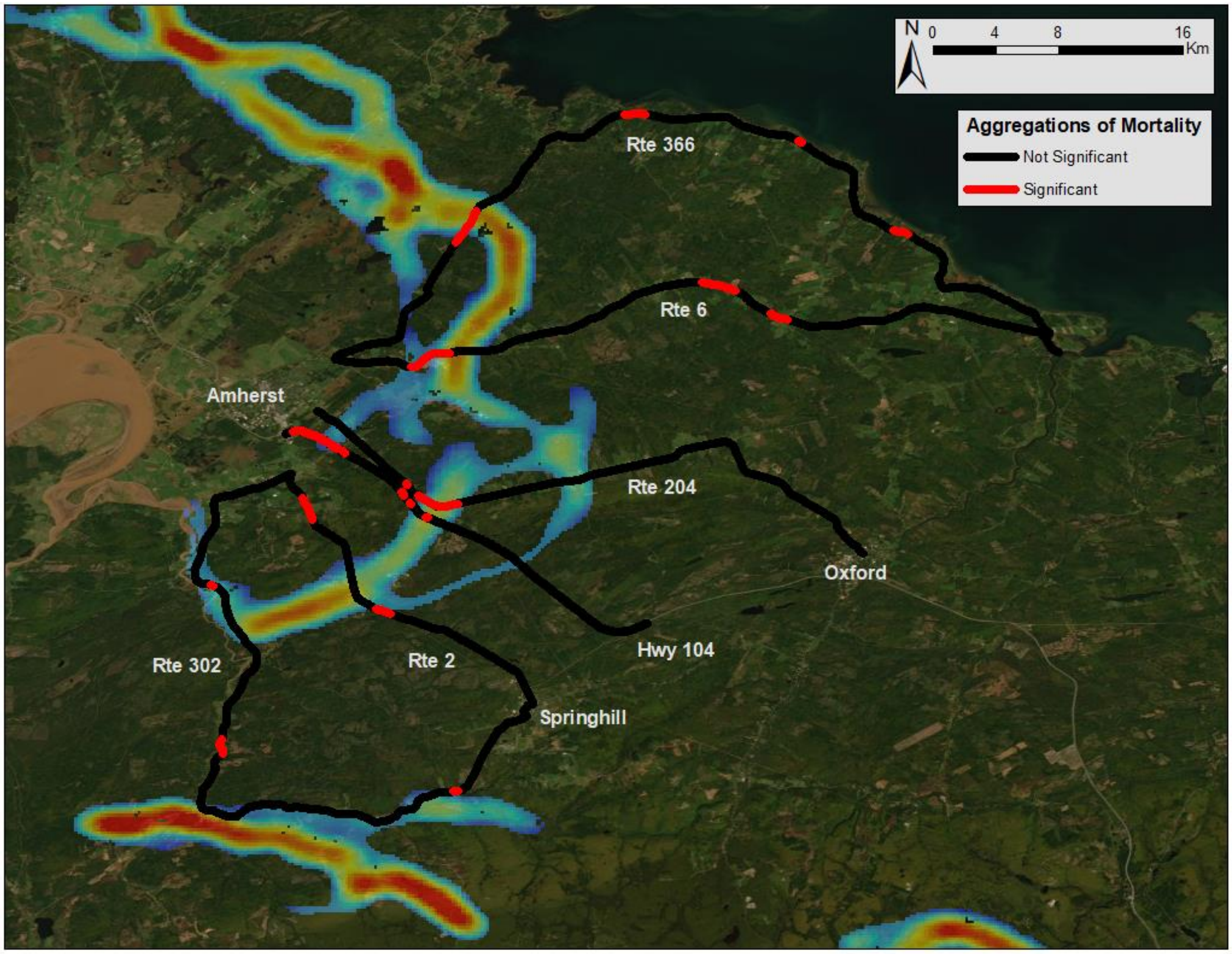

Figure 6. Results of Siriema 2D Hotspot Analysis for mammal roadkill only with raccoon mortality events removed, showing significant aggregations of wildlife mortality in red along the Chignecto Isthmus survey routes, overlaid on the NCC's modeled wildlife movement corridor. Basemap courtesy of ESRI (ESRI, 2016)

Raccoons are not the only species which may skew the results in favour of presenting aggregations of mortality containing species of neither conservation nor human safety concern. Additionally, small-bodied mammals in the dataset are not a safety concern and would require different roadway mitigation measures than larger mammals, such as deer and bear. Small-bodied mammals in this study, defined as

[5] A sample size of n≥10 was chosen as the threshold at which to run the hotspot analysis for any given dataset.

having a mass of < 1 kg, were red squirrel (*Tamiascriurus hudsonicus*), Eastern chipmunk (*Tamias striatus*), mouse species (Family Muridae), and shrew species (*Sorex* spp.). With the smaller wildlife removed, only three roads remained with a sample size large enough to warrant hotspot analyses (n ≥ 10) (Fig. 7). The position of the aggregations which intersect the modeled corridor do not change dramatically with the removal of the small-bodied mammals, however some aggregations outside of the modeled corridor on NS Rte 366 disappear altogether (Fig. 7)

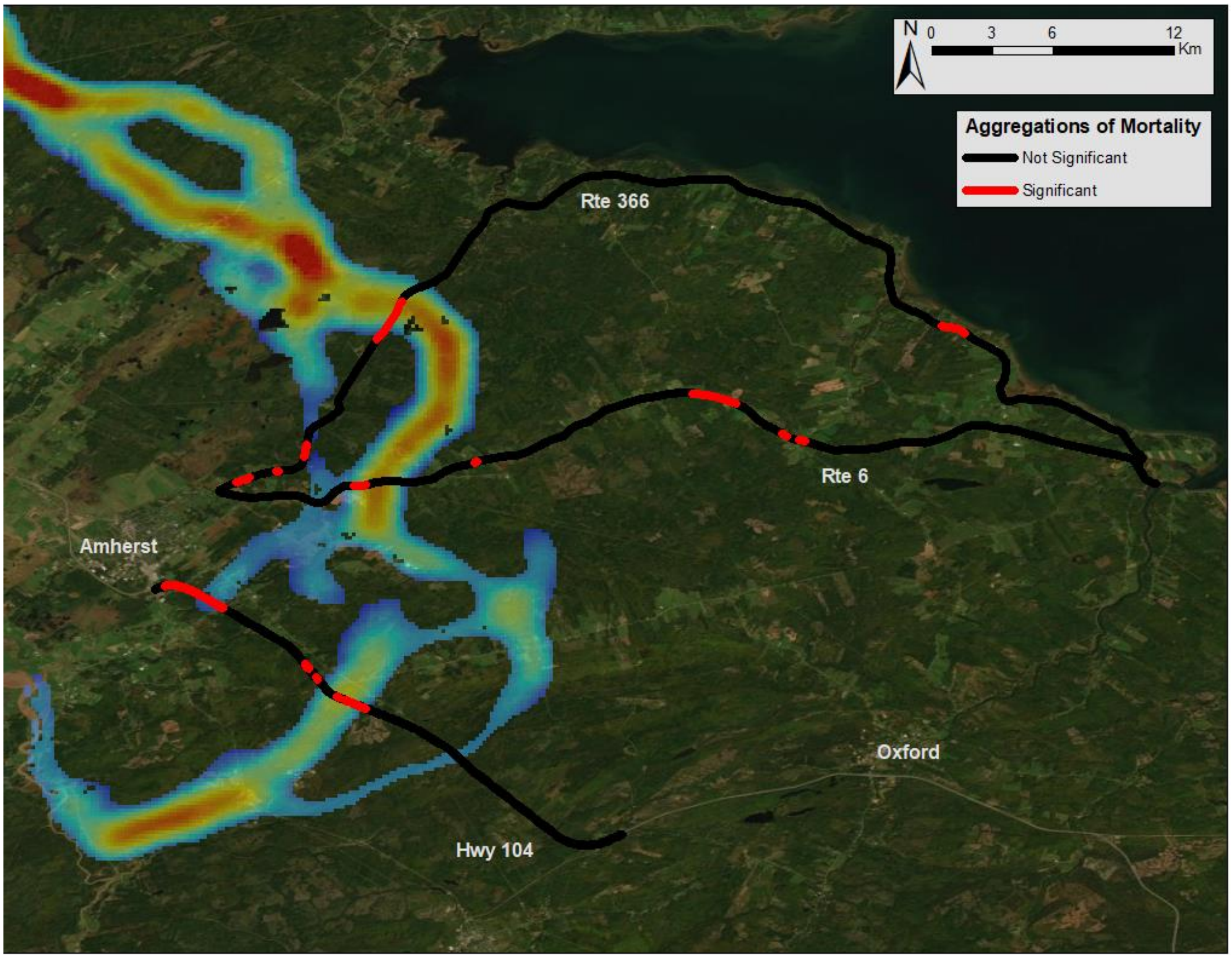

Figure 7. Results of Siriema 2D Hotspot Analysis for mammal roadkill only with raccoon mortality and small-bodied mammal mortality events removed, showing significant aggregations of wildlife mortality in red along the Chignecto Isthmus survey routes, overlaid on the NCC's modeled wildlife movement corridor. Basemap courtesy of ESRI (ESRI, 2016).

A complementary study is being simultaneously conducted with support from the New Brunswick Wildlife Trust Fund (report in preparation) to produce hotspot maps for six additional roads in the New Brunswick portion of the isthmus which correspond with the modeled wildlife movement corridor. Maps for the entire region are included in the appendix.

Reported Collision Data

Over six years (2013-2018), a total of 301 dead wildlife records were reported to NS LAF in Cumberland county for the three largest mammals in the province: moose, deer and bear (Table 3). The highest number of records collected was in 2014, and the lowest numbers were recorded in 2016 and 2017. White-tailed deer were the most frequently reported species, comprising over 80% of the dataset. Black bear were the second most abundantly represented species, at almost 15% of the records, and moose were sparsely represented at almost 3%.

Table 3. Counts of large mammals (moose, deer, bear) recorded dead by Nova Scotia Department of Lands and Forestry listed by year, from 2013-2018 in Cumberland County, Nova Scotia.

Year	American moose	White-tailed deer	Black bear	Year Total
2013	2	61	11	74
2014	0	71	8	79
2015	2	51	4	57
2016	4	18	1	23
2017	0	21	2	23
2018	0	27	18	45
Species Total	8	249	44	
% of Total	2.7	82.7	14.6	

Transportation Infrastructure Surveys

Each of the culverts encountered on the walking survey routes was measured for height and described in terms of accessibility for aquatic connectivity. A summary of the available opportunities for aquatic connectivity on the sections surveyed on foot showed that Rte 6 had the most accessible culverts to allow aquatic organisms and small terrestrial species passageway across the road. A full description of the locations and conditions of each culvert is found in the appendix.

Table 3. Summary of the opportunities for aquatic connectivity along the three roads surveyed by foot at locations where they intersect with the modeled corridor.

Route #	Total opportunities for aquatic connectivity	No passage opening	Culvert ≤0.5 m high	Culvert 0.5 - 1.0 m high	Culvert ≥1.0 m high
6	10	0	0	8	2
366	3	1	1	0	1
204	3	0	0	2	1

Examining the locations for the culvert placements on the three roads where they intersect the modeled corridor, it can be seen that for Rte 6 and Rte 204, the culverts are present on either side of the most probable path for wildlife movement (Fig. 8) and that there is no aquatic connectivity directly located in the range of the highest probability for wildlife movement on that road. Rte 366 does have one potential area of aquatic connectivity located in the highest probability range of the corridor, however it, along with the point directly to the southwest along the same road, represented areas with a pond or wetland on either side of the road, but no perceptible crossing is available for aquatic species.

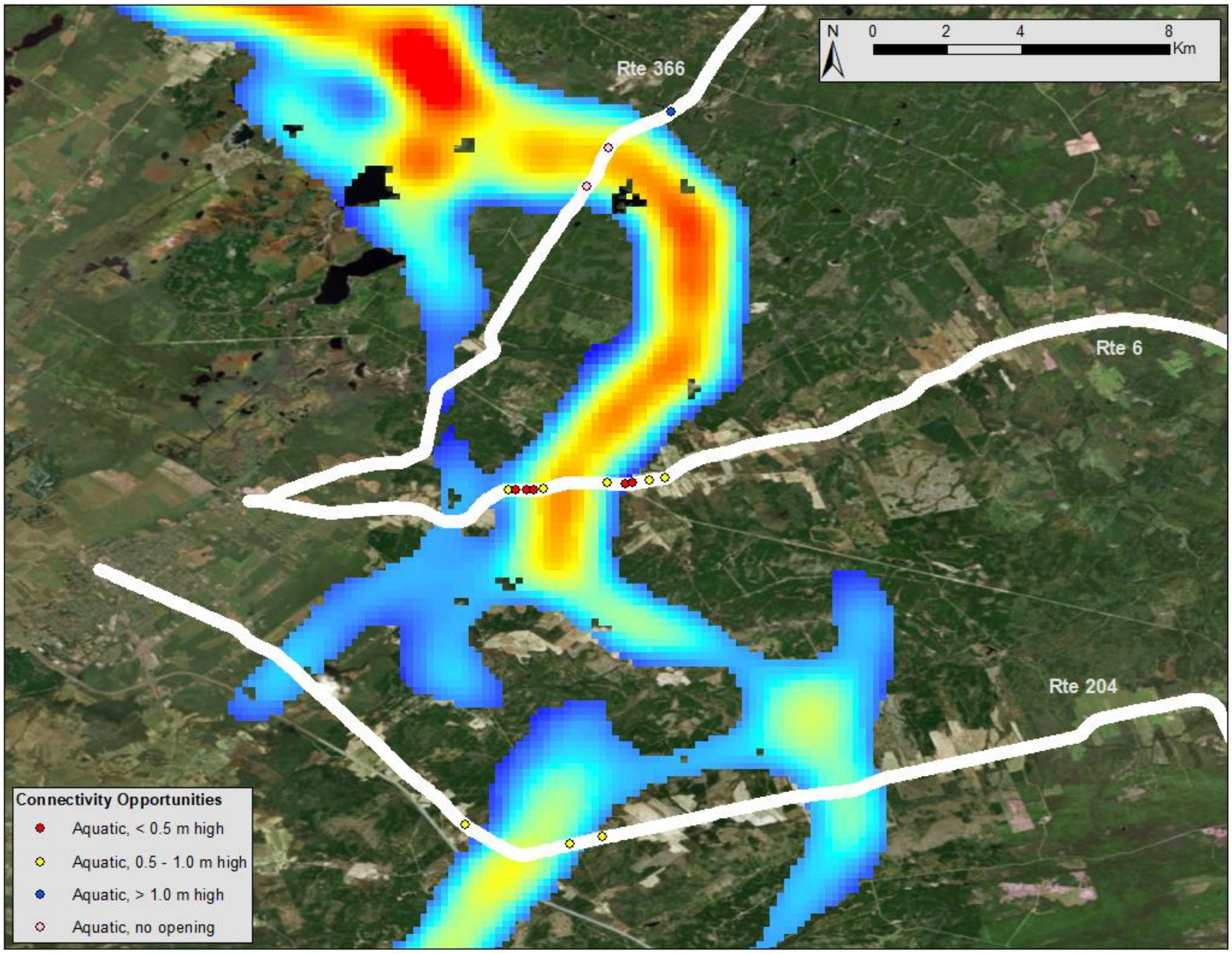

Figure 8. Aquatic connectivity opportunities for the three surveyed roads where they intersect with the modeled corridor.

Terrestrial connectivity was more difficult to determine from the side of the road as the conditions directly beyond what was visible at the roadside were often obscured by vegetation. For this survey, terrestrial crossing opportunities were mainly described as areas where there was clear passageway for wildlife across the road, either because there was a gap in residential structures or a clearing in dense vegetation, such as a trail used for ATVs or cut for large powerlines. Although smaller species such as hare, or porcupines may be more likely to cross where there is dense vegetation on either side of the road, these open, unpopulated areas might provide space and guidance for larger species to cross as they exit the forest and walk along the cleared area for browsing on smaller herbaceous plants or to more easily spot smaller prey. A full description of each identified area of terrestrial connectivity is included in the appendix. Rte 366, with no roadside residences had the most opportunities for terrestrial crossings, while Rte 6 and 204, which both hosted many rural residences along the road within the modeled corridor showed far fewer opportunities for terrestrial connectivity for larger mammals (Fig. 9).

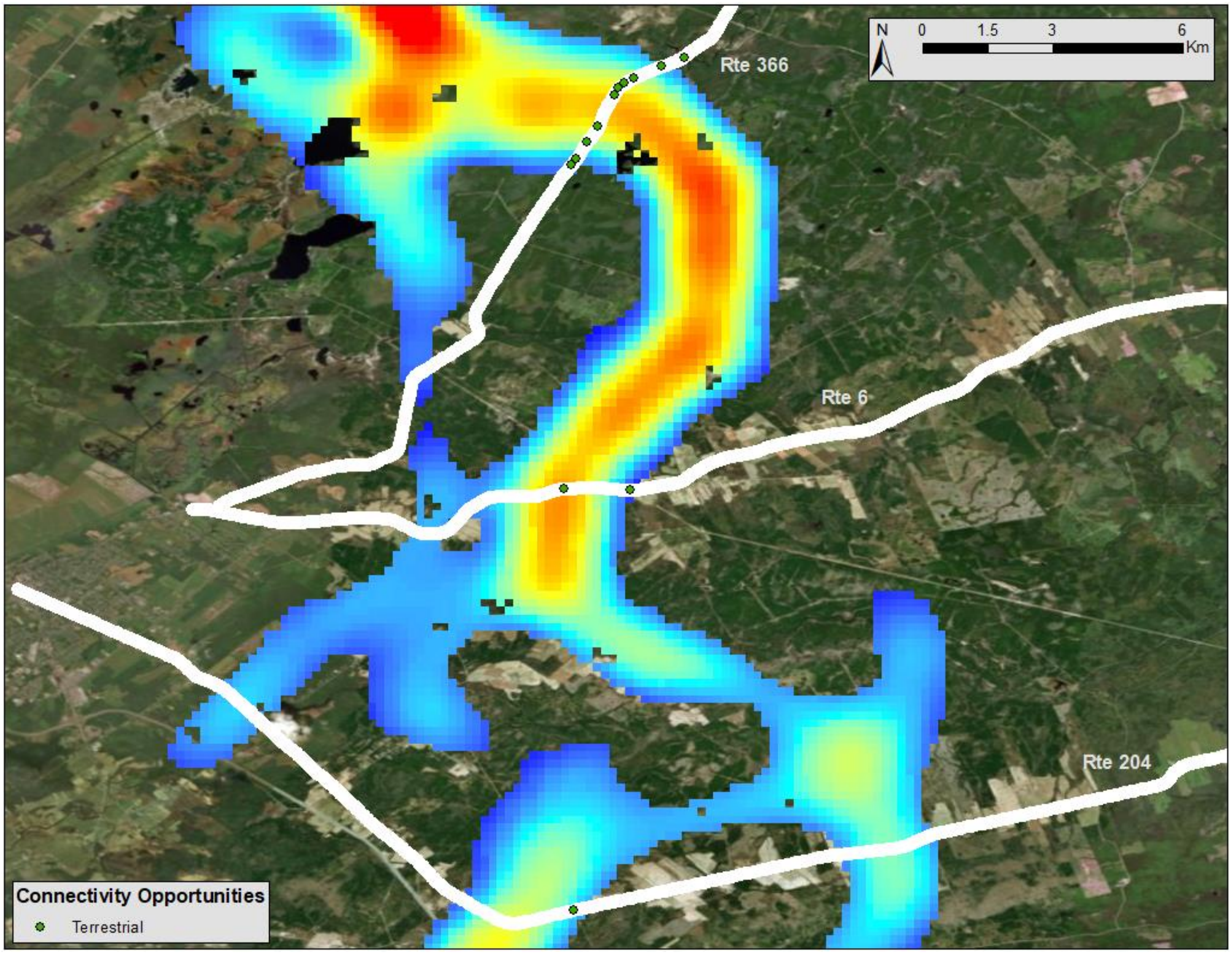

Figure 9. Locations for potential terrestrial connectivity opportunities along the three survey routes where they intersect with the modeled corridor.

Achievements and Lessons Learned

Discussion

This study represents a preliminary investigation into the status of road-wildlife interactions in and around the Chignecto Isthmus as a pinch-point for ecological flow. In many road sections, hotspots found in the roadkill data correspond with key pinch-points in the NCC's modeled wildlife movement corridor (NCC, 2016). There are several aggregations of mortality within the visualized spread of the wildlife movement corridor model, which is a reasonable expectation as the model represents areas of important habitat to a diverse suite of species. The aggregations of mortality found on each road represent the phenomenon that for each of the surveyed roads, some stretches are more problematic for wildlife than others.

The presence of additional significant hotspots on NS Rte 366 and NS Rte 6 outside of the modeled corridor does not negate the use of roadkill data to ground truth wildlife movement, as the corridor is specifically designed to model movement between designated protected areas and for a subset of 12 species, rather than for the over 40 species identified in the roadkill survey. It is also likely that (1) wildlife movement becomes more diffuse outside of the narrowest section of the Chignecto Isthmus and (2) the most suitable habitat patches for some wildlife species, including the NCC's modeled species are not directly associated with the protected areas selected as start and end points for NCC's connectivity analysis. Further, NCC's modeled corridor was generated as the 'least cost path' for each species, combined through a kernel-density analysis to identify the narrowest pathway likely to accommodate all 12 species. As such, it represents a relatively narrow, pseudo-optimized 'high probability movement pathway' for a subset of species, rather than a representation of current movement pathways for all wildlife species across the landscape (such as could be generated through other types of connectivity models, such as Circuitscape). Nonetheless, the results suggest that, as wildlife move across the landscape, they are choosing areas within the modeled corridor, especially where movement outside of the modeled corridor is restricted, such as near areas of high human development.

The hotspot analysis conducted solely on mammal road mortality displays similar patterns to the analysis using the entire dataset, with hotspots generally corresponding with the NCC model.

With the smaller sample size, the hotspots seem to be more diffuse. Although amphibians comprise only ~18% of the dataset, one of the major aggregations of mortality found outside of the model on NS Rte 6 using the full vertebrate dataset was directly due to the movement of amphibians across the road from one wetland feature to another a single over-night event (i.e. recorded on a single survey day). This large-scale mortality event (n > 40 kills), the only such event observed during the field season, occurred after a heavy rainstorm which temporarily flooded low-lying roads in some areas of the isthmus. The presence of the excess water may have made the road surface less of a barrier, causing higher mortality in this area than usual as water on the road surface may have served as a conduit for movement. Amphibian road mortality is often related to specific temporal (e.g. breeding season) or climatic (e.g. heavy rain) events (Langen et al., 2007).

Once the generalists (i.e. raccoons) and small-bodied mammals (i.e. squirrels, chipmunks, mice, and shrews) were removed from the dataset and the hotspot analysis was conducted again, some hotspots shrunk in size or disappeared altogether which relates to the influence that the abundance of these species have on the roadkill record and its usefulness in modeling wildlife movement. Raccoons were also not included in the NCC's original model as they are usually more highly correlated with peri-urban areas than with more "natural" areas.

Birds comprised less than 25% of the mortality events recorded. The main taxon of birds represented in the dataset, family Corvidae, contains crows (*Corvus brachyrhynchos*), which were frequently seen on the road surface, scavenging vehicle-killed carcasses of other animals. Birds that scavenge on the road are more likely to become roadkill, as are those that make use of habitats affected by humans, including corvids and starlings (*Sturnus vulgaris*) (Husby, 2016). The large proportion of warblers present (the second most represented bird family – Parulidae) is potentially due to the ability of species from this family to colonize diverse habitats, such as those which border roads, as there was also the highest number of individual species recorded in this group (Collins et al.,1982). The rural survey routes were surrounded mainly by mixed forest and fields, with wetlands also adjacent along sections of many roads, all good habitat for warblers.

The largest terrestrial mammal in the region, the moose (*Alces alces*), was absent from the roadkill dataset. None were recorded during the daily roadkill surveys, despite this species' frequent involvement in collisions in the New Brunswick part of the Chignecto Isthmus. Moose-vehicle collisions are financially costly and often cause human injury and mortality, as well as moose mortality. While the single field season of data collected for this study did not return any moose roadkill mortality records for either

Nova Scotia or New Brunswick, the results from the NS LAF dataset show that moose have been involved in collisions in the Chignecto Isthmus region of Nova Scotia, although deer and bear are more frequently involved. Mitigation measures targeted for these large mammals (deer, moose, bear) may reduce collisions and increase connectivity for these and other mammals.

Although generally designed to prevent road flooding from streams and wetlands existing before the construction of a road, culverts that pass under a road can have the added benefit of allowing passage for both aquatic and small to medium sized terrestrial animals. This study mapped the size and location of the culverts examined along the walking survey routes, showing that while there are some culverts present for road crossing opportunities, there are few actually located within the area predicted to be of the highest concern for wildlife movement from the NCC's model. This could possibly be due to the fact that some small mammal and amphibian species are using the culverts for crossing, thus reducing roadkill. It may also reflect the fact that the species chosen for NCC's model were all terrestrial species, therefore the presence of water may not have been included as a key habitat feature. Nonetheless, there is an area on Rte 366 where there is a pond and wetland on both sides of the road with no associated under-road passageway. This lack of connectivity could be a potential problem for wildlife seeking habitat and water resources or have already fragmented populations that were once connected within the pond.

Dissemination Activities

The data collected during this field season, with the corresponding surveys from the New Brunswick portion of the isthmus and the subsequent analysis, will contribute to a masters thesis addressing the use of roadkill survey data to ground truth a modeled wildlife movement corridor, and the implementation of multiple sources of evidence to describe wildlife-road interactions, using the Chignecto Isthmus as a study area. The thesis is tentatively scheduled for a November 2019 defence. One chapter of the thesis, entitled "Implementation of Roadkill Survey Data across a Large Regional-Scale Landscape to Ground-Truth a Modeled Wildlife Movement Corridor at Locations where it Intersects Roads" is currently in preparation for submission to a peer reviewed journal for publication.

A report with a preliminary analysis was submitted to the NCC in February 2019 as part of the requirements for Amelia Barnes' internship as the NCC's Dr. Bill Friedman Conservation Intern for 2018. A copy of this report is available upon request.

Preliminary results were presented in poster format at the Northeastern Transportation and Wildlife Conference (NETWC) at the University of Massachusetts Amherst, in Amherst, Massachusetts, September 2018. The poster can be found in the appendix. A brief summary of the results was also presented at the Canadian Maritimes Ecological Connectivity Forum (CMECF) at Dalhousie University, in Halifax Nova Scotia, April 2019. A PDF of this presentation is available upon request.

The research described in this report, as it contributed to support the NCC's Wildpaths Maritimes citizen science project to collect roadkill observations from the public using the iNaturalist cellphone application, was the subject of several media stories through 2018 and 2019. URL addresses for these articles and videos can be found in the appendix.

Follow-up Recommendations

The positions of the modeled hotspots on Hwy 15 and Hwy 16 corresponding with the NCC's modeled wildlife corridor are consistent with the results obtained from the Siriema hotspot analysis of smaller animals. This further suggests that the modeled corridor represents important habitat for a wide variety of species and appropriate locations for the installation of wildlife crossing structures (consistent with recommendations/findings from Gunson et al., 2003). An important distinction is that the hotspot analysis presented here does not compare one road to another, rather it compares the likelihood of roadkill being uniformly distributed versus clustered along any given stretch of road. Overall, systematic roadkill survey data can be useful to help verify modeled wildlife movement corridors where they intersect with roads. Roadkill hotspots at the points of intersection can be used to extrapolate movement patterns from one road to the next and lend further evidence to the need to both protect key habitat corridors across the landscape and to provide safe wildlife crossings where animals are likely to interact with roadways. This study uses preliminary data collected over one season and thus the results should be taken with the caveat that the sample size in terms of number of survey days should be increased for more meaningful results derived from surveys to be conducted over multiple seasons and years. The collection and analysis of multiple seasons of field data will begin to form a more complete picture of where wide-ranging species are crossing roads and moving across the landscape.

Subsections of roads should be identified for targeted future roadkill surveys. Based on our preliminary findings, priority roadway sections to target for repeat surveys include the 20 km section of Hwy 104 from exit 4 to exit 5 between Amherst and Springhill, the 30 km section of Rte 6 between Amherst and Port Howe, and the 17 km section of Rte 366 between Amherst and Tidnish Bridge.

Additionally, the mapping of aquatic and terrestrial crossing opportunities should be extended beyond the boundaries of the NCC's modeled corridor in order to look for similarities between locations of collision hotspots and barriers along the roads (i.e. presence or absence of fences should also be recorded) and reduced collisions where potentially safe crossing opportunities exist (e.g. culverts).

A limitation to roadkill surveys is that they only capture a small portion of what is actually happening when wildlife interacts with roads. These surveys, including less systematic data obtained from motorist reports, record and report the animals that are already dead. Future research should include more focused surveys that examine which species are approaching the roads and turning away or even crossing successfully. As such, camera trap surveys would be beneficial to help understand what interactions are occurring which may have an impact on connectivity but are not directly visible as mortality. Locations for future camera trap surveys should firstly be based on the locations identified as hotspots for collisions as it is likely that if there are high collision rates at these spots, there are also species that are avoiding or not crossing the road.

Wildlife-vehicle collisions continue to be a problem from both conservation and human safety perspectives. Further studies in this region, where wildlife movement is concentrated and mitigation for road crossing is not currently in place, should include additional seasons of systematic roadkill data collection and camera trap studies targeted to 1) the pinch-points shown on the modeled corridor, and 2) road mortality hotspots identified in this and future studies to determine which species are approaching roads but are not prominent in the roadkill record. Future research should help to determine the appropriateness for roadkill mitigation strategies for the largest road, Hwy 104. Although Hwy 104 itself is a controlled access road with forested habitat along both sides, consideration of the landcover beyond the road corridor should be taken into account as connectivity concerns extend well beyond the immediate roadside. At present, the corridor modeled by the NCC represents connectivity extending across the border with New Brunswick, however wildlife could be traveling from other directions, therefore a landcover analysis using a GIS could be useful to demonstrate good habitat connectivity with other regions extending further into Nova Scotia.

A variety of roadkill mitigation strategies exist, some targeting motorist behaviour, such as warning signs and reduced speed limits in known problem areas, others targeting wildlife responses to roads, such as fences and barriers to keep animals from entering the roadway (Glista et al., 2009). The most effective strategy for reducing wildlife-vehicle collisions is one that removes the chance of wildlife appearing on the road altogether, which is a barrier structure such as a wildlife fence (Jaeger & Fahrig, 2004; Rytwinski et al., 2016). However, the road thus becomes a heightened barrier to wildlife and increases habitat fragmentation caused by roads (Jaeger & Fahrig, 2004; Olsson et al., 2008). Good road effect mitigation considers not only the reduction in roadkill as a measure of success, but also an increase in permeability of the road network for safe wildlife movement. Wildlife crossing structures, sometimes called “eco-passages”, are any structures that allow animals to safely move under (e.g. culverts, bridges, underpasses) or over (e.g. overpasses, rope bridges) the road to maintain horizontal ecological flow across the landscape (Clevenger et al., 2001). Fencing without crossing structures reduces roadkill but increases the barrier effect of roads, while implementing crossing structures alone does not guarantee they will be used by wildlife if the roadway is still accessible and more convenient for crossing. Successful road effect mitigation must implement wildlife crossing structures along with properly installed and maintained fences to guide animals to the passageways (Rytwinski, et al., 2016). Currently, this infrastructure of a system of exclusion fences and eco-passages does not exist on the surveyed stretch of Hwy 104 where it could be potentially implemented. As the other roads are not controlled access, it is doubtful that a system involving extensive fencing would be useful because the fence ends would be frequent, and wildlife would still be able to access the road. Targeted fencing around wetlands might be possible to reduce amphibian mortality, but more data on roadkill rates, especially including seasonal comparisons, should be collected to determine if these types of fences would be useful.

In conclusion, roadkill surveys are useful to help verify wildlife movement across roads where suspected connectivity leading to high mortality exists, but they should be intensive and repeated over multiple seasons. Camera studies targeted both to roadkill hotspots and potential crossing locations are also recommended to supplement the road mortality dataset and to help inform locations for the installation of wildlife fences and crossing structures.

Budget Summary

Item	**Budgeted**	**Actual**	**Source of funds**		
			NS HCF	**NCC & Dalhousie**	
				Cash	**In-kind**
Master's student researcher	$10,200	$10,200		$5,000	$5,200
Field assistant	$4,507	$4,507	$4,507		
Technical and logistical support	$10,000	$10,000			$10,000
Field expenses: travel	$1,893	$1,893	$1,893		
Field expenses: accommodations	$3,920	$3,920			$3,920
Field expenses: meals	$1,600	$1,600	$1,600		
Dissemination expenses	$510	$510		$510	
Equipment	$730	$730			$730
Totals	**$33,360**	**$33,360**	**$8,000**	**$5,510**	**$19,850**

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