AN ASSESSMENT OF MOOSE AND ELK TRAIN COLLISIONS IN ONTARIO, CANADA

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ABSTRACT: To better understand train collision mortality of moose (*Alces alces*) and elk (*Cervus elaphus*) in Ontario, we measured collisions along a 20 km segment of railway using post-winter railbed surveys (11 consecutive years), remote cameras, and radio-telemetered elk. We used these data to estimate provincial moose-train collision rates by extrapolating collision rates, moose density, and amount of high use railway per Wildlife Management Unit (WMU). The annual collision rate varied from 0 to 7 moose and 2 to 22 elk on the 20 km section of railway; the combined collision rate of moose and elk was highest in winters with above average snowfall. The extrapolated collision rates of moose indicated that ~1/3 of WMUs had a rate > 0.08 moose/km high use railway/yr; ~2/3 had a rate > 0.04. A conservative estimate of annual mortality was ~265 moose province-wide. Given that railway expansion is predicted globally, and specifically in Ontario, planning should include potential mitigation strategies that minimize ungulate-train collisions.

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Moose (*Alces alces*), elk (*Cervus elaphus*), boreal caribou (*Rangifer tarandus caribou*), and white-tailed deer (*Odocoileus virginianus*) are economically important in Ontario as harvestable game and in ecotourism. Ungulates are critical prey species for large carnivores, common food sources for scavengers, and as browsers and grazers, influence and maintain forest openings and grasslands (Frank et al. 1998). They also provide subsistence and culturally important items such as meat, hides, teeth, and antlers for Indigenous peoples. Concern about decline in numerous North American moose populations (Timmerman and Rodgers 2017), the recent listing of boreal caribou as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Thomas and Gray 2002), and the current stagnation in two of four restored elk populations in central Ontario (Popp et al. 2014) together warrant study of potential mortality sources that influence population dynamics of these species. Although both natural and anthropogenic causes of ungulate declines are recognized and reasonably well understood, including overharvest, habitat degradation, parasites, and diseases (e.g., see Toweil and Thomas 2002, Franzmann and Schwartz 2007), the potential population impact of train collisions has received less attention and study.

Although minimal research has addressed impacts of train traffic on wildlife (Popp and Boyle 2017), collisions obviously cause direct mortality of multiple wildlife species (Van der Grift 1999, Dorsey 2011, Heske 2015), and indirect effects include habitat fragmentation, noise, light, chemical pollution, and general stress (Waller and Servheen 2005, Bartoszek and Greenwald 2009, Dorsey 2011). More relevant to our research, train collisions have been directly implicated in declines of local moose populations in Alaska (Becker and Grauvogel 1991) and Norway (Gunderson and Andreassen 1998).

Several factors make the collection of reliable, wildlife-train collision data difficult, including inaccessibility of remote railways, lack of experienced observers to accurately identify collisions and mortality, and the inherent difficulty of identifying and investigating collisions from moving trains. Thus, wildlife mortality estimates along railways typically lack sufficient resolution to identify specific issues and mitigation strategies (Wells et al. 1999). However, increased local and regional impacts on ungulate populations is likely, given that the global railway network of 1.4 million km is predicted to increase 45% by 2050 (Dulac 2013, Dorsey et al. 2015) and this expansion will bring more train traffic at higher speeds.

In this study we measured and assessed railway use and train collision rates by moose and elk along a 20 km section of a busy railway in central Ontario, Canada. With these data, we estimated local and regional collision rates with the goal of providing natural resource managers a preliminary assessment and methodological approach to address moose-train collisions at these scales.

STUDY AREA

The study area was located south of the City of Greater Sudbury in central Ontario (46° 20’ 30”, 80° 50’ 30” - 46° 11’ 30”, 80° 50’ 00”) and focused on a 20 km railway section which is part of the transcontinental Canadian National Railway (CNR) network (Fig. 1). The railway was situated in the Great Lakes-St. Lawrence Forest that is a mixture of northern coniferous and deciduous trees. The Canadian Shield topography consists of numerous rocky ridges that promote growth of red oak (*Quercus rubra*) in soils mostly composed of shallow surface deposits of silt and sand (Rowe 1972). Mean daily temperature ranges from -13.6 °C in January to 19 °C in July, average annual rainfall is 656.5 mm, and average snowfall is 274.4 cm with measurable snowfall occurring 78 days annually (Sudbury Weather Station data 2006–2016, Environment Canada).

The railway ran northwest to southeast at elevations between 200 and 230 m asl. The Wanapitei River ran parallel to the railway and included ~ 0.2 km² flooded area created by a small hydroelectric dam, and Sled Lake (~1 km²) lay within 1.5 km. The 20 km study section transected 8 open marsh areas of various size. In all, ~30% of the habitat along the railway consisted of wetlands other than the river, and the tracks bisected or ran adjacent to ~ 3 km of open grasslands. There were 5 unprotected road crossings at which approaching trains were obliged to sound the whistle several times within 0.5 km. Train speed varied from 60–80 km/h depending on the railway topography. Although some long straightaways were present, the track had moderately to strongly winding sections, with at least 4 curves approaching 90–100 degrees (Fig. 1). The track was regularly cleared of snow with a specialized rail-plough.

Ontario’s recreational hunting regulations are based on 95 Wildlife Management Units (WMU) of various size and shape, as set by the Ontario Ministry of Natural Resources and Forestry (OMNRF). Moose occur in at least 65 WMUs and this study was conducted in WMU 42 which is located south-centrally within the provincial moose range. In 2015, the estimated moose density in WMU 42 was 36.7 animals/100 km² (OMNRF 2016). The elk population in the

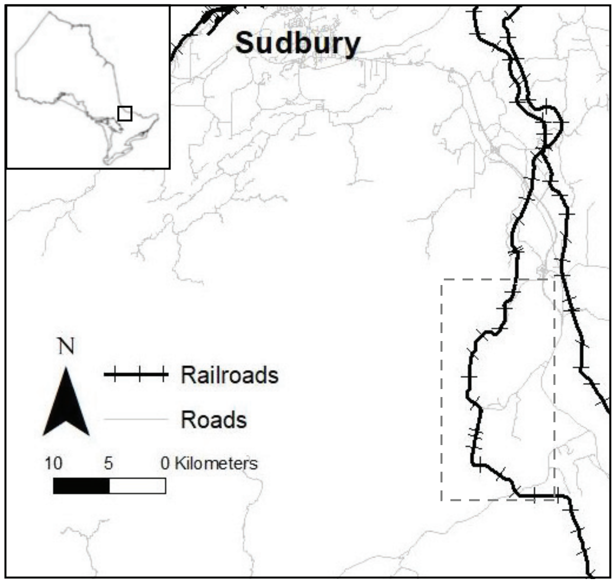

Fig. 1. Location of the 20-km study section of CNR railway (bordered by dashed line) located 20–40 km south of Sudbury in central Ontario, Canada.

study area was estimated at 95–200 animals, and a core subset (~ 60–80 females, yearlings, and calves) regularly travelled along and seasonally traversed the railway (Martin 2011, McGeachy 2014). White-tailed deer were present in the area, but primarily in summer and not during the winter study period (Popp 2017). Ungulate predators in the study area included American black bear (*Ursus americanus*), gray wolf (*Canis lupus*), eastern (Algonquin) wolf (*C. lycaon*), coyote (*C. latrans*), and their hybrids.

METHODS

To monitor train traffic during winter when most ungulate-train collisions occur, a Reconyx© motion-triggered trail camera was placed on a tree directly adjacent to the railway within the 20 km study section in December 2012 and January 2013. Radio-collared elk (20–30 adult females) in the area were located 1–2 times weekly via VHF ground telemetry to provide a temporal assessment of movement, railway use, and collisions. As all collisions with radio-collared elk occurred in December-April, mortality surveys were conducted after the spring thaw in late March-early April 2006 - 2016.

The 20 km section of railway was surveyed entirely during a single day each year. Surveys were completed by 3 crews that walked separate 6–7 km sections. Each crew of 2–4 observers walked on both sides of the railway scanning the immediate rail-bed and a 20–30 m margin for animal remains. Mortalities were identified to species by size, hair, antlers, and skull shape. The location coordinates were recorded with GPS units (5–10 m accuracy). Partial skeletons were classified as either recent or old by the degree of bone bleaching, presence of dried muscle on bones, moisture content of bone marrow, and by comparing the current year's locations with those of the previous year. These surveys were supplemented with opportunistic reports from people in passing trains or vehicles who observed collisions/carcasses. On several occasions CNR workers reported elk collisions, and if accessible, these animals were checked for pregnancy and physical condition.

It was assumed that the number of carcasses was a minimal estimate of train collisions because a struck animal could move and die outside the survey boundary, a dismembered carcass could have been removed by a large scavenger (e.g., bears and wolves), and carcasses salvaged for meat by CNR employees at the time of, or shortly after a collision, would be unaccounted for in the survey. It is possible that an animal could have died within the boundary of another cause; however, the majority of collisions were confirmed by either a severely mangled carcass, or a broken leg(s) and/or spine.

The estimated 2015 moose density (animals/100 km^2) in each WMU that had railways was obtained from a public information website (OMNRF 2016), and the extent of the provincial railway network in moose range was calculated from transportation corridor layers in GIS (ArcMap 10.3.1, Fig. 2 and 3). To avoid overestimation of moose mortality on railway segments with low train volume, estimates were calculated only for those CNR and Canadian Pacific

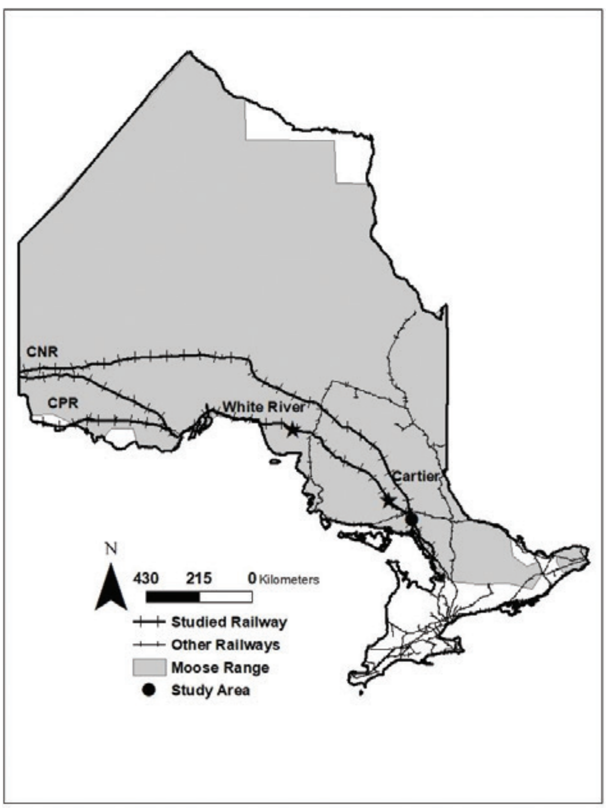

Fig. 2. Location of the Ontario provincial railway network depicting the main CNR and CPR lines traversing the province from the southern Canadian Shield to the Manitoba border (portions used for moose mortality estimates are bolded); moose distribution range in Ontario roughly coincides with the Canadian Shield (shaded). The railroad section between Cartier and White River was used in an earlier unpublished survey of train-induced moose mortality (Heerschap 1982). The present study location is shown by a dot.

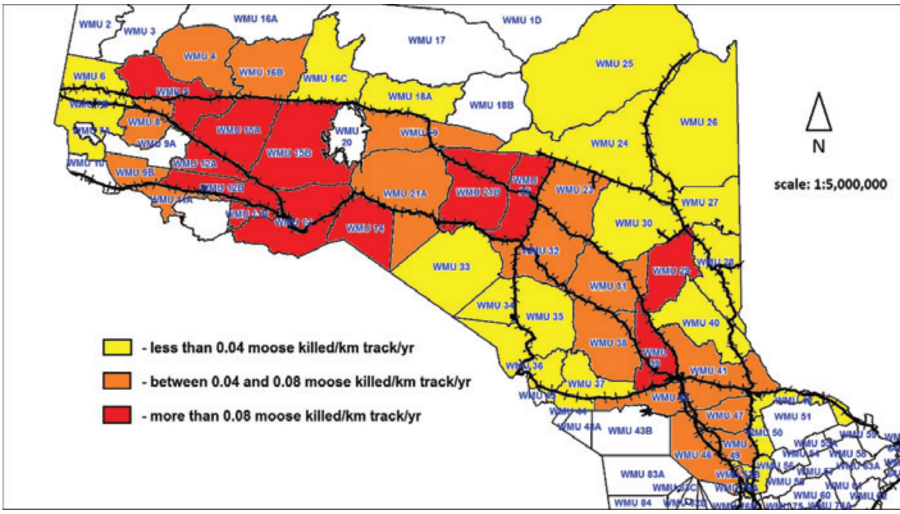

Fig. 3. Estimated annual rate of moose-train collisions in Wildlife Management Units containing high use railway lines (bolded black) within the Ontario moose distribution range.

Railway (CPR) mainlines transecting the province, and only 38 WMUs in largely unpopulated regions of the Precambrian Shield (Fig. 3). Marginal areas of moose range with substantial human populations and agricultural activity (southern Canadian Shield), and sections running through larger urban centers (e.g., Sudbury and Thunder Bay) were omitted from the analysis. Hereafter, the WMU railway segment used in the analysis is referred to as "high-use railway". As the baseline, the 20 km study section was part of the CNR transcontinental line and considered representative of train traffic associated with the main railway system.

The 2015 population density estimate (36.7 moose/100 km²) in WMU 42, and the 11-year (2006–2016) mortality estimate on the 20 km study section within, were used to estimate mortality rates in all WMUs transected by CNR and CPR mainlines within moose range. The 2015 moose density estimate in each WMU was divided by the density estimate in WMU 42 (36.7 moose/100 km²). This fraction was multiplied by the annual mortality rate on the 20 km study section during the 11 years of study (1.3 moose/km). This estimate was multiplied by the length (km) of high-use railway within a WMU to calculate an equivalent estimate of the 11-year mortality rate; mortality estimates were expressed to the nearest whole number. As easily recognized topographical features such as rivers, highways, and railways often delineate WMU boundaries, if a railway segment formed the boundary between adjacent WMUs, 1/2 of the shared segment length was attributed to each adjacent WMU.

RESULTS

Railway traffic volume

Most train traffic moved in a southerly direction in the 20 km study section during the 11-year study period; however, the schedule varied with seasonal customer requirements. Trains passed as frequently as every 20–30 min, but more commonly once every 2–3 h. The remote camera recorded 304 train passes in 26 days of monitoring in the winter 2012–2013. The maximum number of passes was 16 and the minimum 5 during a 24-h period; the average was

~12 trains/d (0.5 train/h). The majority (70.4%) of traffic was in darkness with up to 13 trains certain nights, or nearly 1 train/h; daylight was defined as 0800–1700 hr.

Table 1. The number of moose, elk, and deer killed in train collisions as identified during 11 annual surveys of a 20 km section of CNR railway located in WMU 42 in central Ontario. * identifies winters with above average snow depth.

Year	Moose	Elk	White-tailed deer
2006*	4	8	0
2007	0	2	0
2008	0	1	0
2009*	1	22	0
2010	3	4	1
2011	4	3	0
2012	1	2	0
2013*	7	14	0
2014	2	9	1
2015	2	2	0
2016	2	5	0
Total	**26**	**72**	**2**

Train collision rates

A total of 26 moose collisions were identified during the annual surveys (2006–2016) in the 20 km study section (annual count = 0–7); 0–2 collisions occurred in 7 of 11 years (Table 1). The annual collision rate was 0.13 moose/km on high-use railway. The highest collision rates occurred in 2013 (n = 7) and 2006 (n = 4) when snowfall was above average (1–30 cm; Environment Canada, Sudbury Weather Station, 2006–2016). Conversely, only a single moose collision occurred in 2009 when snowfall was above average, and 4 collisions occurred in 2011 when snowfall was below average (Table 1); small sample size precluded statistical analysis.

Collision rate (# moose/km/yr) ranged from 0.02–0.15 in the 38 WMUs that were extrapolated with data from WMU 42 (Fig. 3). Nearly 1/3 of these WMUs had collision rates >0.08 moose/km/yr (Table 2, Fig. 3). The highest annual mortality (n = 27) was in WMU 12B in northwestern Ontario with 226 km of major railways and a

Table 2. Ontario Wildlife Management Units (WMU) transected by high use railways with the highest estimated moose mortality rates due to trains (Fig. 3, red color). Moose-train collision rates were obtained by multiplying the ratio of the 2015 moose density estimate (WMUx/WMU 42) by the rate of moose-train collisions measured in WMU 42. The length of high use railway within each WMU was then factored into the collision rate calculation (see Methods).

WMU	2015 Moose Density (#/100 km²)	High Use Railway (km)	Collision Rate (moose/km/year)	Mortality (# moose/year)
5	31.2	182.0	0.12	22
11B	39.4	16.3	0.12	2
12A	35.2	34.9	0.14	5
12B	33.8	225.9	0.12	27
13	25.3	220.4	0.09	20
14	40.6	40.1	0.15	6
15A	32.8	115.0	0.12	14
15B	25.1	98.9	0.09	9
21B	26.2	170.1	0.09	15
22	28.6	101.0	0.10	10
29	24.8	30.5	0.10	3
39	24.6	147.5	0.09	13

population density of 34 moose/100 km² (Fig. 3, Table 2). The lowest annual mortality (n = 0.1) was in WMU 53A at the southern fringe of the Canadian Shield with only 1.9 km of high use railway and a moose population density of 17 moose/100 km² (Fig. 3). Three northwestern Ontario WMUs had an estimated annual mortality of ≥20 moose, and 7 central Ontario WMUs (including WMU 42) had an estimated annual mortality of 10–19 moose (Table 2). Total moose mortality estimated in 38 WMUs transected by major railways during the 11-year period was 2,642 animals, or an annual minimum of ~265 moose.

Elk collisions within the 20 km study section varied from 1–22 annually, averaging 6.5 collisions/year (Table 1). The highest collision rates occurred in 2006 (8), 2009 (22), and 2013 (14) during winters with above average snowfall (Environment Canada, Sudbury Weather Station, 2006–2016). Many collisions occurred where the railway curved (Popp et al. 2018), passed through rock-cuts, or was bordered by steep embankments. In such cases, the visibility of an approaching train was obscured and escape from the railbed was hindered by the topography (Fig. 4). Due to the herding behavior of elk during winter, collisions often resulted in multiple simultaneous casualties.

Only 2 white-tailed deer were located over the 11 years of surveys (Table 1), largely confirming that most migrate from the study area prior to winter; neither mortality occurred in a winter with above average snowfall. Given the smaller body size of deer, it is possible that carcasses were scavenged prior to the surveys. Total ungulate collisions within the 20 km study section varied from 1–23 animals annually; 7 of 11 years had <10 collisions, whereas annual

Fig. 4. Adult female elk killed by a CNR train in winter 2013. The curving railbed conceals the approaching train and rock cuts on both sides prevent lateral escape. Browse trees on railbed margins provide easily accessible forage for ungulates (photo J. Hamr).

collisions were >10 in the 3 years (2006, 2009, 2013) with above average snow.

DISCUSSION

Moose-vehicular collisions have presumably received more research attention because of the associated human mortality and direct economic losses; e.g., in Newfoundland (Oosenbrug et al. 1986), Quebec (Grenier 1973, Jolicoeur and Crete 1994), and Maine (Danks and Porter 2010). More recently, increasing attention towards moose-train collisions is occurring globally. Although Belant (1995) reported moose-train collisions were infrequent (3–5 annually) on 1,200 km of railways in northeastern Minnesota nearly 3 decades ago, other studies in western Canada, Alaska, and Europe indicated that railway mortality can be locally significant and possibly influence population dynamics of moose. For example, Child et al. (1991) reported an annual average of 200 moose-train collisions in British Columbia, annual collisions ranged from 9 to 725 along a 756 km stretch of railway in Alaska (0.01–0.96 moose/km; Modafferi 1991), and the collision rate on a 240 km stretch of railway in Norway was 0.4 moose/km, exceeding 80 fatalities annually (Gunderson and Andreassen 1998). Our data and estimates (0.02< and < 0.15 moose/km) are similar in both magnitude and variation with these North American and Scandinavian examples. The aforementioned, our, and other studies (Child 1983, Muzzi and Bisset 1990, Anderson et al. 1991, Gundersen and Andreassen 1998, Bertwhistle 1999, Danks and Porter 2010, Dorsey 2011) identify that moose-train collisions are influenced by several factors including the railway network, volume and frequency of train traffic, animal density, seasonal range use, migration patterns, snow conditions, and the local topography and habitat associated with the railway.

Although moose are mostly solitary and adapted to moving in deep snow and wetlands, elevated moose-train collisions were documented in winters with high snowfall in northwestern Ontario (Muzzi and Bisset 1990). Similarly, we found higher collision rates with moose and elk in years with above average snow when these animals used the railway as a snow-free travel corridor (Table 1). Even in 2015–2016 when snow depth was less than average, our camera captured multiple images of moose (n = 15) and elk (n = 13) on the 20 km study section (Popp and Hamr 2018, Fig. 5). Analysis of videos taken from moving trains indicates that moose are often reluctant to leave a railway when trains approach and may attempt to outrun them (Rea et al. 2010).

A joint OMNRF-CPR survey of moose mortality was conducted 3 decades earlier on the railway (417.6 km) from Cartier to White River between Sudbury and Thunder Bay in central Ontario, and only 75 km from the northern limit of our study area (Fig. 2; Heershap 1982). CPR engineers on the Cartier-White River railway section recorded all wildlife-train collisions and documented 31 moose collisions between June 1981 and May 1982. The extrapolated annual mortality was 0.07 moose/km, about half of our annual estimate of 0.13 moose/km. The Cartier-White River section traverses 3 WMUs with estimated moose densities of 13–22 moose/100 km² in 2015, densities ~40–70% lower than that in our study area (36.7 moose/100 km²), indicating proportional similarity relative to population density, despite the 30-year period between the studies.

Moose-train collisions were sporadically reported throughout Ontario for decades (e.g., Forbes and Theberge 1992), but no systematic surveys were conducted previously. Our annual estimates of provincial mortality are moderate (minimally 250–300 animals),

Fig. 5. Adult female moose using the railway as a travel corridor during winter 2016 (Photo J. Popp).

yet should be considered during harvest planning and allocation of moose hunting permits (tags), particularly in WMUs with higher and local impacts (Fig. 3). Wildlife managers are encouraged to incorporate railway mortality into population modelling where major railroads transect moose and elk habitat (e.g., Stocker 1983, Messier 1994, Eberhardt 2010). Although arguably conservative and based on a single site, our model provides for easy estimation of annual mortality based on moose density and length of railway per WMU.

The elk-train collision rate was ~3x higher than that of moose during the 11-year survey (Table 1). Telemetry locations of reintroduced elk (1998–2001) indicated that this local population incorporated the railway within their seasonal range. It was used as a travel and forage corridor (McGeachy 2014), and importantly, elk were closest to and used the railway most during winter (Popp et al. 2018). Multiple mortalities were documented in winters 2009 and 2013 when trains ploughed through groups composed mainly of pregnant cows and calves (Table 1). Combined, railway mortality and wolf predation have prevented the growth of this un-hunted elk population through constant removal of adult females with live and unborn calves (Popp et al. 2014, 2018). Further, the humane dispatch of injured animals which is rarely addressed, introduces another management concern of train-collisions for both moose and elk.

Because concern about the impact of railways on ungulates and other wildlife was non-existent when most North American railways were constructed over a century ago, it is unsurprising that many railways transect critical wildlife habitats and traditional migratory corridors. As railway networks expand in the near future, it is imperative that ungulate ecology (e.g., movements and seasonal habitat use) be considered in the planning process to minimize what are often local impacts. In Ontario, there is impending potential for railway network expansion associated with the planned Ring of Fire chromite mining operation in the mineral-rich James Bay Lowlands. The project would involve about 400 km of new railway northward through WMUs 18A, 17, and 1D (Fig. 3), currently with low or no wildlife-train collision impact, but located within moose and threatened boreal caribou range.

Our study used three methods to obtain valuable information – radio-telemetry, cameras, and field surveys – to monitor and predict seasonal use and mortality of moose and elk on railways. As in this study with elk (Popp et al. 2018), local hot-spots of moose-train collisions (Anderson et al. 1991, Andreassen et al. 2005, Gundersen et al. 1998) are typically associated with specific habitat features that function as ecological traps along railways. Where possible, mitigation could include fencing, eliminating the attractant, wildlife crossing structures, and reduced speed (Jaren et al. 1991, Wells et al. 1999). A management strategy that incorporates research, monitoring, and specific mitigation strategies aimed at reducing train collisions would proactively address the projected increase in railways and train traffic in the face of provincial and regional moose decline. As railway companies periodically invest in their infrastructure (e.g. https://www.cn.ca/en/news/2018/07/cn-investing-approximately-315-million-to-expand-and-strengthen/), mitigation efforts addressing wildlife-train collisions should be considered and incorporated where feasible into improvement and expansion projects.

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