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Elk (*Cervus elaphus*) railway mortality in Ontario

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Abstract

Wildlife railway research is highly underrepresented in science despite documented wildlife-train collision mortalities. Gathering baseline information is imperative to the development of effective train collision mitigation, especially for at risk or small reintroduced populations such as elk (*Cervus elaphus* Linnaeus, 1758) in eastern North America. We tested our hypotheses that elk-train collision rates vary in relation to railway structure and weather by using a combination of radio-telemetry and railway mortality surveys. Elk were closer to the railway in winter than in any other season. Elk-train collision sites were significantly closer to the apex of bends in the railway than random locations along the railway, and collision rates were positively related to snow depth. Railways may be perceived by elk as easy travel corridors, and deep snow likely prohibits escape from oncoming trains. This study gathered important information about an under-studied aspect of wildlife-human conflicts and provides a basis for the investigation of other species that may be affected by railways.

Keywords

Anthropogenic disturbance, *Cervus elaphus*, elk, human infrastructure, linear feature, railroad, railway, snow, train collision

Introduction

Of the many human infrastructures known to adversely affect wildlife populations, impacts associated with railways are one of the least studied, especially in comparison to the effects of roads on wildlife (Popp and Boyle 2017). Railways have a worldwide footprint of approximately 1 million km which is predicted to rise 45% by 2050 (Dulac 2013). It is important that ecologists increase their focus on investigating the potential effects of railways on wildlife to ensure adequate management and conservation, especially for species at risk or small populations.

Many species of wildlife have been victims of train collisions while travelling on railways (Gundersen and Andreassen 1998; van der Grift 1999; Bertwhistle 2001; Andreassen et al. 2005; Iosif 2012; Kusta et al. 2014; Dasgupta and Ghosh 2015). Such mortalities can have severe impacts on animal populations, such as moose (*Alces alces* Linnaeus, 1758) (Becker and Grauvogel 1991; Gunderson and Andreassen 1998). The effects of railways on wildlife may vary among species, as well as within species. For example, railways can be beneficial to some species such as moose, allowing for easier travel, especially in winters with substantial snow depth (Andreassan et al. 2005; Rea et al. 2010), but also produce negative effects through train collision mortality (Becker and Grauvogel 1991; Gunderson and Andreassen 1998). For other species, such as Marbled salamanders (*Ambystoma opacum* Gravenhorst, 1807) or Mongolian gazelles (*Procapra gutturosa* Pallas, 1777), railways can act as a barrier to movement (Baroszek and Greenwald 2009; Ito et al. 2013).

Although not yet investigated, reintroduced species may be particularly vulnerable to the effects of railways. Translocations are often restricted to a small number of individuals, which

may become at risk if further reduced in size, potentially leading to significant impacts of stochastic events (Gilpin and Soulé 1986). Monitoring programs that identify and quantify causes of mortality for small populations are necessary to gather baseline information and to design mitigation strategies for ensuring populations are sustainable. Given the impacts railways may have on wildlife, as apparent from the limited number of studies available, further monitoring of the effects of railways on wildlife populations is warranted.

Elk (*Cervus elaphus* Linnaeus, 1758) are a native species in North America, which were extirpated from most of their range during the 19th century, and have since been reintroduced in several locations in eastern North America over the past century (Popp et al. 2014). The Burwash elk population in Ontario, Canada, has decreased to approximately 150 individuals from the 172 that were reintroduced between 1998 and 2002. Train collisions are one of the leading causes of mortality for this population (Popp et al. 2014). Identifying factors that contribute to elk-train collision rates can assist in the development of train collision mitigation strategies to help limit further elk population decline. We hypothesized that elk-train collision rates vary spatially and are related to changes in weather and railway structure. To test our hypotheses, we investigated 1) the influence of season on the proximity of elk to the railway; and 2) the effects of weather and rail structure on collision rates.

Materials and methods

Study area

The study area consisted of the Burwash elk core population range in Ontario, Canada, which encompassed approximately 20 km of railway. The area was situated in the Great Lakes-St. Lawrence Ecotonal Forest Region (Rowe 1972) comprised mainly of mixed conifer-hardwood forest (Chambers et al. 1996). Topography was characteristic of Precambrian Shield

and included rugged outcrops, valleys, and many water bodies including marshes, swamps, bogs, and fens. In addition, open abandoned fields; remnants of a historical correctional facility/industrial farm were present throughout the study area. Climate in the region was continental with average winter snow depth of 28 cm (Environment Canada Historical data: mean of December to February 1981-2010).

Mortality

Every March or April from 2002 to 2015, subsequent to snow thaw, winter elk-train collision mortalities were counted and the locations recorded using a Garmin GPS along a 20 km stretch of railway that bisects the elk core population range. During the survey, observers walked the railway and recorded new carcasses or body parts found as an index of train collision mortality. In addition, railway workers occasionally reported mortalities that had been discovered opportunistically to co-author, Dr. Hamr, which were investigated and locations were recorded using Garmin GPS.

Seasonal proximity to railway

To determine if elk proximity to the railway differed among seasons, 12 female elk previously fitted with VHF radio-collars (Lotek Engineering LMRT 4 with motion sensitive mortality sensors) were tracked 1 – 3 times per week, alternating day and night, from 2012 to 2014 from the ground with a Lotek SRX 400 telemetry receiver. To reduce triangulation error, at least three compass bearings were obtained for each elk location from areas of high elevation within the elk population range (White and Garrot 1990). Because elk are gregarious in nature, we used the software “Association” (Weber et al. 2001) to ensure individual movements were independent from each other. Parameters were set to consider females associated (or non-

independent) if they spent more than 60% of their time within 250 m of one another. Seasons were defined based on elk behaviour where “Winter” included the months of January to March, “Spring” included April to June, “Summer” included July to September, and “Fall” included October to December (Popp et al. 2013). We calculated the mean distance of each elk during each season to the railway using ESRI’s ArcGIS v.10.1. We used a repeated measures ANOVA and a post-hoc Tukey HSD test to determine if elk were significantly closer to the railway in any particular season using the ‘R’ statistical software v.3.0.1 (R Core Team 2013).

Train collisions: mortality hotspots, rail curvature, and weather

We used the program SIRIEMA v 1.1.0 (SIREMA 2011) and elk-train collision data from 2002 to 2015 to conduct Linear Hotspot Identification analyses (analysis that linearizes the railway) using Ripley K-Statistics to identify elk-train collision hotspots (areas where collisions occurred more often than expected). Expected values were calculated using uniform probability of occurrence along the railway obtained by Monte-Carlo simulations. This software has been used for road-collision hotspot identification (Coelho et al. 2012; Teixeira et al. 2013), but has not yet been applied to railway-collision hotspots to our knowledge. We examined the number of hotspots using two approaches: 1) Collision locations: all elk mortalities involved in a specific incident were reported as a single event for analytical purposes (gregarious nature predisposes elk to multiple kills at one location), and 2) Collision mortalities: the number of elk mortalities arising from each event at a particular location were used to gain a better understanding of where single-event losses would most impact the elk population.

From our personal observations over time, elk kill events appeared to cluster around bends in the railway, therefore a two-sample *t*-test was performed to determine if elk kill events were significantly closer to the apex of bends of <135 degrees than an equal number of random

points generated along the railway using the “randbetween” function in Microsoft Excel 2016 ($n = 44$). Because trains travel only in a north-to-south direction along this section of railway, the distance to the northernmost bend apex was calculated.

To determine if elk-train mortality was correlated with winter weather conditions, the number of elk mortality events per year ($n = 14$ years) was related to the mean monthly snow depth (cm) and the mean temperature ($^{\circ}\text{C}$) of December to February (Environment Canada Historical Data) using polynomial regression analyses. All statistical analyses were conducted using the ‘R’ statistical software v.3.0.1 (R Core Team 2013).

Results

Seasonal proximity to railway

None of the 12 radio-collared elk had associated movements with one another at the set parameters (250 m, 60% of the time) so all were used in subsequent analysis with their movements considered independent. An average of 15 locations per elk in spring, summer, winter and 14 locations per elk in fall were used to determine that elk proximity to the railway varied significantly among seasons ($F_{3,33} = 31.06, p = 0.001$). In winter, elk were significantly closer to the railway than in summer, spring, or fall (All seasons: $p < 0.001$) (Fig 1).

Train collisions: mortality hotspots, rail curvature, and weather

In total, 67 elk-train collision mortalities were recorded over the 14 year survey period, resulting in 44 collision locations that varied geographically (Fig 2). Upon examining elk collision locations, we found 5 hotspots, most adjacent to each other and within a 2 km span of one another (Fig 3a). When considering the number of elk that died at each collision location, we found 7 hotspots spread over approximately 5 km (Fig 3b) with the majority of “collision mortalities” hotspots overlapping the “collision locations” hotspots (Fig 2). The majority of

hotspots were located along bends in the railway section that was monitored (Fig 2). Collision locations were significantly closer (1358 m +/- 186 m) to the apex of bends (≤ 135 degrees) than were randomly generated locations (3800 m +/- 627 m) along the railway ($p < 0.001$).

There was no correlation found between the mean winter temperature and the number of elk-train collision locations (kill events) over 14 years ($R^2 = 0.009$, $p = 0.75$); however, there was a strong polynomial relationship found between the mean snow depth (December to February) and the number of elk-train kill events per year ($R^2 = 0.71$, $p = 0.001$; Fig 4) where “Number of elk-train kill events = $4.52 - 0.56 (\text{Mean Snow Depth}) + 0.023 (\text{Mean Snow Depth})^2$ ”.

Discussion

We found that elk proximity to the railway did vary temporally, and elk-train collision rates were spatially varied and related to changes in weather and railway structure. Elk were significantly closer to the railway in winter than in any other season, likely an artifact of the close location of their wintering grounds to the railway as observed annually since their reintroduction (J. Hamr, Personal Communication, 2016). Similarly, in Norway, moose-train collisions occurred mainly in winter when moose migrated to winter ranges that were close to the railway (Jaren et al. 1991; Gundersen et al. 1998). Bertwhistle (2001) found that collision rates increased when other large mammals migrated to winter ranges that were adjacent to transportation corridors (i.e.: roads and railways). Although elk proximity to the railway does not necessarily indicate use, when winter snow depths may impede movement, animals may use railways as travel routes with less physical resistance (i.e.: shallow snow) in accordance with Zipf's (1949) Law of Least Effort. With 14 years of railway mortality monitoring, we found that the number of elk-train collisions were highly correlated with snow depth. Increased train

collision rates in deeper snow conditions has been a pattern also found for moose (Gunderson and Andreassen 1998; Gundersen et al. 1998). We suspect that deep snow along the railway augmented by railway plowing, may discourage elk from leaving the railway when trains approach. This is a trend that has been identified with moose (Child 1983; Muzzi and Bisset 1990). Railway footage has shown that moose followed by trains appear to be trapped by deep snow banks along the railway sides (Rea et al. 2010).

It is well documented that elk mortality rates increase and recruitment rates and population growth decrease when snow depths increase (Hebblewhite et al. 2002; Garrot et al. 2003; Creel and Creel 2009; Johnson et al. 2013). Greater snow depths allow more opportunity for predators with light foot-loads when prey movement is restricted (Telefer and Kelsall 1984), especially when prey animals are in poor nutritional condition due to increased energy expenditure (Gese and Grothe 1995). Coupled with limited forage opportunities in winter, increased energy expenditure due to restriction of movement in deep snow is likely to leave elk seeking easy travel corridors. Increased forage opportunities along railways may also be related to increased winter train collision rates. When animal movement becomes restricted and energy expenditure approaches high levels, obtaining adequate calories is essential to survival. Jaren et al. (1991) suggested that forage along railways seemed to attract moose, causing them to stay longer and closer to the railway.

Train collisions have been site-specific in moose (Gundersen et al. 1998) and in turtles (Iosif 2012). Elk-train collision frequency varied over space in our study resulting in several mortality “hotspots”. There were more hotspots identified when the numbers of elk killed in each event were included. This may suggest that elk travelling in groups are sometimes restricted from escaping the railway when trains appear in certain areas. We also found that elk-train

collision sites were significantly closer than randomly generated locations to the northernmost apex of bends of < 135 degrees in the railway. Because very little information exists with respect to the effects of railways on wildlife in general, we can only speculate on some of the relationships between the two. If elk using the railway are close to a bend in the railway, oncoming train detection may be limited and could potentially be the cause for the increased number of collisions that were found close to bends. By understanding where animals are likely to be affected most by trains, researchers can further investigate factors influencing collision rates and develop appropriate mitigation strategies (ex: concentrate mitigation efforts in hotspot areas, especially during years with substantial snow fall, testing measures such as fencing, scent deterrents, sound deterrents, overpasses, etc.). Having a focal point with relative predictive certainty of use would facilitate testing and speed up the development of various mitigation measures. We highly recommend that train collision mortality be considered in studies of factors influencing the population dynamics of wildlife where railways bisect population ranges with significant regional snowfall.

Because different species are likely to display a variety of responses to railways, we recommend species-specific studies, especially when considering species at risk or small reintroduced populations. As displayed by our example with elk, it is important to consider temporal, spatial, and various environmental aspects of railway relationships to wildlife. By determining how railways influence the dynamics of a wildlife populations and identifying factors that are related to such effects, appropriate mitigation strategies to reduce train collisions can be developed and tested.

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References

- Andreassen, H.P., Gundersen, H., and Storaas, T. 2005. The effect of scent-marking, forest clearing, and supplemental feeding on moose-train collisions. *J. Wildl. Manage.* **69**: 1125-1132.
- Bartoszek, J., and Greenwald, K.R. 2009. A population divided: Railroad tracks as barriers to gene flow in an isolated population of marbled salamanders (*Ambystoma opacum*). *Herpetol. Conserv. Biol.* **4**: 91–197.
- Becker, E.F., and Grauvogal, C.A. 1991. Relationship of reduced train speed on moose-train collisions in Alaska. *Alces*, **27**: 161–168.
- Bertwistle, J. 2001. Description and analysis of vehicle and train collisions with wildlife in Jasper National Park, Alberta Canada, 1951-1999. Road Ecology Center.
- Chambers, B.K., Legasy, K., and Bentley, C.V. 1996. Forest plants of central Ontario. Lone Pine Publishing.
- Child, K.N. 1983. Railways and moose in the central interior of British Columbia: A recurrent management problem. *Alces*, **19**: 118-135.
- Coelho, I.P., Teixeira, F.Z., Colombo, P., Coelho, A.V.P., and Kindel, A. 2012. Anuran road-kills neighboring a peri-urban reserve in the Atlantic Forest, Brazil. *J. Environ. Manage.* **112**: 17-26.

- Creel, S., and Creel, M. 2009. Density dependence and climate effects in Rocky Mountain elk: An application of regression with instrumental variables for population time series with sampling error. *J. Anim. Ecol.* **78**: 1291-1297.
- Dasgupta, S., and Ghosh, A.K. 2015. Elephant–railway conflict in a biodiversity hotspot: determinants and perceptions of the conflict in northern west Bengal, India. *Human Dimens. Wildl.* **20**: 81-94.
- Dulac, J. 2013. Global land transport infrastructure requirements: Estimating road and railway infrastructure capacity and costs to 2050. International Energy Agency - Report. 1-54.
- Garrot, R.A., Eberhardt, L.L., White, P.J., and Rotella, J. 2003. Climate-induced variation in vital rates of an unharvested large-herbivore population. *Can. J. Zool.* **81**: 33-45.
- Gese, E.M., and Grothe, S. 1995. Analysis of coyote predation on deer and elk during winter in Yellowstone National Park, Wyoming. *Am. Midl. Nat.* **133**: 36-43.
- Gilpin, M.E., and Soulé, M.E. 1986. Minimum viable populations: processes of species extinction. *In* Conservation biology: the science of scarcity and diversity. *Edited by* E. Soulé Sunderland, Massachusetts: Sinauer Associates. pp 19-34.
- Gundersen, H., and Andreassen, H.P. 1998. The risk of moose *Alces alces* collision: A predictive logistic model for moose-train accidents. *Wildl. Biol.* **4**: 103-110.
- Gundersen, H., Andreassen, H.P., and Storaas, T. 1998. Spatial and temporal correlates to Norwegian moose-train collisions. *Alces*, **34**: 385–394.
- Hebblewhite, M., Pletscher, D.H., and Paquet, P.C. 2002. Elk population dynamics in areas with and without predation by recolonizing wolves in Banff National Park, Alberta. *Can. J. Zool.* **80**: 789-799.

- Iosif, R. 2012. Railroad-associated mortality hot spots for a population of Romanian Hermann's Tortoise (*Testudo Hermannii Boettgeri*): A gravity model for railroad-segment analysis. *Procedia. Environ. Sci.* **14**: 123-131.
- Ito, T.Y., Lhagvasuren, B., Tsunekawa, A., Shinoda, M., Takatsuki, S., Buuveibaatar, B., and Chimeddorj, B. 2013. Fragmentation of the habitat of wild ungulates by anthropogenic barriers in Mongolia. *PLoS One*, **8**: 1–13.
- Jaren, V., Andersen, R., Ulleberg, M., Pedersen, P.H., and Bjornar, W. 1991. Moose-train collisions: the effects of vegetation removal with a cost-benefit analysis. *Alces*, **27**: 93-99.
- Johnson, B.K., Coe, P.K., and Green, R.L. 2013. Abiotic, bottom-up, and top-down influences on recruitment of Rocky Mountain elk in Oregon: A retrospective analysis. *J. Wildl. Manage.* **77**: 102-116.
- Kusta, T., Hola, M., Keken, Z., Jezek, M., Zika, T., and Hart, V. 2014. Deer on the railway line: spatiotemporal trends in mortality patterns of roe deer. *Turk. J. Zool.* **38**: 479-485.
- Muzzi, P.D., and Bisset, A.R. 1990. Effectiveness of ultrasonic wildlife warning devices to reduce moose fatalities along railway corridors. *Alces*, **26**: 37-43.
- Popp, J.N., McGeachy, D.N., and Hamr, J., 2013. Elk (*Cervus elaphus*) seasonal habitat selection in a heterogeneous forest structure. *International Journal of Forestry Research*, **2013**: 1-8.
- Popp, J.N., Toman, T., Mallory, F.F., and Hamr, J. 2014. A century of elk restoration in eastern North America. *Restor. Ecol.* **22**: 723-730.
- Popp, J.N., and Boyle, S.P. 2017. Railway ecology: underrepresented in science? *Basic Appl. Ecol.* **19**: 84-93.

- Rea, R.V, Child, K.N., and Aitken, D.A. 2010. Youtube™ insights into moose-train interactions. *Alces*, **46**: 183–187.
- R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>.
- Rowe, J.S. 1972. Forest regions of Canada. Canadian Forest Service, Ottawa, Canada.
- Rytwinski, T., and Fahrig, L. 2015. The impacts of roads and traffic on terrestrial animal populations. *In Handbook of road ecology. Edited by R. van der Ree, D.J. Smith, and C. Grilo.* Wiley-Blackwell. pp 237-246.
- SIRIEMA. 2011. Spatial Evaluation of Road Mortality Software. v. 1.1.0. Federal University of Rio Grande do Sul State Porto Alegre, RS, Brazil.
- Teixeira, F.Z., Coelho, I.P., Esperandio, I.B., Oliveira, N.R., Peter, F.P., Dornelles, S.S., Delazeri, N.R., Tavares, M., Martins, M.B., and Kindel, A. 2013. Are road-kill hotspots coincident among different vertebrate groups? *Oecologia Australis*, **17**: 36-47.
- Telfer, E.S., and Kelsall, J.P. 1984. Adaptation of some large North American mammals for survival in snow. *Ecology*, **65**: 1828-1834.
- van der Grift, E.A. 1999. Mammals and railroads: impacts and management implications. *Lutra*, **42**: 77-98.
- Weber, K.T., Burcham, M., and Marcum, C.L. 2001. Assessing independence of animal locations with association matrices. *J. Range Manage.* **54**: 21–24.
- White, G.C., and Garrott, R.A. 1990. Analysis of wildlife radio-tracking data. San Diego, California: Academic Press.
- Zipf, G.K. 1949. Human behavior and the principle of least effort. Martino Fine Books.

Figure Caption

Fig 1. Mean seasonal and annual distances (m) of elk (*Cervus elaphus*) to the railway (+/- standard error). *Represents significant difference from all other seasons in respective year.

Fig 2. Elk (*Cervus elaphus*)-train kill sites, collision location hotspots, and collision mortalities (includes number of elk that died during each collision event) from 2002 to 2015 along the railway bisecting the Burwash, Ontario elk core range ($n = 67$ mortalities, 44 mortality events).

Fig 3. Location of elk (*Cervus elaphus*)-train collision mortality hotspots at various distances from the northern end of the studied railway section (approx. 20 km) using **a)** collision locations and **b)** collision mortalities (includes number of elk that died during each collision event).

Dashed lines are 95% confidence intervals.

Fig 4. The number of elk (*Cervus elaphus*)-train collision kill events per year ($n = 14$ years) in relation to the mean snow depth (cm) (December to February) along a 20 km stretch of railway bisecting the Burwash, Ontario elk core population range.

Figure 1

Figure 2.

Figure 3.

Figure 4.