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Blood on the Tracks: Track Mortality and Scavenging Rate in Urban Nature Preserves

Edward J. Heske*

Abstract - Wildlife mortality on roads has received considerable attention, but studies of mortality on railroad tracks are scarce and have focused primarily on large mammals. I conducted 3 studies to (1) examine what species of wildlife suffer mortality from trains passing through urban nature preserves, (2) measure scavenging rates on vertebrate carcasses to assess the accuracy of track mortality surveys, and (3) compare track mortality to roadway mortality at a subset of sites because urban railroad tracks are typically surrounded by roads that also cause wildlife mortality. For the first study, I surveyed railroad tracks running through or adjacent to 8 natural areas in the west Chicago metropolitan area biweekly during the summers of 2009 and 2010. Mortalities included 44 mammals, 14 birds, 7 reptiles, and 58 amphibians. Although most turtles and snakes were observed alive on the ballast, the rails may be a barrier to movement of small turtles. For the second study, I used additional daily track surveys and set carcasses out on tracks at 5 sites in May 2010 to estimate scavenging rates. Small carcasses often were rapidly removed but this did not greatly affect results based on bi-weekly surveys at my study sites, likely because few small mammals and birds were killed by trains. For the third study, I compared track mortality to roadway mortality on equal lengths of track and road at 4 sites in 2010. Roadway mortality was similar to or greater than track mortality for most taxa. Although this study was short-term and included a limited number of sites, it is one of the first to directly compare mortality on roads and railroads and sets the stage for future research on the effects of railroads on urban wildlife.

Introduction

Railroads can negatively impact wildlife by displacing or degrading habitat, forming a barrier to movement that fragments populations or prevents access to critical resources, and by direct mortality from collisions with trains (Davenport and Davenport 2006, Dorsey 2011, Forman et al. 2003, van der Grift 1999). Most studies of wildlife mortality on railroads have focused on large species such as carnivores and ungulates (e.g., Andreassen et al. 2005, Kusta et al. 2011, Wells et al. 1999; but see Havlin 1987, Leiva and Palacios 1997). A problem with quantifying wildlife-train collisions on small vertebrates is that disappearance rates of carcasses due to scavengers is largely unevaluated (Wells et al. 1999). Antworth et al. (2005) found high rates of bird and snake carcass removal by scavengers on roads and cautioned about interpretations of roadkill surveys. Santos et al. (2011) also reported high disappearance rates for carcasses of small vertebrates on roads. Similar studies on railroad track mortality are lacking.

*Illinois Natural History Survey, Prairie Research Institute, University of Illinois Urbana-Champaign, Champaign, IL 61820 USA; eheske@illinois.edu.

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Roads and railways differ in several ways that could influence mortality rates. (1) Traffic volume differs between railways and urban roads. There are many more cars and trucks per day on an urban road than trains on a railway line. (2) The approach of a train is a noisier event than the approach of a car, and vibrations can be felt along the rails that may give warning to some terrestrial vertebrates. In contrast, high traffic activity on some roads may be a more persistent warning of danger. (3) Traffic on roads can be simultaneously two-way, whereas trains approach from one direction at a time. (4) The width of a road is greater than the width of railroad tracks, putting terrestrial vertebrates crossing them at risk for longer times. Scavenging rates also may differ between tracks and roads, biasing mortality surveys differently, because visual scavengers may be able to spot small carcasses more easily on a relatively smooth, flat road surface than among the ties, rails, and rocky ballast (crushed rock forming the foundation for the ties and rails) of railroad tracks, and some scavengers may be deterred by road traffic. Thus, although several studies document scavenging rates on roads (see Santos et al. 2011), it should not be assumed that railroad tracks and roads are equivalent.

I conducted 3 studies to investigate the impacts of railroad traffic on wildlife in urban nature preserves. First, to document what species of terrestrial vertebrates were killed by collisions with trains, I conducted bi-weekly track surveys in the summers of 2009 and 2010 at 8 natural areas along a railway line in the western Chicago metropolitan area, IL, USA. Second, to evaluate scavenging rates on railroad tracks and to estimate how many mortalities might be missed by the bi-weekly surveys, I set out carcasses of birds and mammals on tracks and conducted additional daily track surveys at 5 sites in May 2010. Third, to assess whether railroads cause similar mortality as other transportation infrastructure (i.e., roads), I compared mortality simultaneously on equal lengths of roads and railroads at 4 sites in 2010. The impacts of roadways and railroads are often assumed to be similar (Forman et al. 2003, Seiler and Helldin 2006), but few studies have directly compared mortality on the same populations or at the same site. In combination, these 3 studies will facilitate designing new surveys of track mortality, provide data for comparison with mortality surveys in other landscape contexts, and question assumptions about the similarity of effects of roads and railroads on wildlife.

Methods

Study areas

The Chicago Wilderness is a regional nature preserve system with >910 km^2 of protected natural areas that includes state parks, federal reserves, and county preserves in 7 counties in and around Chicago, IL, USA. I surveyed track mortality in 8 natural areas in the western Chicago metropolitan area that were bordered or bisected by the Elgin, Joliet, and Eastern Railway (Fig. 1). Study sites included MacArthur Woods Forest Preserve (MW; 208 ha, Lake County), Cuba Marsh Forest Preserve (CM; 317 ha, Lake County), Spring Creek Valley Forest Preserve (SC; 1600 ha, Cook County), Poplar Creek Forest Preserve (PC; 1700 ha, Cook County), Pratt's Wayne Woods Forest Preserve (PW; 1654 ha, DuPage County), Fermi

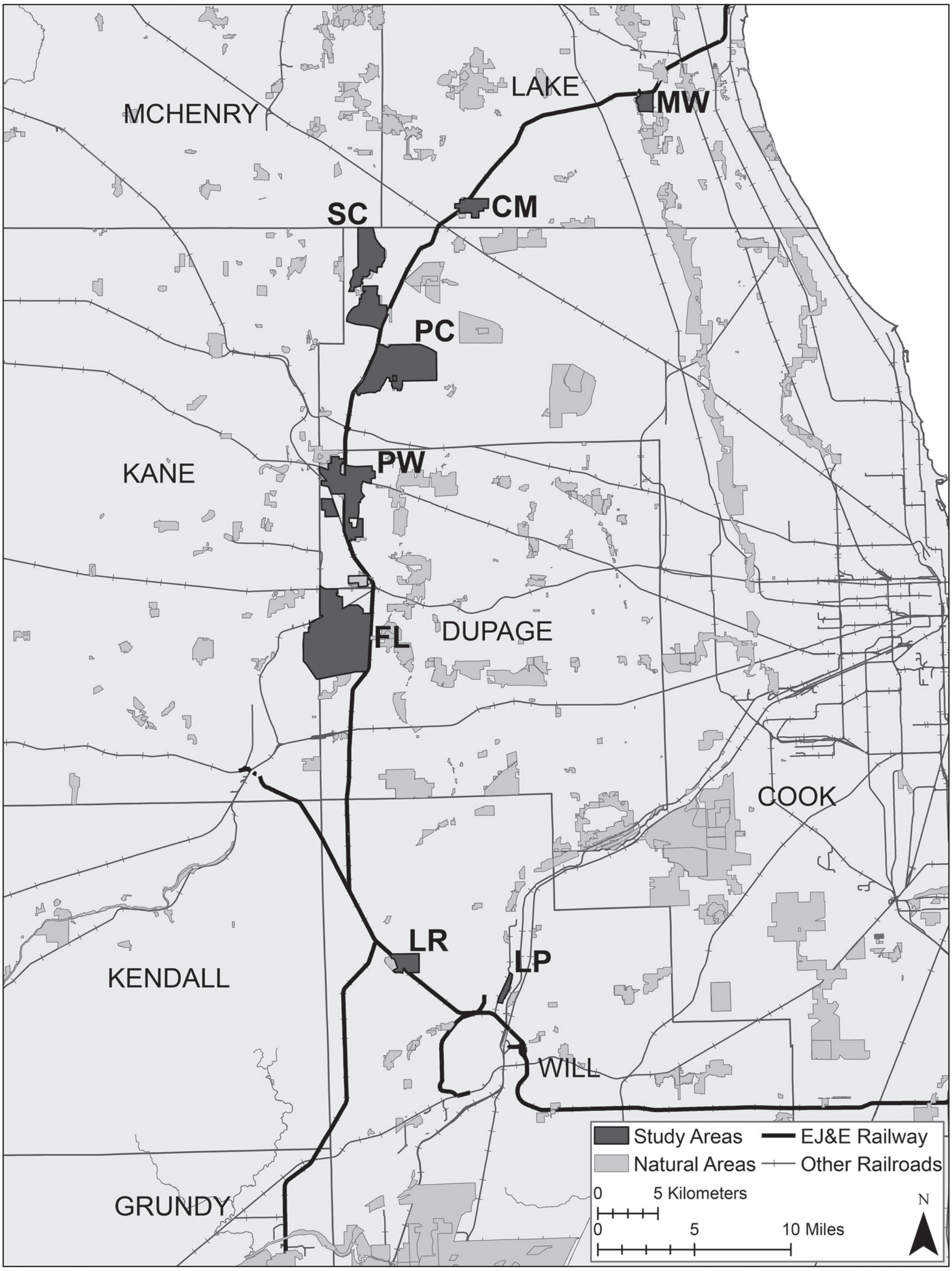

Figure 1. Map of the western Chicago, IL, USA, metropolitan area showing designated natural areas as gray polygons (study sites in black) and railroad tracks as gray lines (study railroad line in black). MW = MacArthur Woods Forest Preserve, CM = Cuba Marsh Forest Preserve, SC = Spring Creek Valley Forest Preserve, PC = Poplar Creek Forest Preserve, PW = Pratt's Wayne Woods Forest Preserve, FL = Fermi National Accelerator Laboratory, LR = Lake Renwick Forest Preserve, LP = Lockport Prairie Nature Preserve.

National Accelerator Laboratory (FL; 2700 ha, DuPage County), Lake Renwick Forest Preserve (LR; 130 ha, Will County), and Lockport Prairie Nature Preserve (LP; 103 ha, Will County). All study sites were designated preserves considered part of the Chicago Wilderness with a variety of forest types, grasslands, prairie restorations, streams, and wetlands within each preserve and adjacent to the tracks; LR also included a lake and a large pond adjacent to part of the tracks at that site (Fig. 1; see Heske and Ruffatto 2014 for maps and descriptions of each site). Each natural area is embedded in a matrix of suburban to urban development with roads and housing developments bordering all sides of the preserves.

Track surveys

I conducted track surveys bi-weekly from June through September 2009 (8 surveys per site) and May through September 2010 (10 surveys per site) to document the number and species of vertebrates killed by train traffic. I walked slowly along the tracks in both directions and recorded all vertebrate carcasses or remnants on the tracks or ballast. Animal remains were removed from the tracks during each bi-weekly survey (except during May 2010, see below) to avoid counting incidents more than once. Live turtles and snakes also were recorded and removed from the tracks. I surveyed the entire length of railroad track running through each preserve at all but 2 sites: the 5-km length of track at PC required >2 h to survey and so I deemed a 2.5-km length between 2 roads as representative; a 1-km length of track at PW was elevated about 5 m above the surrounding habitat with a width only slightly greater than the rails at the top and steep shoulders of ballast that I deemed too dangerous to survey on foot. Approximate lengths of track surveyed were 1 km (MW), 1 km (CM), 1.2 km (SC), 2.5 km (PC), 1.6 km (PW), 1.5 km (FL), 2 km (LR), and 1.5 km (LP).

Distances between preserves meant that surveys of all sites required 2 days. Because of time incurred by travel (about 3 h between the northernmost and southernmost sites, depending on traffic), the order of sampling and time of day of surveys at each site could not be randomized within a bi-weekly survey. To control for potential bias due to time of day at which surveys were conducted, the order of visitation was alternated between surveys that began at the northernmost site and southernmost site so that sites were each surveyed an equal number of times in the morning versus afternoon. To assess the relationship between train-traffic volume at each site and the numbers of vertebrate mortalities detected, I regressed the total number of mortalities detected at each site, excluding frogs and toads, against the mean number of trains per day averaged over the months in which bi-weekly surveys were conducted (data provided by the US Surface Transportation Board, Washington, DC, USA). Mortality data used in this analysis included only the bi-weekly surveys and was divided by the length of track surveyed at each site to obtain mortalities/km. This and all other statistical analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC, USA).

Estimation of detection and scavenging rates

During May 2010, I surveyed 5 sites (CM, SC, PW, LR, LP) daily, Mon–Fri (20 surveys per site). I used the data from May 2010 to calculate a detection error factor (DEF; the number of track kills recorded from daily surveys divided by the number of track kills from bi-weekly surveys) for all vertebrate mortalities pooled, excluding frogs and toads, as per Barthelmess and Brooks (2010). The DEF was calculated only for mammals, birds, and reptiles because amphibian carcasses were small and tended to dry up, degrade, and disappear rapidly. I pooled data for all taxa because sample sizes for individual species or subgroups were too small for meaningful analysis. I assumed that the diverse community of potential scavengers (carnivorous and omnivorous medium-sized mammals, vultures, crows, raptors, etc.) removed smaller carcasses (i.e., songbirds, small mammals, snakes) similarly and thus no information was lost by pooling these taxa. In all cases but one (a *Procyon lotor* [Raccoon] that disappeared in its entirety the day after it was killed), scavenging on large carcasses in this study left behind identifiable remains regardless if the carcass was of a bird or mammal.

To estimate scavenging rates, I left all carcasses in place on tracks during the daily surveys in May 2010 and recorded the number of days that a carcass was still detected in subsequent daily surveys. In addition, I collected carcasses of freshly road-killed birds and mammals opportunistically while traveling between sites and placed these on the tracks. Carcasses were placed on a railroad tie about 30 cm outside one of the rails. I distributed 3 to 7 carcasses per site over a 3-week period, and locations where carcasses were set were >100 m apart to avoid attracting scavengers to a regular resource. I then recorded the number of days a carcass was detected on the tracks in subsequent surveys up to the end of May, when my daily surveys ended.

Comparison of mortality on railroad tracks and roads

Immediately following each track survey at 4 of the 5 sites surveyed daily in May 2010 (CM, SC, PW, LR; no comparable road was available at LP), I surveyed a length of paved road equal in length to the section of railroad tracks surveyed at that site. All roads were paved and had 2 lanes (i.e., one in each direction) with speed limits of 35 to 45 mph. Roads followed the border of the focal preserve and crossed the section of tracks surveyed. It was not possible to match habitats adjacent to roads and tracks exactly, especially as housing developments usually occurred across the roads from the preserves, but roads were as close to the tracks and as similar to the types of habitats along tracks in the preserves as possible. I conducted road surveys from a vehicle that was driven as slowly as traffic permitted in each lane (i.e., two passes at <30 mph, often 20 mph) so that I surveyed one lane and shoulder of each road at a time. Carcasses were readily detectable at these speeds, and when a carcass or suspicious object was detected, I pulled over to confirm the mortality and identify the species. I recorded only road-killed mammals, birds, and reptiles as frogs and toads could not be readily surveyed from a vehicle in traffic. Road-killed vertebrates at these 4 sites were counted during bi-weekly surveys during the rest of summer 2010 as well. I compared numbers of mortalities on roads and railroads by a matched-pairs t-test using site as the unit of replication.

Results

Track mortality

During bi-weekly and daily track surveys in 2009 and 2010, I detected 44 individuals of 11 species of mammal, 14 individuals of 10 species of bird, 30 individuals of 10 species of reptile, and 58 individuals of 4 species of amphibian (Appendix 1). The number of mortalities varied among sites, and was positively related to average daily train traffic at the study sites during the months of the surveys after adjusting for lengths of track surveyed (Pearson's product-moment regression: $r = 0.92$, $P = 0.003$; Table 1). Because each study site is unique in terms of the types and distributions of habitat adjacent to tracks, as well as physical characteristics of tracks such as height of the ballast, sites should not be considered replicates. Comparisons among sites to explain differences in species detected would require detailed data on habitats and resident species at each site that is beyond the scope of this study. Instead, the goal here is to broadly describe the types of species affected by pooling data from several diverse sites.

All species detected as track mortalities in this study were common within the adjacent natural areas (Heske and Ruffatto 2014). Only 3 of the 23 turtles observed on the tracks or ballast were found dead. Overall, the approximate proportion of individuals found on tracks were 30 % mammals, 10% birds, 20% reptiles, and 40% amphibians. Considering only mortalities, the relative abundances shift to 36% mammals, 11% birds, 6% reptiles, and 47% amphibians. The species of mammal

Table 1. Vertebrate animals recorded as mortalities on railroad tracks running through 8 natural areas in the west Chicago, IL, USA, metropolitan area. Surveys were conducted bi-weekly in June–September 2009 and May–September 2010 at all sites, and daily during May 2010 at the 5 sites indicated by asterisks. Site names are given in the text, and species names and number of mortalities by species are given in Appendix 1. Numbers of turtles and snakes observed live on the tracks during surveys are indicated in parentheses. Numbers of large mammals include 14 older carcasses from winter or spring mortalities recorded during the first surveys of each summer (CM: 1, PC: 1, PW: 1, LR: 11).

	Site							
Category	MW	CM*	SC*	PC	PW*	FL*	LR*	LP*
Sm mammals				3	2	1	2	1
Lg mammals		2	2	3	2	3	20	3
Sm birds		1		1	2	1	2	2
Lg birds			3				2	
Turtles	(1)	(4)	(2)	(1)	(3)		3 (7)	(2)
Snakes		(1)	(1)	2			(1)	2
Frogs, toads		12	5	13	15	6	2	5
Total	(1)	15 (5)	10 (3)	22 (1)	21 (3)	11	31 (8)	13 (2)
Mort/km track[1]	0	2	4.2	3.2	3.1	3.3	9	5.3
Trains/day[2]	1	7.2	7.2	7.2	6.4	11.7	18.4	NA

[1]Excluding amphibians and the older mortalities of large mammals from before the first survey each year.

[2]Data provided by US Surface Transportation Board (Washington, DC, USA) as monthly averages for June–September 2009 and May–September 2010. No data are available for LP.

with the most recorded mortalities was *Didelphis virginiana* (Virginia Opossum; 21 of 44 mortalities). In 6 cases, dead opossums were found in proximity to other carcasses, and 3 of those were found on the day following a previous mortality that had been left on the tracks during daily surveys. Opossums are scavengers, and may be killed after being attracted to carcasses on tracks. The high number of amphibians was comprised primarily of *Lithobates pipiens* (Northern Leopard Frog) and *Bufo americanus* (American Toad), which were common at most sites. Mortalities of amphibians were particularly high after rain events, when these species were most active and frequently seen dead on the roads as well.

Detection and scavenging rates

During the bi-weekly surveys in May 2010, all the carcasses first observed in the daily surveys that month (n = 16) were still detectable except for 2 that were no longer present at the time of those surveys (1 *Columba livia* [Rock Dove] and 1 Raccoon). Thus, based on 20 daily surveys and 2 bi-weekly surveys at 5 sites, the DEF was 16/14 = 1.14. The bi-weekly surveys detected 87.5% of the track mortalities by this estimate, although a DEF based on a single month's data should be applied with caution. Five of the 12 detections of live turtles in 2010 occurred during the daily checks in May 2010, and these would have been missed by the bi-weekly surveys. Thus, the bi-weekly surveys did not miss track mortalities of turtles, but missed data that help identify areas of high turtle activity.

During May 2010, I set out freshly road-killed carcasses of 12 songbirds (10 *Turdus migratorius* [American Robin], 1 *Quiscalus quiscala* [Grackle], 1 *Agelaius phoeniceus* [Red-winged Blackbird]), 2 larger birds (*Anas platyrhynchos* [Mallard Duck]), 5 small mammals (2 *Sylvilagus floridanus* [Eastern Cottontail], 2 *Sciurus niger* [Fox Squirrel], 1 *Tamias striatus* [Eastern Chipmunk]), and 1 larger mammal (Raccoon) on tracks at 5 study sites and monitored their fates. Fairly intact carcasses of 1 Rock Dove and 1 Eastern Cottontail found killed on tracks also were monitored during May. Carcasses of smaller birds and mammals often were removed from tracks after only a few days (Fig. 2). Four carcasses were gone on the survey immediately following the day they were set out and thus would not have been detected even

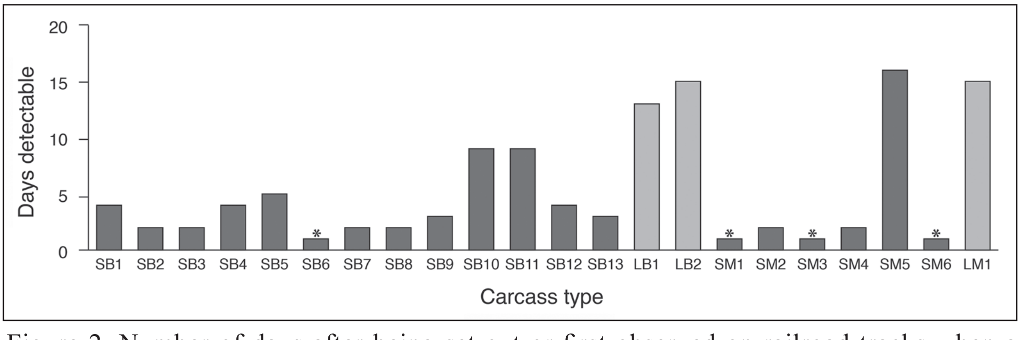

Figure 2. Number of days after being set out or first observed on railroad tracks when a carcass was no longer detected in daily surveys at 5 study sites in May 2010. * indicates 4 carcasses gone the day after being set out. SB = small bird, LB = large bird (Mallard Duck), SM = small mammal, LM= large mammal (Raccoon).

by daily surveys. In 3 cases, parts of carcasses of small vertebrates (i.e., bits of wing from 2 birds, skin of an Eastern Cottontail flayed by a raptor) were left behind by scavengers and remained detectable until the end of the study. In contrast, remnants of 8 carcasses of larger vertebrates recorded at the start of surveys in 2010 (3 Virginia Opossums, 3 *Odocoileus virginianus* [White-tailed Deer], 1 *Marmota monax* [Woodchuck], and 1 *Mephitis mephitis* [Striped Skunk]) plus 4 additional Virginia Opossums and 1 Raccoon recorded as track mortalities during May were scavenged, but enough parts remained on tracks or ballast so that they would be detected by biweekly surveys whenever the mortalities occurred (i.e., persisted for longer than 14 days). These data suggest that if a greater number of small vertebrates is killed at a survey site, the DEF would also be greater, and detection rate lower, at that site than if most mortalities were comprised of larger animals.

Comparison of mortality on railroad tracks and roads

During May 2010, I detected 12 mortalities (excluding amphibians) on the railroad tracks surveyed and 34 mortalities on equal lengths of roads at the 4 sites where both were counted (Fig. 3). The number of mortalities recorded on adjacent roads was significantly greater than the number detected on the tracks (t = 4.62, df = 3, P = 0.019). Common birds such as American Robins, Grackles, and Red-winged Blackbirds were frequently seen dead along roads while driving between sites, but songbirds rarely were observed killed on tracks during the study. Three turtle mortalities were observed on roads adjacent to study sites in May, but none were detected on tracks.

Discussion

This is the first study to describe the diversity of wildlife killed on railroad tracks in urban nature preserves. Mass transit and high-speed rail are part of plans for future economic growth throughout the world (e.g., US Department of Transportation Federal Railroad Administration 2009). Transporting freight by train also leaves a smaller carbon footprint than transporting the same amount of freight by truck (US Environmental Protection Agency 2010). With approximately 227,000 km of railroad tracks in the United States, including 4184 km within the city limits

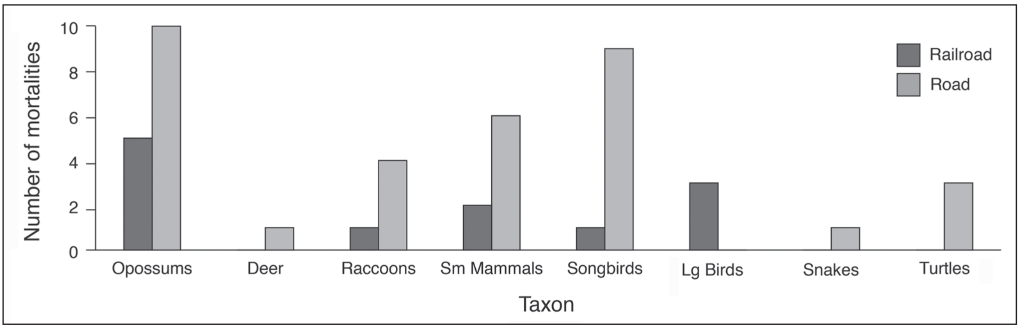

Figure 3. Number of vertebrate carcasses (excluding frogs and toads) recorded on railroad tracks and on an equal length of paved road adjacent to 4 study sites in May 2010.

of Chicago, IL (US Census Bureau 2012), monitoring the effects of train traffic on wildlife communities should be an essential component of developing new transportation infrastructure. My data on scavenging rates suggest that bi-weekly surveys were effective in monitoring mortalities of larger carcasses, but that studies of mortality rates for small vertebrates will have to be specifically designed to estimate and apply correction factors for the potentially rapid disappearance of small carcasses. Finally, although additional studies that control for physical characteristics of roads and rails as well as adjacent habitats are needed, my comparison of mortalities on roads and tracks suggest that mortality risk for many vertebrate taxa differs between these forms of transportation infrastructure, contrary to the general assumption that impacts to wildlife populations are similar.

The vertebrate species detected dead on the railroad tracks surveyed in 2009 and 2010 are considered common in the study area (Heske and Ruffatto 2014). Medium to large-sized omnivores and herbivores comprised the greatest portion of mammal mortalities in my study (32 of 44; including Eastern Cottontails would add 6 more), as reported for roads in North America by Ford and Fahrig (2007). It was beyond the scope of this study to conduct a population-viability analysis for species occurring near the tracks, which would require data on abundance, survival, immigration, emigration, and reproductive variables, but the numbers of individuals I detected as track mortalities did not appear high for any species, with the possible exception of Virginia Opossums. Wells et al. (1999) also noted that scavengers might suffer high mortality rates on railroads because of their attraction to carcasses. Few studies have actually assessed the effects of track mortality relative to other mortality factors at a population level (e.g., Schwartz and Bartley 1991 for *Alces alces* L. [Moose]). Future studies should build on the research needs highlighted here, for example, by examining how wildlife mortality risk, particularly in urban and suburban areas where track density is typically high, is affected by factors such as: physical characteristics of the railroad infrastructure; habitat adjacent to tracks; critical resources such as nesting, feeding, or hibernating areas that induce wildlife to cross tracks regularly; and seasonal effects.

Scavenging of carcasses could cause mortality to be underestimated, particularly for smaller vertebrates (Antworth et al. 2005, Santos et al. 2011, Slater 2002). Santos et al. (2011) recommended daily surveys to assess road-kill mortality of small vertebrates; however, the DEF based on track surveys conducted in May 2010 suggested that few mortalities were missed by conducting bi-weekly compared to daily surveys (87.5% detection rate). In contrast, and consistent with Antworth et al. (2005) and Santos et al. (2011), my carcass-scavenging study demonstrated that most carcasses of small birds and mammals are readily scavenged and would not persist for the two-week interval between bi-weekly studies; only about 36% of the small bird and mammal carcasses deliberately placed on the tracks in May 2010 would have been detected in the bi-weekly surveys. Fifteen of 19 experimental carcasses of small vertebrates were completely removed by scavengers in <5 days (Fig. 2).

The apparent contradiction between the DEF generated from my daily surveys and the high scavenging rates observed in this and studies on roadways (Antworth et al. 2005, Santos et al. 2011) is reconcilable if we consider that vertebrate mortality on roads and railways is not as similar as sometimes assumed (Forman et al. 2003, Seiler and Helldin 2006). Diurnal and vagile species such as squirrels, chipmunks, and songbirds may be more adept at avoiding trains than avoiding cars and trucks on busy, two-way roads. Snakes may be warned of approaching trains by vibrations transmitted through rails or ballast, and it may be easier to quickly move off comparatively narrow tracks than wider roads. In contrast, some larger mammals and birds may use tracks for movement, putting them at greater risk, or be attracted to food on the tracks, such as opossums. For example, a *Branta canadensis* L. (Canada Goose) was killed during a time when pairs of adult geese were regularly seen walking along tracks with their goslings at LR. These geese would typically run along the tracks ahead of me rather than depart the tracks into surrounding habitat, and both goslings and chicks of mallard ducks (1 of 3 mallard mortalities observed was a chick) were observed apparently temporarily entrapped between rails. If larger vertebrates comprise the majority of track mortalities, the DEF would not be as influenced by the disappearance of carcasses, which was quickest for carcasses of small vertebrates in this study.

Turtles are long-lived species and mortality on railroads could impact their populations, but railroad-related mortality of turtles has been studied much less than that of mammals and birds (Dorsey 2011). Kornilev et al. (2006) noted that *Terrapene carolina* L. (Eastern Box Turtle) could become trapped between the rails of railroad tracks. Helms and Stains (1966) hypothesized that turtles could gain entrance between the rails where the railroad bed is eroded, but then fail to find another exit. Although I observed turtles on ballast adjacent to rails in my surveys, I found only 3 train-killed turtles over 2 summers of surveys and all of those were large turtles (1 *Chelydra serpentina* L. [Snapping Turtle] and 2 *Apalone spinifera* Lesueur [Spiny Softshell Turtle], all with carapaces longer than 30 cm). On 2 occasions, I attempted to induce *Chrysemys picta* Schneider (Painted Turtle) of about 15-cm carapace length to climb over the rails by herding them alongside the outside of the tracks or placing them between tracks and herding them toward the sides before releasing them in wetlands away from the tracks. In neither attempt could I induce a small turtle to climb over the rails, and the tracks seemed a barrier to movement. Thus, if the tracks are maintained to prevent gaps between the ballast and the rails, strikes involving smaller turtles should be minimized, although rails then become a barrier to movements. In contrast, roads are easy to enter by turtles of any size and require a longer distance to cross, likely increasing risk of mortality.

The western Chicago metropolitan area is highly developed, and the nature preserves in this study all were bordered by roads to some extent. Only a few studies have directly compared mortality from railroads and roadways. Deaths of bears along railroads often exceed death rates along roads (Boscagli 1987, Waller and Servheen 2005; see also Belant 1995 for Moose), but comparisons of overall mortality are lacking and much greater attention has been paid to mortality along roads than railroads (Seiler and Helldin 2006). I observed greater wildlife mortality along stretches of roads of equal length as the tracks at 4 of my study sites in May 2010, with notably greater mortalities of songbirds, small mammals, and turtles (Fig. 3).

Although this comparison is just a snapshot, and some similarities between roads and railroads were confirmed (e.g., greater impacts on omnivores and herbivores [Ford and Fahrig 2007]; increased vulnerability of scavengers [Wells et al. 1999]; rapid disappearance of small carcasses [Antworth et al. 2005, Santos et al. 2011]), the differences in mortality rates for some taxa are intriguing. Clearly, more detailed studies of mortality rates on roads versus railroads would be helpful to assess their relative impacts on wildlife populations.

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Literature Cited

Andreassen, H.P., H. Gundersen, and T. Storaas. 2005. The effect of scent-marking, forest clearing, and supplemental feeding on Moose–train collisions. Journal of Wildlife Management 69:1125–1132.

Antworth, R.L., D.A. Pike, and E.E. Stevens. 2005. Hit and run: Effects of scavenging on estimates of roadkilled vertebrates. Southeastern Naturalist 4:647–656.

Barthelmess, E.L., and M.S. Brooks. 2010. The influence of body-size and diet on road-kill trends in mammals. Biodiversity Conservation 19:1611–1629.

Belant, J.L. 1995. Moose collisions with vehicles and trains in northwestern Minnesota. Alces 27:31–45.

Boscagli, G. 1987. Brown Bear mortality in central Italy from 1970 to 1984. International Conference on Bear Research and Management 7:97–98.

Davenport, J., and J.L. Davenport (Eds.). 2006. The Ecology of Transportation: Managing Mobility for the Environment. Springer, Dordrecht, The Netherlands.

Dorsey, B.P. 2011. Factors affecting bear and ungulate mortalities along the Canadian Pacific Railroad through Banff and Yoho National Parks. M.Sc. Thesis. Montana State University, Bozeman, MT, USA.

Ford, A.T., and L. Fahrig. 2007. Diet and body size of North American mammal road mortalities. Transportation Research Part D 12:498–505.

Forman, R.T.T., D. Sperling, J.A. Bissonette, A.P. Clevenger, C.D. Cutshall, V.H. Dale, L. Fahrig, R. France, C.R. Goldman, K. Heanue, J.A. Jones, F.J. Swanson, T. Turrentine, and T.C. Winter. 2003. Road Ecology: Science and Solutions. Island Press, Washington, DC, USA.

Havlin, J. 1987. On the importance of railway lines for the life of avifauna in agrocoenoses. Folia Zoologica 36:345–358.

Helms, D.R., and H.J. Stains. 1966. Kill of mammals and birds and entrapment of turtles on railroad tracks. Transactions of the Illinois Academy of Sciences 59:297.

Heske, E.J., and D.M. Ruffatto (Eds.). 2014. Impacts of the Elgin, Joliet, and Eastern railway line on natural areas in the western Chicago metropolitan area, Vol. 1. Full Technical Report. Illinois Natural History Survey, Prairie Research Institute, University of Illinois, Champaign, IL, USA. 137 pp. Available online at http://hdl.handle.net/2142/72733.

Kornilev, Y.V., S.J. Price, and M.E. Dorcas. 2006. Between a rock and a hard place: Responses of Eastern Box Turtles (*Terrapene carolina*) when trapped between railroad tracks. Herpetological Review 37:145–148.

Kušta, T., M. Ježek, and Z. Keken. 2011. Mortality of large mammals on railway tracks. Scientia Agriculturae Bohemica 42:12–18.

Leiva, R., and O.L. Palacios. 1997. Mortalidad de aves en un tramo de linea de ferrocarril. Grupo Local SEO-Sierra de Guadarrama, Spain. 32 pp.

Santos, S.M., F. Carvalho, and A. Mira. 2011. How long do the dead survive on the road? Carcass persistence probability and implications for road-kill monitoring surveys. PLoS ONE 6:e25383. Available online at doi:10.1371/journal.pone.0025383.

Schwartz, C., and B. Bartley. 1991. Reducing incidental Moose mortality: Considerations for management. Alces 27:93–99.

Seiler, A., and J O. Helldin. 2006. Mortality in wildlife due to transportation. Pp. 165–198, *In* J. Davenport and J.L. Davenport (Eds.). The Ecology of Transportation: Managing Mobility for the Environment. Springer, Dordrecht, The Netherlands.

Slater, F. 2002. An assessment of wildlife road casualties: The potential discrepancy between numbers counted and numbers killed. Web Ecology 3:33–42.

US Census Bureau. 2012. Statistical Abstract of the United States: 2012 (131st Edition). Washington, DC, USA. Available online at http://www.census.gov/compendia/statab/. Accessed 22 October 2014.

US Department of Transportation Federal Railroad Administration. 2009. Vision for High-Speed Rail in America. 18 pp. Available online at https://www.fra.dot.gov/eLib/Details/L02833. Accessed 27 January 2015.

US Environmental Protection Agency. 2010. Freight Locomotive Emissions Overview. Available online at http://www.epa.gov/midwestcleandiesel/sectors/rail/material/ls.pdf. Accessed 27 January 2015.

van der Grift, E.A. 1999. Mammals and railroads: Impacts and management implications. Lutra 42:77–98.

Waller, J., and C. Servheen. 2005. Effects of transportation infrastructure on Grizzly Bears in northwestern Montana. Journal of Wildlife Management 69:985–1000.

Wells, P., J.G. Woods, G. Bridgewater, and H. Morrison. 1999. Wildlife mortalities on railways: Monitoring methods and mitigation strategies. Pp. 237–246, *In* G. Evink, P. Garrett, and D. Zeigler (Eds.). Proceedings of the Third International Conference on Wildlife Ecology and Transportation, Tallahassee, FL, USA.

Appendix 1. Species and numbers of vertebrates detected on railroad tracks or ballast in 8 natural areas in the western Chicago (IL, USA) metropolitan area during bi-weekly surveys in June–September 2009 and 2010 plus daily surveys in May 2010. Alive = individuals found alive on the tracks and removed to adjacent habitat (all reptiles).

Scientific name	Common name	Dead	Alive
Mammals			
Didelphis virginana Kerr	Virginia Opossum	21	
Sylvilagus floridanus Allen	Eastern Cottontail	6	
Marmota monax L.	Woodchuck	2	
Sciurus niger L.	Eastern Fox Squirrel	1	
Ondatra zibethicus L.	Muskrat	2	
Peromyscus leucopus Rafinesque	White-Footed Mouse	1	
Procyon lotor L.	Raccoon	2	
Mephitis mephitis Schreber	Striped Skunk	1	
Mustela frenata Lichtenstein	Long-Tailed Weasel	1	
[*Vulpes vulpes* L.?]*	Small canid, possibly Red Fox	1	
Odocoileus virginianus Zimmermann	White-Tailed Deer	6	
Birds			
Ana platyrhynchos L.	Mallard Duck	3	
Branta canadensis L.	Canada Goose	1	
Phalacrocorax auritus Lesson	Double-Crested Cormorant	1	
Tachycineta bicolor Viellot	Tree Swallow	1	
Turdus migratorius L.	American Robin	1	
Quicalus quiscula L.	Common Grackle	2	
Zenaida macroura L.	Mourning Dove	1	
Columba livia Gmelin	Rock Dove	1	
Melospiza melodia A. Wilson	Song Sparrow	1	
Porzana carolina L.	Sora	2	
Reptiles			
Chelydra serpentina L.	Snapping Turtle	1	7
Chrysemys picta Schneider	Painted Turtle		9
Graptemys geographica Lesueur	Common Map Turtle		1
Trachemys scripta Schoepff	Common Slider		1
Apalone spinifera Lesueur	Spiny Softshell Turtle	2	1
Terrapene carolina L.	Eastern Box Turtle		1
Thamnophis sirtalis L.	Common Garter Snake	3	1
Storeria occipitomaculata Storer	Redbelly Snake		1
Storeria dekayi Holbrook	Brown Snake	1	
Elaphe obsoleta Say in James	Black Rat Snake		1
Amphibians			
Lithobates pipiens (Schreber)	Northern Leopard Frog	43	
Rana catesbeiana Shaw	Bullfrog	1	
Rana clamitans Latreille	Green Frog	1	
Bufo americanus Holbrook	American Toad	13	

*Only some bones found, but included distinctive canid baculum.