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Do turtle warning signs reduce roadkill?

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Abstract

Roadkill is a serious threat for many species of freshwater turtles. One of the most common road mitigation tools is wildlife warning signs to alert drivers. These warning signs have commonly been used for large mammals, although there is little evidence that they are effective in reducing roadkill. We tested the effectiveness of turtle warning signs at four known roadkill hotspots along a provincial highway in eastern Ontario and compared the results with four control sites on a nearby major road in a before-after-control-impact (BACI) study. We found 30 dead turtles in the four hotspots in 2017 before the signs were installed and 27 in 2018 after the signs were installed. The number of turtles killed on the road after the signs were installed did not change significantly ($\chi^2_1 = 1.1$, $P > 0.2$). Although turtle warning signs may alert some drivers, they should not be considered a replacement for more effective road mitigation tools, such as wildlife fencing and crossing structures.

Key words: Turtles; reptiles; road mitigation; wildlife signs; BACI design

Introduction

Roadkill is a major risk for many species of freshwater turtles (Gibbs and Shriver 2002; Steen and Gibbs 2004; Aresco 2005). It can lead to population declines (Gibbs and Shriver 2002) or male-biased populations from disproportionate roadkill of female turtles (Steen and Gibbs 2004; Dupuis-Désormeaux *et al*. 2017). Turtle populations are sensitive to any threat that increases the adult mortality rate (Congdon *et al*. 1993; Cunnington and Brooks 1996) and are extremely slow to rebound from declines (Keevil *et al.* 2018). As a result, roadkill can have a negative effect on turtle populations near roads (Rytwinski and Fahrig 2012).

Wildlife warning signs are one of the most commonly used tools to attempt to reduce roadkill, although there is little evidence that they are effective (Huijser *et al.* 2015). They can take the form of standard road signs as well as enhanced road signs with flashing lights or symbols (Pojar *et al*. 1975; Huijser *et al*. 2015). Most studies on the effectiveness of wildlife warning signs have found that they do not significantly reduce roadkill (e.g., Pojar *et al.* 1975; Coulson 1982; Bullock *et al.* 2011; but see Found and Boyce 2011). Most wildlife warning sign studies have focussed on large mammals, and we are unaware of any published studies on the effectiveness of standard wildlife signs on reducing turtle roadkill.

Given that all eight species of freshwater turtles that occur in Canada are listed as species at risk (Government of Canada 2019), it is important to assess whether turtle warning signs lead to a significant reduction in roadkill. To test the effectiveness of turtle signs (Figure 1) we examined roadkill before and after signs were installed at known hotspots in eastern Ontario. The importance of before-after-control-impact (BACI) research design has been stressed in evaluating the effectiveness of road mitigation strategies (Lesbarrères and Fahrig 2012); thus, we also compared roadkill rates with those on a control road over the same period.

Methods

As part of a larger project on turtle conservation, road surveys were conducted in eastern Ontario in 2017, and from those surveys four hotspots were identified. In spring 2018, the Ministry of Transportation installed standard turtle signs at these hotspots to help reduce roadkill. The four hotspots were located along provincial highway 15 north of Smiths Falls in Lanark County, along a section of road ~36 km in length (45.0°N, 76.0°W; Figure 2). Turtle warning signs were installed facing oncoming traffic at both ends of each hotspot. The signed road segments at each location averaged 1010 m (range 750–1675 m) in length. Daily traffic at these locations ranged from an

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FIGURE 1. Example of turtle sign installed by the Ministry of Transportation along provincial highway 15 in eastern Ontario in May 2018. Photo: David Seburn.

annual average daily traffic of 4950 to 9400 vehicles (Ministry of Transportation 2019).

The four control road segments were located along Roger Stevens Drive east of Smiths Falls in Lanark County, along a section of road ~28 km in length (Figure 2). Highway 15 and Roger Stevens Drive intersect in Smiths Falls and the two roads are less than 25 km apart at any point. Each control segment was 1000 m in length and was selected based on the presence of at least four roadkilled turtles during 2017. Daily traffic in the four control segments varied

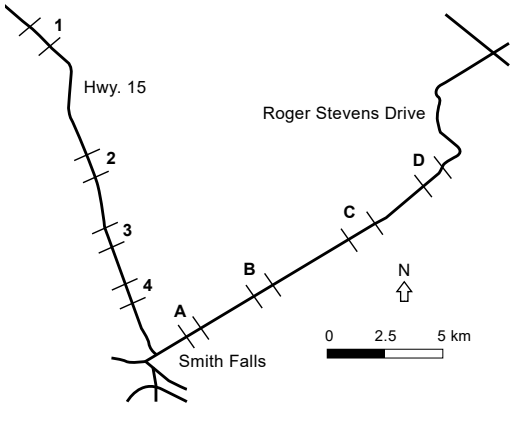

FIGURE 2. Location of two roads used in test of the effectiveness of turtle signs in eastern Ontario in 2017 and 2018. Roadkill hotspots were located along provincial highway 15 and are numbered 1–4. Turtle signs were installed at each end of all four hotspots in spring 2018. Four segments of road along Roger Stevens Drive, labelled A–D, served as control sections.

by section, and ranged from an annual average daily traffic volume of 2860 to 3900 vehicles (roads department, Lanark County unpubl. data). Both the control and impact roads were paved, two-lane roads, with a posted speed limit of 80 km/h, although this limit was frequently exceeded by drivers (D.C.S. and H.M.-A. pers. obs.).

Road surveys were usually conducted with at least two people in the vehicle, but on some occasions, only one person conducted a road survey. Surveys were conducted during the day, typically from 0900 to 1600. Roads were surveyed by driving at ~50–60 km/h and scanning the road surface and road shoulders for dead turtles. The location of each roadkilled turtle was recorded using a handheld global positioning system unit (eTrex or eTrex 20×, Garmin Ltd., Olathe, Kansas, USA) with a spatial accuracy of at least ± 5 m. All dead turtles were removed from the road or road shoulder to prevent double counting on a subsequent survey. Road surveys were conducted approximately weekly from May until early September in 2017 and 2018. Both control and impact roads were typically surveyed on the same day.

The turtle warning signs were installed at the end of May 2018. Only dead turtles found in 2018 after the signs were installed were included in the analysis for both control and impact roads. Similarly, for 2017, only turtles from after the end of May were included so that the same period in both years was compared. In addition, all live turtles found on the road were excluded to examine only the effect of the road signs on turtle mortality. Live turtles made up <10% of all turtles found on roads. This is as expected, as, if turtles successfully cross a road, they are only present for a few minutes and would only be detected if the crossing coincided with the survey.

A chi-squared 2×2 contingency table was used to compare differences in the number of turtles in 2017 and 2018 for both roads (Minitab 8.3; Minitab Inc., State College, Pennsylvania, USA). The turtles from all four hotspots were pooled to prevent pseudoreplication (Hurlbert 1984) and the two years compared. Similarly the four control road segments were pooled and the two years compared. Statistical significance was defined as $P < 0.05$.

Results

Three species of turtles were found during surveys: Painted Turtle (*Chrysemys picta*), Snapping Turtle (*Chelydra serpentina*), and Blanding's Turtle (*Emydoidea blandingii*). We found 30 dead turtles in the four hotspots in 2017 before the signs were installed, and 27 in 2018 after the signs were installed. In the four control sections, we found 19 dead turtles in 2017 and 26 in 2018 after the signs were installed

along the other road. There was no statistically significant difference in the number of turtles found before or after the signs were installed (Table 1; $\chi^2_1 = 1.1$, $P > 0.2$).

Discussion

Our road surveys likely did not detect all of the turtles killed on the roads, as they were conducted approximately weekly and turtle carcasses along roads may not persist that long (Santos *et al.* 2011). In addition, compared with walking surveys, driving surveys may fail to detect some carcasses (Santos *et al.* 2016). There is no reason to assume that carcass persistence or detectability would have differed significantly between the two years, and survey methods and survey frequency were the same in both years.

There were similar numbers of roadkilled turtles in the control road sections in both years, suggesting that roadkill numbers in the impact road sections would also have been similar in both years without the presence of any mitigation. Thus, any significant changes in roadkill numbers in the impact road sections between 2017 and 2018 should be attributable to the road signs. The lack of any significant decrease in roadkill indicates that the signs were not effective. A larger sample size would have increased our chances of detecting a statistically significant difference in the amount of roadkill, if one existed. Nonetheless, a decrease of only 10% in roadkill in 2018 from 2017 is not indicative of effective mitigation, as wildlife barriers and crossing structures can reduce roadkill by more than 90% (Dodd *et al.* 2004). Any road mitigation strategy that results in only a 10% reduction in roadkill should be considered a failure.

Wildlife warning signs are one of the most commonly installed road mitigation tools (Huijser *et al.* 2015), likely because of their low cost. However, despite their wide use, there is little evidence that such warning signs are effective at reducing roadkill. Few drivers are even aware of such warning signs. In one study, only 5–10% of drivers who were stopped 200 m after passing a warning sign were able to recall the sign (Drory and Shinar 1982).

For warning signs to be effective, they should result in drivers reducing their speed. Animated deer (*Odocoileus* spp.) warning signs have led to a reduction in speed, but only by <5 km/h (Pojar *et al.* 1975). Similarly, camel (*Camelus* spp.) warning signs have resulted in a decline in vehicle speed, but only by 3–7 km/h (Al-Ghamdi and AlGadhi 2004). Moose (*Alces americanus*) warning signs reduced driving speeds by only 1.5 km/h in a driving simulator (Jägerbrand *et al.* 2018). Greater speed reductions (~10 km/h) have occurred when deer carcasses were placed next to warning signs to emphasize the reality of the threat (Pojar *et al.* 1975). The effectiveness of animal warning signs on driving speed may also decline over time as drivers become habituated to the signs (Pojar *et al.* 1975; Khalilikhah and Heaslip 2017). Hence, it seems that even large-mammal warning signs may only have a small effect on vehicle speeds, even though collisions can result in the injury or death of the driver (e.g., Conover *et al.* 1995; Niemi *et al.* 2017).

Ultimately, the main issue is whether animal warning signs result in a reduction in collisions and roadkill. Deer crossing signs did not reduce the number of deer killed in Colorado (Pojar *et al.* 1975), but deer collisions were reduced, at least for the first year, after warning signs were installed at known hotspots in the city of Edmonton, Alberta (Found and Boyce 2011). Temporary, flashing warning signs installed at known deer migration locations resulted in a significant reduction in vehicle collisions, but this effect lessened during the second year of the study (Sullivan *et al.* 2004). Warning signs were also not effective at reducing roadkill of kangaroos in Australia (Coulson 1982; Shima *et al*. 2018), mammals and birds along a major road in South Africa (Bullock *et al.* 2011), or snakes in Illinois (Shepard *et al.* 2008).

Enhanced warning signs may be effective under some limited circumstances. Diamond-backed Terrapins (*Malaclemys terrapin*) suffer high rates of road mortality during nesting forays, which are associated with diurnal high tides (Crawford *et al.* 2014). Flashing warning signs installed but only activated for a 2-h period each day corresponding to the diurnal high tide during the nesting season, significantly reduced Diamond-backed Terrapin roadkill (Crawford *et al.* 2018). It is also possible that wildlife warning signs may be more effective along roads with a lower speed limit as speed limit is often positively correlated with roadkill (Farmer and Brooks 2012).

Although wildlife warning signs may not significantly reduce roadkill, they can still be valuable within a comprehensive mitigation strategy for public education and sending a message that roadkill of wildlife is a serious issue. Wildlife warning signs should not replace more effective road mitigation tools such as wildlife fencing and crossing structures (e.g., Dodd *et al.* 2004; Aresco 2005; Baxter-Gilbert *et al.* 2015; Crawford *et al.* 2017).

Table 1. Results of 2×2 chi-squared contingency table comparing the observed number of dead turtles on the control and impact roads, both before and after turtle signs were installed.

Site	Roadkill (expected value)	
	Before	After
Impact (with signs)	30 (27.4)	27 (29.6)
Control (no signs)	19 (21.6)	26 (23.4)

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Literature Cited

Al-Ghamdi, A.S., and S.A. AlGadhi. 2004. Warning signs as countermeasures to camel–vehicle collisions in Saudi Arabia. Accident Analysis and Prevention 36: 749–760. https://doi.org/10.1016/j.aap.2003.05.006

Aresco, M.J. 2005. Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. Journal of Wildlife Management 69: 549–560. https://doi.org/10.2193/0022-541x(2005)069[0549:mmtrhm]2.0.co;2

Baxter-Gilbert, J.H., J.L. Riley, D. Lesbarrères, and J.D. Litzgus. 2015. Mitigating reptile road mortality: fence failures compromise ecopassage effectiveness. PLoS ONE 10: e0120537. https://doi.org/10.1371/journal.pone.0120537

Bullock, K.L., G. Malan, and M.D. Pretorius. 2011. Mammal and bird road mortalities on the Upington to Twee Rivieren main road in the southern Kalahari, South Africa. African Zoology 46: 60–71. https://doi.org/10.1080/15627020.2011.11407479

Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (*Emydoidea blandingii*): implications for conservation and management of long-lived organisms. Conservation Biology 7: 826–833. https://doi.org/10.1046/j.1523-1739.1993.740826.x

Conover M.R., W.C. Pitt, K.K. Kessler, T.J. DuBow, and W.A. Sandborn. 1995. Review of human injuries, illnesses, and economic losses caused by wildlife in the United States. Wildlife Society Bulletin 23: 407–414.

Coulson, G.M. 1982. Road-kills of macropods on a section of highway in central Victoria. Wildlife Research 9: 21–26. https://doi.org/10.1071/wr9820021

Crawford, B.A., J.C. Maerz, N.P. Nibbelink, K.A. Buhlmann, T.M. Norton, and S.E. Albeke. 2014. Hot spots and hot moments of diamondback terrapin road-crossing activity. Journal of Applied Ecology 51: 367–375. https://doi.org/10.1111/1365-2664.12195

Crawford, B.A., C.T. Moore, T.M. Norton, and J.C. Maerz. 2017. Mitigating road mortality of diamond-backed terrapins (*Malaclemys terrapin*) with hybrid barriers at crossing hot spots. Herpetological Conservation and Biology 12: 202–211.

Crawford, B.A., C.T. Moore, T.M. Norton, and J.C. Maerz. 2018. Integrated analysis for population estimation, management impact evaluation, and decision-making for a declining species. Biological Conservation 222: 33–43. https://doi.org/10.1016/j.biocon.2018.03.023

Cunnington, D.C., and R.J. Brooks. 1996. Bet-hedging theory and eigenelasticity: a comparison of the life histories of loggerhead sea turtles (*Caretta caretta*) and snapping turtles (*Chelydra serpentina*). Canadian Journal of Zoology 74: 291–296. https://doi.org/10.1139/z96-036

Dodd, Jr., C.K., W.J. Barichivich, and L.L. Smith. 2004. Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation 118: 619–631. https://doi.org/10.1016/j.biocon.2003.10.011

Drory, A., and D. Shinar. 1982. The effects of roadway environment and fatigue on sign perception. Journal of Safety Research 13: 25–32. https://doi.org/10.1016/0022-4375(82)90015-9

Dupuis-Désormeaux, M., V. D'Elia, C. Cook, J. Pearson, V. Adhikari, and S.E. MacDonald. 2017. Remarkable male bias in a population of midland painted turtles (*Chrysemys picta marginata*) in Ontario, Canada. Herpetological Conservation and Biology 12: 225–232.

Farmer, R.G., and R.J. Brooks. 2012. Integrated risk factors for vertebrate roadkill in southern Ontario. Journal of Wildlife Management 76: 1215–1224. https://doi.org/10.1002/jwmg.358

Found, R., and M.S. Boyce. 2011. Warning signs mitigate deer–vehicle collisions in an urban area. Wildlife Society Bulletin 35: 291–295. https://doi.org/10.1002/wsb.12

Gibbs, J.P., and W.G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology 16: 1647–1652. https://doi.org/10.1046/j.1523-1739.2002.01215.x

Government of Canada. 2019. Species at risk public registry. Government of Canada, Ottawa, Ontario, Canada. Accessed 4 February 2019. https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html.

Huijser, M.P., C. Mosler-Berger, M. Olsson, and M. Strein. 2015. Wildlife warning signs and animal detection systems aimed at reducing wildlife-vehicle collisions. Pages 198–212 *in* Handbook of Road Ecology. *Edited by* R. van der Ree, D.J. Smith, and C. Grilo. John Wiley & Sons, Chichester, United Kingdom. https://doi.org/10.1002/9781118568170.ch24

Hurlbert, S.H. 1984. Pseudoreplication and design of ecological field experiments. Ecological Monographs 54: 187–211. https://doi.org/10.2307/1942661

Jägerbrand, A.K., H. Antonson, and C. Ahlström. 2018. Speed reduction effects over distance of animal–vehicle collision countermeasures—a driving simulator study. European Transport Research Review 10: 40. https://doi.org/10.1186/s12544-018-0314-8

Keevil, M.G., R.J. Brooks, and J.D. Litzgus. 2018. Post-catastrophe patterns of abundance and survival reveal no evidence of population recovery in a long-lived animal. Ecosphere 9: e02396. https://doi.org/10.1002/ecs2.2396

Khalilikhah, M., and K. Heaslip. 2017. Improvement of the performance of animal crossing warning signs. Journal of Safety Research 62: 1–12. https://doi.org/10.1016/j.jsr.2017.04.003

Lesbarrères, D., and L. Fahrig. 2012. Measures to reduce population fragmentation by roads: what has worked and how do we know? Trends in Ecology & Evolution 27: 374–380. https://doi.org/10.1016/j.tree.2012.01.015

Ministry of Transportation. 2019. Ontario provincial highways traffic volumes on demand. Ministry of Transportation, Toronto, Ontario, Canada. Accessed 20 January 2019. http://www.raqsa.mto.gov.on.ca/techpubs/TrafficVolumes.nsf/tvweb?OpenForm& Seq=1.

Niemi, M., C.M. Rolandsen, W. Neumann, T. Kukko, R. Tiilikainen, J. Pusenius, E.J. Solberg, and G. Ericsson. 2017. Temporal patterns of moose–vehicle collisions with and without personal injuries. Accident Analysis & Prevention 98: 167–173. https://doi.org/10.1016/j.aap.2016.09.024

Pojar, T.M., R.A. Proscence, D.F. Reed, and T.N. Woodard. 1975. Effectiveness of lighted, animated deer crossing sign. Journal of Wildlife Management 39: 87–91. https://doi.org/10.2307/3800469

Rytwinski, T., and L. Fahrig. 2012. Do species life history traits explain population responses to roads? A meta-analysis. Biological Conservation 147: 87–98. https://doi.org/10.1016/j.biocon.2011.11.023

Santos, R.A.L., S.M. Santos, M. Santos-Reis, A.P. de Figueiredo, A. Bager, L.M. Aguiar, and F. Ascensão. 2016. Carcass persistence and detectability: reducing the uncertainty surrounding wildlife–vehicle collision surveys. PLoS ONE 11: e0165608. https://doi.org/10.1371/journal.pone.0165608

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. https://doi.org/10.1371/journal.pone.0025383

Shepard, D.B., M.J. Dreslik, B.C. Jellen, and C.A. Phillips. 2008. Reptile road mortality around an oasis in the Illinois corn desert with emphasis on the endangered Eastern Massasauga. Copeia 2008: 350–359. https://doi.org/10.1643/CE-06-276

Shima, A.L., D.S. Gillieson, G.M. Crowley, R.G. Dwyer, and L. Berger. 2018. Factors affecting the mortality of Lumholtz's tree-kangaroo (*Dendrolagus lumholtzi*) by vehicle strike. Wildlife Research 45: 559–569. https://doi.org/10.1071/WR17143

Steen, D.A., and J.P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18: 1143–1148. https://doi.org/10.1111/j.1523-1739.2004.00240.x

Sullivan, T.L., A.F. Williams, T.A. Messmer, L.A. Hellinga, and S.Y. Kyrychenko. 2004. Effectiveness of temporary warning signs in reducing deer–vehicle collisions during mule deer migrations. Wildlife Society Bulletin 32: 907–915. https://doi.org/10.2193/0091-7648(2004)032[0907:eotwsi]2.0.co;2

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