TG RESEARCH & MONITORING

ROAD MORTALITY MITIGATION AND BEST MANAGEMENT PRACTICES

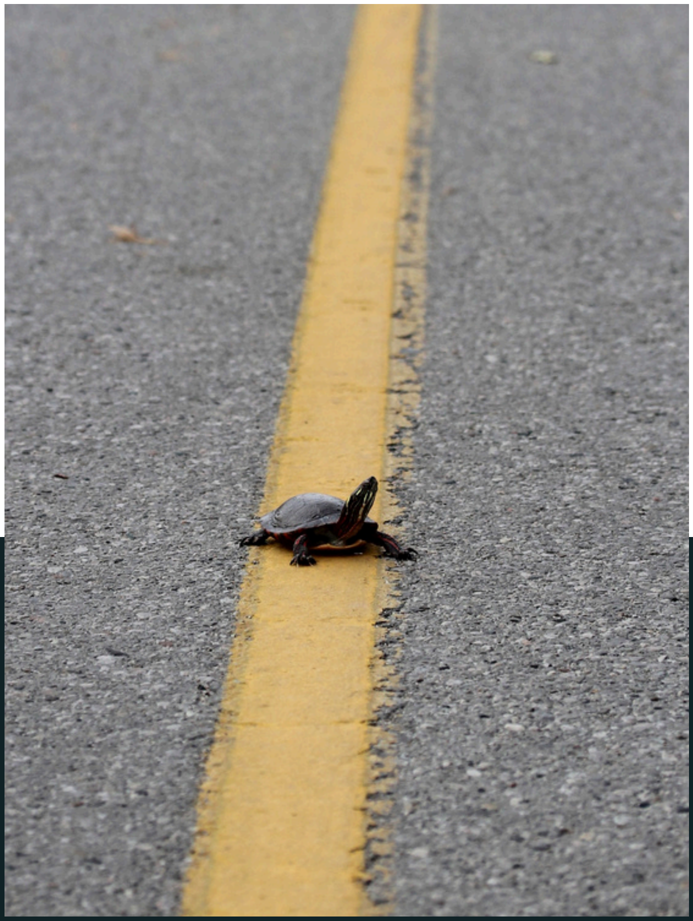
LITERATURE

REVIEW

Overview

For many reptile and amphibian species, connectivity between the aquatic and terrestrial environment is a requirement for foraging, overwintering, and life history events, which are all necessary for the persistence of these species at the population and individual level. Roads are a common barrier to this connectivity. In the face of increasing habitat loss and fragmentation, road mortality has become a leading cause of population declines in herpetofauna. Mitigation systems such as barriers, ecopassages, and selected substrates are a way to allow conservation and development to coexist in a sustainable way.

The following review provides a summary of the Best Management Practices for Mitigating the Effects of Roads on Amphibian and Reptile Species at Risk in Ontario (Gunson et al., 2016). In addition, an analysis and comparison of several mitigation designs will be provided to guide future projects.



Road mortality is a leading cause of population declines in reptiles.

Ontario Best Management Practices

Adapted from Best Management Practices for Mitigating the Effects of Roads on Amphibian and Reptile Species at Risk in Ontario (Gunson et al., 2016), the following provincial guidelines have been considered for barrier fencing and ecopassages:

Table 1. Overview of selected BMPs for crossing structures and ecopassages.

Structure Type	Application	Engineering and Maintenance Considerations	Relative Cost (CAN)
Box tunnel	Open-top box tunnels have been used on low-use cottage roads. Open tops may increase crossing success similar to larger underpasses.	Open-top tunnels must be at grade with the road surface. Size of tunnel needs to fit the vertical road profile to ensure structural stability.	$800-$3000
Arch/round tunnel	The arch structure can be pre-assembled or assembled at the site. Corrugated steel arch/concrete side slabs are placed on footings.	Large structures allow for more accessible maintenance. Natural substrate and cover objects must be maintained.	$145-1500
Large underpass	Inclusion of cover objects, small ponds, and vegetation is possible in large designs. If human-use is incorporated, it should be separated from wildlife.	May require irrigation for pools and vegetation. Overpass decks can integrate natural footings.	$2-4 million

Table 2. Overview of selected BMPs for fencing and barriers.

Fence Type	Benefits	Drawbacks	Considerations
Hardware mesh cloth	Moderately durable, moderately low maintenance, good drainage.	Rusts in wet areas unless heavy gauge wire is used.	Must use 0.25 inch or smaller gauge to avoid small snakes getting stuck. Attach to posts at regular intervals to prevent collapse.
Chain link	Highly durable, low maintenance, good drainage.	Mesh size exceeds many species specifications.	Combine buried hardwire cloth at the base of the fence to allow for multi-species use. Lip extension may increase effectiveness.
Concrete	Highly durable, low maintenance, difficult to climb.	Prevents drainage and may cause pooling.	Aluminum sheeting and vinyl walls are less durable than concrete. Corrugated steel can be obtained from steel pipes cut in half and allow for lip extension.
Prefabricated plastic sheet fencing	Highly durable options available (ACO fencing, Animex fencing).	Inhibits drainage and may cause pooling.	Backfill on the road side of the fence allows for jump-outs. Best suited for flat dirt terrain.

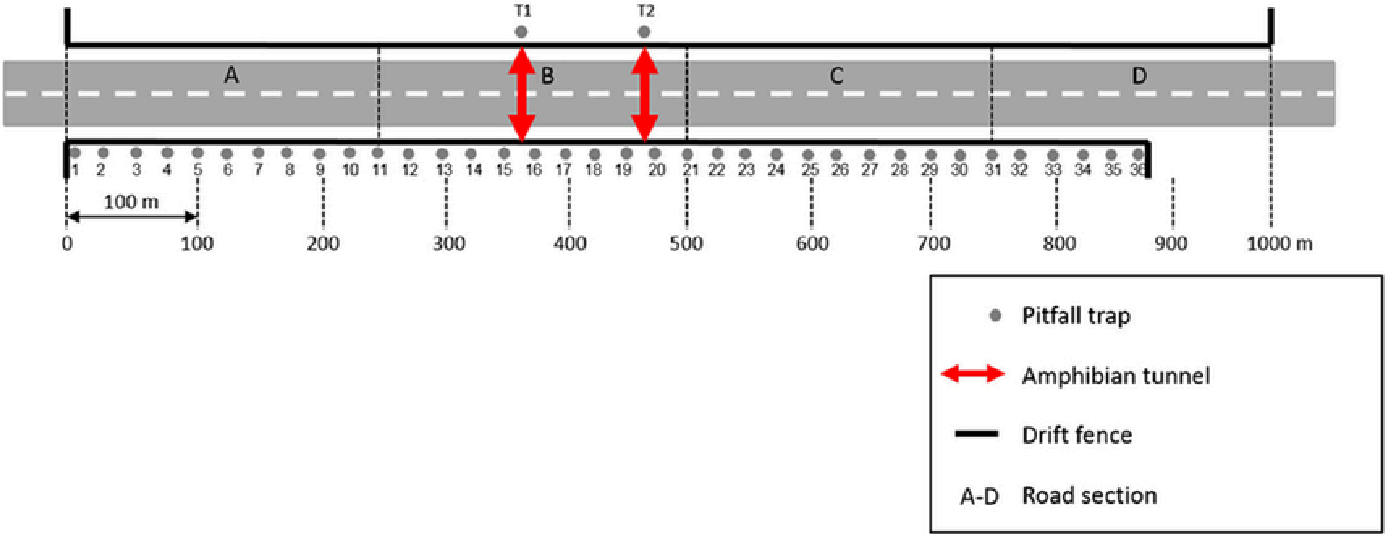
Review of Herptile Focused Projects

Study: Effectiveness of Road Mitigation for Common Toads (*Bufo bufo*) in the Netherlands (Ottburg and van der Grift, 2019)

Species: Common Toad (*Bufo bufo*)

Mitigation Types: Two amphibian Tunnels and permanent drift fences. Two-way tunnels consist of concrete (8.6 m long, 0.50 m wide, 0.30 m high) with an open grid roof. The drift fences are 0.40 m high smooth, black barriers made of high density polyethylene (HDPE). On the south and north sides of the road, the fences are 900 m and 1000 m long, respectively, with a 20 m long drift fence perpendicular to the road. Small cattle guards are used to prevent toads from entering where access roads cross the fences.

Outcome: Density of tunnels (2.2/km) contributed to the low use of tunnels by toads. The toads traveled an average of 60 m along the drift fences, but the nearest tunnels were usually 160 m. More tunnels would solve this problem. Design of tunnels is important in determining willingness to utilize: tunnels that are too small, too large, or considered an inhospitable microclimate may not be used.



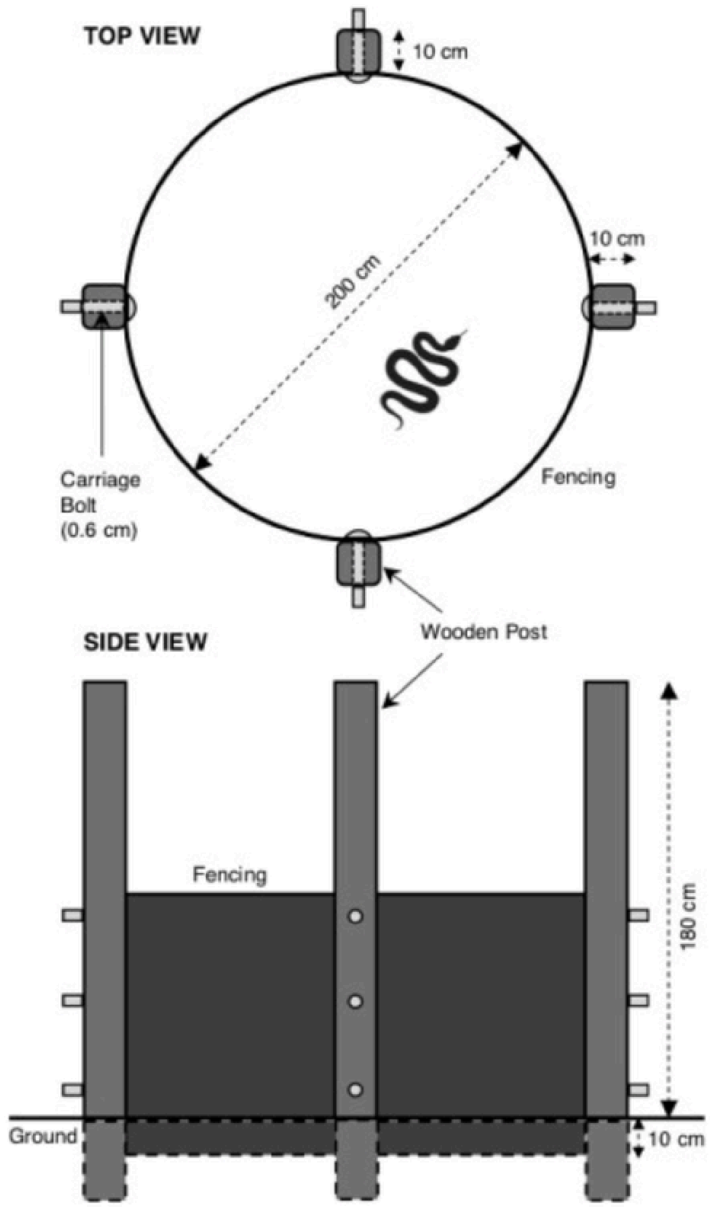
Schematic of mitigation system (Ottburg and van der Grift, 2019)

Study: Barriers for Big Snakes: Incorporating Animal Behaviour and Morphology into Road Mortality Mitigation Design (Macpherson et al. 2021)

Species: Grey Ratsnake (*Pantherophis spiloides*)

Mitigation Types: Fencing was composed of two materials: hardware cloth and vinyl sheeting. Some fencing was 60 cm and some was 100 cm, and were either straight or lipped. The hardware cloth was made of couple zinc-coated wire with 6.3 mm gaps, and the vinyl sheeting was made of black HDPE-2 plastic with thickness of 2 mm. The lips/overhangs were 10 cm in width and extended 90° from the top of the fencing. These combinations result in 8 types of fencing.

Outcome: Snakes were 100% successful at climbing over the 60 cm vinyl sheeting, regardless of whether the lip was present. The most effective combination was 100 cm high hardware cloth fencing with a lip (6.7% climb over success rate). Vinyl sheeting was less effective.



Schematic of fencing design (Macpherson et al. 2021).

Study: The True Cost of Partial Fencing: Evaluating Strategies to Reduce Reptile Road Mortality (Markle et al. 2017)

Species: Blanding's Turtles (*Emydoidea blandingii*) and Spotted Turtles (*Clemmys guttata*).

Mitigation Types: Over 5 km of exclusion fencing was installed over various parts of a causeway. This fencing was originally silt (1 m in height) but was replaced with woven geotextile (122 cm). The geotextile material was mounted on 5 x 10 cm pressure treated wooden posts using non-corrosive, large washers and deck screws. The bottom of the fencing was backfilled. Some sections of the geotextile were replaced with small gauge (0.32 cm) polyvinyl chloride (PVC) mesh netting with small gauge galvanized hardware cloth. One hydraulic concrete box culvert, three terrestrial open-grate culverts, and three concrete block culverts were installed under the causeway. Concrete or sheet metal piling barriers were beyond the financial limitations of the project.

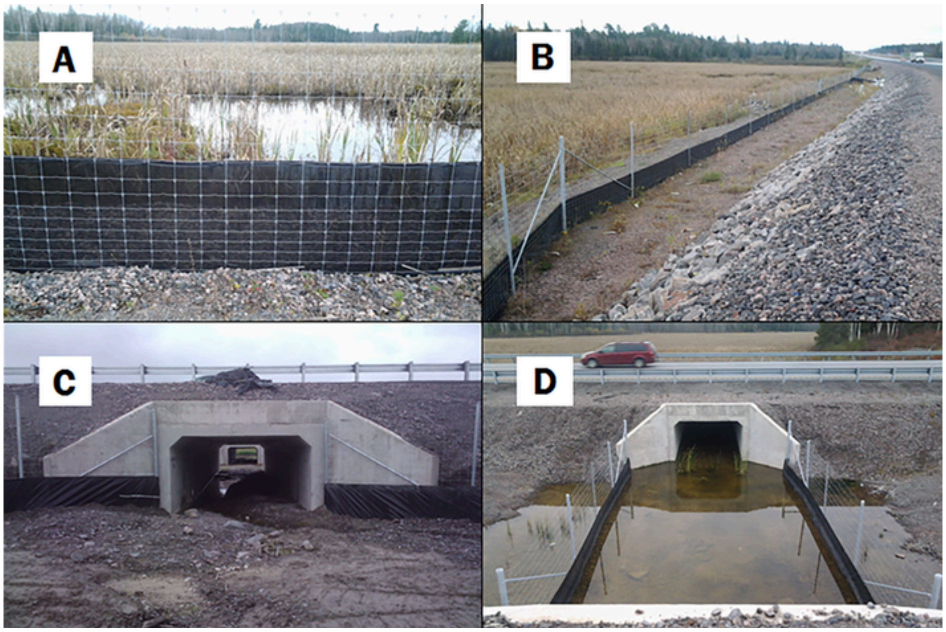
Outcome: When total fencing was present, turtle abundance on the road declined by 89%. In areas with partial fencing, it increased by 6%; greater effect was found in snake species. Silt fencing was inexpensive but suffered from UV and wild damage, metal staples that attached the fencing to wooden stakes had rusted away. The geotextile replacement fencing ripped off the posts and sagged due to wind damage. After replacing this with mounted galvanized hardware cloth, additional failure occurred from resting and ripping in damp marsh conditions. PVC was used as a replacement in marsh areas, and it withstood conditions and had small enough mesh to not entrap snakes. Most reptiles that got onto the road did so by traveling around the fences. A combination of windy upland areas and wet marsh conditions required both PVC mesh and woven textile fencing, and regular maintenance was still required; larger snakes are not deterred by this fencing.

Study: Mitigating Reptile Road Mortality: Fence Failures Compromise Ecopassage Effectiveness (Baxter-Gilbert et al. 2015)

Species: Species at risk snakes and turtles

Mitigation Types: Exclusion structures (reptile fencing) and 3 population connectivity structures (ecopassages) were used. The reptile fencing consisted of heavy-gauge plastic textile (0.8 m above and 0.2 m below-ground with a 0.1 m wide lip running perpendicular underground). Fence was fixed to the base of a 2.3 m tall chain-link fence, used to exclude large mammals. Reptile fence connected the 3 ecopassages (450-600 m apart), each made of two 3.4 m x 24.1 m concrete box culverts, with ample light entering the ecopassages.

Outcome: Ecopassages were mostly used by non-herpetofaunal taxa; existing drainage culverts were more commonly employed by reptiles, which may be because they were pre-existing movement corridors before the study began. Turtle road mortality and snake road mortality increased by 20% and 25% post-mitigation, respectively. This is because of a corralling effect of reptiles entering the roadway through fence-gaps and being unable to exit due to a lack of corresponding gap on the other side of the road, resulting in an increased amount of time on the road. Therefore, non-continuous, flexible-plastic fencing is not capable of reducing reptile abundance on roadways. Failure in both the installation and material of the fencing resulted in this lack of effectiveness. Over 115 gaps were located in the fencing from rips, holes and washouts.



Fencing (A and B) and ecopassages (C and D); (Baxter-Gilbert et al. 2015)

Over 30% of the fence was semi-submerged during spring melt, allowing reptiles to swim over. Plastic and mesh fencing are both easily climbed, and will degrade overtime in water. An alternative mitigation is concrete or steel gravity walls fitted into the sloped gravel between the shoulder and ditch.

Study: Culverts Alone Do Not Reduce Road Mortality in Anurans (cunnington et al. 2014)

Species: Frogs and Toads

Mitigation Types: Twenty pre-existing concrete box drainage culverts along a 24 km stretch of paved highway. This study had areas where the culverts were grated off to keep anurans out of them (grate treatment), areas with fences installed without the grates (fence treatment) and other areas had only uncovered culverts (control).

Outcome: Culverts alone did not reduce anuran road mortality, and placing grates on the culverts did not increase mortality. Without fencing, anurans do not use culverts because they aren't being directed toward it. Therefore, the first priority of mitigation should be fencing.

Grate treatment (a), fence treatment (b, c), and control (d) sites (Cunningham et al. 2024).

Study: Mitigation Measures to Reduce Highway Mortality of Turtles and Other Herpetofauna at a North Florida Lake (Aresco, 2005).

Species: Freshwater turtles.

Mitigation Types: Temporary fencing made of 0.6 m high woven vinyl erosion control fencing installed at the edge of the mowed right-of-way along 700 m of highway. The below ground fencing was buried 20 cm and the above-ground height of the fencing was 0.4 m. The fences were turned back gradually toward the lake 80-100 m.

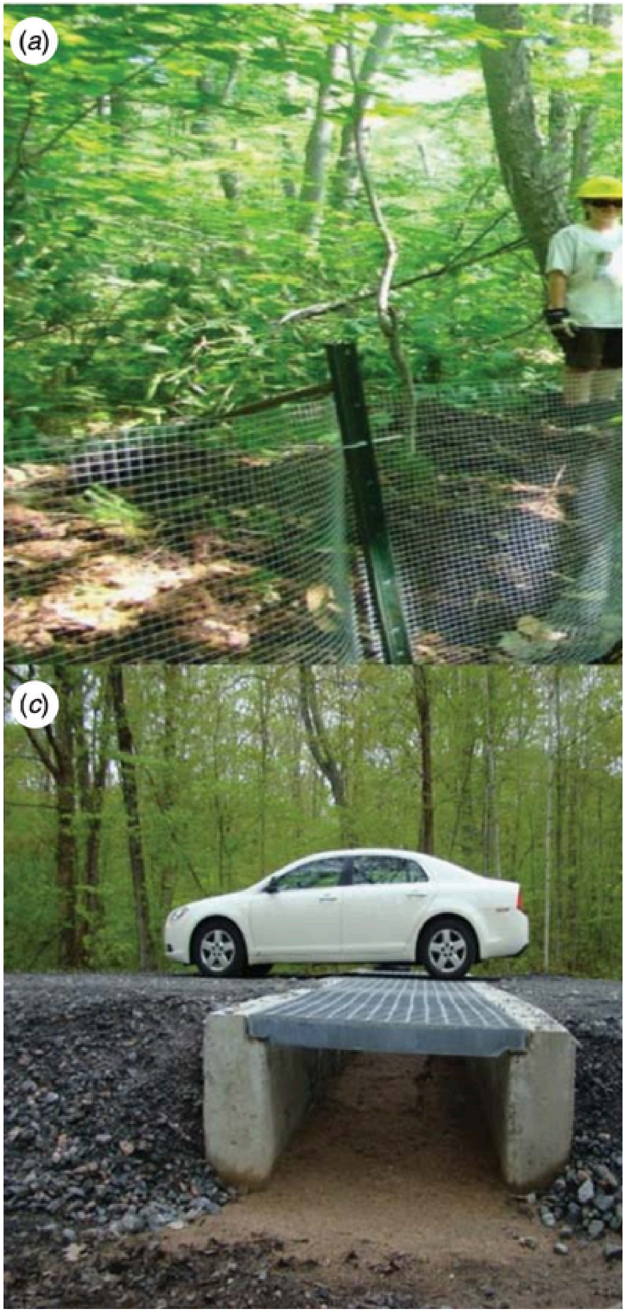
Outcome: Vinyl erosion control fencing with existing culverts are an effective way of reducing road mortality of turtles at a low cost until a more permanent design can be constructed. Turtles used the large-diameter culverts when light was visible from each side and a natural sand/silt substrate was present. The fence extensions on each end of the barrier was important for deterring wandering turtles onto the highway. The drift fences required extensive monitoring to prevent snapping turtles and other species prone to climbing from breaching the top of the fence. Every 18 months, the wooden stakes and vinyl fencing must be replaced to avoid the implications of damage from mowers, stormwater flow and direct sunlight exposure. More permanent barriers should include a smooth vertical surface (approx 1 m tall) with an inward overhanging lip with a series of large culverts under the highway.

Study: Mitigations Reduce Mortality of a Threatened Rattlesnake (Colley et al. 2017).

Species: Eastern Massasauga Rattlesnakes (*Sistrurus catenatus*).

Mitigation Types: Barrier fencing and grate-top culverts. Barrier fencing is composed of light-gauge metal hardware cloth (1 x 1 cm gauge mesh). The fencing is L-shaped and extends 75 cm above ground and 30 cm below ground, with a 15 cm section bent at a right angle projecting toward the non-road habitat as a way to avoid burrowing under it. Some areas of this fencing were replaced with new hardware cloth augmented with a geotech fabric with a 20 year lifespan against water and UV damages. The walls of the ecopassages (8.5 m long, height 50-60 cm, and width 1.2 m) are constructed using concrete, and the top is open with a metal grate.

Outcome: The fencing was effective at reducing massasauga on roads, however it required extensive and labour-intensive monitoring and repair and should only be used in situations where this upkeep is practical and funded into the future. This fencing did not keep smaller bodied snakes from entering the roadway, so it is only practical to massasaugas. Despite intentions to maintain fencing, campers and black bears created weak and open sections and decreased the effectiveness of the system. A better solution would be to install a more durable fence. Snakes were willing to use the ecopassages as a result of the grid tops allowing for a suitable micro-climate and light source.



Barrier fencing (a) and ecopassages (c); (Colley et al. 2017).

Study: Road-effect Mitigation Promotes Connectivity and Reduces Mortality at the Population-level (Boyle et al. 2021).

Species: General herpetofauna.

Mitigation Types: Approximately 1000 m of Animex 'Vertical Above Ground" exclusion fencing along both sides of the road with large turnarounds. The fencing was 0.865 m tall with 0.15 m perpendicular lip pointing away from the road and supported by posts pointing toward the road for stability. Instead of digging a trench, 0.1 m of gravel buried and secured the fence. Two crossing structures were installed under the park road; they were 10 m length x 0.5 m width x 0.32 m high, and had a slot for light and rain penetration.

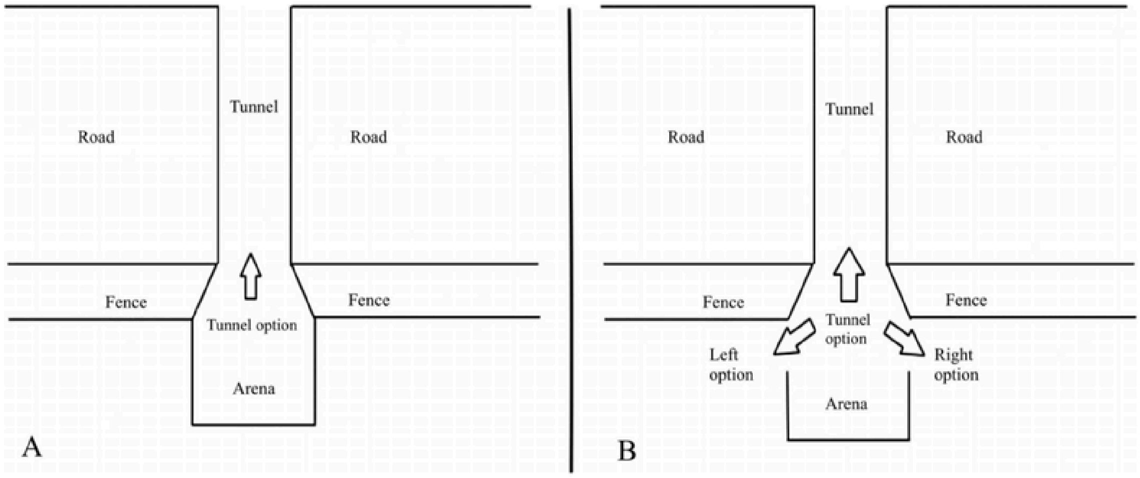
Outcome: Road mortality was significantly reduced in turtles and amphibians, but not snakes. There were no impacts on the number of snakes on the roads. It is likely that the snakes were able to go through the fence, which consisted of overlapping HDPE sheets. Tunnel usage is highly dependent on fencing, but all taxa, sex and age classes used them equally.

Study: Build It and Some Will Use It: A Test of Road Ecopassages for Eastern Gartersnakes (Dillon et al. 2020).

Species: Eastern Gartersnakes

Mitigation Types: An arena style willingness to utilize experiment to test ecopassage interactions. The ecopassages were 2 concrete AT-500 culverts (10 m long x 0.5 m wide x 0.32 m tall, with slots to allow light and rain penetration). Black Animex exclusion fencing was installed to guide the snakes from the arena to the ecopassages. The fencing was 0.865 m tall with a 0.15 m lip pointing away from the road and a 0.15 m lip buried with 0.1 m of gravel.

Outcome: In this experiment, the snakes displayed neither attraction nor aversion to the ecopassages, and more than half of snakes chose to use them even if they had the option to bypass them. The gartersnakes also completed their crossing, unlike in Colley et al., 2017, where only 40% exited the other side. It is important to note that although the concrete ecopassages did not deter the gartersnakes, this substrate may not be suited for other herps, such as ranid frogs. Other studies have shown that a larger culvert yields stronger willingness to utilize in snakes, although that was not the case in this experiment. An ideal culvert for Thamnophis is 1.33 m wide. Learning behaviour was demonstrated when looking at time to utilize between naive and experienced snakes; experienced snakes were quicker to use the culverts, which is important because this suggests the value and effectiveness of ecopassages increases with time for snakes.



Schematics of each arena trial when testing ecopassage willingness-to-use (WTU) in Eastern Gartersnakes (Dillon et al. 2021).

Study: A Rocky Solution: Evaluating the Use of Common Construction Materials as Road-effect Mitigation for Turtles Communities in a Rock Barren Landscape (Kentel, 2023; Thesis).

Species: Blanding's, Painted, and Snapping Turtles.

Mitigation Types: Existing culverts were upgraded to act as aquatic crossing structures, and angular riprap (300 mm diameter) was layered 450 mm deep on either end of the culverts. The roadbed was raised by 2.5 cm and resurfaced using a tar-and-chip method. Road shoulders were paved to meet the rip-rap and in approximately 100 m sections on either side of the rip rap. Despite the paving, loose gravel remained in most of the road shoulders and a gap of exposed gravel remained between the rip-rap and paved shoulders.

Outcome: This option was a cost-effective mitigation strategy that was implemented during the construction process, however it was not effective. Turtles of all three species did not nest in the rip-rap, but rather they nested in the nearest available roadside habitat, including the paved shoulders. If turtles are not physically prevented from accessing the roadside, they will nest on the road, and exclusion barriers are necessary to avoid turtle road mortality.

Mitigation design, including upgraded culverts, rip-rap, and paved road shoulders (Kentel, 2023).

Study: Hatchling Turtle Behavioural Responses to Rip-rap Used on Road Embankments to Prevent Turtles from Nesting (Drektaan, 2023; thesis).

Species: Hatchling Snapping and Painted Turtles.

Mitigation Types: Arena style experiments comparing the movements of hatching turtles on gravel versus rip-rap embankments to ensure that turtles who hatch on road shoulders can successfully traverse the adjacent rip-rap. The arenas were created using plexiglass sides and plywood ends (1.83 m long, 1.22 m tall, 0.305 m wide). Inside, there was a sloping decline to simulate embankments, which were covered by 300 mm rip-rap.

Outcome: Rip-rap caused both the Painted and Snapping Turtle hatchlings to become stuck and unable to free themselves. This causes them to become vulnerable to desiccation, predation, and alters their visual cues to migrate. Thus, this experiment outlines the importance of considering all life history stages when implementing a mitigation plan.

Rip-rap testing arena (Drektaan, 2023).

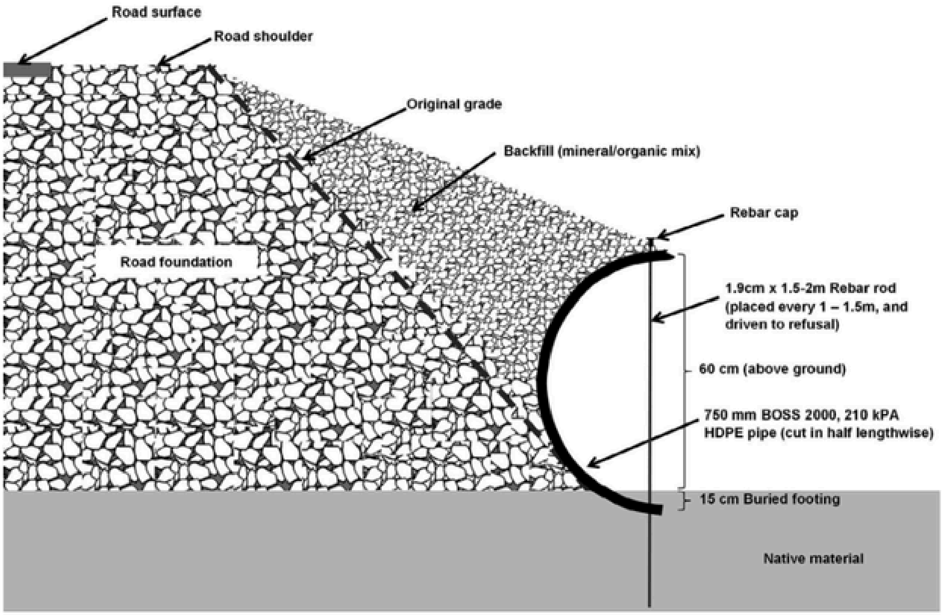
Study: A Unique Barrier Wall and Underpass to Reduce Road Mortality of Three Freshwater Turtle Species (Heaven et al. 2019).

Species: Blanding's, Painted, and Snapping Turtles.

Mitigation Types: Barrier walls (220 m long on each side of road) consisting of 75 cm Boss 2000 high-density polyethylene (HDPE) culvert pipe cut in half lengthwise, which are terminated in a curve at driveways. They were placed at the base of the road shoulder and held upright using 1.9 cm steel rods of 1.5 m and 2 m lengths. The lengths of culvert pipe were attached with standard Boss 2000 culvert couplers. The base of the barrier walls were buried 15 cm into the ground and height of barrier walls was set in accordance with the high water mark of the existing culvert. Backfill was graded to both ensure drainage and provide jump outs for the turtles. The pre-existing culverts that were used as ecopassages were 1.22 m in diameter and 21 m long, with an openness ratio of 0.07. During the spring freshet, waterflow was at 80 cm in the culvert. Wall materials were $43/m, and total cost of installation and materials was approximately $43,000.

Outcome: During the 3-year study, the barrier walls and culverts remained intact and fit, indicating a long life span of these materials. The impact site showed a decrease in turtles on the road, outlining the success of this design. In addition, a relatively high number of turtles successfully completed movement though the ecopassages compared to other studies. The curved ends of the barrier redirected 23% of the turtles, suggesting they are beneficial. To increase their effectiveness, it is suggested that the curved ends be extended to 75 m, rather than the 12 m that was used in this design. If the turtles that are being redirected by the curved ends are nesting females, a possible enhancement to this design would be to implement artificial nesting mounds at termination.

HDPE barrier wall and culvert design (Heaven et al. 2019).



Cross-section schematic of the barrier wall and backfill (Heaven et al. 2019).

Conclusion

Road mortality mitigation is an essential component of conserving the persistence of herpetofauna in an increasingly developed landscape. In order to allow conservation to coexist with development, sustainable and cost-effective designs are required to offset the negative impacts of roads on wildlife. Poor quality fencing is known to compromise ecopassage effectiveness, and can increase rates of mortality by trapping animals on the road instead of deterring them from accessing it. This both nullifies the convenience of low-cost, low quality materials and reduces the ecological value of the design. Therefore, in order for road mitigation to be successful, commitment and dedication of all stakeholders is necessary to ensure that monitoring, maintenance and funding are all continuous efforts. Mitigation materials should be no less durable than the road they are interacting with in order to offset long-term costs and adverse outcomes.

In order to assure the success of a design, willing-to-utilize experiments should be completed. It is important to emphasize design and material use of fencing, because tunnel use is dependent on the efficiency of the barriers associated. Culverts and tunnels do not mitigate herpetofaunal road mortality alone. The use of jump-outs to allow animals to exit the roadway without being able to breach onto the road is critical to prevent them from becoming trapped on the roadway. Future designs should focus on prioritizing high-quality, low-cost materials with an emphasis on frequent and tested jump-outs. Avoiding the trade off between quality and cost will allow for durable, effective barriers that require minimal maintenance and negate the need for subsequent replacements of materials. Special focus should be placed on recycled, environmentally friendly materials with a simplistic installation and resistance to the extreme demands of a northern climate, such as frost damage, high winds, flooding, and photodegradation.

Literature Cited

Aresco, M. J. (2005). Mitigation Measures to Reduce Highway Mortality of Turtles and Other Herpetofauna at a North Florida Lake. The Journal of Wildlife Management, 549-560.

Baxter-Gilbert, J. H., Riley, J. L., Lesbarrères, D., & Litzgus, J. D. (2015). Mitigating reptile road mortality: fence failures compromise ecopassage effectiveness. PLos one, 10(3), e0120537.

Boyle, S. P., Keevil, M. G., Litzgus, J. D., Tyerman, D., & Lesbarrères, D. (2021). Road-effect mitigation promotes connectivity and reduces mortality at the population-level. Biological Conservation, 261, 109230.

Colley, M., Lougheed, S. C., Otterbein, K., & Litzgus, J. D. (2017). Mitigation reduces road mortality of a threatened rattlesnake. Wildlife Research, 44(1), 48-59.

Cunnington, G. M., Garrah, E., Eberhardt, E., & Fahrig, L. (2014). Culverts alone do not reduce road mortality in anurans. Ecoscience, 21(1), 69-78.

Drektraan, L. (2023). Hatchling turtle behavioural responses to rip-rap used on road embankments to prevent turtles from nesting [unpublished honours thesis]. Laurentian University.

Dillon, R. M., Boyle, S. P., Litzgus, J. D., & Lesbarrères, D. (2020). Build it and some will use it: a test of road ecopassages for eastern gartersnakes. Journal of Herpetology, 54(1), 19-23.

Heaven, P. C., Litzgus, J. D., & Tinker, M. T. (2019). A unique barrier wall and underpass to reduce road mortality of three freshwater turtle species. Copeia, 107(1), 92-99.

Kentel, J. (2023). A rocky solution: evaluating the use of common construction materials as road-effect mitigation for turtle communities in a rock barren landscape [Unpublished master's thesis]. Laurentian University.

Macpherson, M. R., Litzgus, J. D., Weatherhead, P. J., & Lougheed, S. C. (2021). Barriers for big snakes: incorporating animal behaviour and morphology into road mortality mitigation design. Global Ecology and Conservation, 26, e01471.

Markle, C. E., Gillingwater, S. D., Levick, R., & Chow-Fraser, P. (2017). The true cost of partial fencing: evaluating strategies to reduce reptile road mortality. Wildlife Society Bulletin, 41(2), 342-350.

Ottburg, F. G., & Van der Grift, E. A. (2019). Effectiveness of road mitigation for common toads (Bufo bufo) in the Netherlands. Frontiers in Ecology and Evolution, 7, 23.