NCHRP 25-25, Task 113

ROAD PASSAGES AND BARRIERS FOR SMALL TERRESTRIAL WILDLIFE SPECIES

CASE STUDIES 5 & 6, DESIGNATED UNDERPASSES

Prepared for:

AASHTO Committee on Environment and Sustainability

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CASE STUDY 5: A REVIEW OF UNDERPASSES FOR AMPHIBIANS

Collectively, amphibians are relatively small animals in all life-stages that move relatively short distances. For example, spring-breeding, wetland-forest amphibians in Canada and in the northeastern United States move up to 1 kilometer (km) (Patrick et al. 2012). In Europe, the Great crested newt (*Triturus cristatus*) is an example of a small newt that moves very short distances. A study by Matos et al. (2018) showed the Great crested newt typically moved short distances each night (3.21 m per night in spring and 6.72 m per night in autumn), with a maximum of 25.6 m travelled inside an underpass tunnel.

Amphibians have highly permeable skin and are at high risk of desiccation; this risk may be exacerbated when travelling through dry tunnels (Rittenhouse et al. 2008). Lesbarreres et al. (2004) found that agile frogs and water frogs preferred tunnels lined with soil rather than dry concrete. Therefore, various tunnel types including those with open top slots have been designed to reduce desiccation risk in tunnels. Open-top tunnels are likely to be moist inside when amphibians are moving to wetlands during rainy spring evenings in eastern North America.

A variety of studies in North America and Europe have monitored amphibian use of underpasses, primarily open slot tunnels manufactured by ACO Wildlife Ltd. (Table 1; Figure 2). Passage rates for amphibians in tunnels varied from 3% for the Great crested newt to more than 50% for spotted salamanders (Jackson and Tyning 1989) and frog species in Ontario (Pomezanski 2017) (Table 1).

Figure 2: *Open slotted ACO tunnel (0.5 m high by 0.5 m wide) installation in Waterton National Park, Alberta. Photo Credit: Cyndi Smith, Parks Canada Agency.*

Table 1: A Summary of Studies That Have Monitored Amphibian Use of Tunnel Underpasses in Europe and North America.

Reference	Structure type	Species	Site	Passage rate	Comments
Allabacks and Laabs (2003)	Six ACO open slot tunnels (five 32 centimeters (cm) high by 47 cm wide by 11.1 meters (m) long; one 21 cm high by 23 cm wide by 12.0 m long	Santa Cruz long-toed salamander	Ventana Way (residential road), California	9% (4 of 44 adults) detected at the fence	2 tunnels situated closest to the breeding pond
Bain et al. (2017)	Three steel pipes (25 cm diameter by 22 m long); 35 m apart	California tiger salamander	Stony Point Road, upland pasture and breeding pool	51%	Passage influenced by amount of rainfall, not moisture levels.
Hill et al. 2018	3 ACO open slot tunnels (50 cm high and 50 cm wide and 13.4 m long)	Common frog, Common toad, Smooth newt (*Lissotriton vulgaris*) and Palmate newt (*L. helveticus*).	Residential access road, Seven Lochs Wetland Park, Scotland	Tunnel rejections (all amphibians) were about 8–9%	Spaced along 100 m of road, about 50 m apart. Each tunnel is 13.4 m long and has a series of 6 cm × 3 cm holes for air, water, and light permeability.
Jackson and Tyning (1989)	2 ACO open slot tunnels (21 cm high by 23 cm wide by 7.0 m long)	Spotted salamanders	Henry Street, Amherst, Massachusetts	68% (65 of 95 adults)	
Jarvis et al. (2019)	4 ACO open top tunnels (0.5 m wide by 0.5 m high by 24 m long).	Great crested newt	Access road for development, Yorkshire, England	57.1 -82.6%.	Installed in pairs, 12 m between two pairs; more juveniles in the autumn
Pagnucco et al. (2011, 2012)	4 ACO open slot tunnels (50 cm high by 50 cm wide by 12 m long)	Long-toed salamanders	Main access road, Waterton National Park, Alberta	23% over a 2-3 year period	Almost half of them (49%) used one tunnel, the one with the highest soil moisture (~30%); funnel

Reference	Structure type	Species	Site	Passage rate	Comments
					fencing extremely important.
Matos et al. (2017)	1 ACO open top tunnel (0.5 m wide by 0.5 m high by 30 m long); two large ARCO concrete and metal sheet underpasses (5.5 m wide by 2 m high by 40 m long)	Great crested newt	Hampton Nature Reserve, Peterborough, England, road for new housing development	ARCO tunnels combined 267 newt captures, followed by 23 in the central ACO tunnel	spaced 100 m apart; more use in wider tunnels; longest tunnels with amphibian use; biased use in autumn and by males; crossing rates low compared to individuals along fence.
Matos et al. (2018)	1 ACO open top tunnel (0.5 m wide by 0.5 m high by 30 m long); two large ARCO concrete and metal sheet underpasses (5.5 m wide by 2 m high by 40 m long)	Great crested newt	Hampton Nature Reserve, Peterborough, England, road for new housing development	3% of newts captured along fence found the tunnels	Fence did not direct newts to tunnels
Ottburg and van der Grift (2019)	2 ACO open top tunnels (0.5 m wide by 0.5 m high by 8.6 m long)	Common toad	Local road near Ede, Netherlands	31% of marked adults	Low tunnel density (2.2/km); population decline
Pomezanski (2017)	2 ACO open top tunnels (0.5 m wide by 0.5 m high by 8.6 m long)	Amphibians	Local road for new subdivision, Guelph, Ontario	53-93%	Influenced by substrate

Crossing success largely varies by site, species, and tunnel length, and there are some similarities between studies:

- Use by amphibians is correlated to rainfall in some cases (Jackson and Tyning 1989).
- Tunnel use is biased to autumn dispersal for Great crested newts; whether or not these tunnels facilitate spring migration remains unclear (Matos et al. 2017, 2018; Jarvis et al. 2019).

- In North America, tunnel use is biased to spring breeding migrations; whether or not the tunnels facilitate autumn migrations remains unclear (Jackson and Tyning 1989; Pagnucco et al. 2012).
- Wider tunnels (5.5 m) have higher passage rates for the Great crested newt than smaller tunnels (0.5 m) when underpasses are 30- to 40-m wide (Matos et al. 2017).
- Passage for Great crested newts in ACO open top tunnels is optimized when tunnels are 24-m long, i.e., passages rates are 57.1 to 82.6 % (Jarvis et al. 2019).
- The amount and orientation of the drift fence is critical for amphibians because these animals do not move far (Allaback and Laabs 2003; Jackson and Tyning 1989; Jarvis et al. 2019).
- The success of tunnel systems may be improved by spacing tunnels closer together approximately 30 m (for Common toads) with 20 m of guide-wall guiding animals towards entrances.

Conclusions: Careful consideration must be given to whether an amphibian underpass and guide-wall/barrier system is effective for amphibians because they move short distances. In one study reviewed, the amphibian population was thought to decline as a result of having provided insufficient connectivity for the Common toad (*Bufo bufo*) (Ottburg and van der Grift 2019). The exclusion/guide wall is an additional barrier to the road itself and is not beneficial unless the tunnels are adequately spaced so target species may find the structures before finding the barrier ends.

Additionally, the structures must be adequately designed for the target species, so passage rates are adequate for all movement types by all age-classes to maintain population stability. If in doubt, then it is recommended to provide critical habitat, such as breeding ponds, on both sides of the road (Repository IA-4 technical drawing for pond), which will allow animals to carry out critical life-cycle processes without necessarily navigating a road or new mitigation structures.

Careful monitoring is essential to understand all factors relating to whether new mitigation measures are effective at the population level. In a follow-up study by Atkinson-Adams (2015), the Long-toed salamander (*Ambystoma macrodactylum*) population was declining in Linnett Lake where road crossing structures were successfully being used by the salamanders. This is likely a result of predacious fish colonizing the lake, likely during a natural flooding event. This study indicates that comprehensive monitoring to understand all stressors on a population could be used to adequately assess benefits of implementing specific mitigation measures.

Alternative Designs: Elevating new roads may provide under-road passage for rare species that are impacted by road mortality and when road crossing locations are known, reoccur, and are concentrated. For example, the United States Geological Service (USGS) is currently testing whether elevated roads are effective underpasses for the rare Yosemite toad (*Anaxyrus canorus*) (Figures 3 and 4). See https://www.usgs.gov/center-news/toad-crossing-ahead-new-study-tests-elevated-roads-underpasses-rare-toad?qt-news_science_products=1#qt-news_science_products.

Figure 3: *Elevated road for under-road passage of Yosemite toads in Sierra National Forest, California. Photo credit: Cheryl Brehme and Jeff Tracey, Western Ecological Research Station, USGS.*

Figure 4: *Side-view or toad's view of elevated road for wildlife passage under road in Sierra National Forest, California. Photo credit: Cheryl Brehme and Jeff Tracey, Western Ecological Research Station, USGS.*

Supporting Repository Materials: AB-2 through to AB-14 (images from Waterton National Park; Pagnucco et al. 2011 and 2012) CA-6 (Allabacks and Laabs 2003); ON-40 and ON-57 (image PA150363; other open-top structures with fencing from Ontario, unpublished data).

CASE STUDY 6: DESIGNING UNDERPASSES FOR SNAKES

Collectively, snakes are relatively slender animals that are able to fit through narrow spaces and use a variety of different habitats. Temperature is known to affect every aspect of snake biology, including locomotion, prey capture, and digestion (Dorcas and Wilson 2008). Some snakes, (e.g. garter snake [*Thamnophis sirtalis parietalis*]) have been shown not to cross roads possibly due to a direct response to abiotic stimuli such as temperature, or more complex responses that have evolved to enhance organismal fitness (e.g., avoid open areas because of higher risk from predation [Shine et al. 2004]).

Therefore, it is essential to design underpasses for snakes that provide favorable microclimates otherwise snakes may reject a crossing structure entirely. In fact, research has shown that snakes are less tolerant to move through smaller crossing structures (< 3m) than turtles. A review showed that both turtles and snakes approached the culverts equally, but once they entered, their crossing rates were significantly different (81% for turtles and 63% for snakes).

This case study provides a summary of the response of Massasauga Rattlesnakes (*Sistrurus catenatus*) to a designated underpass and fence system in a provincial park in Ontario, Canada. This study is unique because it also looked at the microclimatic conditions e.g., temperature in the underpass as compared to the surrounding environment.

Name road: Killbear Provincial Park roads: Camp Road and Day Road

Project type: Existing road

Partners: Ontario Parks, Ontario Ministry of Natural Resources and Forestry Species at Risk Stewardship Fund, Environment Canada Habitat Stewardship Program, Laurentian University, Queen’s University, and the Friends of Killbear.

Construction year: Crossing structures installed in 2010 and 2011, two on Camp Road and two on Day Road.

Construction costs: Unknown

Location: Killbear Provincial Park

Target species: Massasauga Rattlesnake (*Sistrurus catenatus*)

Structure type:

- Open-grate; open-bottom with dirt substrate (Figure 5).
- 8.5-m long with a span of 1.2 m and a height of 50 to 60 cm between the underside of the grate and the backfilled substrate.
- Concrete footings and bases.

Figure 5: *Open-grate, open-bottom underpass in Killbear Provincial Park. Photo Credit: K. Gunson.*

Barrier type and dimensions:

- Light-gauge metal hardware cloth and t-posts.
- L-shaped with 75-cm extension above-ground and 30-cm buried.
- 600-m fence on each side of road on both Day Road and Camp Road.

Habitat: Canadian Shield landscape with exposed Precambrian bedrock. Vegetation includes upland maple-beech communities with scattered stands of white pine black spruce and cedar. Hemlock stands occur along the southern slope of the central ridge of the peninsula. Sedge and grass meadows, along with various wetland types, are also present.

Effectiveness in providing connectivity: Mark-recapture surveys with passive integrated transponder (PIT) tags in 2013 and 2014; camera monitoring (Bushnell Trophy) infrared motion; installed at 1 entrance of 4 tunnels in 2013, and both entrances in 2014. In 2014, cameras used time lapse every 1-minute interval from May to October. Five snakes were recorded in tunnels with PIT tags (2013) and 9 in 2014.

Influence of temperature: During the entirety of the study period, temperatures inside the underpasses did not extend outside the activity range of Massasaugas (1.1°C to 44°C; Harvey & Weatherhead 2010, 2011). All nine crossings in 2014 occurred during the afternoon, between 12:47 and 17:32. Eight out of 9 crossings occurred within a 3 hour time span (14:46-17:32). Of the 9

Conclusions: The open-top design suggests a more appropriate thermal environment than a traditional box culvert. Temperatures inside the tunnels were generally higher than those in the forest, lower than those on the road, and always within the activity range of a Massasauga Rattlesnake (Colley et al. 2017). Although the microhabitat conditions were tolerable for the snakes, snakes adjusted the time of travel to correspond to the warmest time of day (afternoon) inside the passages rather than what was expected (these snakes are crepuscular and generally move in the morning and night) (Shepard et al. 2008).

More research is required to understand the microhabitat conditions tolerated by various species of reptiles at underpasses. Snakes may be more ‘specialized’ or less tolerant of microhabitat conditions than other reptiles such as turtles (Gunson 2019). Anecdotal evidence shows that semi-aquatic snakes will enter and turn around in ‘wet’ smaller drainage culverts and this may be influenced by the thermal environment (K. Gunson, personal observation). Other monitoring has shown that snakes may be more willing to enter smaller drainage culverts with dry conditions with natural sand substrates on the floor of the underpasses (Figure 6 and 7).

Figure 6: *Massasauga Rattlesnake travelling into a 1.2-m round culvert with dry, natural substrate at bottom on Highway 69, Ontario, Canada. Photo credit: Kari Gunson with funding from the Ministry of Transportation.*

Figure 7: *Western rattlesnake travelling into a 68-cm by 50-cm dry Corrugate Steel Pipe culvert with dry natural substrate at bottom in British Columbia, Canada. Photo credit: White Lake Snake Project, Thompson Rivers University.*

Alternative designs: An open-grate, open-bottom design was also implemented in nearby Bruce Peninsula National Park (Figure 8).

Figure 8: *Open-grate underpass installed in Bruce Peninsula National Park. Photo credit: Kari Gunson.*

Supporting repository materials: ON-44; ON-58 (Technical drawings and photos for forming model for open grate box culverts; lined with granular A materials); UT-3 (underpass for tortoises with open grate image).

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