Road Passages & Barriers for Small Terrestrial Wildlife

Project Summary Report

Prepared for

AASHTO Committee on Environment and Sustainability

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Disclaimer

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I. MATERIALS CREATED AS PART OF THIS PROJECT

1) Literature Review Report & Annotated Bibliography
2) Expert Survey Report
3) Consideration Reports
4) Case Studies (7)
5) Project Summary Report
6) Presentation Slides
7) Repository of Designs

All of the above materials are organized on the project website:

https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4337

in the following zip folders and stand-alone files:

1) 25-25-113 Background Information.zip (Literature Review Report and Annotated Bibliography; Expert Survey Report)
2) 25-25-113 Consideration Reports.zip (6)
3) 25-25-113 Case Studies.zip (7 studies; 4 documents)
4) 25-25-113 Project Summary Report.pdf
5) 25-25-113 Presentation.pptx
6) 25-25-113 Repository.zip (image and design files; index to files; instructions to find and access files)

II. DESIGNATED AND NON-DESIGNATED CROSSING STRUCTURES

This document summarizes the current state of practice, design considerations, and research needs for designated and non-designated crossing structures and barriers for small animal species and is based on the literature review, expert survey, consideration documents, and knowledge and experience of the authors. The literature review with Annotated bibliography, expert survey, consideration reports, and case studies are available as separate documents produced for this project (NCHRP 25-25, Task 113).

A. SUMMARY

Based on the expert survey, designated crossing structures were the most common method for providing safe crossing opportunities across roads for all small animal species groups (70% of the respondents). In some cases (4% of respondents), amphibians and reptiles were actively carried across roads. Based on the literature review, designated crossing structures were primarily implemented (72% of the time) as part of general road construction or reconstruction. Structures were mostly implemented when a road bisected habitat used by a rare species or the road bisected a natural area, regardless of whether it was formally protected.

Designated crossing structures were most often installed for amphibians and reptiles followed by small terrestrial mammals. Underpasses were more commonly installed with a bottom, but in 20% of the cases, bottomless structures were installed. Open-top tunnels were installed 45% of the time compared to closed-top tunnels, primarily for amphibians and reptiles. Cover was added to the structures 52% of the time.

Existing non-designated structures that were installed for other purposes than the passage of small animal species (e.g., hydrology, large mammal passage, or motorized vehicle use) can, depending on the location, dimensions, and other factors, also serve as a safe crossing opportunity for small animal species. Such non-designated structures were monitored for small animal species in 25% of the studies reviewed.

Drainage culverts can be effective passages for amphibians and turtles, and when dry for terrestrial small mammals. Passage for terrestrial (small) mammals can also be accommodated through a dry pathway on the ground, primarily for structures with a height or width greater than 3 meters [m], or shelving above water levels for structures where height or width was less than 3 m. Other modifications to both non-designated and designated structures included addition of cover or natural substrate, creation of water pools at or near the entrances, and the implementation of a suitable path (fine substrate, flat) through rip rap on a steep slope (e.g., through larger rocks and boulders implemented to stabilize a stream or river bank).

Maintenance issues were mainly a concern for structures designed or modified for amphibians and reptiles. This included flooding of the structures, accumulation of road salt and other pollutants, garbage, and debris from vegetation. Several respondents reported vegetation overgrowth at structure entrances. In two cases, beaver exclusion screens were removed to create functional passage for turtles. In some cases, rip rap (e.g., larger rocks inside and at entrances to structures) inhibited movement of small animal species and trapped tortoises and amphibians. In three cases, overpasses were at least partially designed or completely designed for small animal species: amphibians in the Netherlands; snakes in Canada, and small animals in Washington state.

In the literature review, almost all the studies (49 of 57 or 86%) monitored the crossing structures for use by the target group(s) or species. In the expert survey, crossing structures were monitored 77% of the time, but effectiveness at reducing the barrier effect was unknown in 48% of cases.

Multiple techniques were used to monitor amphibian and reptile movements along barriers or at crossing structures: e.g., pit-fall traps, Passive Integrated Transponders (PIT) tags, tracking (e.g., sand, marble dust, "ink" pads), fluorescent pigments, and cameras (active, motion, and time-lapse). Cameras were most often used to monitor small mammal usage of tunnels; however, other methods included tracking with paper, telemetry, and trapping with fluorescent dye. Monitoring was most often conducted for three seasons after crossing structures were implemented.

B. DESIGN CONSIDERATIONS

- Crossing structures can provide habitat connectivity, but they do not necessarily reduce road mortality. Barriers (fences or walls) can reduce road mortality and can guide or funnel animals to the crossing structures. Therefore, as a general rule, always consider including barriers and connecting them to the crossing structures.
- The length of a structure (i.e., road width) is negatively correlated with passage, especially for amphibians and small mammals. Therefore, consider increasing the width and/or height of a structure for wider roads. Alternatively, create two separate structures, one for each travel direction, with an open median in between. The fenced median may also serve as a "resting" place before the animals proceed to the second structure.

- Small animal passage was positively correlated with cover, especially for small mammal species. Consider keeping or implementing cover at the entrances and inside the crossing structures. However, care must be taken at structures that also have a hydrology function; cover should not reduce or block water flow.
- The temperature inside structures should be similar to that of the surroundings, especially for amphibians, snakes and turtles. To achieve this, consider wider, taller, and shorter structures, and skylights or openings in the top of the structure (e.g., slots or grates).
- Light inside underpasses is important and can be provided through skylights, openings in the top of the structure (e.g., slots or grates), or through two separate structures, one for each travel direction, with an open median in between.
- High water velocity inside structures can inhibit movement of small animal species including amphibians. Consider providing dry refugia (e.g. boulders that stick out above the water level), and a structure that is sufficiently wide and tall to also have riparian and terrestrial habitat along the sides of the stream or river.
- Structures need to accommodate a sufficiently high enough number of small animals to pass to maintain connectivity and to ensure population viability. This can be achieved by building the structures in the correct location, having enough structures, and having the right dimensions. While this concept applies to all species, this is perhaps best illustrated by amphibian and snake species that have mass spring or fall migration between their winter habitat and breeding habitat and need to have many individual animals move from one side of a road to the other side of the road in a very short time.
- Crossing structures should be level with surroundings; animals should not have to “climb up” into a structure or “descend” out a structure. This ensures a better “line of sight” through the structures for the animals that approach, and it also ensures that substrate and soil humidity inside the structures are similar to that of the immediate surroundings.
- Location in relation to habitat and relatively short distances between crossing structures (e.g. several dozens of meters at the most for many amphibian species) are extremely important. Consider the home range size and daily (or nightly) travel distances of the target species when deciding on the appropriate interval between crossing structures. Also consider elevating a road when it is practical and feasible, and when the known crossing hotspot is reoccurring and an adequate distance.
- Structures need to be maintained to ensure that the requirements of the species continue to be met (e.g., soil, water, vegetation, cover) and allow permeability, e.g. free of obstruction to movements of the target species. Maintenance efforts can be reduced by integrating routine protocols and referring to best management practices for beaver management, e.g., pond leveler pipes.

C. RESEARCH NEEDS

Dozens of survey respondents thought more research (especially monitoring of effectiveness) was required to inform best practices for implementation of designated wildlife crossing structures for small animal species. In addition, respondents thought more research and subsequent recommendations were required to modify existing non-designated structures to facilitate passage by small animal species. The highest priority is for reptiles, followed by amphibians, and finally small mammals. Research needs as formulated by the respondents to the survey:

- Evaluate whether target species move through crossing structures during essential periods of their life cycle (e.g., juveniles during dispersal periods, and adults during breeding periods).
- Evaluate if both male and females of a target species are crossing through structures.
- Evaluate crossing structure use up to at least five years or five seasons to cover a potential "learning period" for the animals regarding the location of the structures and how to access them, and to monitor potential changes in population size after the mitigation measures were implemented.
- Evaluate the importance of structure dimensions (height, width, and length) and modifications to existing structures originally built for other purposes with regard to use by small animal species. Examples are varying cover and substrate, open-top versus closed-top, and open-bottom versus closed bottom. Develop experimental approaches for appropriate design characteristics of the crossing structures
- Formulate hypotheses and implement study designs that allow researchers to measure if the barrier effect has been reduced as a result of the implementation of the crossing structures. Move beyond assessing the use of crossing structures and evaluate effectiveness (e.g., through Before-After-Control-Impact study designs).
- Improve methods for detecting cold-blooded animals such as amphibians and reptiles using crossing structures (e.g., through break-the-beam triggers associated with a camera (e.g. Hobbs and Brehme, 2017), time-lapse systems that have sufficient power supply, software that focuses on identifying animals in images (to differentiate from the many images that do not show animals), and detection methods that work in or under water (e.g., for turtles).

III. BARRIERS

This section summarizes the current state of practice, design considerations, and research needs for exclusion barriers for small animal species. This summary is based on the literature review, the expert survey, the consideration reports, and the knowledge and experience of the authors. The literature review, expert survey and consideration reports are available as separate documents produced as a part of this project (NCHRP 25-25, Task 113).

A. SUMMARY

Barriers such as fences and walls were the most commonly implemented measure to mitigate road mortality for amphibians, reptiles, and small mammal species. Outreach and warning signs were also regularly implemented. Barriers were most frequently installed for reptiles, followed by amphibians and small mammals. In most cases, effectiveness of the barriers was unknown or not measured.

Woven wire (reptiles) and plastic sheets (amphibians) were the most commonly used materials for barriers. Multiple, diverse materials were used for small mammals, but chain-link or woven wire were the most common fence materials. Chain-link and plastic sheets were deemed the most effective. Concrete barriers were used in six cases to exclude small animal species from roads.

A climbing deterrent was installed at the top of the barrier most often for amphibians (53%) followed by reptiles (46%) and small mammals (33%). In 92% of the cases, the barrier was buried in the ground to stop animals from digging or crawling under the barrier.

The average length of road with a barrier on both sides was 2.05 miles (3.3 kilometers [km]) with a minimum of 0.19 mile (0.3 km), a maximum of 18.8 miles (30 km) and a standard deviation 4.2 miles (6.7 km). Barriers were most often shorter than 0.62 mile (1 km) long for amphibians (43% of the time) and most often longer than 3.1 miles (5 km) for reptiles (37% of the time).

Forty-four of the studies that had installed barriers reported an issue or concern within an average of 2.2 years after barrier installation. Continuous maintenance was required as a result of poor design, installation, vandalism (e.g., trampling by all-terrain vehicles), mowing practices, holes, washouts caused by erosion, snow and ice damage, fallen trees, and vegetation overgrowth. In 17 cases, the barrier material was not suited for the target species, and at some sites the barrier material was replaced after initial installation.

When the effectiveness of the barriers was monitored (67% of the time), presence of both live and dead animals on the road were measured 85% of the time. A control transect was included in the study design 42% of the time. For all study designs reviewed in the literature, 23 studies reported an average road-kill reduction of 65% (minimum 16%, maximum 100%, standard deviation 31%). Fencing ineffectiveness was primarily caused by gaps in the fence, washouts or barrier deterioration, or animals crossing at or beyond the fence-ends. In some cases, animals were able to climb over or move under the fence, e.g., at washouts or through digging.

B. DESIGN CONSIDERATIONS

- Effective barriers reduce road mortality and make the road corridor into a near absolute barrier for the target species. Therefore, as a general rule, always include safe crossing opportunities for the target species when implementing a barrier. The location, spacing and dimensions of the crossing structures should be designed for the target species.
- Barriers are often too short; they do not completely cover the roadkill hotspot and animals still access the road at or beyond the fence-end. Barriers should cover the entire length of a road mortality hot spot and an adjacent buffer zone.
- Barriers are most likely to be effective at locations where target species predictably cross in the same location every year. Prioritize the installation of barriers along road sections that have shown a consistent mortality problem over many years to minimize the risk of mitigating the wrong road sections.
- Partial barriers (i.e., barrier on one side of the road or with gaps) are typically not effective. Implement barriers on both sides of a road and start and end the barriers at the same location

on opposite sides of the road when suitable habitat or terrain exists (i.e., no staggered fence ends).

- Effective barrier-end treatments are required to reduce fence-end mortality. The best fence-end treatment is to extend a fence beyond the road crossing hotspot (e.g., adjacent buffer zone), and to tie the fence-end into an approporate feature, such as a concrete bridge abutment, or rock cliff. If this is not possible, then, technical designs such as curved ends that limit crossings at or immediately beyond a fence-end are advisable.
- Amphibians and reptiles that walk alongside barriers can overheat. Consider implementing a component such as shrubs, cover objects, or overhangs in the barrier that provide shade.
- Amphibians have been observed walking by crossing structures. When animals cannot move far, e.g. amphibians, the location of the barriers and guide-walls are extremely important to reduce the movement distance of the animals and to maximize crossing structure use.
- Barrier walls or fences that are integrated into the roadbed e.g. below-grade may allow animals to escape to the safe-side of the barrier along its length. When barriers or fences are above ground, proven designs for jump-outs or other escape opportunities should be considered.
- Fence effectiveness is reduced e.g. road mortality occurs at gaps in barriers at intersections, access roads, driveways, and private property. Consider effective treatments such as passages or grates and barriers at these gaps to reduce animal breach locations.
- Barriers are often compromised with high water levels and wash-outs from below ground weater flow especially when barriers are near the road pavement surface. Consider effective placement of barriers, selection of materials, and installation methods to reduce water flow impacts.
- Some animal species (e.g., snakes) can use vegetation that grows adjacent to barriers to climb over barriers. Therefore, consider vegetation maintenance close to the barriers to reduce the likelihood of animals breaching the barriers.
- Barriers on steep slopes or near the road shoulder are more likely to be affected by erosion, resulting in substantial gaps and breach points. Carefully consider the location of barriers on slopes with regard to potential erosion.

C. RESEARCH NEEDS

- Develop innovative and robust barrier designs and installation methods for specific animal groups and species at reduced costs. Barriers need to be designed so that they are both highly effective and require no or minimal maintenance.
- Develop alternative mitigation strategies for birds and arboreal species because traditional barriers are not effective for non-terrestrial animals. Avian scavengers that feed on road-kill are a specific concern. This may be, at least partially, addressed through frequent carcass removal.

- Investigate effective designs of jump-outs or escape ramps for specific target species.
- Evaluate the effectiveness of other mitigation strategies aimed at reducing direct road mortality for small animal species such as awareness, signage, and animal detection systems designed for small species.
- Combine road mortality (and connectivity) studies with information on the population size of the target species.
- Improve safety protocols for people who help carry animals across roads (e.g., during mass spring migration of amphibians).

IV. OVERALL RECOMMENDATIONS

The costs for oversight during construction, maintenance, monitoring, and adaptive management of barriers and crossing structures should be integrated into the project costs by the responsible road authority or developer. If these costs are not budgeted for, mitigation measures may be installed incorrectly compromising effectiveness. Further, monitoring will allow adaptive management measures to be implemented, and routine maintenance will ensure effectiveness. Coordination is required between multiple agencies, and those charged with construction, maintenance personnel, and monitoring during the planning, construction, and monitoring phases.

Compared to large mammals, small animal species move more slowly over shorter distances and require specialized habitat and physiological conditions in both aquatic and terrestrial environments. This has consequences for the design and implementation of measures aimed at reducing road mortality and at maintaining or improving habitat connectivity. The location of crossing structures and the interval between structures must be carefully considered in relation to the home range, daily (or nightly) movement distances, and adjacent suitable habitat.

Structures that best fulfill the abiotic and biotic needs for small animal species are structures that provide consistent and homogenous microhabitat conditions (e.g., temperature, substrate, light, and vegetation) required by the target species. This is more easily provided with overpasses and/or large open-span bridge and perhaps with open-slot and open bottom shorter tunnels.

Non-designated, existing structures built for other purposes can also provide safe crossing opportunities for small animal species. These may include small (< 9.8 feet [3 meter]) drainage culverts but larger box culverts and span bridges; and structures built for livestock, recreation, or large animal passage are ideal because they are generally large in size and able to accommodate suitable microclimates. Additional modification to facilitate use may be best implemented during structure upgrades or replacements, e.g., concrete bench or walkway or skylight/grates in smaller structures. Other modifications may or may be retro-fitted into an existing larger structure, e.g., added shelf, cover objects, or substrate. Other modifications may include providing dry refugia such as boulders or altering the water flow through a structure with baffles. Multi-species considerations for both dry and wet passage can be accommodated with installation of concrete, metal or wood shelving, rails, or benches.

Barriers need to cover the entirety of road mortality hotspots and adjacent buffer zones and they should be connected to suitable crossing structures with guide-walls. Barrier design and installation must be suited to the terrain, target species, and subsequent maintenance protocols. Barriers must consider potential breach points such as fence-ends or gaps due to access roads to be effective. When animals breach a barrier, jump-outs and other escape measures are required to allow passage back to the safe-side of the exclusion barrier.

Although maintenance may be the responsibility of road maintenance contractors, it is often conducted by research personnel during monitoring assignments, primarily because enforcement, coordination, and education between road agencies and maintenance contractors does not occur. For example, a review of 24 crossing projects in the Netherlands found that most of the fencing was overgrown with vegetation or damaged from mowing equipment or vehicle strikes and had not been maintained (Cremers and Struijk 2012). Best practices include educating and managing roadway maintenance staff to ensure that crossings and barriers are properly maintained.

When routine and thorough maintenance is not secured for a mitigation project, it is especially important to properly install the most durable and robust measures. Several designs for barriers should be considered because different materials and installation methods may be required along varying terrestrial and wet terrain. Concrete barriers, with drainage allowance have been shown to need minimal maintenance and can be cost-effective in the long run due to dramatically reduced maintenance requirements.

V. REFERENCES

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