Western Toad Roadkill Mitigation in Kentucky-Alleyne Provincial Park, July – August 2014

Prepared for

BC Parks, Thompson-Cariboo Region

Biolinx Environmental Research Ltd[1]. and Nicola Naturalist Society[2]

[1]1759 Colburne Place, North Saanich, BC V8L 5A2
250.655.4602; info@biolinx.ca

[2] P.O. Box 2539, Merritt, BC V1K 1B8
nicolanaturalists@gmail.com

DECEMBER 2014

ACKNOWLEDGEMENTS

This project was conducted within the framework of an ongoing community-based amphibian monitoring program by Nicola Naturalist Society and Biolinx Environmental Research Ltd. Contributions from Nicola Naturalist Society included the following: Andrea Lawrence coordinated volunteers and conducted surveys; Alan Burger designed the drift fences and together with Ted Cederland and Chris Lepsoe built the fence sections; Sheila Curnow, Ted Cederland, Ken Davis, Chantelle Forseille, Liis Jeffries, Dave, Marg and Nolen Kerridge, Chris Lepsoe, Dakota, Sunshine and Megan O'Donovan, Ginny and Niah Prowal, Gail and Dana Smith, and Michelle Wiebe provided able and enthusiastic field assistance. Special thanks to the Kentucky-Alleyne camp operators Teresa and Derek Wood for their advice and help with the project. Kristiina Ovaska, Lennart Sopuck, and Christian Engelstoft of Biolinx Environmental Research Ltd. conducted site visits, analyzed and consolidated data, and prepared this report. Purnima Govindarajulu and Barb Beasley shared with us their experiences with amphibian road crossing structures and provided useful information.

We are grateful to Sarma Liepins, Bruce Petch, and Mike Friars from BC Parks, whose support was invaluable and made this project possible. Sarma Liepins acted as our contact with BC Parks and helped with logistics, including providing materials for the drift fence; we greatly appreciate her support, encouragement, and dedication. Leonard Sielecki from BC Ministry of Transportation generously provided time-lapse cameras for our use.

The underpass structure was donated by BC Timber Sales and procured, repaired and installed under the supervision of BJ Moore of the Ministry of Forests, Lands and Natural Resource Operations.

Funding for the project came from the Parks Enhancement Fund to Nicola Naturalist Society and from Habitat Conservation Trust Fund to Biolinx Environmental Research Ltd.

Cover photo: K. Ovaska, collage of two images (not to scale).

Funded by: Parks Enhancement Fund and Habitat Conservation Trust Fund

Table of Contents

EXECUTIVE SUMMARY

Kentucky-Alleyne Provincial Park contains a communal breeding site of the Western Toad (*Anaxyrus boreas*), a species listed as Special Concern in Canada and on Schedule 1 of the federal *Species at Risk Act*. Tens of thousands of juvenile toads migrate from the breeding (West Pond) into the surrounding forest in late July – early August. In May 2013, BC Parks installed an underpass on the park road leading to the Kentucky Lake campsites, where previous monitoring results indicated that large numbers of juvenile toads were killed. Drift fences lead the toads from the breeding pond into the underpass (a semi-cylindrical half culvert) and then into the forest on the other side of the road. In 2013, both time-lapse camera data and observations by Nicola Naturalist Society volunteers indicated that toadlets used the underpass extensively, but some circumvented the fences and were killed. In 2014, we refined the design of the drift fences to make them longer lasting and continued monitoring the effectiveness of the structures in reducing roadkill.

As in previous years, the toadlet migration across the Kentucky Campsite road took place over a short period in the last week of July and first week of August. In 2014, toadlets were first detected crossing the road on 23 July, five days later than in 2013, but as in 2013, most of the toadlets had crossed the road by 3 August. The timing of movements corresponded with the pattern of rainfall.

In both 2013 and 2014, toadlets entered the underpass with no apparent hesitation. Its large diameter (180 cm), earthen floor, and relatively short span (366 cm), probably contributed to its attractiveness. In 2014, an unknown proportion of the toadlets entered into the forest towards the north and east of the pond, where they did not need to cross roads. This pattern was in contrast to 2012 and 2013, when almost the entire migration was to the south and southwest and across the park road leading to the Kentucky Lake campsites. A substantial number, however, did move in these directions in 2014 and were funneled into the underpass. A total of 2,804 toadlets were counted from time-lapse camera images at the entrance of the underpass; the corresponding number in 2013 was 7,481 toadlets. Direct observations by volunteers during 19 days from 19 July to 8 August 2014 resulted in a count of 888 toadlets at the tunnel entrance and 1026 toadlets at the tunnel exit. Toadlets appeared to use the tunnel as a refuge during the night, accounting for somewhat higher numbers observed leaving than entering the tunnel, especially in the morning counts. Both the camera data and direct observations represent snapshots in time but provide an index of the numbers of toadlets using the underpass.

The actual numbers are unknown, but very rough estimates, making several assumptions about detectability of live and dead toadlets, suggest that the proportion of

toadlets using the underpass might have been in the range of 55 – 75% in 2014 and 77 – 87% in 2013 of all toadlets migrating to the south and southwest. Roadkill was similar in both 2014 and 2013 and might have represented 5% or less of the toadlets given similar assumptions; it resulted largely from some toadlets circumventing the end of the drift fence in the east, closest to the breeding pond. Comparisons of the pattern of mortality in 2013 and 2014 with that in 2012 before the underpass installation show a reduction in roadkill in the vicinity of the underpass but somewhat higher mortality to the east towards the campsites. Direct comparisons with data from 2012 are complicated by (a) lower search effort in 2012, including reduced efficiency of camera counts without the tunnel and less frequent transect surveys, (b) apparent lower overall numbers in 2012, and (c) wider spread and use of more eastern migration routes in 2013 and 2014 probably associated with a larger migration, as also anecdotally observed in the past. However, both the model results and observations show that significant numbers crossed the road safely using the underpass.

In July and August 2014, 19 volunteers spent a total of 200 hours constructing and inspecting drift fences, counting toads along transects, opportunistically searching other areas of the park for toads, and explaining the project to park visitors. The underpass was highly effective as an outreach tool and generated much interest from park visitors, drawing attention to the problem of amphibian roadkill and its responsible management.

Recommended activities for 2015 include completion of the information sign explaining the need for the underpass and fencing by BC Parks, inspection of the condition of the drift fences in early spring, repair of any possible damage, and construction of one-way ramps to allow adult toads easy access the pond. We suggest continued monitoring with a time-lapse camera at the entrance of the underpass and periodic visits to the sites to assess the timing of the migration and predominant movement direction. BC Parks should consider continuing with temporary closures of paths around the breeding pond during the peak toadlet migration period and erecting interpretive signage. BC Parks is expected to assume responsibility for maintaining the underpass structures and the required monitoring over the long term. The new semi-permanent wood fence developed and installed as part of this project greatly facilitates further maintenance requirements.

1.0 INTRODUCTION

Roadkill is a significant cause of mortality for a variety of wildlife inhabiting human-modified landscapes (Fahrig and Rytwinski 2009). The problem of road mortality on herpetofauna (amphibians and reptiles) in British Columbia is gaining increasing attention and was addressed at a recent conference held at the Vancouver Island University (Herpetofauna and Roads 2011). Road mortality has been assessed as a threat for almost all the herpetofaunal species listed to be at risk in BC (Govindarajulu 2011). Amphibians are slow-moving and particularly vulnerable where roads intercept their seasonal migration routes between aquatic breeding sites and upland foraging areas.

The Western Toad (*Anaxyrus boreas*) is listed as "Special Concern" in Canada by COSEWIC (2002, 2013) and is on Schedule 1 under the federal *Species at Risk Act*. The toads are vulnerable to roadkill during their migrations to and from aquatic breeding sites and upland foraging and hibernation areas.

Western Toads breed communally in one of the ponds (referred to as West Pond) between the two main lakes in Kentucky Alleyne Provincial Park (Biolinx Environmental Research and Nicola Naturalist Society 2012, 2013). Newly transformed toadlets leave the pond *en masse* in late summer during the peak visitor period and cross the park road leading to the Kentucky Lake campsites, where they are subject to roadkill. Migration of adult toads to the pond is not impeded by the road, as park is closed when this takes place in May. Mitigating roadkill in the park not only helps conserve the local toad population but also emphasizes the importance of mitigating human impacts on biodiversity and show-cases actions taken by the park.

In May 2013, BC Parks installed a wildlife underpass in the park based on previous monitoring of toad movements (Biolinx Environmental Research and Nicola Naturalist Society 2012). Follow-up monitoring was conducted in July – August 2013 to investigate the effectiveness of the underpass in facilitating toad movements (Biolinx Environmental Research Ltd. and Nicola Naturalists 2013). In July – August 2014, we refined the drift fence structures leading toads in and out of the underpass and continued monitoring the effectiveness of the structures. The project was conducted within the framework of a broader community-based amphibian monitoring program started in the area in 2011 (Ovaska *et al*. 2012, 2013, 2014).

2.0 OBJECTIVES

The objectives for 2014 were as follows:

- Design and install more permanent drift fencing leading toads to and from the underpass
- Monitor the effectiveness of the drift fences and use of the underpass by newly metamorphosed toadlets during their migration away from the breeding pond.
- Monitor roadkill mortality with focus on the previously identified travel route across the park road leading to Kentucky Lake campsites.
- Examine possible entrapment or predation events associated with the underpass and drift fencing.
- Provide recommendations for further monitoring and refinements of the structures.

3.0 METHODS

3.1 Underpass and drift fences

On 6 May 2013, BC Parks installed an underpass across the paved park road leading to the Kentucky Lake campsites. The underpass consisted of a semi-cylindrical "half-culvert" with an earthen floor (length: 366 cm; width at ground level: 180 cm; height of opening: 50 cm; height from top of opening to road surface: 30 cm). The tunnel was placed in a natural depression along the toad migration route, as determined previously (Biolinx Environmental Research and Nicola Naturalist Society 2012).

In July 2013, Nicola Naturalist Society volunteers, with help from Biolinx Environmental Research Ltd. biologists, installed temporary drift fencing intended to direct toads from the breeding pond to the underpass, and once through the underpass, away from the road and into the forest (Biolinx Environmental Research and Nicola Naturalist Society 2013). While the temporary drift fencing, constructed of landscaping cloth and supported by wooden stakes, was effective in channeling movements of toadlets, it would require reinstallation each year. In 2014, we experimented with a more durable fence design that would require only minimal maintenance and attention each year (Figure 1; see Appendix 1 for details of the new fence). In addition, fencing closest to the pond (east arm) was extended by 15 m (from 61 m to 76 m) and the other fence of the funnel (north arm) by 32 m to include more toadlets into the drift fence funnel catchment area, as suggested by monitoring work in 2013 (Biolinx Environmental Research and Nicola Naturalist Society 2013).

Figure 1. Drift fencing used in 2014 to funnel toadlets from the breeding pond uphill and through the underpass safely across parks road into the forest on the other side.

3.2 Transect surveys

To determine the effectiveness of the underpass and drift fence system in directing toadlets safely across the road, Nicola Naturalist Society volunteers conducted surveys along the road and at the tunnel entrance and exit. Toadlets within approximately 2 m from the tunnel entrance and exit were counted from the road. In addition, observers checked the ends of the drift fences from the pond and counted toadlets visible inside and outside of the fence. Surveys were conducted from 19 July to 13 August 2014, with multiple surveys per day during the peak migration period.

As in 2012 and 2013, a 180 m long transect was established along the park road leading to the Kentucky Lake campsites (referred to as Kentucky Campsite Road) to monitor roadkill. Toads (live and dead) encountered on the road surface were counted within each 10 m section of the transect; the location of each dead toad was marked with white chalk to avoid double counting during subsequent surveys. In 2014, road counts of toadlets were also conducted from the end of the transect to the end of the Kentucky Campsite Road, using campsite numbers as section markers (adding a 431 m stretch of road to the 180 m transect; see Appendix 2 for survey times and conditions along the road transects). The observers also sporadically checked other areas of the park, including boat launch and beach areas along Kentucky Lake.

3.3 Time-lapse cameras

A time-lapse camera (Reconyx PC900), loaned to the project by the Ministry of Transport, was used to monitor the timing of toadlet migration and their use of the underpass, from 20 July to 15 August 2014. The camera was placed at the entrance to the tunnel in a tree, facing downwards (Figure 2). The camera view covered about half of the tunnel entrance; a higher position that would have shown the entire entrance was not feasible because of the small size of the toadlets, impeding their detectability in images taken from farther away. We did not use a camera at the exit of the tunnel this year because no suitable attachment sites existed and because herbaceous vegetation would have obstructed a clear view. It was felt that direct observations during road surveys would establish whether toadlets that entered the tunnel would move through it, as found in 2013.

The camera was set to take an image every 15 min throughout the 24 h period. This interval was deemed appropriate to provide an index of numbers of toadlets using the tunnel during different times. Because the toadlets generally moved continuously towards the tunnel, the subsequent images probably largely represent different individuals, although a few individuals that lingered at the entrance may have been double-counted. The images were analyzed by flipping back and forth between subsequent images to improve detection and counting the number of toadlets at the

images. In addition to time-lapse, the camera motion sensor was set to monitor activity by potential predators and human disturbance.

Figure 2. Location of the surveillance camera at the tunnel entrance on the park road leading to campsites along Kentucky Lake.

4.0 RESULTS

4.1 Timing of life history activities and toadlet migration

In spring 2014, mating and egg-laying by Western Toads in the West Pond took place in early May, up to two weeks earlier than in 2013. On 3 May, approximately 20 pairs were seen in amplexus (mating position) with additional 20 – 30 unpaired adults swimming in the water. Most toads were in the narrow hour-glass "neck" of the pond, but some were at its south end. On 5 May, masses of toad egg strings were observed at two sites in the pond: an approximately 1 x 5 m area just north of the hour-glass narrows and 1 x 8 m area at the south end. Communal egg-laying is typical for Western Toads with females laying their eggs in small traditionally used areas of a wetland, often on top of eggs of other females, resulting in large, tangled masses of egg-strings (COSEWIC

2013). The toads and the egg masses are extremely vulnerable to disturbance at this time. Masses of small tadpoles (1 – 2 cm in total length) were noted on 25 May, and large aggregations of tadpoles were seen in early summer until metamorphosis took place in mid-July.

The start and end dates of regular surveys of the toadlet migration were determined from reconnaissance checks at the breeding pond. Metamorphosed toadlets typically congregate on the shoreline before moving *en masse* away from the pond (COSEWIC 2016). On 17 July 2014, such congregations were first seen along the grassy shoreline of the breeding pond up to 2 m from water; large tadpoles with fore- and hind-limbs were also observed. On 19 July, tens of thousands of toadlets were aggregated along the shoreline, and some had started moving away from the pond, crossing paths encircling the pond; no tadpoles were seen at this time. Interestingly, most toadlets were initially concentrated at the northeast side of the pond (by the children's fishing beach), rather than at the south and southwest of the pond as in 2012 and 2013. On 19 July, on suggestion from Nicola Naturalist Society, BC Parks installed sensitive area signage and closed selected paths by the pond where toadlet movements were noted.

In both 2013 and 2014, the toadlet migration across the Kentucky Campsite road took place over a short period in the last week of July and first week of August (Figure 3). In 2014, toadlets were first detected crossing the road on 23 July, five days later than in 2013. As in 2013, most of the toadlets had crossed the road by 3 August, based on camera data at the tunnel entrance.

Movements of toadlets occurred during a wide range of air temperatures (Figure 4). Rainfall, rather than temperature, appeared to be more important in triggering movements. During the survey period, rain fell daily from 19 – 24 July, and again on 1 and 12 August 2014. The rain was light, registering 1 – 4 mm in a rain gauge installed near the underpass, except on 23 July, when 13 mm of rain fell. The rainfall and associated high relative humidity in late July apparently triggered the migration movements.

Figure 3. Timing of toad migration in 2013 and 2014 as determined from time-lapse camera at the tunnel entrance. Arrows represent main rainfall events during the survey periods in the two years.

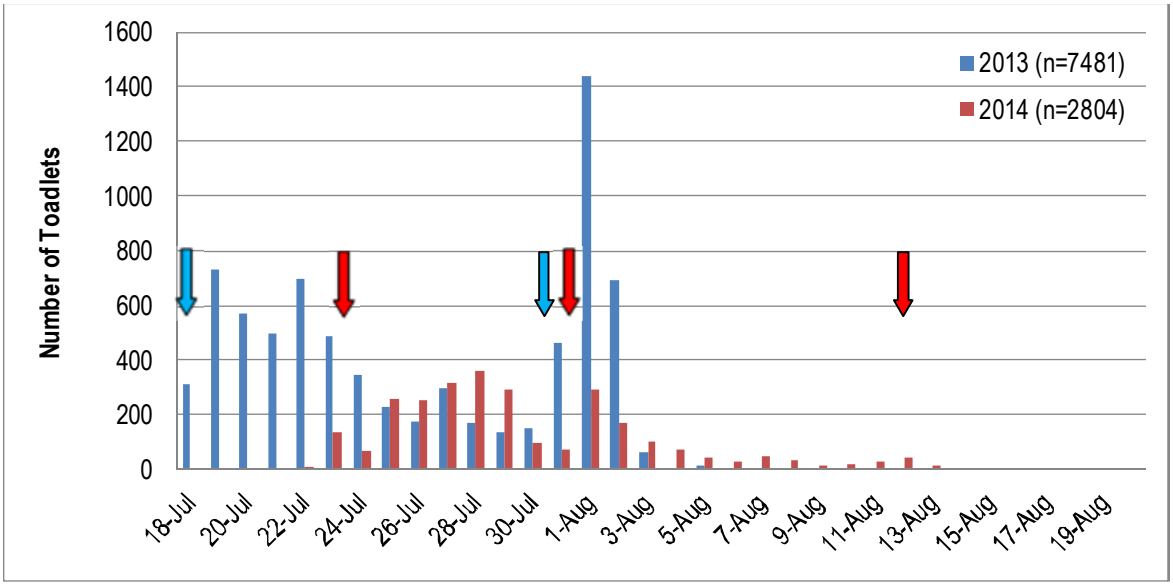
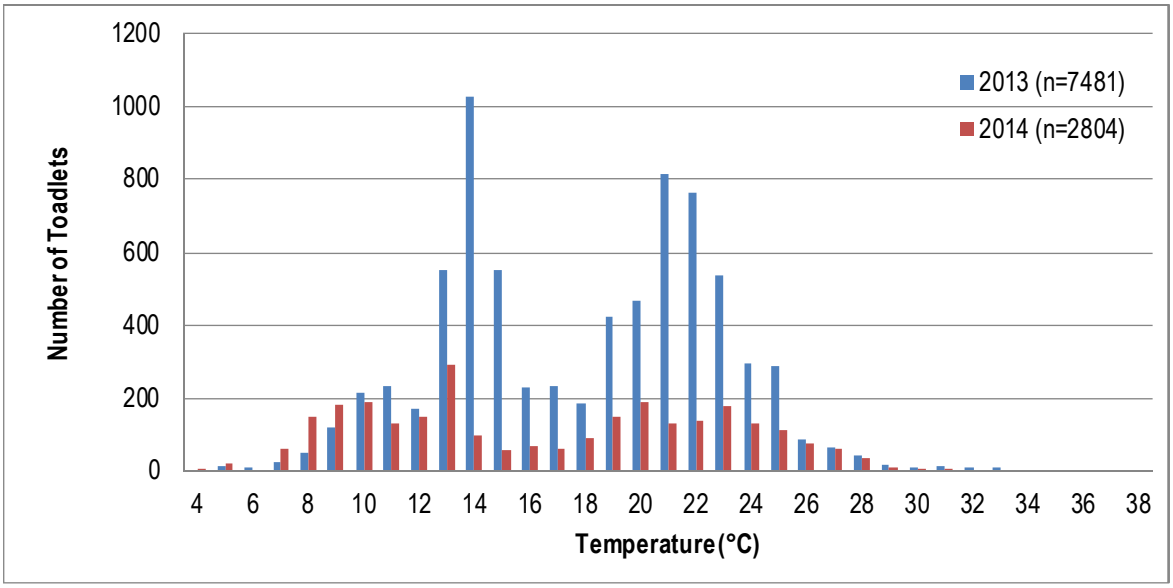


Figure 4. Movements of toadlets in relation to air temperature, as recorded by the time-lapse camera at the entrance of the tunnel in July – August 2013 and 2014.



4.2 Migration movements and use of the underpass

In 2014, there was a large congregation of toadlets on the northeast shore of the breeding pond, and an unknown proportion of the toadlets, likely less than 10% based on regular observations, entered into the forest towards the north and east, where they did not need to cross roads (see Figure 5 for presumed migration directions). This pattern was in contrast to 2012 and 2013, when almost the entire migration was to the south and southwest, and no toadlets were seen massing along the shore at the north and northeast end. The majority of the toadlets, however, did move along the beach south and southwest in 2014 and were funneled into the underpass. The differences among years are possibly due to lower water levels and higher water temperatures at the south and southwest end of the pond in 2014 due to an unusual spring hot spell.

As in 2013, both direct observations and camera data indicated that toadlets used the underpass extensively. A total of 2804 toadlets were counted from camera images at the entrance to the tunnel. This number represents 37.5% of comparable numbers recorded in 2013 (7481 at the tunnel entry in 2013), indicating either that there were fewer toadlets overall this year and/or some used a different migration route, based on the location of toadlet aggregations along the pond perimeter (Figure 5).

Transect counts during 19 days from 19 July to 8 August 2014 resulted in a total count of 888 toadlets at the tunnel entry and 1026 toadlets at the tunnel exit (Figures 6 and 7). These numbers represent snapshots of toadlet activities at the time of the checks but were also lower than similar counts obtained in 2013 (1212 at the entry and 1788 at the exit in 2013) (Figure 7). As also observed in 2013, both camera data and direct observations indicated that toadlets showed no hesitation in entering the tunnel and moved in a highly directional manner. Toadlets appeared to use the tunnel as a refuge during the night, accounting for somewhat higher numbers observed exiting than leaving the tunnel, especially in the morning counts.

A gray Jay was seen and photographed picking up two toadlets at the tunnel entrance in the morning of 27 July 2014. No other predation events associated with the tunnel or fencing were detected, based on direct observations or camera data. The motion sensor images at the tunnel entrance revealed Columbia Ground Squirrels (5 occasions), Snowshoe Hares (7 occasions), Bobcat (1 occasion), vole (1 occasion), and adult Western Toads (2 occasions). In addition, there were children (7 occasions) and dogs (2 occasions) at the tunnel entrance, mostly after the toad migration was over.

Figure 5. Overview of migration movements and roadkill locations of Western Toads in Kentucky-Alleyne Provincial Park in July August 2014. See Figure 11 for a detailed view of distribution of dead and live toadlets on the road.

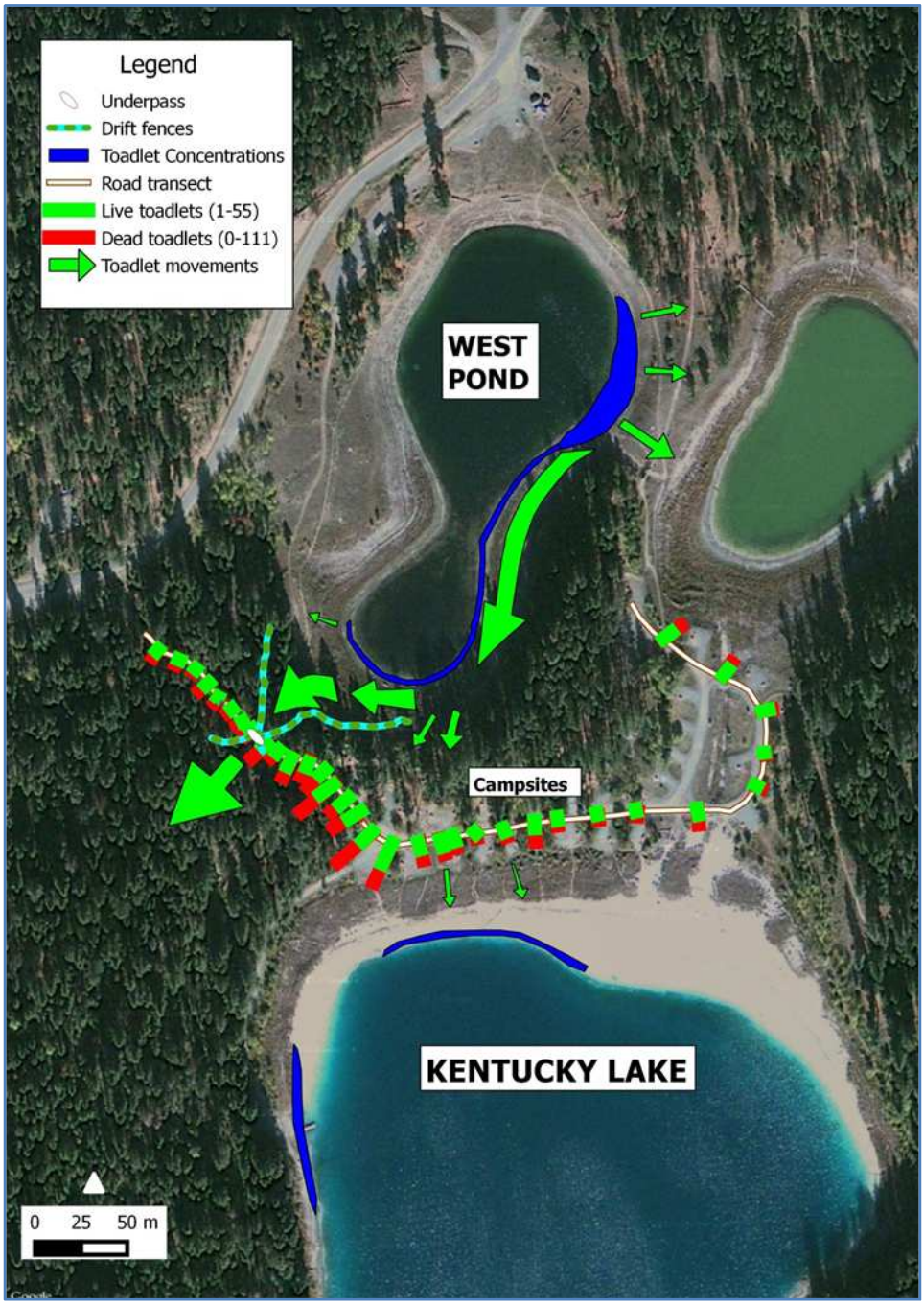


Figure 6. Summary of counts of toadlets at tunnel entrance and exit from transect survey data.

See Figure 3 for corresponding time-lapse camera data at the tunnel entrance.

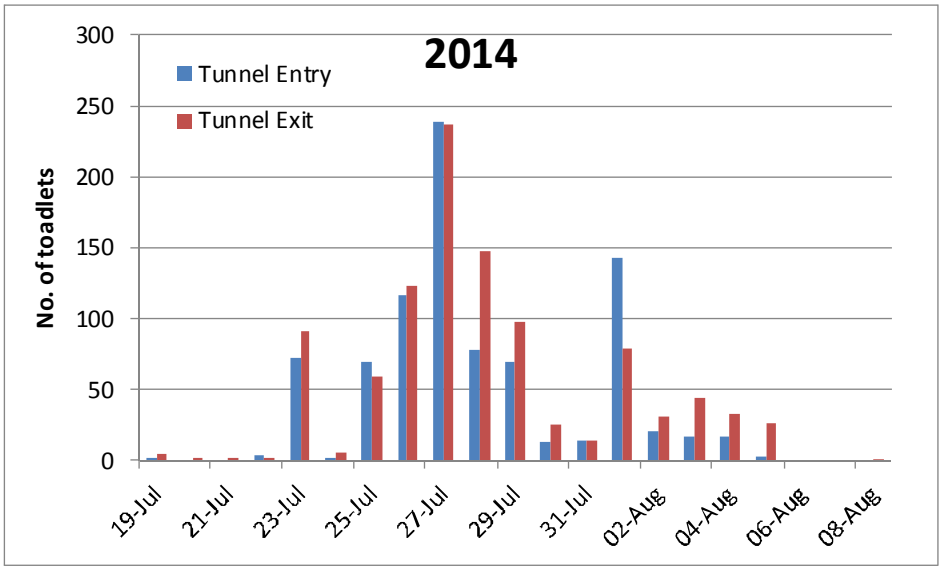
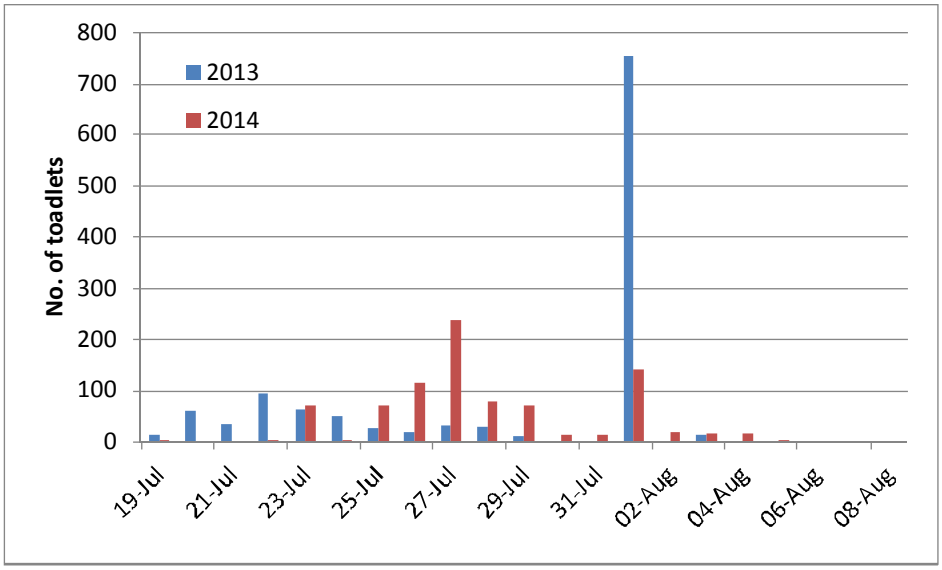


Figure 7. Comparison of counts of toadlets at tunnel entrance between 2013 and 2014 from transect survey data.



4.3 Effectiveness of the drift fencing in channeling movements

The new drift fences effectively directed movements of toadlets towards the underpass, as revealed by observations of their movements. When encountering the fence, toadlets typically did not attempt to climb it but continued moving alongside it in a directional manner (Figure 8). However, some confusion occurred at the end of the fence closest to the breeding pond (east arm of the funnel leading to the underpass), and many toadlets initially ended up on the outer or south side of the fence.

Figure 8. Toadlets moving towards the underpass along the drift fence.

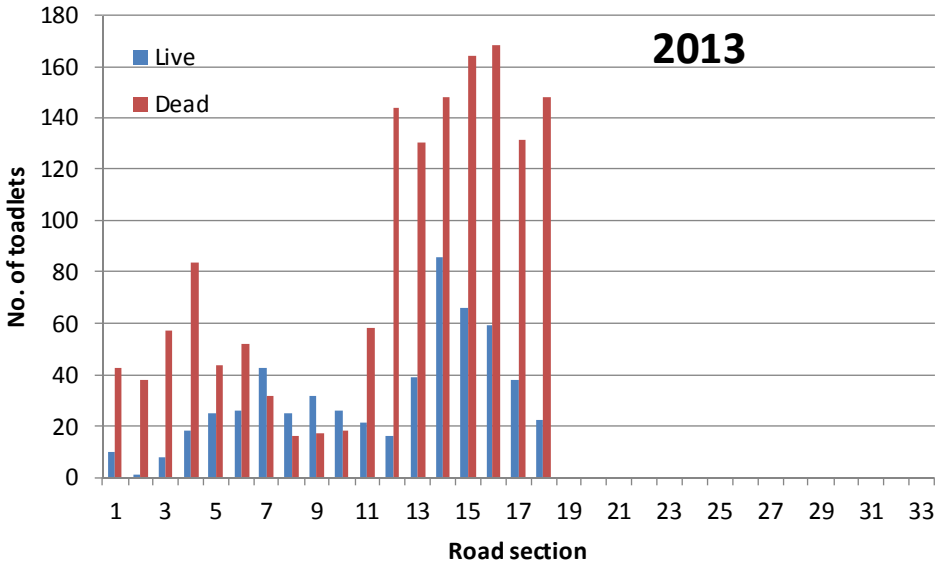
To reduce the rate of bypass by toadlets along the fence near the pond, on 26 - 27 July we constructed two earthen mounds (ramps) against the outside wall of the fence to act as one-way gates, allowing toadlets to move back towards the pond and into the funnel catchment area but not vice versa (Figure 9). The ramps were approximately 20 m and 10 m from the end of the fence, respectively. The toadlets immediately started using the structures, substantially reducing their numbers on the outside of the fence. In the morning of 26 July, before the construction of the first mound, there were about 10 times as many toadlets on the outside than on the inside of the fence, milling up and down, while only about 6% of the toadlets were on the outside of the fence during subsequent checks on the same day following the ramp installation.

Figure 9. Earthen mound against the outside of the drift fence, allowing toadlets access back towards the pond and into the funnel leading to the underpass. Insert shows toadlets on top of the fence, ready to hop down into the catchment area of the funnel.

4.4 Toad movements across the road and frequency of road kill

In total, 920 dead and 627 live toads were recorded during road transect counts on the Kentucky Campsite road in 2014. These numbers represent snapshots of the numbers of toads on the road but probably about 90% of the roadkills were detected. Based on the counts on the first 18 road sections that were consistently monitored, roadkill was less than half (41.6%) in 2014 of what it was in 2013, possibly reflecting reduced overall numbers that used this migration route this year (620 versus 1492 dead toadlets in the two years, respectively). In 2014 and 2013, most of the mortality continued to take place towards the east near the breeding pond, where toadlets circumvented the end of the drift fence (Sections 13 – 18; Figures 10, 11) There were 1254 roadkills counted on this section of the road in 2012, before the installation of the underpass, but the transect was not monitored daily and the migration was smaller that year, so the numbers are not directly comparable. However, comparison of roadkill along the transect monitored before and after underpass installation clearly shows a reduction in mortality at the underpass location (Figure 12). Mortality was somewhat higher towards the east (Sections 12 – 18 in 2013 and 14 – 18 in 2014) after the installation of the underpass, but this shift probably resulted from a shift in migration routes, possibly associated with higher overall numbers of toadlets. As a result some toadlets bypassed the drift fence leading to the underpass.

Figure 10. Counts of toadlets on the road surface of the Kentucky Campsite Road during transect surveys; transects were numbered from west (left) to east (right). Top panel – toadlet counts by date; Bottom panel – toadlet counts by 10 m section of the road from west to east. Note: Sections 19 – 33 were checked only irregularly in 2013 because few toadlets were found.



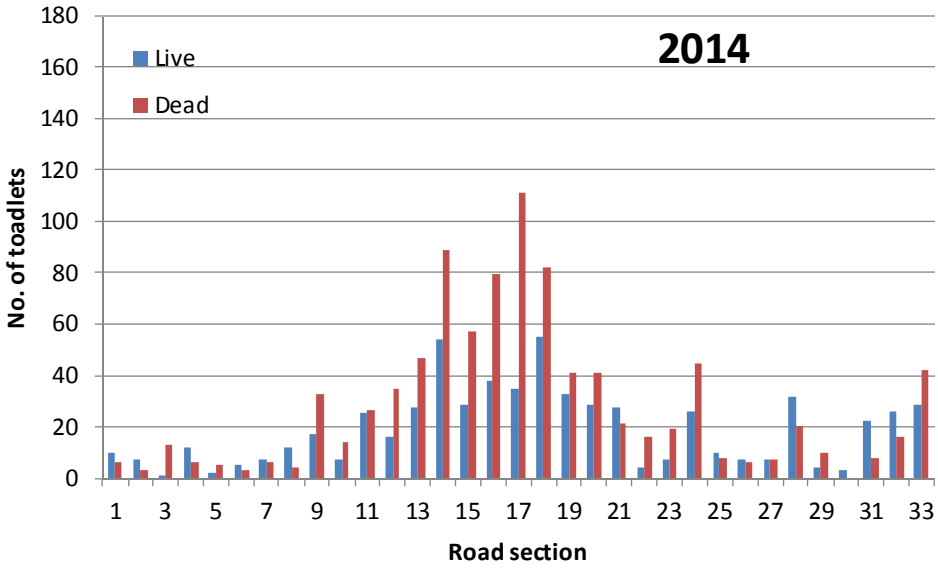


Figure 11. Location of dead and live toadlets based on road transect counts on Kentucky Campsite road in July - August 2014.

The numbers on the north side of the road refer to road transect sections: 1 – 19: 10 m long sections; numbers east of 19: sections of variable length, using campsite numbers as markers (hence non-consecutive numbering)

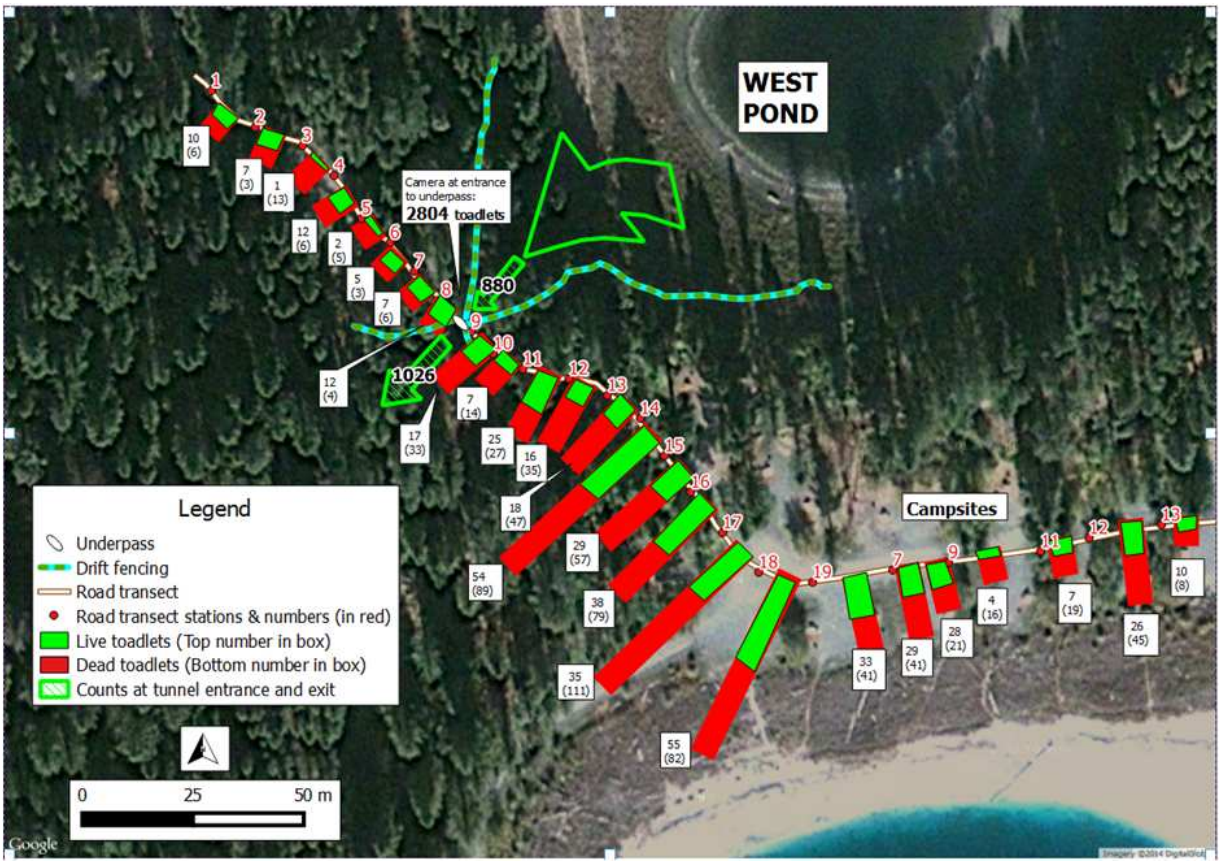
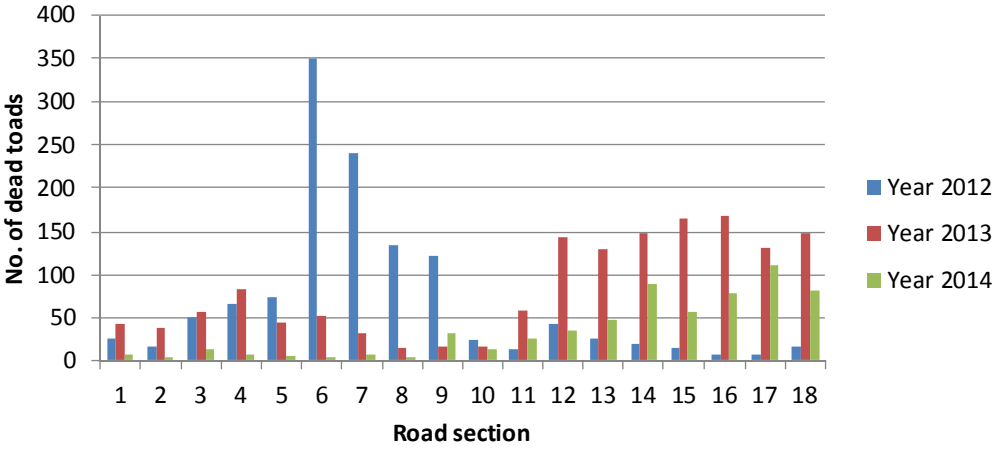
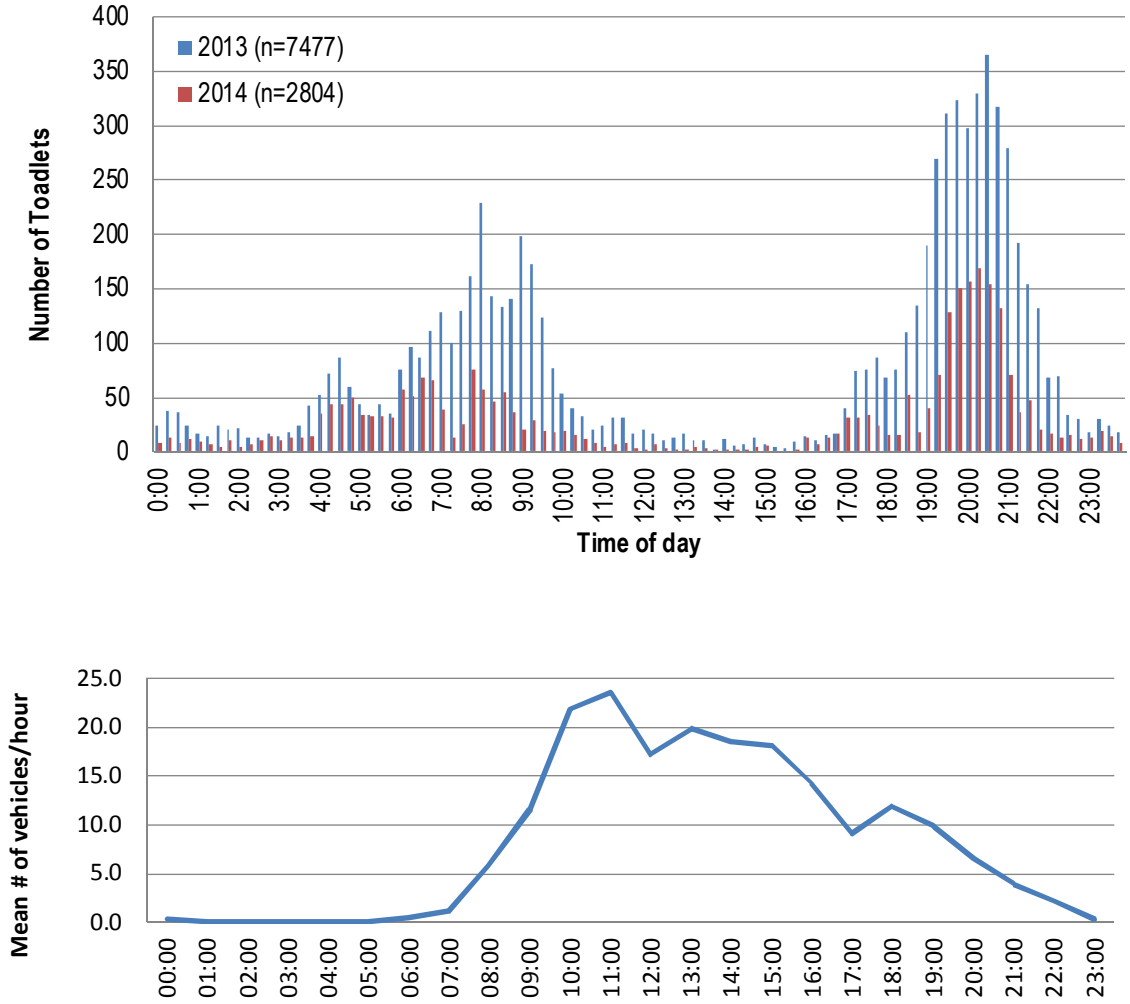


Figure 12. Road mortality of toadlets along 10 m sections of Kentucky campsite road, as revealed by transect surveys in July - August 2012 - 2014. An underpass was installed between Sections 8-9 in May 2013. Note that survey effort was lower in 2012 (7 surveys in 7 days) than in 2013 (58 surveys in 14 days) and 2014 (60 surveys in 20 days).



The camera data revealed a daily pattern of movement that was consistent over the two years (Figure 13). Toad movements occurred mostly in the morning, peaking from 6:00 h – 10:00 h, and in the evening, peaking from 17:00 h – 22:00 h. Comparing the timing of movements to vehicle counts obtained in August 2012 from a traffic counter on the Kentucky Campsite road, the times of the day when the toads are most vulnerable to roadkill are in the morning from 8:00 h – 10:00 h and again in the evening from 17:00 h – 21:00 h (Figure 13).

Figure 13. Time of day of toadlet movements in 2013 and 2014 as revealed by time-lapse camera at the tunnel entrance (top panel) in relation to mean hourly traffic volume measured in 1 – 14 August 2012 by traffic counter installed by BC Parks (bottom panel).



5.0 COMMUNITY SUPPORT AND VOLUNTEER EFFORTS

Dedicated volunteers from Nicola Naturalist Society participated in all aspects of this project and were instrumental in making it a success. In July and August 2014, 19 volunteers spent a total of 200 hours constructing and inspecting drift fences, counting toads along transects, opportunistically searching other areas of the park for toads, and explaining the project to park visitors.

The underpass continued to attract interest from park visitors, and many people walked up to the underpass from the campsites to view the toad migration. A temporary information sheet about the project was posted here for visitors to read. This provided an excellent opportunity for outreach and to respond to questions about the toads in general, their migration, and the efforts by BC Parks to mitigate threats from roadkill. On several occasions, visitors' children assisted observers in spotting toads on the road.

A field trip to the site was conducted as part of BC Federation of Naturalists spring camp on 30 May 2014. The study was also presented at the Canadian Herpetology Society's annual meeting in Calgary on 11 September 2014.The project is featured on the Nicola Naturalist Society website (http://www.nicolanaturalists.ca/projects/amphibian-monitoring/).

6.0 DISCUSSION

6.1 Timing and direction of the migration

As in 2012 and 2013, the migration of toadlets away from the breeding pond occurred in late July – early August within a relatively narrow time window. As is typical for amphibians, there were some minor shifts in the timing of the peak period, probably in response to annual variability in environmental conditions. In 2014, the main migration took place over approximately 12 days from 23 July – 2 August, and there were no sharp peaks in movements. This pattern contrasts with the migration in 2013, when the movements began earlier, on 18 July, and occurred in two waves with the majority of movements over a period of three days on 31 July – 2 August. These differences can be explained by patterns of rainfall that appeared to initiate movements in both years.

The toadlets moved in the morning and evening when relative humidity was high and temperatures moderate; the diurnal pattern of movements was remarkably similar between 2013 and 2014. Consequently, the times of the day when the toads are most vulnerable to roadkill are in the morning, when visitors' vehicles are leaving the camp sites, and again in the evening, when visitors are arriving in the park.

The migration direction was somewhat different in 2014 than in 2012 and 2013, when most of the toadlets initially congregated along the south and south west shores of the

breeding pond and then moved upland and away from the pond in these two directions. In 2014, most toadlets emerged from the pond along the northeast and east shores of the pond. Our observations indicated that some of these toadlets migrated in these directions where they would not encounter roads. However, a relatively large number of toadlets moved south along the pond shore and towards the forest at the south end as in previous years. Toadlets that were counted at the underpass or along the Kentucky campsite road represented this portion of the migration. It is unclear whether the reduced numbers of toadlets observed at the tunnel in 2014 when compared to 2013 resulted from population fluctuations or northeast direction of the migration by some toadlets that would have escaped attention. These results emphasize the importance of long-term monitoring studies to encompass annual variability in amphibian migration movements and population fluctuations.

6.2 Evaluation of mitigation effectiveness

As in 2013, both camera monitoring and direct observations indicated that toadlets readily used the underpass in 2014. The proportion of the total population leaving the breeding pond that used the tunnel is unknown, and obtaining accurate estimates would require intensive study using mark-recapture methods. However, a rough estimate can be made given a number of assumptions about (a) the proportion of total numbers of toadlets using the underpass based on camera images and (b) detectability of roadkill and live toadlets that successfully crossed the road based on transect counts on the Kentucky campsite road (see Appendix 1 for assumptions and calculations). The greatest uncertainty is in the estimated number of toadlets that successfully crossed the road away from the underpass.

Applying the above assumptions, the proportion of toadlets that used the underpass was 55 – 75% in 2014 and 77 – 87% in 2013, while roadkill was similar in both years and approximately 3 – 5% (Table 1). The underpass was clearly effective in channeling a large proportion of the toadlets across the road and into the forest in both years. It should be noted that the above values apply only to toads that used the south and west migration routes; an unknown but relatively small proportion of toads travelled to the east and northeast, especially in 2014. These figures represent rough estimates only and rely on a number of assumptions; therefore, the results should be used with extreme caution. A more direct way of investigating changes in patterns of roadkill before and after the installation of the underpass is through transect counts within the 180 m section that was monitored each year from 2012 to 2014. This comparison shows a reduction in mortality in the vicinity of the underpass location but somewhat higher mortality to the east in 2013 and 2014 (Figure 12). However, direct comparisons among years are complicated by (a) lower search effort in 2012, including reduced efficiency of camera counts without the tunnel and less frequent transect surveys, (b)

apparent lower overall numbers in 2012, and (c) wider spread and use of more eastern migration routes in 2013 and 2014, probably associated with a larger migration. Anecdotal information suggests extensive use of the more eastern movement routes through the campsites in some years in the past, probably associated with years with large migrations (Biolinx Environmental Research Ltd. and Nicola Naturalist Society 2012). Both the model results and observations support the suggestion that the underpass did not simply shift the pattern of mortality and that significant numbers crossed the road safely using the underpass.

Table 1. Estimated numbers of toadlets and roadkill along the Kentucky campsite road. There was insufficient data to estimate number of live toadlets that crossed the road in 2012 before the underpass installation in May 2013. See Appendix 1 for model assumptions and calculations.

Parameter	2014 (low)*	2014 (high)*	2013 (low)*	2013 (high)*	2012 (low)*	2012 (high)*
Total estimated through tunnel	16824	NA	44886	NA	NA	NA
Estimated roadkill on 180 m transect on Kentucky campsite road	682	NA	1641	NA	2516	5032
Estimated roadkill on Kentucky campsite road east of transect	330	NA	794			
No. that made it across road elsewhere than underpass (180 m transect & east of it)	4470	12516	3995	11186	Unknown	Unknown
Total estimated no. of toadlets that crossed or attempted to cross the road	22306	30352	51316	58507	Unknown	Unknown
% road kill of total	5	3	5	4	Unknown	Unknown
% through underpass of total	75	55	87	77	NA	NA
% made it across road elsewhere	20	41	8	19	NA	NA

*(low) and (high) after the year refer to low and high estimates of live toadlets that crossed the road in 2013 and 2014 and roadkill estimates in 2012.

The new wood fence effectively channeled movements of toadlets. However, although the fence was extended by 15 metres in 2014 at the east arm of the funnel, many toadlets still ended up on the outside of the fence. The construction of one-way ramps helped to alleviate the problem and allowed toadlets an opportunity to move back towards the pond and to the catchment area leading to the underpass. When constructing mitigation structures, it is important not to restrict movements of animals more than necessary to avoid unexpected harmful effects.

We suggest that the present length of the fencing is adequate to mitigate road impacts on the majority of toadlets.

6.3 Maintenance of the crossing structures

The wood fence provides a cost-effective, semi-permanent alternative to annual installation of drift fencing. While volunteer efforts have played a large part in

implementing this project, over the long term, BC Parks is expected to assume responsibility for maintaining the structures. The drift fence needs to be inspected annually before the toadlet migration, and any breaches repaired. Because the fence will remain permanently in place, it must be ensured that it does not impede access by adult toads to the breeding pond. This can be accomplished either by removing selected sections of the fence, which are part of the fence design, or by installing additional one-way ramps on the outside of the fence. We recommend the latter option, as it would require the least effort and maintenance in the future.

6.4 Project as an outreach tool

Because of its location in a popular park, the underpass is highly effective as an outreach tool. It generates much interest from park visitors, drawing attention to the general problem of amphibian roadkill. We have prepared an interpretive sign for BC Parks, which will be displayed at the site in the future.

7.0 CONCLUSIONS

- Toadlets used the underpass extensively both in 2013 and 2014, and overall, it appeared to be effective in facilitating their movements across the road.
- No evidence of entrapment or excessive predation was noted along the drift fences.
- The new wood drift fence provided a cost-effective and semi-permanent solution for directing toads.
- Roadkill still occurred, mostly to the south and east were toadlets circumvented the fence around the east arm of the funnel.
- The road crossing structures were highly effective as an outreach tool and a model system of amphibian roadkill mitigation.

8.0 RECOMMENDATIONS FOR 2015

- Inspection of the condition of the drift fence is required in spring to evaluate how well the fence has withstood winter condition and identify possible maintenance needs. At the same time, a set of one-way ramps should be constructed to allow adult toads easy access to the breeding pond. This activity should take place before the spring migration in May, preferably at the end of April.
- Continued monitoring of the migration using time-lapse camera is recommended. Continued surveys of the road transects are deemed unnecessary, but periodic visits to the site to assess the timing of the toadlet migration and predominant movement direction would be beneficial.

- Temporary closing of paths around the breeding pond should be continued during the peak toadlet migration period.
- The outreach and educational opportunities provided by the underpass system should be optimised with the placement of an information sign explaining the movements of the toadlets, the problem with roadkill, and the mitigation provided by the tunnel and fencing.

9.0 LITERATURE CITED

Biolinx Environmental Research Ltd. and Nicola Naturalist Society. 2012. Western Toad monitoring study in Kentucky Alleyne Provincial Park, July – August 2012. Report prepared for BC Parks, Thompson-Cariboo Region. 58 pp. http://www.nicolanaturalists.ca/files/Kentucky-Alleyne-Toad-Report-FINAL-Dec-2012.pdf (accessed De 2014).

Biolinx Environmental Research Ltd. and Nicola Naturalist Society. 2013. Western Toad monitoring study in Kentucky Alleyne Provincial Park, July – August 2013. Report prepared for BC Parks, Thompson-Cariboo Region. 26 pp. http://www.nicolanaturalists.ca/files/KA-Toad-Report-final-revised-2013.pdf (accessed De 2014).

COSEWIC. 2013. COSEWIC assessment and status report on the Western Toad *Anaxyrus boreas* in Canada. Committee On the Status of Endangered Wildlife In Canada, Ottawa.

Fahrig, L. and T. Rytwinski. 2009. Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society 14(1): 21. [online] URL: http://www.ecologyandsociety.org/vol14/iss1/art21/

Govindarajulu, P. 2011. Do roads affect herpetofauna in B.C.? Extended abstract of oral presentation, pp 5 – 6, in Herpetofauna and Roads. 2011. Workshop held in 22-23 February 2011 at Vancouver Island University, Nanaimo, BC.

Herpetofauna and Roads. 2011. Workshop held in 22-23 February 2011 at Vancouver Island University, Nanaimo, BC. Web site: http://www.env.gov.bc.ca/wld/frogwatch/docs/2011/Herpetofauna_and_RoadsWorkshopProgram_Feb222011.pdf

. Ovaska, K., Sopuck, L., and Engelstoft, C. 2011 Community-based amphibian monitoring program in multi-use landscapes in south-central B.C. Progress Report, 2011. Report prepared by Biolinx Environmental Research Ltd. for Nicola Naturalist Society with funding from Habitat Conservation Trust Fund. 19 pp. Web site: http://www.nicolanaturalists.ca/files/Nicola-amphibian-monitoring-rep-website-version-Dec-11.pdf (accessed De 2014).

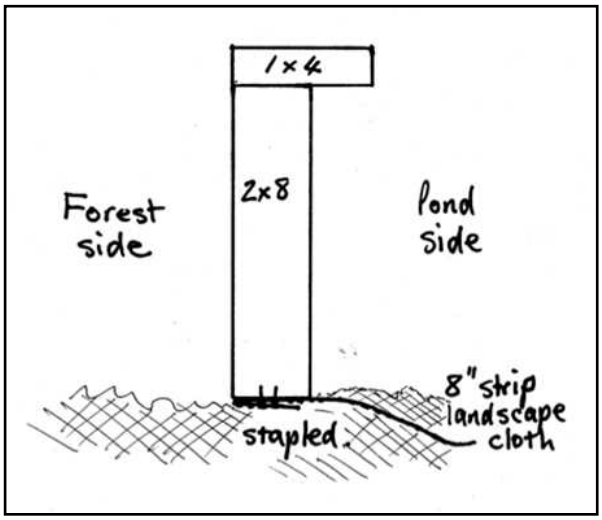
Ovaska, K., Sopuck, L., and Engelstoft, C. 2012. Community-based amphibian monitoring program in multi-use landscapes in south-central B.C. Annual Report, 2011. Report prepared by Biolinx Environmental Research Ltd. for Nicola Naturalist Society with funding from Habitat Conservation Trust Fund. 19 pp. Web site: http://www.nicolanaturalists.ca/files/Nicola-Amphibian-Monitoring-2012-WEB-version-18-Apr-13-COMPR.pdf (accessed Dec 2014).

Ovaska, K., Sopuck, L., and Engelstoft, C. 2013. Community-based amphibian monitoring program in multi-use landscapes in south-central B.C. Annual Report, 2012. Report prepared by Biolinx Environmental Research Ltd. for Nicola Naturalist Society with funding from Habitat Conservation Trust Fund. 32 pp. Web site: http://www.nicolanaturalists.ca/files/Nicola-Amphibian-Monitoring-2012-WEB-version-18-Apr-13-COMPR.pdf (accessed Dec 2014).

Ovaska, K., Sopuck, L., and Engelstoft, C. 2014. Community-based amphibian monitoring program in multi-use landscapes in south-central B.C. Annual Report, 2013. Report prepared by Biolinx Environmental Research Ltd. for Nicola Naturalist Society with funding from Habitat Conservation Trust Fund. 21 pp. Web site: http://www.nicolanaturalists.ca/files/Nicola-Amphibian-Monitoring-2012-WEB-version-18-Apr-13-COMPR.pdf (accessed Dec 2014).

Appendix 1. Details of the construction of the toadlet fence – July 2014, prepared by Alan Burger.

The fence was made of 2x8-inch boards with a 1x4-inch lip nailed to the top to make it more difficult for the toadlets to climb over (see diagram below). Eight-inch strips of heavy-duty (30-year) landscape cloth were stapled on the bottom of the 2x8 boards, folded over to ensure a tight fit and reduce the chance of tearing. The function of the landscape cloth at the base of the boards is to close any gaps beneath the boards due to uneven ground. Dirt and duff was placed on top of the landscape cloth strip along the base of each board to ensure there were no gaps under the boards.



Cross-section of the toadlet fence

The boards were held in place by two methods:

- wooden stakes driven into the ground and screwed to the back of the boards (forest side) for non-removable sections; or
- 2 ft rebar lengths driven into the ground and held in place with ½-inch pipe straps screwed to the back of the board (forest side), for the removable sections.

We made roughly every fourth board removable to allow gaps for adult toads to pass through and easily access the breeding pond from west in spring. An alternative and preferred approach is to construct ramps on the outer side of the fence that will allow these movements.

The sections of fence were attached to each other with a metal plate across the join at the back of the fence. These metal plates will have to be unscrewed to allow the removable sections to be removed. Gaps where two boards abutted were covered with landscape cloth stapled tightly to the front of the board. The length of cloth closing the gap was long enough to go under the 1x4 lip and extend at least 6-8 inches beyond the base of the 2x8 to be covered with dirt. Care was taken to use enough staples here so there were no loose bits of landscape cloth which toadlets might be able to climb.

Appendix 2. Dates and survey conditions for transect surveys along Kentucky Lake campsite road in July - August 2014.

Wind: 1- calm; 2- light; 3 moderate; 4-heavy; Cloud cover: 1-clear; 2-<50%; 3>50%, 4-overcast
Transect: KC-trans – 180 m transect monitored in 2013 and 2014; K-camp – remainder of the campsite road to the east of the transect; Path A and B – trails along northeast site of pond; Check # per day refers to multiple checks of the transects conducted on the same day; the numbers are not consecutive for K-camp road checks because this section of the road was not checked during each transect survey.

Date	Check # per day	Air temp °C	Wind	Cloud cover	Rel. Humidity %	Time (start)	Transect	Toadlets, live (#)	Toadlets, dead (#)
19-Jul-2014	1	18	3	3		11:40	KC-trans	0	0
20-Jul-2014	1	16	2	2	63	8:00	KC-trans	0	0
21-Jul-2014	1	22	2	2		18:55	KC-trans	0	0
22-Jul-2014	1	13	1	3		7:00	KC-trans	0	0
22-Jul-2014	2	15	1	3		8:28	KC-trans	0	0
22-Jul-2014	3	16	2	3		18:00	KC-trans	0	0
22-Jul-2014	4	16	1	2		19:00	KC-trans	0	0
23-Jul-2014	1	11	1	4		6:50	KC-trans	0	0
23-Jul-2014	2	14	1	2		8:30	KC-trans	0	0
23-Jul-2014	3	14	1	4	92	18:05	KC-trans	0	0
23-Jul-2014	4	14	1	4	100	19:18	KC-trans	7	2
24-Jul-2014	1	9	2	4	80	6:34	KC-trans	10	144
24-Jul-2014	2	11	3	4	73	8:00	KC-trans	41	0
24-Jul-2014	3	14	3	3	64	18:50	KC-trans	31	140
24-Jul-2014	4	12	2	2	58	20:00	KC-trans	28	36
25-Jul-2014	1	10	2	4	90	7:10	KC-trans	6	86
25-Jul-2014	2	12	2	4	70	8:25	KC-trans	77	0
25-Jul-2014	3	12	1	2	75	19:26	KC-trans	13	98
25-Jul-2014	4	12	1	2	80	22:04	KC-trans	5	7
26-Jul-2014	1	13	2	1	70	8:50	KC-trans	24	7
26-Jul-2014	2	22	1	1	35	18:52	KC-trans	7	15
26-Jul-2014	3	15	1	1	70	21:24	KC-trans	6	7
27-Jul-2014	1	8	1	1	90	6:28	KC-trans	2	9
27-Jul-2014	2	14	2	1	78	8:28	KC-trans	2	4
27-Jul-2014	3	24	1	1	24	19:00	KC-trans	1	2
27-Jul-2014	4	20	1	1	39	20:15	KC-trans	0	1
28-Jul-2014	1	10	2	2	90	7:12	KC-trans	2	1
28-Jul-2014	2	18	2	2	60	8:30	KC-trans	3	2
28-Jul-2014	3	24	1	1	25	19:53	KC-trans	0	2
28-Jul-2014	4	20	1	1	40	20:57	KC-trans	0	0
29-Jul-2014	1	12	1	1	89	7:36	KC-trans	1	1
29-Jul-2014	2	17	1	1	63	8:21	KC-trans	1	0

Date	Check # per day	Air temp °C	Wind	Cloud cover	Rel. Humidity %	Time (start)	Transect	Toadlets, live (#)	Toadlets, dead (#)
29-Jul-2014	3	27	1	1	15	19:04	KC-trans	0	0
29-Jul-2014	4	21	1	1	23	20:32	KC-trans	0	0
30-Jul-2014	1	12	1	1	84	7:48	KC-trans	0	1
30-Jul-2014	2	16	1	1	61	8:23	KC-trans	0	0
30-Jul-2014	3	23	1	1	19	19:48	KC-trans	0	0
30-Jul-2014	4	20	1	1	70	20:50	KC-trans	0	0
31-Jul-2014	1	15	1	1	78	8:10	KC-trans	1	0
31-Jul-2014	2	18	1	1	80	9:10	KC-trans	1	0
31-Jul-2014	3	26	1	1	80	19:30	KC-trans	0	1
31-Jul-2014	4	22	1	1	21	20:30	KC-trans	0	0
1-Aug-2014	1	12	2	2	92	7:31	KC-trans	2	0
1-Aug-2014	2	16	1	1	70	8:33	KC-trans	1	1
1-Aug-2014	3	18	1	4	90	20:43	KC-trans	43	4
2-Aug-2014	1	17	1	2	70	7:45	KC-trans	24	24
2-Aug-2014	2	29	2	4	15	18:20	KC-trans	1	5
3-Aug-2014	1	16	2	1	74	7:50	KC-trans	3	2
3-Aug-2014	2	24	1	3	40	19:57	KC-trans	3	2
3-Aug-2014	3	22	1	3	55	20:50	KC-trans	0	2
4-Aug-2014	1	13	1	1	80	7:29	KC-trans	5	0
4-Aug-2014	2	16	1	1	78	8:26	KC-trans	5	3
4-Aug-2014	3	28	2	2	26	18:35	KC-trans	1	0
4-Aug-2014	4	27	2	2	28	19:42	KC-trans	0	0
5-Aug-2014	1	16	2	1	76	8:26	KC-trans	5	1
5-Aug-2014	2	22	3	1	55	9:10	KC-trans	2	0
5-Aug-2014	3	25	3	2	28	19:12	KC-trans	0	0
5-Aug-2014	4	24	3	2	36	20:09	KC-trans	0	0
8-Aug-2014	1	15	1	3	50	7:57	KC-trans	0	4
13-Aug-2014	1	16	2	3		19:48	KC-trans	3	6
19-Jul-2014	1	18	3	3		11:40	Tunnel entry	2	0
20-Jul-2014	1	16	2	2	63	8:00	Tunnel entry	0	0
21-Jul-2014	1	22	2	2		18:55	Tunnel entry	0	0
22-Jul-2014	1	13	1	3		7:00	Tunnel entry	0	0
22-Jul-2014	2	13	1	3		8:28	Tunnel entry	0	0
22-Jul-2014	3	16	2	3		18:00	Tunnel entry	2	0
22-Jul-2014	4	16	1	2		19:00	Tunnel entry	4	0
23-Jul-2014	1	11	1	4		6:50	Tunnel entry	12	0
23-Jul-2014	2	14	1	2		8:30	Tunnel entry	10	0

Date	Check # per day	Air temp °C	Wind	Cloud cover	Rel. Humidity %	Time (start)	Transect	Toadlets, live (#)	Toadlets, dead (#)
23-Jul-2014	3	14	1	4	92	18:05	Tunnel entry	22	0
23-Jul-2014	4	14	1	4	100	19:18	Tunnel entry	28	0
24-Jul-2014	1	9	2	4	80	6:34	Tunnel entry	1	0
24-Jul-2014	2	11	3	4	73	8:00	Tunnel entry	1	0
24-Jul-2014	3	14	3	3	64	18:50	Tunnel entry	0	0
24-Jul-2014	4	12	2	2	58	20:00	Tunnel entry	0	0
25-Jul-2014	1	10	2	4	90	7:10	Tunnel entry	0	0
25-Jul-2014	2	12	2	4	70	8:25	Tunnel entry	3	0
25-Jul-2014	3	12	1	2	75	19:26	Tunnel entry	45	0
25-Jul-2014	4	12	1	2	80	22:04	Tunnel entry	22	0
26-Jul-2014	1	13	2	1	70	8:50	Tunnel entry	1	0
26-Jul-2014	2	22	1	1	35	18:52	Tunnel entry	15	0
26-Jul-2014	3	15	1	1	70	21:11	Tunnel entry	100	0
27-Jul-2014	1	8	1	1	90	6:28	Tunnel entry	20	0
27-Jul-2014	2	14	2	1	78	8:28	Tunnel entry	70	0
27-Jul-2014	3	24	1	1	24	19:00	Tunnel entry	9	0
27-Jul-2014	4	20	1	1	39	20:15	Tunnel entry	40	0
28-Jul-2014	1	10	2	2	90	7:12	Tunnel entry	13	0
28-Jul-2014	2	18	2	2	60	8:30	Tunnel entry	0	0
28-Jul-2014	3	24	1	1	25	19:53	Tunnel entry	35	0
28-Jul-2014	4	20	1	1	40	20:57	Tunnel entry	30	0
29-Jul-2014	1	12	1	1	89	7:36	Tunnel entry	22	0
29-Jul-2014	2	17	1	1	63	8:21	Tunnel entry	30	0
29-Jul-2014	3	27	1	1	15	19:04	Tunnel entry	3	0
29-Jul-2014	4	21	1	1	23	20:32	Tunnel entry	15	0
30-Jul-2014	1	12	1	1	84	7:48	Tunnel entry	1	0
30-Jul-2014	2	16	1	1	61	8:23	Tunnel entry	0	0
30-Jul-2014	3	23	1	1	19	19:48	Tunnel entry	4	0
30-Jul-2014	4	20	1	1	70	20:50	Tunnel entry	8	0
31-Jul-2014	1	15	1	1	78	8:10	Tunnel entry	5	0
31-Jul-2014	2	18	1	1	80	9:10	Tunnel entry	4	0
31-Jul-2014	3	26	1	1	80	19:30	Tunnel entry	3	1
31-Jul-2014	4	22	1	1	21	20:30	Tunnel entry	2	0
1-Aug-2014	1	12	2	2	92	7:31	Tunnel entry	2	0
1-Aug-2014	2	16	1	1	70	8:33	Tunnel entry	11	0
1-Aug-2014	3	18	1	4	90	20:43	Tunnel entry	130	0
2-Aug-2014	1	17	1	2	70	7:45	Tunnel entry	15	0

Date	Check # per day	Air temp °C	Wind	Cloud cover	Rel. Humidity %	Time (start)	Transect	Toadlets, live (#)	Toadlets, dead (#)
2-Aug-2014	2	29	2	4	15	18:20	Tunnel entry	5	0
3-Aug-2014	1	16	2	1	74	7:50	Tunnel entry	5	0
3-Aug-2014	2	24	1	3	40	19:57	Tunnel entry	4	0
3-Aug-2014	3	22	1	3	55	20:50	Tunnel entry	8	0
4-Aug-2014	1	13	1	1	80	7:29	Tunnel entry	3	0
4-Aug-2014	2	16	1	1	78	8:26	Tunnel entry	13	0
4-Aug-2014	3	28	2	2	26	18:35	Tunnel entry	0	0
4-Aug-2014	4	27	2	2	28	19:42	Tunnel entry	1	0
5-Aug-2014	1	16	2	1	76	8:26	Tunnel entry	0	0
5-Aug-2014	2	22	3	1	55	9:10	Tunnel entry	1	0
5-Aug-2014	3	25	3	2	28	19:12	Tunnel entry	0	0
5-Aug-2014	4	24	3	2	36	20:09	Tunnel entry	2	0
8-Aug-2014	1	15	1	3	50	7:57	Tunnel entry	0	0
13-Aug-2014	1	16	2	3		19:48	Tunnel entry	0	0
19-Jul-2014	1	18	3	3		11:40	Tunnel exit	5	0
20-Jul-2014	1	16	2	2	63	8:00	Tunnel exit	2	0
21-Jul-2014	1	22	2	2		18:55	Tunnel exit	2	0
22-Jul-2014	1	13	1	3		7:00	Tunnel exit	0	0
22-Jul-2014	2	13	1	3		8:28	Tunnel exit	0	0
22-Jul-2014	3	16	2	3		18:00	Tunnel exit	2	0
22-Jul-2014	4	16	1	2		19:00	Tunnel exit	0	0
23-Jul-2014	1	11	1	4		6:50	Tunnel exit	22	0
23-Jul-2014	2	14	1	2		8:30	Tunnel exit	9	0
23-Jul-2014	3	14	1	4	92	18:05	Tunnel exit	34	0
23-Jul-2014	4	14	1	4	100	19:18	Tunnel exit	26	0
24-Jul-2014	1	9	2	4	80	6:34	Tunnel exit	5	0
24-Jul-2014	2	11	3	4	73	8:00	Tunnel exit	1	0
24-Jul-2014	3	14	3	3	64	18:50	Tunnel exit	0	0
24-Jul-2014	4	12	2	2	58	20:00	Tunnel exit	0	0
25-Jul-2014	1	10	2	4	90	7:10	Tunnel exit	0	0
25-Jul-2014	2	12	2	4	70	8:25	Tunnel exit	0	0
25-Jul-2014	3	12	1	2	75	19:26	Tunnel exit	55	0
25-Jul-2014	4	12	1	2	80	22:04	Tunnel exit	4	0
26-Jul-2014	1	13	2	1	70	8:50	Tunnel exit	0	0
26-Jul-2014	2	22	1	1	35	18:52	Tunnel exit	23	0
26-Jul-2014	3	15	1	1	70	21:11	Tunnel exit	100	0
27-Jul-2014	1	8	1	1	90	6:28	Tunnel exit	23	0

Date	Check # per day	Air temp °C	Wind	Cloud cover	Rel. Humidity %	Time (start)	Transect	Toadlets, live (#)	Toadlets, dead (#)
27-Jul-2014	2	14	2	1	78	8:28	Tunnel exit	15	0
27-Jul-2014	3	24	1	1	24	19:00	Tunnel exit	11	0
27-Jul-2014	4	20	1	1	39	20:15	Tunnel exit	70	0
28-Jul-2014	1	10	2	2	90	7:12	Tunnel exit	27	0
28-Jul-2014	2	18	2	2	60	8:30	Tunnel exit	40	0
28-Jul-2014	3	24	1	1	25	19:53	Tunnel exit	55	0
28-Jul-2014	4	20	1	1	40	20:57	Tunnel exit	25	0
29-Jul-2014	1	12	1	1	89	7:36	Tunnel exit	45	0
29-Jul-2014	2	17	1	1	63	8:21	Tunnel exit	28	0
29-Jul-2014	3	27	1	1	15	19:04	Tunnel exit	15	0
29-Jul-2014	4	21	1	1	23	20:32	Tunnel exit	10	0
30-Jul-2014	1	12	1	1	84	7:48	Tunnel exit	8	0
30-Jul-2014	2	16	1	1	61	8:23	Tunnel exit	0	0
30-Jul-2014	3	23	1	1	19	19:48	Tunnel exit	12	0
30-Jul-2014	4	20	1	1	70	20:50	Tunnel exit	5	0
31-Jul-2014	1	15	1	1	78	8:10	Tunnel exit	4	0
31-Jul-2014	2	18	1	1	80	9:10	Tunnel exit	3	0
31-Jul-2014	3	26	1	1	80	19:30	Tunnel exit	3	0
31-Jul-2014	4	22	1	1	21	20:30	Tunnel exit	4	0
1-Aug-2014	1	12	2	2	92	7:31	Tunnel exit	6	0
1-Aug-2014	2	16	1	1	70	8:33	Tunnel exit	13	0
1-Aug-2014	3	18	1	4	90	20:43	Tunnel exit	60	0
2-Aug-2014	1	17	1	2	70	7:45	Tunnel exit	30	0
2-Aug-2014	2	29	2	4	15	18:20	Tunnel exit	1	0
3-Aug-2014	1	16	2	1	74	7:50	Tunnel exit	5	0
3-Aug-2014	2	24	1	3	40	19:57	Tunnel exit	12	0
3-Aug-2014	3	22	1	3	55	20:50	Tunnel exit	27	0
4-Aug-2014	1	13	1	1	80	7:29	Tunnel exit	2	0
4-Aug-2014	2	16	1	1	78	8:26	Tunnel exit	14	0
4-Aug-2014	3	28	2	2	26	18:35	Tunnel exit	6	0
4-Aug-2014	4	27	2	2	28	19:42	Tunnel exit	11	0
5-Aug-2014	1	16	2	1	76	8:26	Tunnel exit	5	0
5-Aug-2014	2	22	3	1	55	9:10	Tunnel exit	7	0
5-Aug-2014	3	25	3	2	28	19:12	Tunnel exit	5	0
5-Aug-2014	4	24	3	2	36	20:09	Tunnel exit	10	0
8-Aug-2014	1	15	1	3	50	7:57	Tunnel exit	2	0
13-Aug-2014	1	16	2	3		19:48	Tunnel exit	1	0

Date	Check # per day	Air temp °C	Wind	Cloud cover	Rel. Humidity %	Time (start)	Transect	Toadlets, live (#)	Toadlets, dead (#)
19-Jul-2014	1	18	3	3		10:50	K-camp	0	0
20-Jul-2014	1	16	2	2	63	8:18	K-camp	0	0
21-Jul-2014	1	22	2	2		18:22	K-camp	0	0
22-Jul-2014	3	16	2	3		18:22	K-camp	0	0
23-Jul-2014	3	14	1	4	92	18:30	K-camp	1	0
23-Jul-2014	4	14	1	4	100	19:30	K-camp	3	0
24-Jul-2014	1	9	2	4	80	7:00	K-camp	11	20
24-Jul-2014	3	14	3	3	64	19:30	K-camp	0	18
24-Jul-2014	3	14	3	3	64	19:30	K-camp	5	20
24-Jul-2014	3	14	3	3	64	19:30	K-camp	5	12
24-Jul-2014	3	14	3	3	64	19:30	K-camp	4	14
24-Jul-2014	3	14	3	3	64	19:30	K-camp	5	23
24-Jul-2014	3	14	3	3	64	19:30	K-camp	2	2
24-Jul-2014	3	14	3	3	64	19:30	K-camp	3	1
24-Jul-2014	3	14	3	3	64	19:30	K-camp	1	1
24-Jul-2014	3	14	3	3	64	19:30	K-camp	5	2
24-Jul-2014	3	14	3	3	64	19:30	K-camp	1	1
24-Jul-2014	3	14	3	3	64	19:30	K-camp	1	7
24-Jul-2014	3	14	3	3	64	19:30	K-camp	32	101
25-Jul-2014	1	10	2	4	90	7:32	K-camp	40	35
25-Jul-2014	2	12	2	4	70	8:38	K-camp	45	0
25-Jul-2014	3	12	1	2	75	20:30	K-camp	7	25
25-Jul-2014	4	12	1	2	80	23:09	K-camp	10	10
26-Jul-2014	1	13	2	1	70	9:30	K-camp	15	1
26-Jul-2014	2	22	1	1	35	19:22	K-camp	1	8
26-Jul-2014	3	15	1	1	70	21:45	K-camp	4	3
27-Jul-2014	1	8	1	1	90	6:28	K-camp	1	9
27-Jul-2014	2	14	2	1	78	8:35	K-camp	0	0
27-Jul-2014	3	24	1	1	24	19:17	K-camp	0	0
28-Jul-2014	1	10	2	2	90	7:23	K-camp	0	0
28-Jul-2014	2	18	2	2	60	8:47	K-camp	0	0
28-Jul-2014	3	24	1	1	25	20:12	K-camp	4	0
29-Jul-2014	1	12	1	1	89	7:45	K-camp	2	2
29-Jul-2014	3	27	1	1	15	19:12	K-camp	0	0
30-Jul-2014	1	12	1	1	84	7:55	K-camp	0	0
30-Jul-2014	3	23	1	1	19	19:55	K-camp	0	0

Date	Check # per day	Air temp °C	Wind	Cloud cover	Rel. Humidity %	Time (start)	Transect	Toadlets, live (#)	Toadlets, dead (#)
31-Jul-2014	1	15	1	1	78	8:18	K-camp	0	0
31-Jul-2014	3	26	1	1	80	19:40	K-camp	0	0
1-Aug-2014	1	12	2	2	92	7:50	K-camp	0	4
1-Aug-2014	3	18	1	4	90	21:09	K-camp	6	1
2-Aug-2014	1	17	1	2	70	8:30	K-camp	66	43
2-Aug-2014	2	29	2	4	15	18:50	K-camp	0	10
3-Aug-2014	1	16	2	1	74	8:10	K-camp	3	0
3-Aug-2014	2	24	1	3	40	20:15	K-camp	0	3
4-Aug-2014	1	13	1	1	80	7:44	K-camp	4	0
4-Aug-2014	4	27	2	2	28	20:02	K-camp	0	0
5-Aug-2014	1	16	2	1	76	8:41	K-camp	0	0
5-Aug-2014	3	25	3	2	28	19:25	K-camp	0	0
8-Aug-2014	1	15	1	3	50	8:18	K-camp	0	0
13-Aug-2014	1	16	2	3		19:25	K-camp	12	25
19-Jul-14	1	18	3	3		10:50	Path A	0	0
20-Jul-14	1	16	2	2	63	8:18	Path A	0	0
21-Jul-14	1	22	2	2		18:22	Path A	0	0
23-Jul-14	3	14	1	4	92	18:30	Path A	555	0
24-Jul-14	1	9	2	4	80	7:43	Path A	10	0
24-Jul-14	3	14	3	3	64	19:55	Path A	190	0
26-Jul-14	3	15	1	1	70	21:45	Path A	0	0
26-Jul-14				1		11:40	Path A	0	0
27-Jul-14	3	24	1	1		19:52	Path A	0	0
28-Jul-14	3	24	1	1	25	20:37	Path A	0	0
30-Jul-14	3	23	1	1	19	20:30	Path A	0	0
31-Jul-14	1	15	1	1	78	8:42	Path A	0	0
19-Jul-14	1	18	3	3		10:50	Path B	0	0
20-Jul-14	1	16	2	2	63	8:18	Path B	0	0
23-Jul-14	3	14	1	4	92	18:30	Path B	135	3
24-Jul-14	1	9	2	4	80	7:43	Path B	20	0
24-Jul-14	3	14	3	3	64	19:55	Path B	290	0
26-Jul-14				1		11:40	Path B	0	0
27-Jul-14	3	24	1	1		19:52	Path B	0	0
28-Jul-14	3	24	1	1	25	20:37	Path B	0	0
30-Jul-14	3	23	1	1	19	20:30	Path B	0	0
31-Jul-14	1	15	1	1	78	8:42	Path B	0	0

Appendix 3. Model parameters and correction factors used to estimate the proportion of roadkill and numbers of toadlets using the underpass based on camera data and direct observations along the Kentucky campsite road transect.

Parameter	2014	2013	2012	Notes
Number recorded at tunnel entrance (camera data)	2804	7481	NA	
Correction factor for % coverage camera angle	2	2	NA	Appr. 1/2 shown in camera view, including one of the two fences along which toadlets preferred to move
Correction factor for time from 15 min interval used for time-lapse camera	3	3	NA	Assuming that it takes 5 min for toads disappear from camera view
Total estimated through tunnel	16824	44886	NA	
No. dead recorded on 180 m transect on Kentucky campsite road	620	1492	1258	
Correction factor for roadkill (detectability & disappearance from vehicles or scavengers)	1.1	1.1	2 - 4 (low - high)	Estimate 90% of the dead toadlets found with 2 checks in the evening and morning in 2013 & 2014; checked on 7 non-consecutive days (1 check/day) in 2012 versus am & pm checks in 14 days in 2013 and 20 days in 2014
Estimated no. of dead on 180 m transect	682	1641	2516-5032 (low-high)	Applying the correction factors above
No. additional dead recorded (2014) or estimated (2013; at 48.4% of toadlets on transect) on rest of campsite road	300	722	NA	Assuming that the proportions are similar in 2013 and 2014; might be an overestimate for 2013. No mortality was recorded in section of the road in 2012, but the checks were less frequent.
Estimated no. additional dead on rest of campsite road east of transect	330	794	NA	Applying the same correction factors as for the 180 m transect
Total road kill, estimated	1012	2435	NA	
No. live toadlets on the road along the 180 m transect	627	561	31	Inaccurate for 2012 due to infrequent surveys
No. live on rest of the road (2014); estimated for 2013 based on 42.5% of live on transect	267	238	NA	Assuming that the proportions are similar in 2013 & 2014; might be an overestimate for 2013; cannot be estimated for 2012 due to infrequent surveys
Correction factor for live toadlets on road	5-14	5-14	NA	6 - 10 am: average of 2 checks during 4 h period of morning peak activity; 17 - 22 pm: 2 checks during 5 h period of evening peak activity; 9 h = 18 x .5 h or 36 x .25 h. If each check represents 0.5 h, then could have been 14x as many; if each represents 1 h, then there could have been 5 x as many; cannot be estimated for 2012 due to infrequent surveys
No. that made it across road elsewhere than underpass	4470-12516	3995-11186	NA	
Total crossed or attempted to cross (estimate)	22306-30352	51316-58507	NA	
% road kill of total	4.5-3.3	4.7-4.2	NA	
% through underpass of total	75.4-55.4	87.5-76.7	NA	
% made it across road elsewhere	20-41.2	7.8-19.1	NA	