Are Salamander Crossing Brigades an Effective Tool for Addressing Amphibian Road Mortality? A Pilot Study at the North Lincoln Street (Keene, NH) Amphibian Road Crossing Site

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Figure 1. A spotted salamander (*Ambystoma maculatum*) awaits release in a pitfall trap at North Lincoln Street, Keene, NH. *photo: Alexandra Kirk*

INTRODUCTION and BACKGROUND

Amphibian road mortality is a considerable conservation issue, particularly during the highly-synchronized annual spring migrations ("Big Nights") undertaken by vernal pool-breeding species in the Northeast. Observed road mortality rates along even low-traffic rural roads may be high enough to lead to localized extirpation of pool-breeding amphibian species, and long-term impacts of roads on amphibian population dynamics can be severe (Beebee 2013; Cooke 2011; Glista et al. 2007; Gibbs and Shriver 2005). Design and installation of wildlife infrastructure (amphibian tunnels) are costly, and temporary road closures are often met with resistance by the general public. Over the last decade, conservation groups throughout the Northeast have responded by organizing "Salamander Crossing Brigades," in which trained volunteers move migrating amphibians across the road by hand during periods of peak traffic.

In Keene, New Hampshire, hundreds of amphibians migrate on rainy spring nights from forested habitat in Robin Hood Park to the wetlands adjacent to the Woodland Cemetery (**Fig. 2**), where they breed and lay eggs. Nearly all of these amphibians must cross North Lincoln Street in order to reach the breeding wetland. Species that have been documented at this location include: wood frog (*Lithobates sylvaticus*), Northern spring peeper (*Pseudacris crucifer*), spotted salamander (*Ambystoma maculatum*), American toad (*Anaxyrus americanus*), Eastern newt (*Notophthalmus viridescens*), gray tree frog (*Hyla versicolor*), and Eastern red-backed salamander (*Plethodon cinereus*). On "Big Nights," when hundreds of frogs may cross North Lincoln Street in just a few hours, the potential for road mortality is enormous. Every spring, AVEO ("Ashuelot Valley Environmental Observatory") – the citizen science arm of the Harris Center for Conservation Education – seeks to reduce road mortality at this site and more than a dozen other amphibian road crossings in the Monadnock Region by training and coordinating Salamander Crossing Brigade volunteers, who count migrating amphibians and move them across the road by hand. AVEO's Salamander Crossing Brigade volunteers have shuttled nearly 20,000 amphibians across roads throughout southwestern New Hampshire since 2007, but how effective are these amphibian brigades as an applied conservation measure?

Research on the conservation value of amphibian crossing brigades is limited, with most studies focused on common toads (*Bufo bufo*) in Europe, where volunteers have been

taking part in "toad patrols" since the 1980s (Bonardi et al. 2011; Cooke 2011). In April and May 2014, as a first step towards assessing the effectiveness of amphibian brigades focused on vernal pool-breeding species in the northeastern United States, we installed and monitored a pitfall array at the North Lincoln Street crossing site in Keene, NH. Although pitfall arrays are a common amphibian survey technique (Heyer et al. 1994), their use in the evaluation of amphibian road crossing brigades has thus far been extremely limited. This array was designed to capture amphibians who slipped by volunteers during Big Nights, as well as those amphibians who made their migration late at night, after Crossing Brigade volunteers had left the site for the evening. By comparing the pitfall data with the volunteer road crossing data, we can begin to understand what percentage of the amphibian population at this site is being carried across the road by hand each spring.

METHODS

The pitfall array was installed along the western (wetland-side) right-of-way of North Lincoln Street (**Fig. 2 & 3**), and was comprised of approximately 450 feet of silt fencing, dug several inches into the topsoil, with 13 size #10 aluminum can "traps" (recycled from the Keene State College Dining Commons) dug flush into the ground and against the fence on each side, for a total of 26 traps. The traps were placed approximately 10 meters apart. 5 to 7 holes were drilled in the bottom of each trap for drainage, and each trap contained a sponge for moisture and a wooden dowel to serve as an escape "ladder" for small mammals (**Fig. 1**). Due to concerns about proximity to the

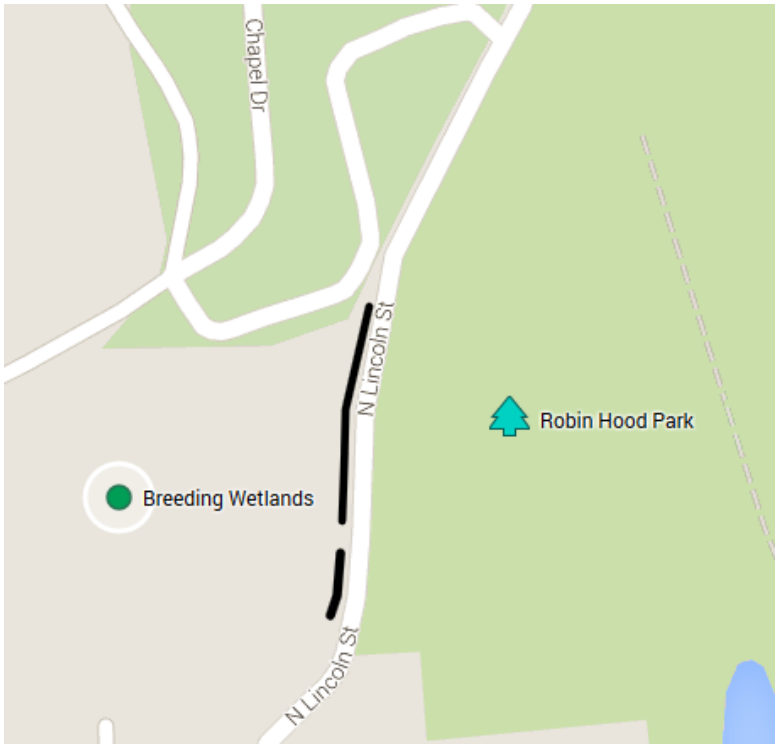

Figure 2. Approximate location and extent of the pitfall array.

Figure 3. The pitfall array was comprised of silt fencing and aluminum can traps. It was checked daily from April 9 to May 9, 2014. *photo: Brett Amy Thelen*

wetland at the southern end of the site, the pitfall array did not extend the full length of the amphibian crossing. There was also an approximately 20-foot-long gap in the fencing, where dense rocky fill made it impossible to dig the fencing into the soil. Although we originally planned to install the array in late March, prior to any amphibian migrations, a thick shelf of ice – the remnants of a snow berm created by successive rounds of winter snow plowing – persisted at the site for well over a week after the surrounding forest floor had thawed. As a result, we were unable to dig the fence into the ground until April 8, the morning after the first significant amphibian migration of the 2014 season.

Once installed, the pitfall array was checked daily, at or before 8:30 a.m., from April 9 to May 9. The traps were also checked on migration nights, both upon our arrival at the site and before departing for the evening. For each amphibian capture, we recorded the species, age class (adult or juvenile), gender, and trap number. In addition, we took photographs of each spotted salamander's unique spot pattern (**Fig. 5**). After the data were recorded, all animals were removed from the traps and carefully placed on the opposite side of the fence.

On migration nights (April 4, 7, 11, 15, 22, 26, and 30, and May 1), we were joined at the site by Salamander Crossing Brigade volunteers (2 to 15 additional people, depending on the night). All volunteers were instructed to wear reflective vests for safety; we also set up traffic cones and reflective "Caution! Salamander Crossing" signs at both ends of the crossing site to warn incoming drivers of the activity on the road. Together, we used flashlights to look for migrating amphibians; live animals were carried across the road by

hand or in buckets (**Fig. 4**). To ensure that the hand-carried amphibians were not captured in the pitfall traps, volunteers were instructed to release the animals at the fence gap or on the wetland side of the fence. When possible, we photographed the spot patterns of spotted salamanders encountered by volunteers, though this was done with less consistency in the early part of the season. We also recorded amphibian mortalities due to road traffic.

Figure 4. A bucket of wood frogs (*Lithobates sylvaticus*) and Northern spring peepers (*Pseudacris crucifer*), carried across North Lincoln Street by Salamander Crossing Brigade volunteers on April 11, 2014. *photo: Brett Amy Thelen*

RESULTS

In total, the pitfall array captured 164 amphibians (94 spring peepers, 38 wood frogs, 28 spotted salamanders, 2 American toads, and 2 Eastern newts) heading toward the wetland (inbound), and 19 amphibians (11 spotted salamanders, 6 spring peepers, and 2 wood frogs) heading away from the wetland (outbound) (**Table 1**). By comparison, Salamander Crossing Brigade volunteers hand-carried a total of 1,536 amphibians across the road, including 1,172 spring peepers, 334 wood frogs, 25 spotted salamanders, 3 Eastern newts, and 2 American toads (**Table 2**). They also noted 263 road-killed amphibians (231 spring peepers, 22 wood frogs, 5 Eastern newts, 3 spotted salamanders, 1 gray tree frog, and 1 red-backed salamander). Although volunteers were not asked to record the direction of travel for the amphibians they carried across the road, anecdotal observations indicate that the vast majority of hand-carried amphibians were inbound. In total, 1,963 amphibians (calculated as the number of inbound pitfall array captures + the number of individual amphibians carried across the road by Salamander Brigade volunteers + the number of recorded road-killed animals) were thus observed at the North Lincoln Street road crossing site in 2014.

Species	Inbound	Outbound	Total
American Toad	2	0	**2**
Eastern Newt	2	0	**2**
Spotted Salamander	28	11	**39**
Spring Peeper	94	6	**100**
Wood Frog	38	2	**40**
Total	**164**	**19**	**183**

Table 1. Number of individual amphibians caught in the **pitfall array** at North Lincoln Street between April 9 and May 9, 2014, by species and direction of travel.

Date	Observer-Hours	American Toad		Eastern Newt		Gray Tree Frog		Red-backed Salamander		Spotted Salamander		Spring Peeper		Wood Frog		Total	
		Live	*Dead*	*Live*	*Dead*	*Live*	*Dead*	*Live*	*Dead*	*Live*	*Dead*	*Live*	*Dead*	*Live*	*Dead*	*Live*	*Dead*
4/04/14	2	0	0	0	0	0	0	0	0	0	0	7	1	2	0	**9**	1
4/07/14	18.75	0	0	0	0	0	0	0	0	3	0	203	9	104	0	**310**	9
4/11/14	15	0	0	0	0	0	0	0	0	9	2	644	158	157	13	**810**	173
4/15/14	26	0	0	1	3	0	0	0	0	10	1	173	31	24	2	**208**	37
4/22/14	4	1	0	1	0	0	1	0	0	2	0	117	22	44	5	**165**	28
4/26/14	0.75	0	0	0	0	0	0	0	0	1	0	21	7	1	0	**23**	7
4/30/14	2	0	0	0	1	0	0	0	0	0	0	4	0	0	0	**4**	1
5/01/14	0.50	1	0	1	1	0	0	0	1	0	0	3	3	2	2	**7**	7
Total	69	2	0	3	5	0	1	0	1	25	3	1172	231	334	22	**1536**	263

Table 2. Number of individual amphibians moved across North Lincoln Street and encountered dead in the road by **Salamander Crossing Brigade volunteers** in 2014, by species and migration date.

In addition, we positively identified five unique individual spotted salamanders on both their inbound and outbound migrations (**Fig. 5**).

Figure 5. This spotted salamander was captured at North Lincoln Street on its inbound migration on 4/11/14 (left) and its outbound migration on 4/27/14 (right). Note the distinctive spot pattern on the animal's head and upper back, which is unique to this individual salamander. *photos: Brett Amy Thelen*

DISCUSSION

By rough estimate, approximately 90% of the amphibians who successfully crossed North Lincoln Street on their inbound migration in 2014 were moved across the road by Salamander Crossing Brigade volunteers, while 10% crossed themselves and were captured in the pitfall array. The Salamander Crossing Brigades may thus have a meaningful conservation impact on amphibian populations at the North Lincoln Street road crossing site. However, this finding should be interpreted with caution, for several reasons: (1) The degree of "trespass" – that is, animals eluding the pitfall array through the gap in the fence and around the edges – is unknown and potentially significant, so the pitfall capture data likely underestimate the number of amphibians who successfully crossed the road without intervention by Salamander Crossing Brigade volunteers. (2) The pitfall traps are not designed to capture tree frog species (gray tree frogs and spring peepers), which can easily climb out of the traps or over the fence, so our pitfall capture counts for these species may again be significant underestimates. (3) Amphibian migrations are highly weather-dependent events, so the timing of the migration can vary greatly from year to

year. This has a direct impact on the number of individual animals that are moved across the road by Crossing Brigade volunteers. In the spring of 2014, most of the season's warm rains occurred before midnight, when volunteers were awake and therefore more likely to assist with the crossings. (There is also a greater need for assistance, as road traffic is presumably busier in the earlier evening hours than in the wee hours of the morning.) During other years, the warm rains that spur amphibian migrations may occur in the middle of the night, when volunteers are sleeping; at those times, most of the amphibians who successfully cross the road likely do so without the assistance of the Salamander Brigades. Thus, our calculation of the percentage of the total population of spring-breeding amphibians who are hand-carried across North Lincoln Street by Crossing Brigade volunteers is likely an overestimate. Additional study is needed to see if this figure holds true at other road crossing sites and across multiple years.

It should also be noted that many volunteers chose only to focus on assisting and recording data on live amphibians, and all observers left the crossing site by midnight each night and were therefore not present for the entire duration of any single migration event; as a result, our figures for dead (road-killed) animals and the total number of amphibians utilizing the North Lincoln Street road crossing certainly underestimate both the total population size and the road mortality rate for amphibians at this site.

Lastly, it is notable that we captured many more inbound than outbound amphibians. We have a few hypotheses as to why this may have happened: (1) It is possible that amphibians are heading to other areas once they are done breeding (that is, not immediately re-crossing the road into Robin Hood Park); however, the breeding wetland is bounded by residential yards and the Woodland Cemetery, neither of which represents high-quality amphibian habitat, so this scenario seems unlikely. (2) This spring's unusually cold temperatures (on April 16, the entire site was encased in ice and snow after a late-night freeze) may have prolonged breeding time, keeping individuals – particularly spotted salamanders – in the wetland beyond the duration of the study period. (3) Some outbound migrants surely slipped past the pitfall array via the gap in the fence. For instance, on the night of April 22, we documented 18 adult wood frogs heading outbound through the gap in the fence; the next morning, there were no adult wood frogs in the traps. (4) Most significantly, we believe that the traps may have been too shallow to keep adult wood frogs

and American toads contained until morning. On May 1 at 10 p.m., we noted an adult American toad in Trap 12 and a juvenile wood frog in Trap 9, and left them there; at 8:30 a.m. the next morning, only the juvenile wood frog remained. We did capture adult wood frogs in the pitfall array on the inbound migration, when temperatures were lower and the cold-blooded animals were perhaps moving more slowly, but the toad escape during warmer weather suggests that adult wood frogs may also have been capable of hopping out of the traps when temperatures were warmer.

RECOMMENDATIONS for FUTURE STUDY

Although this pilot study was designed to assess the effectiveness of amphibian road crossing efforts, the roadside setting presented several challenges that are not typically encountered by pitfall array studies at undeveloped sites: (1) rocky fill made it impossible to dig the fencing in along the entire length of the amphibian crossing, creating a gap that allowed for a potentially significant number of amphibians to avoid the traps, and (2) the persistence of frozen ground along the road edge long after adjacent forest soils had thawed – a consequence of snow compaction caused by wintertime plowing – prevented us from installing the array in time for the first amphibian migration of the season. A warmer, drier spring might allow for earlier pitfall array installation, but rocky roadside fill will continue to be a challenge for pitfall array installation at this site, and potentially at many other road crossing sites as well.

Another challenge was the apparent ability of adult frogs and toads to hop or climb out of the traps, once temperatures had warmed. For this reason, for future pitfall studies with both salamanders and frogs as focal species, we recommend using deeper traps and/or placing wide-mouthed funnels in the top of each trap, to narrow the opening so frogs and toads cannot easily escape (as recommended in Heyer et al. 1994).

Pitfall arrays have the potential to yield important information about local amphibian populations, but they are inherently labor intensive: in order to ensure the safety of the amphibians, the traps must be checked daily for the duration of the survey period. In addition, this particular array took 7 people nearly 10 hours to install. When paired with the difficulties associated with roadside siting, this survey technique might not

be practicable for evaluating the effectiveness of amphibian crossing brigades across a large geographic range without significant funding for staffing.

Photo mark-recapture may, however, be a more easily replicable, cost-efficient alternative: although documenting spotted salamander spot patterns won't provide immediate, site-specific data and is limited to spotted salamanders as a focal species, it does have the potential for providing meaningful long-term data on population variability and year-to-year survival in spotted salamander populations that must cross roads to reach their breeding pools. It is also a minimally invasive technique that could be performed by trained citizen scientists at a variety of road crossing sites. If the response of this year's Salamander Brigade volunteers is any indication ("Wow, that is *way cool*!!"), it would be very well-received by citizen scientists throughout the Northeast.

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