

## **WILDLIFE TUNNELS UNDER A BUSY, SUBURBAN BOSTON ROADWAY**

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## **ABSTRACT**

Wildlife use of passage structures has been documented in rural locations but infrequently in suburban settings. State Route 2 in Concord, MA is 20 miles west of Boston and has an average daily volume of about 50,000 vehicles. The roadway bisects some of the few remaining areas of open space, presenting a major potential barrier to wildlife movement. In 2005 MassHighway completed the installation of four wildlife crossing structures along a 2.5-mile segment of Route 2. The underpasses were constructed to mitigate wildlife habitat fragmentation exacerbated by the road safety improvement project that further divided the highway. The Town of Concord Division of Natural Resources formed the volunteer Wildlife Passages Task Force (WPTF) to study how wildlife responded to the underpasses. The four pre-cast concrete box culverts measure either 82.5' or 96' long and contain a 2-inch layer of dirt substrate. The internal dimensions are 6' high by 9' wide (two tunnels), 5' by 8', and 3' by 5'. Wildlife activity was determined by two complementary methods: a tracking bed made from sifted substrate in the one tunnel that was sufficiently dry, and passive infrared-triggered digital photography in all underpasses. We recorded 32 species that used the tunnels, some frequently. The mean annual rate of passage detected by the tracking bed and cameras was calculated for each species recorded. The tracking bed documented species missed by cameras, primarily most small animals such as mice, voles, frogs, salamanders and snakes. Rate of passage varied widely by species and also by location and method of capture. Most species common to the area were recorded using the underpasses; however, the rate of use for some species was inconsistent with our expectations based on their relative abundance in the area. Road kill and snow tracking studies demonstrated that wildlife continue to cross Route 2 outside the underpasses. Remote photography recorded behaviors (e.g., carrying prey, scent marking, travel with young) that indicate the crossing structures provided linkage within species' home ranges. We conclude that the Route 2 underpasses can facilitate wildlife movement even in areas severely impacted by human activity. Future studies will continue to monitor trends in species use over time, and possibly to evaluate wildlife responses to varied conditions within the tunnels.

## **PROJECT HISTORY**

Route 2 runs east-west along the north part of Massachusetts from Boston to the NY state border. When it goes through Concord, MA, it has four lanes, two in each direction, and a daily traffic volume of about 50,000 (see Figure 1). It is commuter roadway and has major rush hour traffic. At the same time, despite the traffic and suburban location, there is a variety of wildlife that frequent the roadside, as shown by a tracking study (L. Rogers, unpubl. data) and other reports (Forman and Deblinger 1998; Open Space Task Force 2004). To increase driver safety and avert head-on collisions, MassHighway planned to upgrade the roadway and further divide the highway with additional median barriers. To help mitigate the increased obstruction to wildlife movement that this would likely entail, MassHighway and the Town of Concord decided to install wildlife crossing structures while the road was under construction. (In this report, "tunnel" and "underpass" are used interchangeably to mean a box culvert installed under the roadway that functions as a wildlife crossing structure.) MassHighway worked with the town, Massachusetts Fish and Wildlife, and consultants at the University of Massachusetts to determine tunnel size and locations.

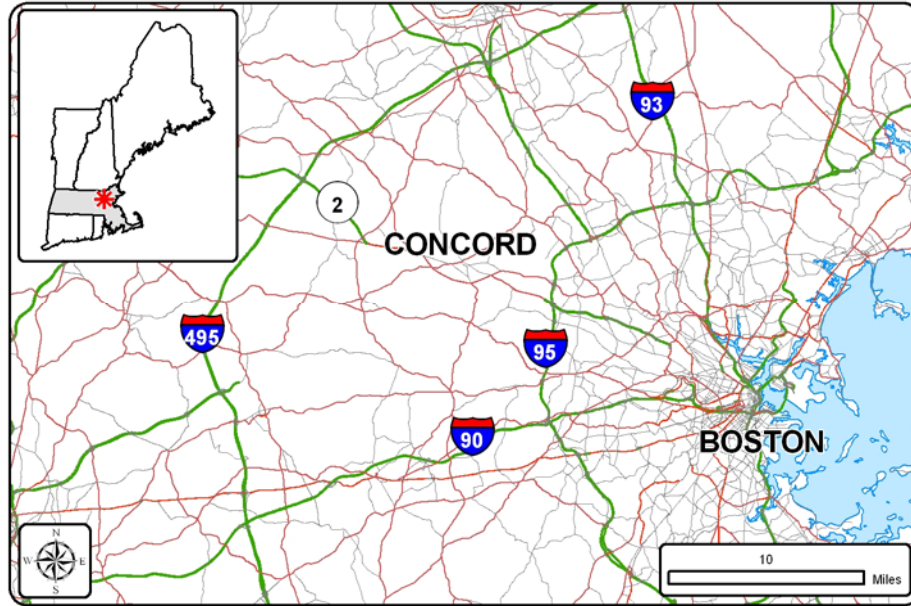


Figure 1. Location of study area. Map created by Sudbury Valley Trustees (SVT). GIS data provided by Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Energy and Environmental Affairs.

The construction project included no provisions to monitor the tunnels for animal crossings. For that purpose, the Town of Concord Division of Natural Resources created an eight-member volunteer group, the Wildlife Passages Task Force, to investigate wildlife use of the underpasses. Currently, there are twenty-four sites with wildlife crossing structures in MA, eleven of which are for general wildlife, of which the Route 2 underpasses are the only ones being monitored (D. Paulson, pers. comm.).

## STUDY AREA

The study area is a 2.5 mile portion of Route 2 in Concord that runs east-west, from Crosby's Corner to the Sudbury River. The segment includes three intersections with traffic lights and turning lanes, smaller feeder roads (two eastbound and three westbound), and one active railroad line passing under Route 2. After construction, Jersey barriers (both 42" and 32" high) and median guardrails at intersections divide most of Route 2 in Concord. There are guardrails along the side of the road over most of this section. The medians are unvegetated. About a third of the roadway is somewhat elevated above the adjacent land, especially in wetlands where fill was added during earlier construction.

The surrounding land is a patchwork of different uses: residential, open space (town, state and private land trust), wetlands, agricultural and playing fields, and commercial property. Development in Concord is mostly residential. Concord is about 25 square miles and has a population of 15,397 (Concord Town Clerk's Office 2009). Route 2 forms part of the border with the Town of Lincoln, which is 14.6 square miles and has 5990 residents (Town of Lincoln 2008). The highway largely appears tree-lined; a band of deciduous and mixed coniferous-deciduous forests and forested wetlands line both sides within 10 to 30 feet of the road. Route 2 bisects the Sudbury River and its floodplain. At the landscape scale, the road separates larger

patches of open space to its north and south, including Walden Woods and the Great Meadows National Wildlife Refuge (see Figure 2). Local accounts show Concord has a diversity and abundance of wildlife, likely an outcome of the town's diverse wetland resources (Open Space Task Force 2004).

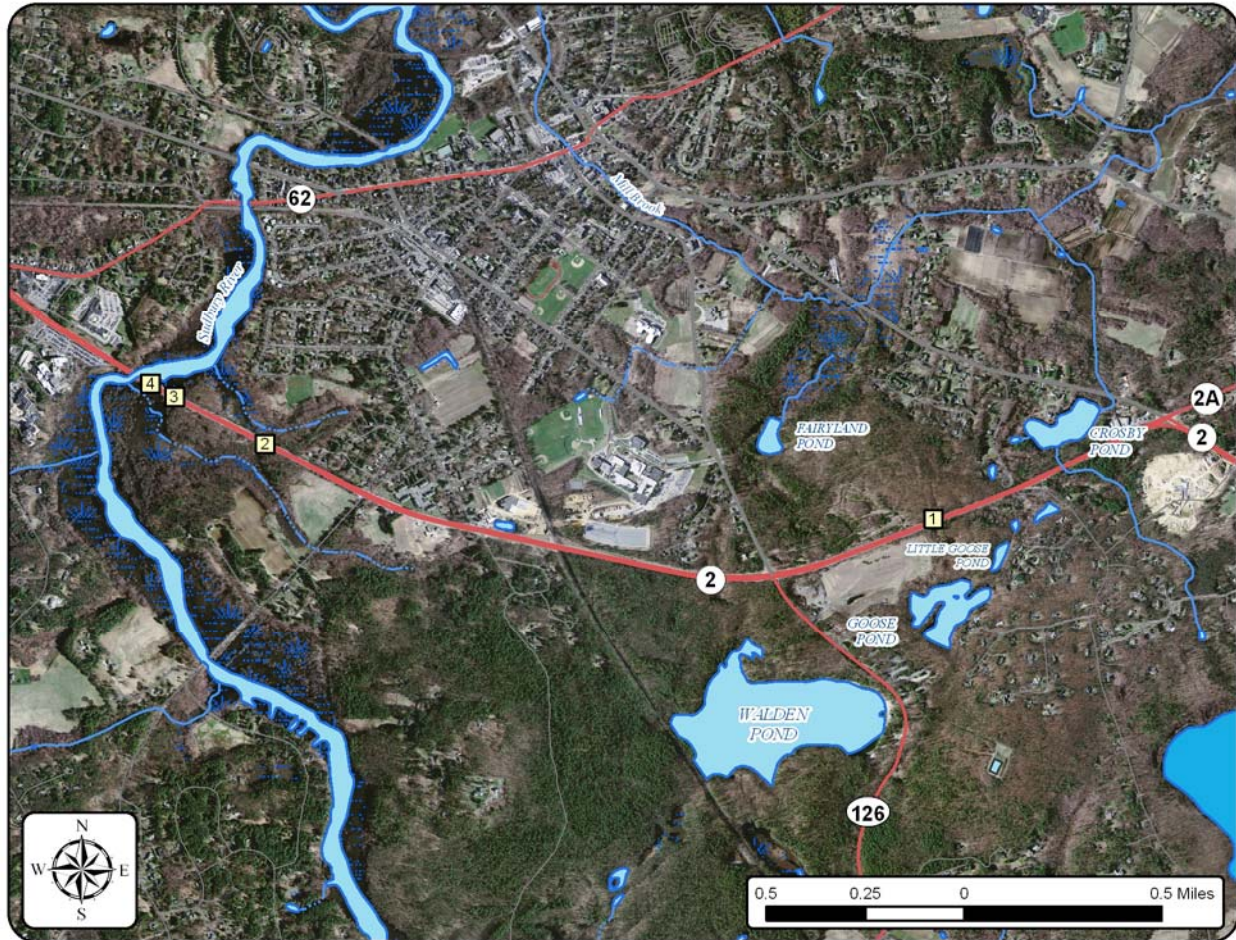


Figure 2. Aerial photograph of Route 2, Concord, MA with underpass locations. Map created by SVT. GIS data provided by Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs.

## WILDLIFE CROSSING STRUCTURES

Together MassHighway, the town staff and consultants considered different locations for the multi-species wildlife underpasses. A good site was easily located for one underpass (#1) by previous snow tracking. The locations of the other three underpasses were chosen based on a combination of construction and habitat issues: Given the topography, where would the largest structures fit and be reasonably expected to facilitate movement? Four pre-cast concrete box culverts (in 10' sections) were installed under the four-lane highway (see Figure 3). See Table 1 for tunnel dimensions and “openness” (Reed et al 1975, Jackson 1999, Clevenger and Waltho 1999).





Figure 3. Photograph of underpass # 1

Table 1. Dimensions of four wildlife underpasses in meters and feet, Concord, MA. Height times width divided by length was used to calculate “openness”.

No.	Length (meters)	Height (meters)	Width (meters)	Openness (meters)	Length (feet)	Height (feet)	Width (feet)	Openness (feet)
1	30.5	1.83	2.74	0.164	96	6	9	0.562
2	25.2	0.91	1.52	0.055	82.5	3	5	0.182
3	25.2	1.83	2.74	0.197	82.5	6	9	0.654
4	25.2	1.52	2.44	0.147	82.5	5	8	0.485

Underpass entrances were graded with dirt-covered riprap aprons. Stock-piled material that had been excavated from the site during construction was spread in the structures as substrate to a depth of about 2”. To make underpasses less conspicuous and disturbing to wildlife, the retaining wall surface (in the raised sections of highway) had a simulated quarried rock appearance, and native plantings were added at entrances and along the adjacent retaining walls. There was no added fencing for funneling animals into the underpasses or keeping them off the highway. However, there are different types of fencing (including cyclone, wood, barbed wire) of varying heights near residences, playing fields, state highway property, the railroad tracks, and other sections. In places where the roadway is higher than the surrounding land, the retaining walls partly block wildlife movement onto the roadway. The underpasses and other road construction were completed in the fall of 2005, after which we began evaluating monitoring techniques.

## PROJECT GOALS

The goal of the study was to determine whether wildlife would use the crossing structures; if so, which species and how frequently? Also, how would a group of volunteers accurately monitor animal crossings?

## METHODS

### Track Bed Study

A tracking bed was made in one underpass by sifting the dirt substrate through wire screening onto black plastic between two 2" by 4" boards to a depth of about ½". When dry, this fine, sandy dirt proved to be very good for registering tracks. The bed was in the center of the underpass, the width of the tunnel floor and about 10' long. See Figure 4. Usually two experienced trackers read the track bed twice weekly. The bed was visited 158 times between January 2006 and June 2008. We recorded species, direction of travel, location within the track bed and degree of certainty. When necessary, tracks were identified to a group of species, e.g., "small mammal" for mice and vole, or "weasel" for both long- and short-tailed weasel. Unidentifiable tracks were noted. We "erased" the track bed after each reading with a synthetic duster. The track bed and tracks of interest were photographed for future reference. There was a track bed in only one underpass (#1).



Figure 4. Track bed with Reconyx camera in underpass # 1.

### Camera Monitoring Study

We tested several camera models and configurations to find the most reliable way to record photographic images of the animals while they registered tracks in the bed at the same time. The first model was a homemade unit using a Sony P41 camera and Pixcontroller ([www.pixcontroller.com](http://www.pixcontroller.com)) pyroelectric infrared sensor, or "PIR" sensor. The camera was modified with an infrared filter to eliminate the white flash. The unit captured very high quality images, but the relatively slow triggering time caused many misses. See Figure 5. Modification with an external power source (6V battery) improved trigger speed by enabling the camera to run in an "always on" mode. However, replacing and charging the battery weekly was labor intensive, and the camera still missed many animal crossings. The Leaf River Model iR-3BU Infrared Digital Game Camera as tested in the underpass lacked sufficient illumination and also missed most passages.



Figure 5. Images from Sony P41. Clockwise from top left: two raccoons, cottontail rabbit, woodchuck, and long-tail weasel.

We found the Reconyx Silent Image Recreational Model RM30 ([www.reconyx.com](http://www.reconyx.com)) cameras to be more successful at recording most animal crossings. The Reconyx models were also triggered by a PIR sensor but were substantially faster in recording the first image, resulting in a many fewer misses. The RM30 contained infrared LEDs to illuminate the images, though a very visible red glow was noticeable when operating under the low-light conditions within the tunnels. Through trial and error, we found that instead of aiming cameras perpendicular to the animals' line of travel, angling the camera down the underpass captured more passages because it allowed enough time after triggering to photograph the animal with sufficient illumination.

We then installed cameras on the walls of the other underpasses. Wooden camera mounts were affixed to the concrete walls using heavy-duty construction adhesive. The camera and motion-detector unit was mounted on a tripod head (VersaMount™) and secured with a cable and padlock. In two underpasses (# 3 and # 4) cameras were mounted in the center of the underpass 58" or 44", above the ground, respectively. The camera in the smallest underpass (# 2) was mounted 19" above the ground in the north entrance, rather than in the center of the underpass so it could be easily accessed. The cameras installed in the underpass with the track bed (# 1) were mounted 14" and 53" from the floor. The lower location more successfully photographed the small mammal crossings. From 2006 to 2008 in tunnels one, two, three, and four, cameras were active for 404, 275, 457, and 466 nights, respectively.

The Reconyx cameras were powered by rechargeable AA nickel-metal hydride batteries. Compact flash media cards stored 1/2 megapixel images. The cameras were set to record three images per triggered event with one second between each photo. Subsequent triggers were possible without lapsed time. The cameras were in place for weeks at a time. We visited cameras every three or four weeks to swap batteries and the flash card and change desiccant pack as needed. We rotated the three cameras in the four tunnels.

### **Data Analysis**

For the camera analysis, we calculated crossing rates for each species by counting the number of individuals recorded crossing through the tunnels and dividing by the number of days the cameras were active. We only included individuals that appeared to cross all the way through the tunnels. If it looked as though the animal turned back to exit from the side it entered from, we did not count this as a passage. Motion-sensor cameras will take multiple images of the same animal if it stays in front of the camera. To avoid repeatedly counting a single tunnel visit, we counted as one crossing event any series of images of the same species in which there is not a ten-minute gap (recorded in time-stamps on the photographs) between any two successive frames. When multiple individuals of the same species could be distinguished in the photographs, we counted each individual as a separate crossing event.

For the track bed data, we counted each of the 158 visits by the trackers to the tunnel as a separate observation window. During each observation, trackers recorded the number of trails of each species that had been created since they last erased the track bed on their previous visit. The number of nights that elapsed between visits varied. To obtain crossing rates, we divided the number of trails observed for each species during a given observation window by the number of nights that had elapsed since the previous visit. This methodology gave us 158 crossing rates for each species, from which we calculated mean and standard errors of estimated crossing rates. We did not include tracks in this analysis for which the identity could not be determined with high confidence.

### **RESULTS**

At least 32 different animal species were documented using the wildlife culverts by either the track bed or the remote cameras. There were no Massachusetts listed endangered, threatened or species of special concern. See Table 2.



Table 2. Animal passages through wildlife underpasses in Concord, MA detected by tracking bed and remote photography 2006 to 2008. Plus (+) denotes presence recorded.

Species	By Tracks	By Camera
Humans ( <i>Homo sapiens</i> )	+	+
Domestic cat ( <i>Felis catus</i> )	+	+
White-tailed deer ( <i>Odocoileus virginianus</i> )		+
Domestic dog ( <i>Canis familiaris</i> )	+	+
Eastern coyote ( <i>Canis latrans</i> )	+	+
Red fox ( <i>Vulpes vulpes</i> )	+	+
Gray fox ( <i>Urocyon cinereoargenteus</i> )	+	+
Northern raccoon ( <i>Procyon lotor</i> )	+	+
Virginia opossum ( <i>Didelphis virginiana</i> )	+	+
Striped skunk ( <i>Mephitis mephitis</i> )	+	+
Northern river otter ( <i>Lutra canadensis</i> )		+
Fisher ( <i>Martes pennanti</i> )	+	+
American mink ( <i>Mustela vison</i> )	+	+
Weasel ( <i>Musela frenata</i> or <i>M. erminea</i> )	+	+
Eastern cottontail rabbit ( <i>Sylvilagus floridanus</i> )	+	+
American beaver ( <i>Castor canadensis</i> )		+
Woodchuck ( <i>Marmota monax</i> )	+	+
Muskrat ( <i>Ondatra zibethicus</i> )		+
Eastern gray squirrel ( <i>Sciurus carolinensis</i> )	+	+
Eastern chipmunk ( <i>Tamias striatus</i> )	+	+
Mice spp.( recorded as “small mammal”)	+	+
Vole spp. (recorded as “small mammal”)	+	+
Mole (species not determined)	+	
Common snapping turtle ( <i>Chelydra serpentina</i> )		+
Snake sp. (one garter snake, <i>Thamnophis sirtalis sirtalis</i> observed)	+	
Frogs (species not determined)	+	
Salamander sp. (dead northern redback salamander, <i>Plethodon cinereus</i> , observed)	+	
Mallard ( <i>Anas platyrhynchos</i> )		+
American robin ( <i>Turdus migratorius</i> )		+
Mourning dove ( <i>Zenaida macroura</i> )	+	
Bird spp.	+	
Bat sp.		+

Figure 6 shows the passage frequency by species detected by the tracking bed in underpass # 1.

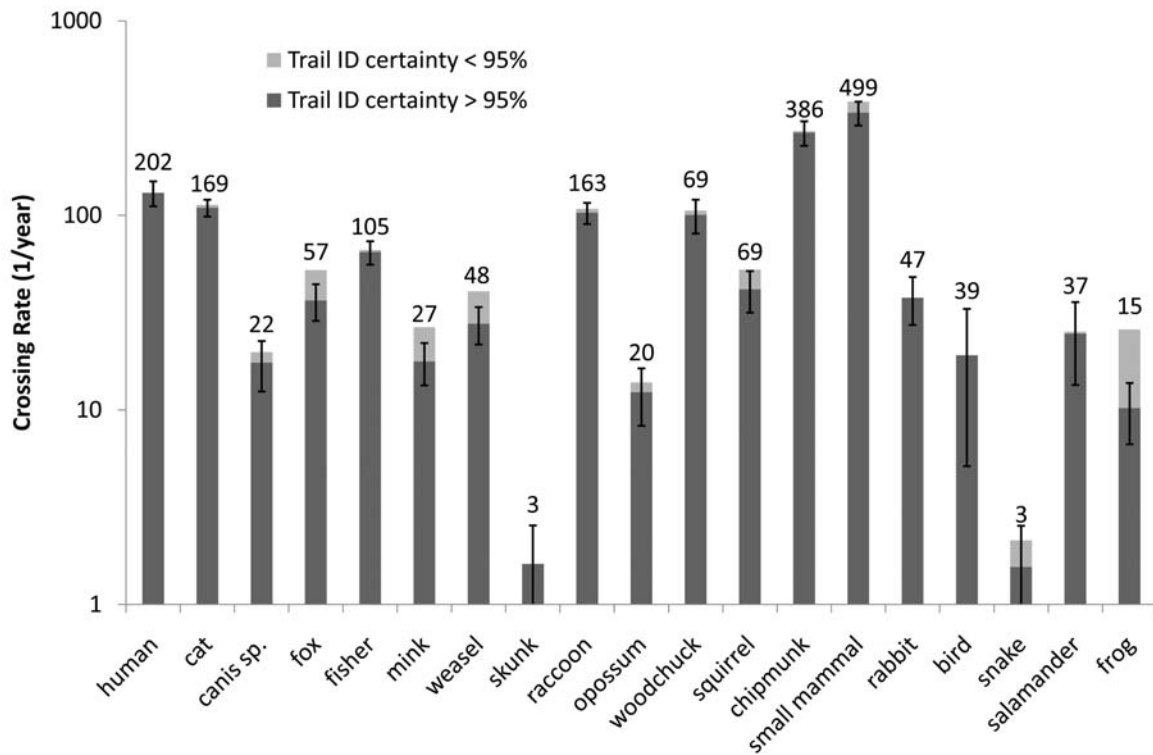


Figure 6. Mean crossing rates through one wildlife underpass based on track bed data monitored along Route 2 in Concord, Massachusetts from 2006 to 2008. For each visit to the track bed, crossing rate is calculated as the number of trails observed divided by the number of track-nights since the last visit to the track bed. Track beds were visited on 158 occasions. Light gray bars represent tracks that observers were not highly confident the species identity. Error bars represent standard error of rate estimate based on high-ID-certainty trails. The numbers above the bars represent the number of high-ID-certainty trails observed.

For the camera data, we calculated the mean crossing rates for each species based on the combined results from cameras in the four underpasses during 2007 and 2008. See Figure 7.

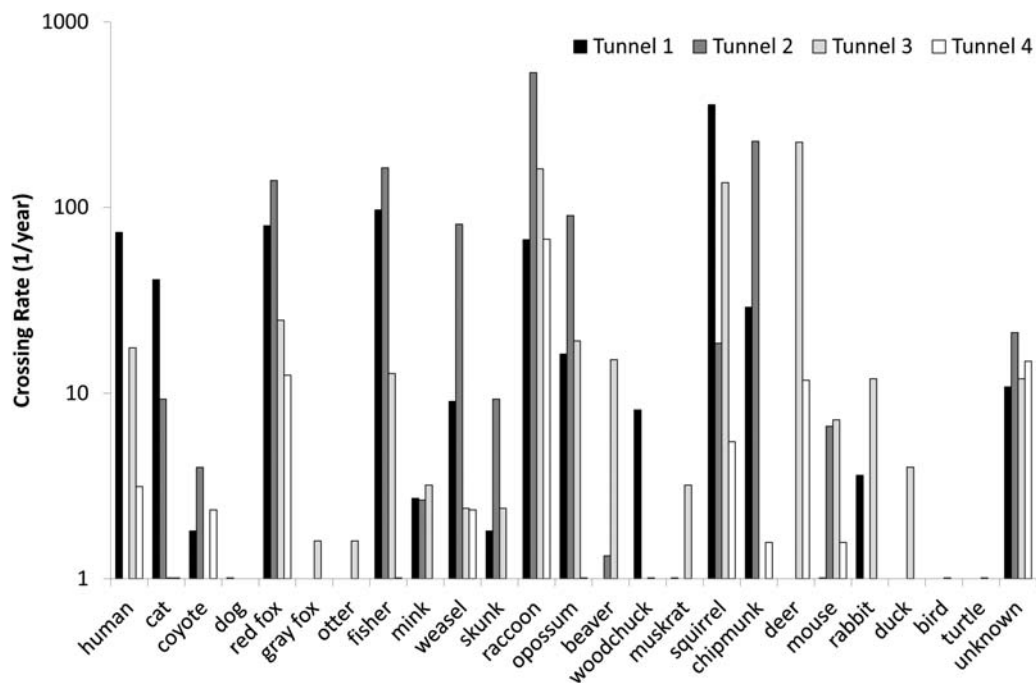


Figure 7. Estimated crossing rate for species based on camera data from four wildlife underpasses monitored along Route 2 in Concord, Massachusetts during 2006, 2007, and 2008. The number of camera monitoring days for tunnels one, two, three, and four are 404, 275, 457, and 466, respectively. The unknown category represents animals for which positive species identification was not possible. Animals that did not appear to cross through the tunnels are not included.

## DISCUSSION

### Comparison of Remote Photography and Tracking Bed Methods

We mounted a camera over the track bed in tunnel # 1 so that we could compare passages detected by the camera with those recorded in the same time period within the track bed. Figure 8 compares mean crossing rates for each species that used the underpass obtained by the two methods over this interval. For some species (e.g., raccoon) the passage rates whether by camera or track bed were similar. For other species (e.g., chipmunk), the camera detected fewer passages than the track bed. For an additional group of species, (e.g., salamander), the camera missed passages altogether.

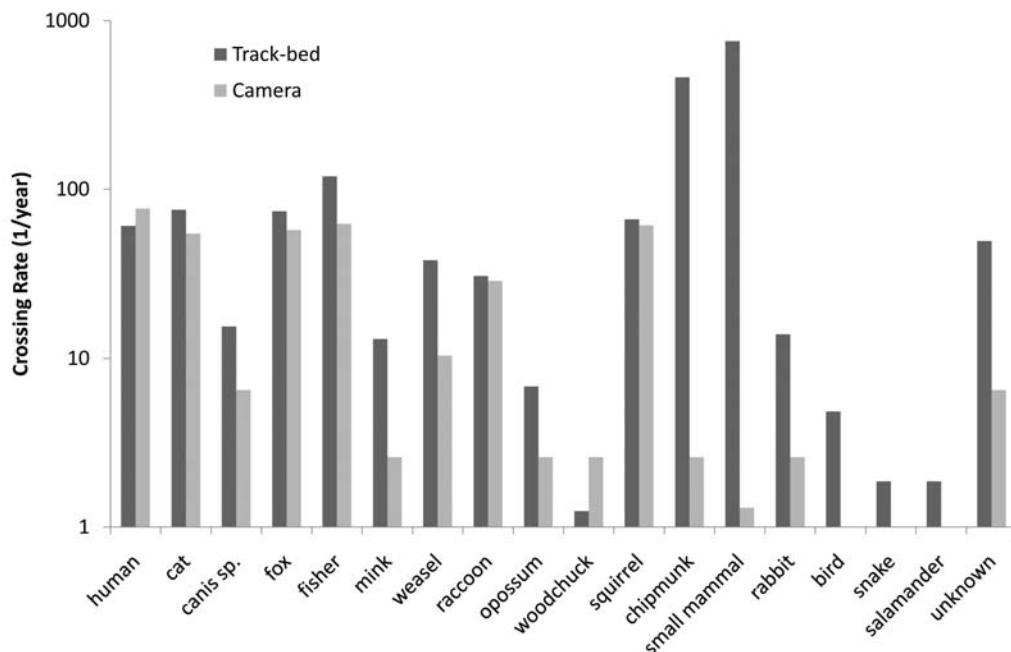


Figure 8. Mean crossing rates for species estimated using track-beds and cameras to monitor one wildlife underpass under Route 2 in Concord, Massachusetts during 2007 and 2008.

We found some drawbacks to using tracking beds to document species movement through the underpasses. The tracking bed was only useful under dry conditions. When the substrate was water saturated, it was too compacted to be cleared of tracks or to reliably register tracks of animals except for deer, which was the case in three of the underpasses. The track bed method required twice weekly visits and occasional added maintenance, such as removal of blown leaves and debris. A sign posted at the underpass entrances explained the purpose of the crossing structures and requested that the public refrain from entering. However, people did walk through and their prints (as well as overlapping animal trails, such as woodchuck) could confound track identification. Species identification from tracks was not necessarily self-evident (Rezendes 1999); it required experience and training, and more than one observer when possible.

The Reconyx cameras had the advantage that they could be left for weeks at a time, even in the winter. However, when we compared passages recorded in the track bed with photographs taken by a camera mounted over the track bed for the same time interval (Figure 8), we found the cameras missed many animal crossings. The Reconyx cameras are triggered by a moving object with a substantially different temperature than the background environment. Almost all snakes, and all frogs and salamanders did not trigger the cameras. The cameras also missed most small mammals, though success was improved by lowering the height of the camera. Precise aim of the camera affected image capture and was hard to consistently replicate. The camera also sometimes missed even fisher and other medium-sized mammals going through the underpass. Occasionally, blurry photographs of rapidly moving animals were difficult to interpret.



There was considerable difference in cost and maintenance of the two methods. The Reconyx cameras cost about \$900 each. It took less than half an hour per person per week to maintain operation and another person-hour to enter the data. The track bed cost less than \$20 in materials but took about five person-hours to initially install it. The track bed required about four to six person-hours per week to read and maintain it and only a few minutes to enter the data.

Since we were concerned that the camera monitoring would deter wildlife from using the crossing structures, we used only cameras without white flash. It was clear from the photographs that wildlife were quite wary of the Reconyx RM30 cameras; they were silent but had a visible red glow. (According to the Reconyx website, newer models have NoGlow™ illumination.) Some animals balked and attempted passage repeatedly, eventually either leaving the tunnel or going through. Photographs taken at the tracking bed indicated the bed was much less disturbing than the camera, though not completely.

Remote photography, despite its drawbacks, provided information that could not be garnered from tracking alone. Cameras documented exactly when animals crossed, whereas the passages in the track bed occurred within a three- to five-day window. Also, the photographs recorded interesting behaviors that showed how animals were interacting with the underpasses.

### **Passage Frequency**

The crossing structures are relatively small and long (see Table 1), there is no fencing to direct wildlife, and locations are somewhat arbitrary. Nonetheless, most wildlife species documented within the surrounding areas were also recorded using the underpasses, some frequently. The exceptions to this were red squirrel (*Tamiasciurus hudsonicus*), southern flying squirrel (*Glaucomys volans*), and wild turkey (*Meleagris gallopavo*). Frequency of passage rates for gray fox and eastern cottontail rabbit was lower than anticipated from snow tracking along the roadside. In one tunnel (# 1), although snow tracking recorded extensive deer trails in the immediate area before and after construction, and deer tracks were often found in the south entrance of the underpass, there were no recorded deer passages.

The detection of a given species within the underpass could be quite variable over time. It took months before some species (e.g., cottontail rabbit, coyote, gray fox) were recorded using the underpasses. For some species, there were very high passage rates. Since in most instances we were not able to distinguish individual animals by photographs, the many crossings recorded of fisher, red fox, and raccoon may represent a few busy individuals. Also, mice photographed using the small weep holes inside the tunnel (which were, in turn, visited by predators) were more likely residents than animals crossing through. Woodchuck, chipmunk and gray squirrel crossing frequencies were high in the fall.

Since rivers can serve as natural movement corridors, we had anticipated that the underpass closest to the Sudbury River (# 4) would show high crossing rates. However, comparison of passage rates in the tunnels did not show this (Figure 5). One reason may be that during flood conditions, the tunnel becomes isolated by high water. Adding space for crossing under the bridge, especially on the other (west) side of the river, when the bridge span is updated may provide more opportunities for animal crossings (Mullin et al 2007).

We also monitored road kill in the study area. Road kill with odometer location was recorded while driving the speed limit (45 mph) along the study area in both east- and westbound directions. (Lower speeds or walking were unsafe due to traffic and little to no roadside space.) Species were identified if possible or recorded as “small” (e.g., squirrel), “medium” (e.g., raccoon), or “large” (e.g., coyote). There were 159 road kills from 194 days of observation over 35 months. At 45 mph these data have limited validity but do demonstrate that a variety of wildlife still attempt crossing over the roadway. Preliminary road kill data for white-tailed deer as reported to the Concord Police suggest that there may be a slight reduction in deer-vehicle collisions since completion of the underpasses (Detective Forten, pers. com).

During the winter of 2007, a snow-tracking study was done 24-48 hours after snowfall on six occasions. Positively identified tracks within 25 yards of the roadway and GPS coordinates were recorded using CyberTracker software on a Palm Pilot. We recorded and mapped the following seven movement patterns: movement along side the road, movement onto the road, movement off of the road, approach and retreat from the road, entering crossing structure, exiting crossing structure, and approach and then retreat from a crossing structure. Snow tracking data indicates that wildlife continue to cross over Route 2 as well as going through passage structures and that animals often parallel the roadway and may make repeated crossing attempts. Tracking in the study area was constrained by the fact that there is a lot of wildlife activity in a small space with many intersecting trails. Following a trail soon led the observer to an impassable wetland or someone’s backyard. Snow tracking gave an interesting snapshot of how animals interacted with the roadway and underpasses, and presented more questions for future study. Over time, would there be relatively more passages through the underpasses than over the roadway? Would the animals that approached and retreated from the underpass, eventually go through?

## **CONCLUSIONS AND RECOMMENDATIONS**

### **Crossing Structure Design**

There may be ways to even further enhance the design of the underpasses. Water from leakage between concrete sections, road runoff released at tunnel entrances, and river flooding curtailed monitoring at times and most likely influenced animal usage (deer, raccoon, weasel, and kayakers were often undaunted). It would have been interesting to see if shelves retrofitted into the underpasses in the floodplain would have facilitated more passages, especially for small mammals (K. Foresman, 2003). Snow plowed and pushed over the roadway accumulated and partly blocked underpass entrances and once may have compelled a red fox to go over the roadway with fatal results.

The dry underpass (# 1) enabled us to set up the track bed and record salamander, frog and snake passages that cameras missed. However, dryness had its downside as well; the underpass may have been a conduit for some salamander crossings, but several salamanders were found dead in the substrate, apparently victims of desiccation. It would be desirable to add a moisture source in this underpass that does not interfere with the track bed but helps the salamanders survive. We were unable to record salamander use of the three other underpasses.

The crossing structures will require maintenance. Underpass substrate and dirt that covered riprap at entrances was partly washed out by flooding will need replacement. Trash rapidly accumulates along the study section. The Department of Corrections road crew removed a

tremendous amount of trash in several sections. Many of the added plantings did not survive, and some original (and invasive) plants overgrew them. Both planted and preexisting roadside vegetation will need management so that it does not obstruct wildlife movement.

### **Human Usage**

We assumed that human activity could deter at least some wildlife use, even if the animals were already habituated (Clevenger and Waltho 2003). Signs posted at underpass entrances informed the public about the project and requested their cooperation in staying out. When talking about the structures to the public, we avoided describing exact underpass locations. Nonetheless, photographs show approximately 100 human crossings per year. People were photographed on foot, in boats, with dogs, on cross country skis, snowshoes, and bikes.

Not surprisingly in a residential area cut by a busy highway, there was considerable interest in connecting access to open space on either side of Route 2. The *Walden Passage Feasibility Study December 2007* (Mullin 2007) evaluated the plan to build an additional crossing structure within this same study area that would provide recreational and “cultural connectivity”, while further facilitating wildlife passage. Although they concluded that “the existing wildlife crossing culverts under Route 2 are already being used successfully by a majority of species”, pressure to provide pedestrian crossing continues. Our data were insufficient to document how human presence affects wildlife use of the underpasses.

### **Volunteer Monitoring**

Citizen groups have contributed important data for a number of projects, such as the Christmas Bird Count and local chapters of Keeping Track®. In this study, all observations about wildlife use of these underpasses were the result of volunteer efforts. We had intended to include more volunteer trackers; however, having a small, core group minimized observer-related variability in track interpretations (Hardy 2003). Also, we felt the need to balance the value of sharing the project with the public with the need to limit human visitations to the structures.

### **Effectiveness of crossing structures**

The tracking bed and remote photography results estimated wildlife use of four crossings structures by measuring the rate of detections for each species (van der Ree et al 2007). The results clearly show that a wide variety of animal species use the underpasses, some frequently, despite somewhat arbitrary locations, relatively small size of the structures, and a highly fragmented suburban setting. This study was not able to determine if the crossing structures were used in preference to crossing over the road surface or if road mortality declined compared to levels before the underpasses were installed. However, if the desired “effect” of the underpasses is to allow individual animals to cross the road, the Route 2 underpasses are a success.

It is not clear how effective the tunnels will be in the long term at mitigating the negative impacts of habitat fragmentation (Hardy et al 2003). The most desirable mitigation goal would most likely be preventing a reduction in the viability of local populations over the long-term (van der Ree et al 2007). Even if, as our results would suggest, the underpasses enabled wildlife to access resources and move without hindrance between both sides of the roadway, it is unknown whether this permeability is sufficient to counter the other negative impacts of the roadway on the long-term health of wildlife populations (Roedenbeck et al 2007).

On the other hand, the monitoring results indicate that wildlife species present in the remnant patches of land close to Route 2 are surprisingly adept at dealing with the highway and human-impacted landscape. Photographic images suggest that wildlife are successfully incorporating the underpasses in their activities and linking parts of their home range. Raccoon were usually photographed in pairs and larger family groups. Photographs record unexpected crossings, such as coyote using even the smallest, 3' by 5' (# 2), underpass. Deer often moved in small groups. Two different bucks were photographed using the same underpass in one season. A doe and her fawn were repeatedly photographed together in one underpass. In an amazing display of fidelity to a flooded underpass, a deer swam through, upstream. A fisher was photographed carrying prey to one side of the road June to September, presumably to a den. Fisher, red fox and raccoon marked with scent inside the underpass and at the entrances. One industrious gray squirrel traveled back and forth, leaf by leaf, to build a nest on the other side of the road. See Figure 9.



Figure 9. Reconyx photos from within four underpasses, Concord, MA. By row, left to right: kayaker, fisher, doe and fawn, fisher with skunk, gray squirrel with leaf, raccoon family; swimming deer, coyote, and buck.



Irrespective of the biological value of the crossing structures, the Route 2 underpasses have proven successful in terms of social and political factors (Servheen et al 2007). Publicity about the underpasses in local and regional media helped educate the public about the presence of wildlife near roadways in their communities, the impacts roads have on wildlife, and measures taken to mitigate the negative effects. The photographs gathered by this study proved to be a valuable public relations and educational tool. Citizen involvement has been part of the project from the beginning. The underpasses were planned and installed in part because of local interest; they were monitored by a volunteer group who were curious and committed to finding out if they “worked”. Ultimately it will be the public that decides whether the crossings structures are “worth” the expenditure.

We conclude that the underpasses facilitate wildlife movement under Route 2 in Concord, MA. The two methods we developed to monitor usage did record usage but had different advantages and disadvantages. Future study will focus on trends in wildlife populations over the long-term and perhaps how wildlife crossings are affected by different conditions. In particular, we would like to design a controlled study to determine whether human presence in the crossing structures affects wildlife use.

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Noah Charney has conducted research on amphibians, mammals, birds, a variety of conservation issues and experimental physics. He is currently pursuing a PhD in salamander terrestrial ecology at the University of Massachusetts, Amherst as a National Science Foundation Graduate Research Fellow. He has studied and taught about animal tracking for over a decade and is co-author of an upcoming field guide to invertebrate tracks and sign.

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