BERKSHIRE WILDLIFE LINKAGE: ROADS AND WILDLIFE CROSSINGS

A Report To

The Massachusetts Chapter of The Nature Conservancy

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EXECUTIVE SUMMARY

From May–December 2017, I contracted with The Nature Conservancy of Massachusetts to research wildlife mortality and behavior at road-stream crossings and along segments of Route 8, Route 2, and Interstate 90 in western Massachusetts. In total, our group assessed aquatic organism passage at 48 crossings, camera trapped at 11 sites, and recorded 207 roadkill incidents. We piloted new protocols for assessing terrestrial wildlife passage at road-stream crossings.

The study section of Route 8 acts as a barrier for many amphibians. We do not believe that this section of Route 8 poses a significant barrier for other terrestrial wildlife species, although mortality does occur. It appears that wildlife can cross over or under Route 8 with limited risk of mortality. Route 8 acts as a barrier to aquatic organism passage in a number of locations.

Our work on Route 2 was limited to the area around one bridge over the Hoosic River, which currently is capable of passing a variety of terrestrial and aquatic organisms, although no dry passage is available through this structure.

On Interstate 90, our work at three crossings revealed that terrestrial mammals, including deer, bobcat, bear, and fisher are able to cross the interstate at certain crossings. Camera trapping at these sites is ongoing, and will provide more information on the frequency of wildlife use at these crossings. Both culverts we studied pose a barrier to aquatic organism passage.

We caution readers that this short-term, single-season study does not capture the full demographic and behavioral variability of wildlife populations along roads (Clevenger and Wierzchowski 2006). As such, this report should be interpreted as a preliminary, rapid assessment of wildlife activity near a variety of road features. We recommend focused, question-based research as a follow-up to this project. Personnel with limited training can perform most methods we used; however, investing in expertise during key points in the research process will generate higher quality data.

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Cover Image: Bobcat (*Lynx rufus*) crossing Interstate 90 culvert.

PROJECT INTRODUCTION

Western Massachusetts contains large, intact forests, wetlands, and other habitat features that offer potential routes for wildlife movement between the Green Mountains of Vermont and the Hudson Highlands of New York. The Staying Connected Initiative (SCI), a regional conservation partnership, refers to this potential corridor as the *Greens to Hudson Highlands Linkage*, known locally as the *Berkshire Wildlife Linkage*. Although the Berkshire Wildlife Linkage could serve as a high-quality corridor, road networks crisscross the region, creating barriers to wildlife movement (Forman et al. 2003).

Not all offending roads can be mitigated for wildlife passage in the short term. To identify roads with the greatest influence on wildlife habitat connectivity, the *Critical Linkages Project,* a partnership between the University of Massachusetts-Amherst, Massachusetts Department of Transportation (MassDOT), and The Nature Conservancy, conducted GIS-based analyses. *Critical Linkages* identified twenty-two "priority road segments" in western Massachusetts. Mapping where these priority road segments coincide with anticipated highway projects allows conservation partners to provide input during early stages of road project planning.

Although a GIS-based approach provides useful information, researching how wildlife actually move on the ground provides much-needed local context. Few field-based wildlife studies have been conducted along Berkshire Linkage priority road segments. In 2017, we piloted a study along four *Critical Linkages* priority road segments. Our aim was to create a package of field data identifying problem areas for wildlife connectivity and potential locations to prioritize infrastructure upgrades that enhance wildlife passage across, and under, roads. The training materials in the appendices of this report can be used by conservation organizations conducting similar work along the remaining 19 priority road segments, or in other areas.

Chapter 1 covers our results from road-stream crossing assessments for barriers to aquatic and terrestrial wildlife. **Appendix A** discusses survey methods for measuring aquatic organism passage and terrestrial wildlife passage at road-stream crossings.

Chapter 2 summarizes our findings from roadkill surveys. **Appendix B** includes training materials, data sheets, and other resources for conducting roadkill surveys.

Chapter 3 reviews our Camera Trapping results. **Appendix C** provide resources for conducting camera trapping research.

Appendix D includes resources for researchers working with private landowners.

Appendix E outlines the project files transferred to the Massachusetts Chapter of The Nature Conservancy.

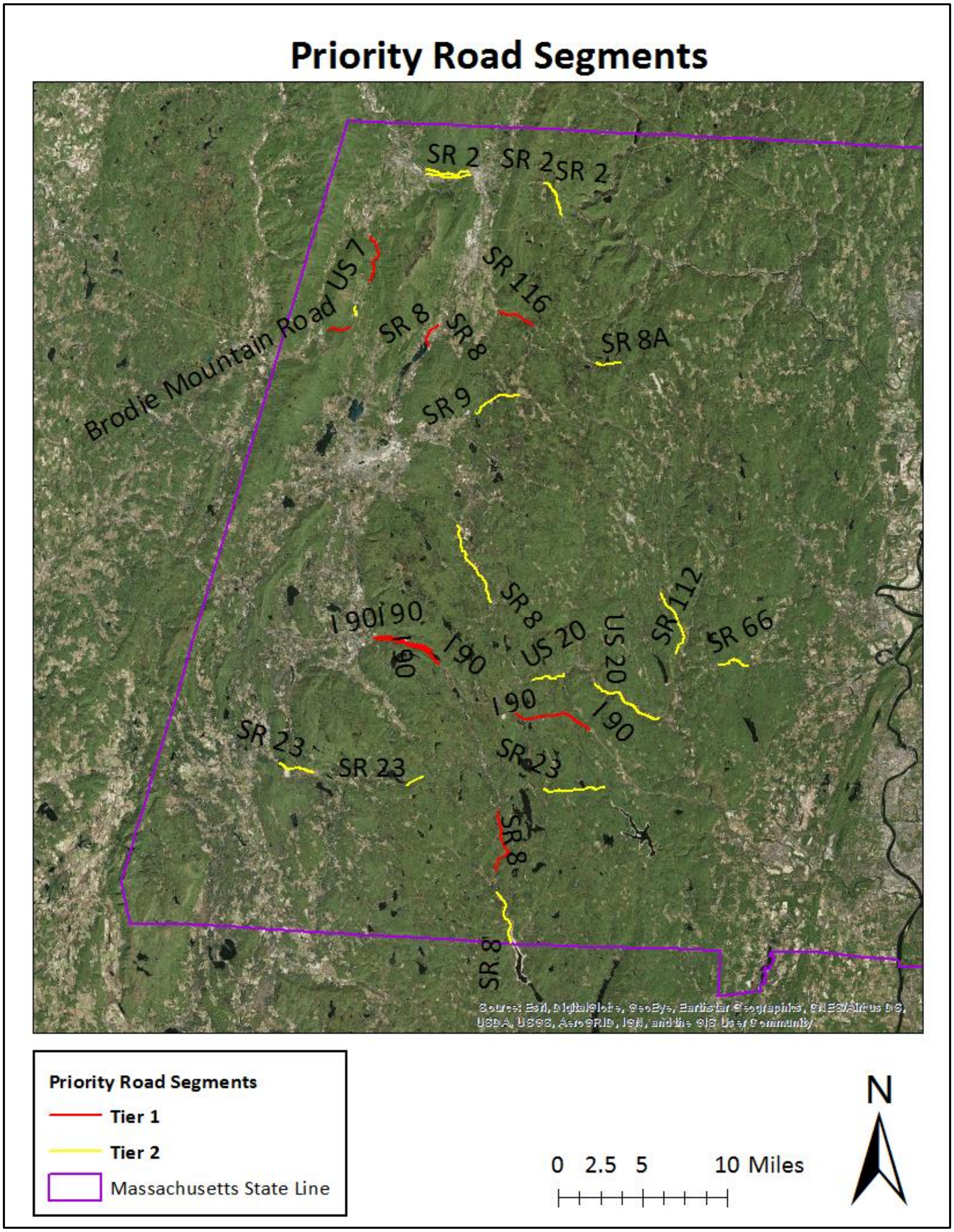

Figure 1. *Priority road segments in western Massachusetts identified by the Critical Linkages Project.*

STUDY AREA

Massachusetts State Route 8

Route 8 is a state highway that runs north-to-south approximately 66 miles from the Vermont-Massachusetts border to the Connecticut-Massachusetts border. We studied two of the four *Critical Linkages* priority road segments identified on Route 8: one segment near Otis (mile marker 4.8—9.0), and one segment near the Connecticut border (mile marker 0—3.4). Both segments run roughly parallel to the West Branch of the Farmington River, a Connecticut River tributary. In this area, Route 8 is a paved, two-lane highway. Together, these priority road segments cut through a matrix of public and private lands, including several State Forests. Our team received permits from MassDOT to conduct roadkill surveys, crossing assessments, and camera trap studies on Route 8. We also received permits from Massachusetts Department of Conservation and Recreation to camera trap in Tolland State Forest, Otis State Forest, and Sandisfield State Forest.

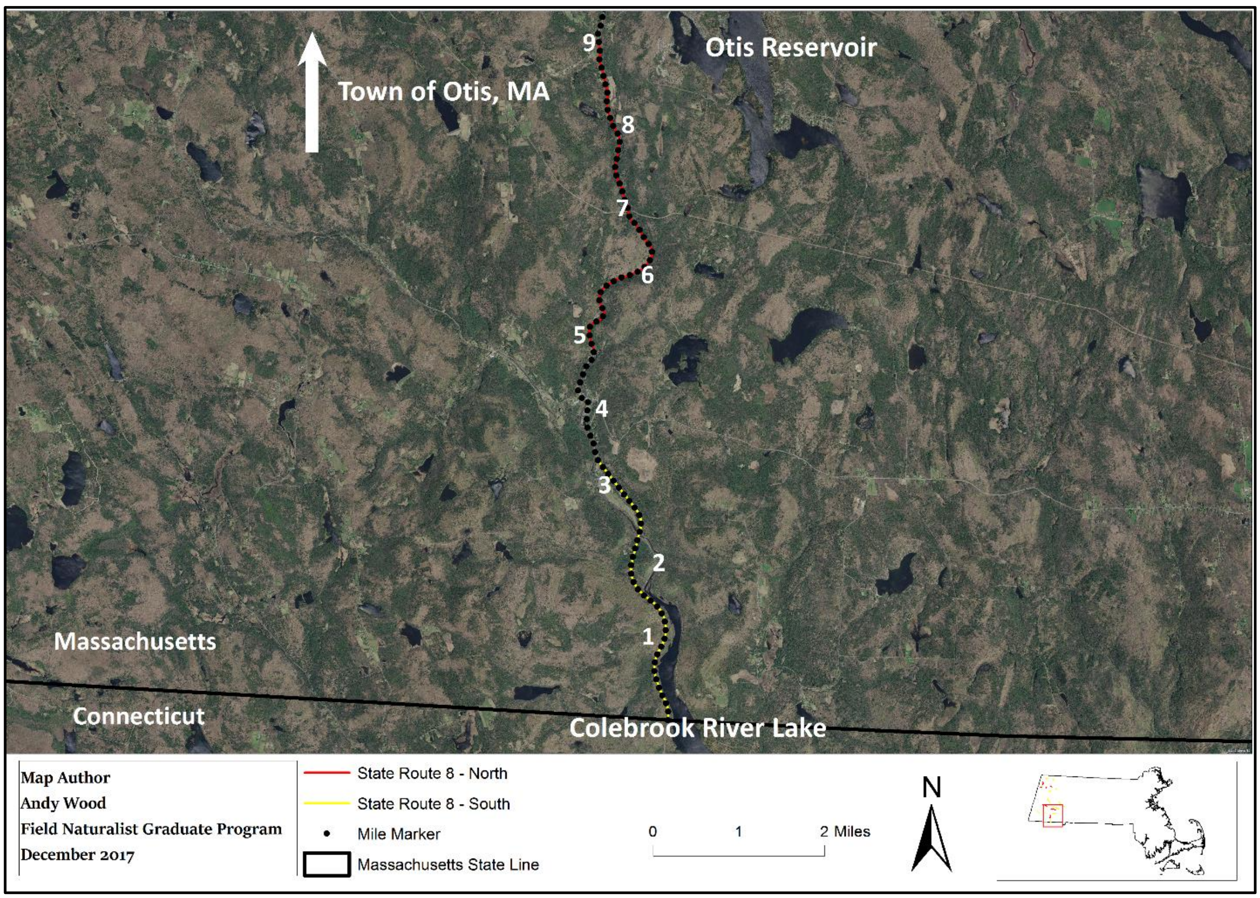

***Figure 2**. Priority road segments of Route 8 near Sandisfield and Otis, Massachusetts.*

Massachusetts State Route 2

Route 2 is a major east-to-west state highway that runs 142 miles from Boston to the western border of Massachusetts. *Critical Linkages* identified a priority road segment in North Adams (mile marker 8.4—11.1). In this area, Route 2 is a paved two-lane road. The land surrounding this section of Route 2 includes a numerous houses and businesses; however, the Hoosic River is nearby, as are several large blocks of forest, such as the Mount Greylock State Reservation. We focused our efforts on a subsection of this segment near a bridge over the Hoosic River slated for repair in 2021. Our team received permits to conduct roadkill surveys, crossing assessments, and camera trap studies at this site.

Figure 3. *Subsection of priority road segment on Route 2 in North Adams, Massachusetts.*

US Interstate 90

Interstate 90 is a major east-west highway in Massachusetts. Our segment of interest was limited to an area between the towns of Blandford and Lee. *Critical Linkages* identified two priority segments between mile marker 11.2 and mile marker 15.7 (one segment for each direction of travel on a divided highway). This area of I-90 is the only major section in western Massachusetts without an exit, and large forest blocks line each side of the interstate. We received permits to conduct crossing assessments and camera trap studies at culverts near mile marker 12.4 and mile marker 13.7. We did not request permits to conduct roadkill surveys, and consequently did not enter the roadway.

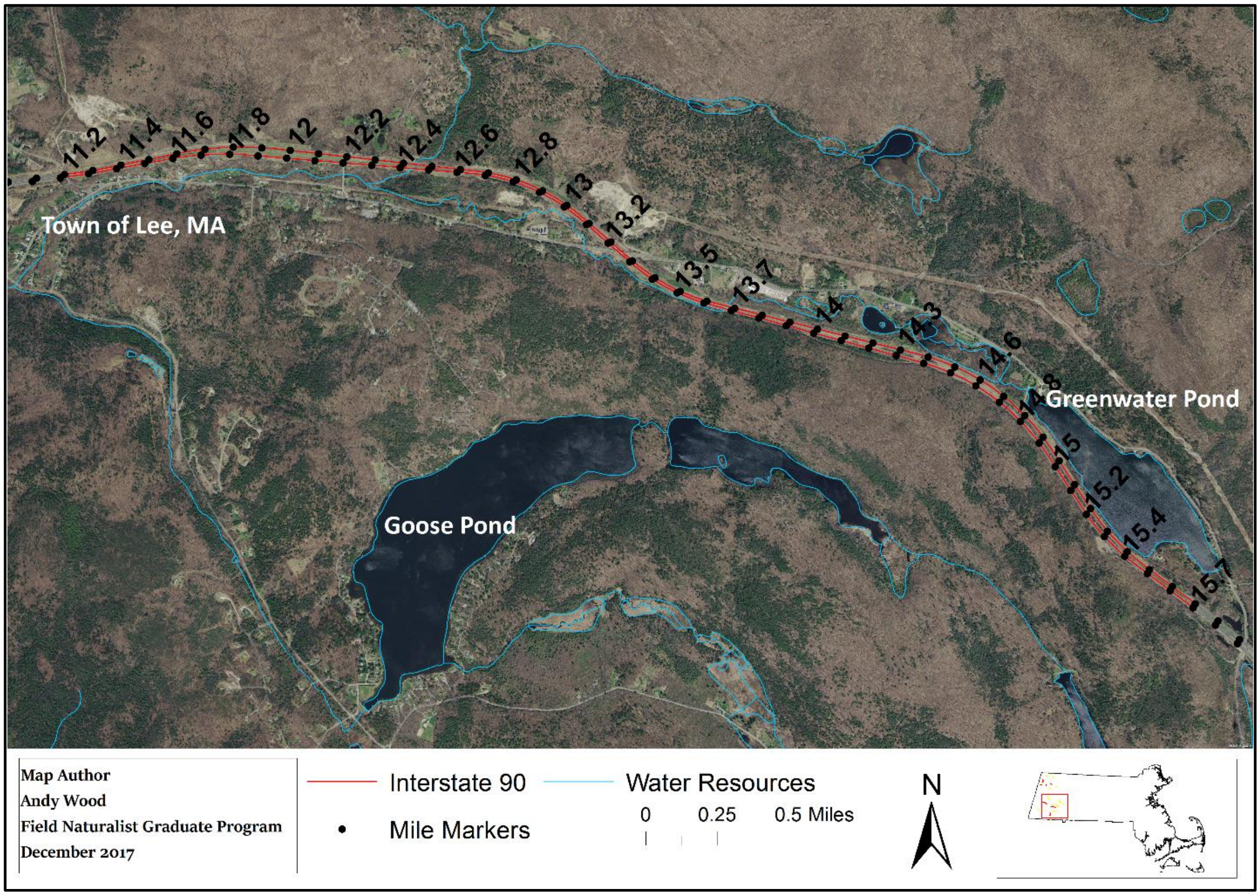

***Figure 4**. Subsection of priority road segment on Interstate 90 near Lee, Massachusetts.*

Additional Field Sites

We assessed road-stream crossings along other priority road segments, including Route 20 in the towns of Becket, Chester, and Lee; Route 23 in the towns of Otis and Blandford; and Route 7 in the towns of Williamstown and New Ashford. We assessed several culverts on side roads near these priority road segments.

CHAPTER 1
Road-Stream Crossings

***Figure 5**. Large box culvert underneath Route 8 near Sandisfield, Massachusetts.*

INTRODUCTION

Culverts at road-stream crossings commonly fragment stream networks. For aquatic organisms, such as fish and freshwater mussels, these barriers can alter stream habitat and restrict movement between stream reaches (Bey and Sullivan 2015). Road networks and their culverts also affect ecological and geomorphological processes (Jones et al. 2000; Pehenick et al. 2014; Wemple et al. 2001). Yet many culverts serve as unintended pathways underneath roads for terrestrial wildlife (Ng et al. 2004; Taylor and Goldingay 2003; Yanes et al. 1995). Documenting where road-stream crossings occur, and assessing their impacts on aquatic and terrestrial wildlife is an important precursor to mitigation efforts (Kintsch & Kramer 2011)

Many organizations and government agencies currently document and assess road-stream crossings for their capacity to pass aquatic organisms. One group, the North Atlantic Aquatic Connectivity Collaborative (NAACC), works across thirteen northeastern states using a well-developed survey protocol to evaluate road-stream crossings for aquatic organism passage (AOP). NAACC observers to date have evaluated over 40,000 crossings, including nearly 6,000 crossings in Massachusetts. NAACC data is publicly available to regional planners, transportation agencies, and conservation organizations. Data applications range from prioritizing infrastructure upgrades to improving hydrologic modeling (*S. Jackson pers comm. July 2017*). Since the NAACC protocol is widely used, it is a logical springboard for developing an accompanying protocol to assess terrestrial wildlife passage at culverts and bridges.

In 2017, we piloted a new terrestrial wildlife passage protocol adapted for northeastern wildlife species. This new protocol will eventually accompany the NAACC aquatic passage protocol, allowing field staff to simultaneously collect data relevant to both aquatic and terrestrial connectivity. A complete record of our aquatic organism passage surveys is available on the NAACC database at: https://www.streamcontinuity.org/cdb2/naacc_search_crossing.cfm

METHODS

Aquatic Organism Passage Surveys

We assessed aquatic organism passage (AOP) at road-stream crossings along *Critical Linkages* priority road segments in western Massachusetts. Trained NAACC Coordinators or Lead Observers supervised all AOP surveys. Crews of 2-6 people conducted all surveys during low-flow conditions. Structures were classified as providing *Full*, *Reduced*, or *No Passage*. Crossings also receive a numerical connectivity score, ranging from 0 (worst connectivity) to 1 (perfect connectivity). The NAACC database calculates additional scores to assist planning and mitigation efforts. These scores are relative values—in other words, not necessarily "true," but representing deviation from an ideal crossing structure (NAACC Steering Committee 2015).

Terrestrial Wildlife Passage Surveys

We assessed terrestrial wildlife passage at known road-stream crossings that presented a range of characteristics to test the protocol's ability to handle unusual bridges and culvert. Since no complete protocol or datasheet existed at the time of our survey, we compiled a list of general observations and problems to share with NAACC collaborators (**Appendix A).**

RESULTS

We surveyed 48 road-stream crossings in western Massachusetts for AOP and 15 crossings for terrestrial wildlife passage (**Fig. 6**). Most of our sites occurred along Route 8, which had a high concentration of un-assessed crossings. We identified and scored what we believe to be all of the road-stream crossings along the priority segments of Route 8 in Otis and Sandisfield, Massachusetts. These crossings ranged in size from small, circular culverts to large bridges spanning large headwater streams (**Table 1**).

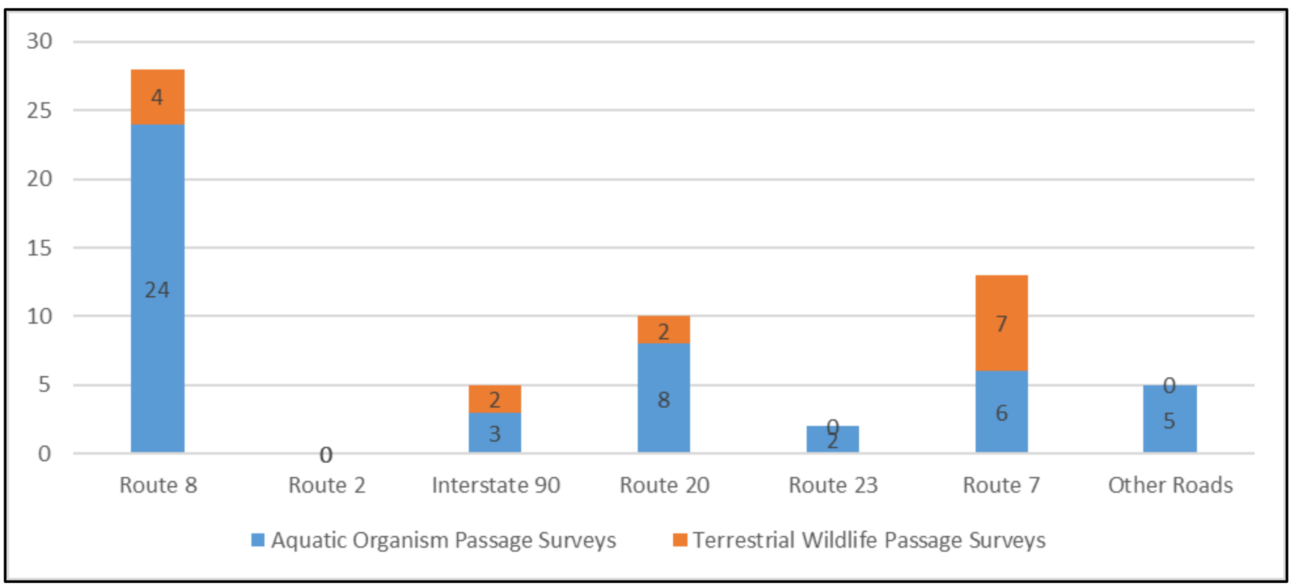

__Figure 6__ Crossing surveys along priority road segments in western Massachusetts. Note: Crossings on side roads intersecting Route 8 were lumped with Route 8 crossings in this figure.

Table 1. *AOP survey results from Route 8 priority road segments. □ = box culvert; □∏ = box/bridge with abutments; ⊗ = Round culvert; ⊗⊗=multiple culvert; ∏ = bridge, ∩=open bottom. *Denotes "Bridge Adequate" for large bridges spanning more than bankfull width. Adequate Bridges typically do not receive a full assessment, under the assumption that they provide Full AOP and a perfect Connectivity score.*

Route 8: Southern Priority Segment									
Crossing Code	**Type**	**Length (ft.)**	**Outlet Open-ness**	**Inlet Open-ness**	**AOP Score**	**Connectivity Score**	**Dry Passage (Y/N)**	**Height Above Dry Passage (ft.)**	**Barrier Evaluation**
xy4204802 373059179	∏*	no data	no data	no data	Full	1.000	Y	~ 20	None
xy4205587 073056879	□	115.0	0.739	0.739	None	0.000	N	0	Severe
xy4204984 073059360	⊗	113.0	0.467	0.467	Reduced	0.789	N	0	Minor
xy4206414 673064749	□	106.0	2.264	2.264	None	0.000	N	0	Severe
xy4207102 873063282	∏*	-	-	-	Full	1.000	Y	~ 20	None
xy4207769 073066600	⊗	69.0	0.410	0.410	missing data	0.826	Y	6	Insignificant
xy4208209 073071466	□	82.0	1.537	1.537	Reduced	0.863	N	0	Insignificant
Route 8 – Northern Priority Segment									
xy4211219 073072460	⊗⊗	18.6	0.137	0.071	Reduced	0.788	N	0	Minor
xy4212471 073066760	⊗	44.0	0.161	0.161	Reduced	0.796	N	0	Minor
xy4212575 073067130	⊗	74.0	0.024	0.024	Reduced	0.653	N	0	Minor
xy4214824 973073166	∏	32.2	2.099	1.645	Full	0.897	N	0	Insignificant
xy4214112 473071481	⊗	65.8	0.107	0.107	Reduced	0.681	N	0	Minor
xy4213520 873069657	⊗	40.0	0.177	0.214	Reduced	0.820	N	0	Insignificant
xy4210647 173074805	∩	50.0	0.298	0.340	None	0.093	N	0	Severe
xy4211223 673072573	∩	60.3	0.312	0.312	None	0.332	N	0	Significant
xy4215310 573074231	□∏	32.0	3.096	3.096	Full	0.875	N	0	Insignificant

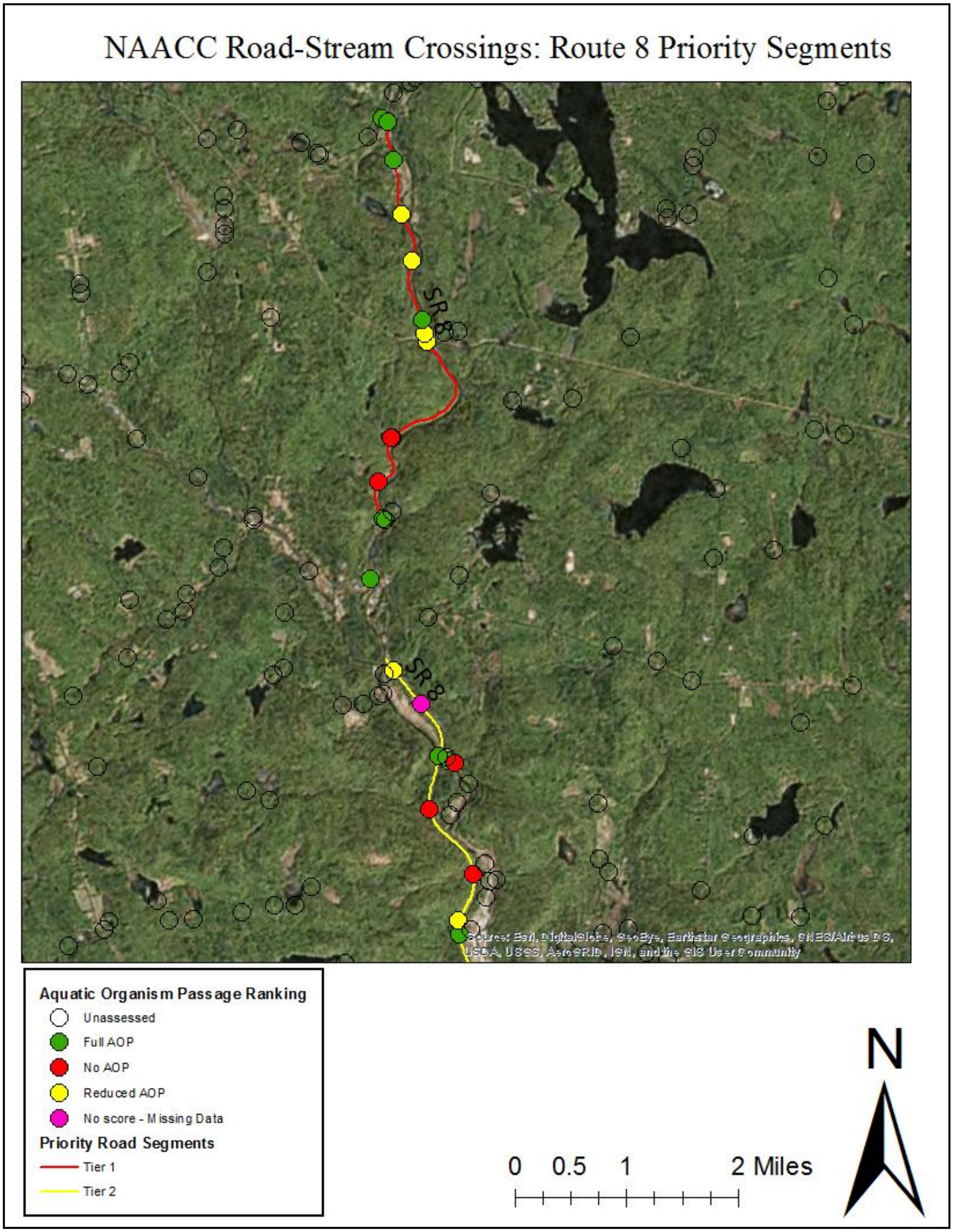

***Figure 7**. Route 8 road-stream crossings, and their associated AOP scores.*

DISCUSSION

Route 8

We encountered a wide range of structure types. Many crossings along Route 8 are small (approximately 3' diameter), round culverts that transport small or ephemeral streams underneath the road. For the most part, these structures pose minor or insignificant barriers for aquatic organisms; mitigation efforts may be more important elsewhere where severe barriers exist. These small structures may offer passage for small-to-medium sized mammals, although they typically do not offer dry passage.

Figure 8. *Small culvert along Route 8.*

Several large box culverts exist along the southern priority segment of Route 8. One such structure at Thorp Brook was 106 feet long, with a 10-foot outlet drop (**Fig. 9**). From the inlet side, this structure could accommodate many species of terrestrial wildlife, but its 10-foot outlet drop would discourage most wildlife from completing a crossing. Another similar structure nearby is 115 feet long with a 13-foot outlet drop. This unusual structure included a 150-foot chute leading to the structure and an additional 67 feet of armoring at the outlet (**Fig. 10**).

Figure 9. *Inlet (left) and outlet (right) at Thorp Brook on Route 8.*

Figure 10. *Extensive outlet armoring (left) and chute leading to inlet (right).*

Both of these crossing structures received failing AOP scores and were classified as *Severe Barriers*. From a functional perspective alone, they make good candidates for upgrades; however, managers should strategically replace culverts in a way to best improve overall network connectivity. In other words, the replacement strategy should include spatial criteria, since the impact on the entire stream network is more important, and the spatial arrangement of barriers matters (Cote et al. 2009). Transportation managers can use this information to prioritize mitigation projects, either by using scores generated automatically by the NAACC database, or through their own internal decision-making processes. Managers should take note that structure assessments from NAACC surveys may not perfectly align with other protocols, a possible introduction of uncertainty (Anderson et al. 2012).

Many structures we visited provide opportunities for wildlife to cross underneath Route 8. Some structures are clearly large enough to pass most medium-to-large mammal species (**Fig. 11, 12**). Looking only at the structures available (and ignoring wildlife behavioral responses), it appears wildlife could cross under Route 8 at many locations. We expect that the wide range of sizes, substrates, and landscape position greatly influences whether or not wildlife actually use these passages.

Figure 11*. Circular culverts provide full or partial dry passage for terrestrial wildlife. The culvert at left could functionally pass large mammals, such as bear. The culvert at right is smaller in diameter (5 feet), which is still large enough for many species.*

__Figure 12.__ Bridges along Route 8 offering wide banks of dry passage for wildlife. Passage under the bridge at left includes natural substrate, while passage at the bridge at left is along placed riprap.

Route 2

We visited one road-stream crossing on Route 2: a large bridge over the Hoosic River in the city of North Adams. This structure should pass most aquatic organisms. Its lack of dry banks inside the bridge cell limits the functionality of this structure for terrestrial wildlife; however, our tracking and camera trapping at this site suggests that some species, such as deer, cross through the structure in shallow water (**Fig. 13**). Our camera trapping work detected several other mammal species, including bobcat and gray fox, at the bridge outlet. Conversations with local landowners indicated that black bear occasionally pass through nearby neighborhoods. Our data suggest that a variety of wildlife species are present in the area, and could benefit from improvements to this bridge. We recommend, if possible, that transportation managers explore designs for this structure that would better accommodate terrestrial wildlife passage, such as a ledge or riprap bank.

__Figure 13__. Shallow water in the west cell of this bridge (left) permits dry passage. The approach to this cell (right) funnels wildlife movement along the concrete wingwall on the western side of the bridge.

Interstate 90

Of the two crossing structures we visited on Interstate 90, both present significant problems for aquatic organism passage. The culvert at mile 12.4 includes a significant outlet drop (**Fig. 14**), limiting aquatic passage. The culvert at mile 13.7 similarly includes a large outlet drop through a weir, effectively restricting aquatic passage (**Fig. 14**).

Figure 14. *Outlet drops at culverts on I-90 near mile 12.4 (left) and mile 13.7 (right).*

Our camera trapping work suggests that a variety of terrestrial wildlife species use the culvert at mile 12.4, while very few use the culvert at mile 13.7. Our team will continue to monitor these two culverts with camera traps, which may shed additional insight into patterns of wildlife activity underneath this section of Interstate 90. For a more complete discussion of wildlife use at these structures, see **Chapter 3**.

Figure 15. *Culvert inlets on I-90 at mile 12.4 (left) and mile 13.7 (right). Although both culverts are large enough to accommodate many species, they differ in many characteristics. The culvert at left received substantially more wildlife activity.*

CONCLUSIONS

Many tributaries passing under Route 8 remain functionally connected to the downstream stream network; however, some stream segments are severely disconnected by inadequate culverts at road-stream crossings. These structures vary greatly in their attributes. Since our protocols are not yet developed, and since many factors influence wildlife use of crossing structures, we can only offer limited from structural assessments. In **Chapter 3**, we provide additional context for understanding wildlife use at some of these crossings.

RECOMMENDATIONS

- Focus NAACC aquatic assessment efforts along roads where improvements are likely to occur. Consulting with the local DOT district can help identify which areas are most likely to receive upgrade attention.

- Continue improving terrestrial wildlife passage protocol. See **Appendix A** for additional recommendations and discussion.

CHAPTER 2
Roadkill

***Figure 16**. River otter (Lontra canadensis) killed on Route 8 near Sandisfield, Massachusetts.*

INTRODUCTION

Wildlife-vehicle collisions (WVCs) are a significant cause of mortality for terrestrial vertebrates (Forman & Alexander 1998). WVCs remove individuals from populations, decrease genetic flow among populations (Thomassen et al. 2017; Riley et al. 2014; Riley et al. 2006), and fragment habitat (Forman et al. 2003; Forman & Alexander 1998). WVCs are also hazardous for people and expensive to society. The estimated average cost of each car-deer collision is over $6,000, collectively costing society millions of dollars per year (Clevenger et al. 2008). To reduce this hazard, transportation agencies track roadkill incidents and attempt to reduce their frequency with mitigation efforts. Many conservation organizations and wildlife management agencies also track roadkill to determine impacts on wildlife populations.

Roadkill surveys are widely used across the globe, in part because they are logistically simple and do not require advanced technology or extensive training. Accordingly, many organizations recruit citizen scientists to aid in roadkill data collection. These citizen science programs have collected large numbers of roadkill records. Maine Audubon's Roadwatch program recorded nearly 6,000 roadkill records from 2010-2014 (Charry 2015). The California Roadkill Observation System has documented over 55,000 roadkill incidents to date (www.wildlifecrossing.net). A variety of other groups, including Cold Hollow to Canada and the Connecticut Department of Energy and Environmental Protection, use the *iNaturalist* web platform (www.inaturalist.org) to collect citizen-sourced roadkill data. The popularity of web-enabled cellphones and tablets is accelerating the rate of collection and amount of roadkill data available to researchers (Vercayie & Herremans 2015).

Analyses of roadkill data include baseline inventories (Kioko et al. 2014) and comparisons of data sources (Schillings & Waetjen 2015). The spatial and temporal arrangement of roadkill has been used to identify “hotspots” and “hot moments” (Cureton & Deaton 2012; Heigl et al. 2017; Hobday & Minstrell 2008; Teixeria et al. 2013; Langen et al. 2007). Clusters of roadkill in space and time are presumed “problem” areas, which then guide mitigation efforts.

We tested several methods and data sources to produce an efficient, cost-effective way to study roadkill in western Massachusetts. **Appendix A** includes training materials to guide citizen science roadkill surveys.

METHODS

We conducted roadkill surveys along three *Critical Linkages* priority road segments in Berkshire County, Massachusetts. We sampled our two focal priority segments of Route 8 weekly from May to August, 2017. On the Route 2 priority road segment, we concentrated survey efforts between mile marker 9.4 and mile marker 10. We did not request permits to survey for roadkill on Interstate 90.

Walking surveys occurred on weekdays between 8:00am and 3:00pm. We surveyed both traffic lanes by walking parallel to the guardrail and visually scouting towards the median for roadkill. Driving surveys were conducted at an average speed of 45mph, with an observer scouting for roadkill from the front passenger seat. During several weeks, one person conducted driving surveys alone, pulling over to record data as needed. All field observers received printed maps of survey routes and datasheets to standardize survey efforts and roadkill documentation.

At each roadkill incident, we recorded GPS coordinates and identified the carcass to the finest taxonomic group possible. Species-level identification was preferred, although many roadkill were identified only to a coarse taxonomic group (*e.g*. bird, reptile, rodent, and snake). Observers ranked their identification confidence for each roadkill record as either *High* or *Low*. From September to November 2017, we equipped one MassDOT employee with a GPS unit and field notebook to compare our data with agency-collected data.

We collected data with an iPad tablet (using a custom-built GIS ESRI Collector platform), handheld GPS units, and GPS-enabled smartphones. We screened each record for reliability using written observations, photographs, and the observer’s identification confidence. In several cases, species identification was questionable enough that we excluded the entire record. We combined data from different observers and technology platforms using ArcGIS 10.4.1. In cases where multiple nearby carcasses were assigned to the same GPS coordinate, we split the group record into individual records with matching coordinates to ensure that each carcass had its own point and attributes within the geodatabase.

RESULTS

During thirteen weeks of surveys on Route 8, plus three months of DOT data collection, we recorded 207 roadkill carcasses. We encountered no roadkill on Route 2 during five weeks of surveys (**Fig. 17**). Although we did not conduct any surveys on Interstate 90, we encountered one black bear carcass in the woods near I-90 mile marker 15.6 during culvert surveys near the southeast end of Greenwater Pond in Becket, MA.

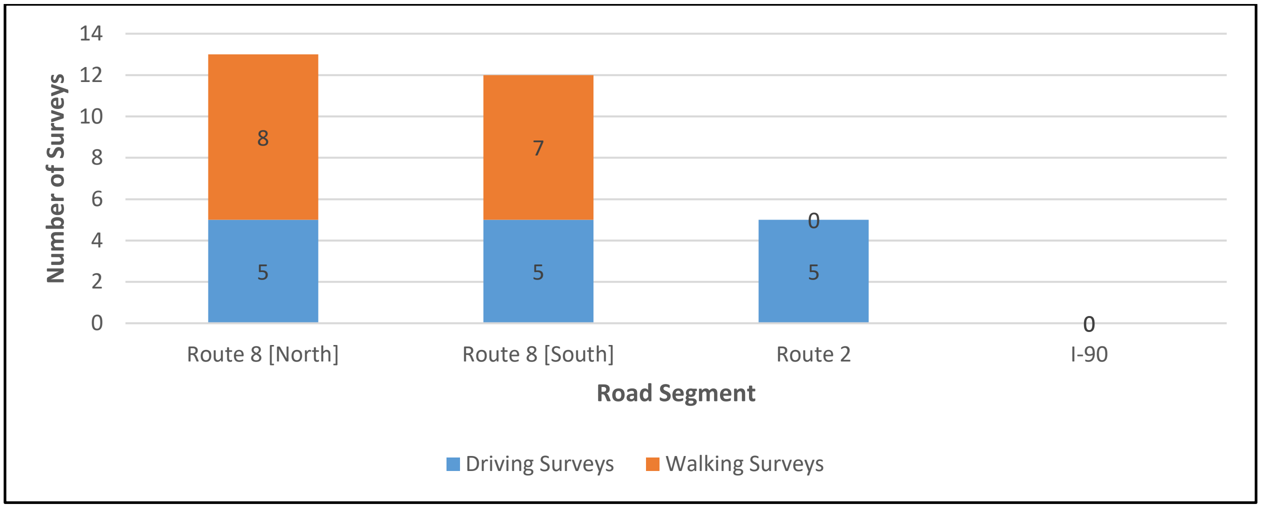

Figure 17. Roadkill survey effort (excluding DOT surveys along Route 8).

On Route 8, amphibian roadkill was more common than reptile, mammal, or bird (**Fig. 18**). Mammal roadkill was distributed among seven species, although nearly half of mammal kills could not be identified to species because of their condition (**Fig. 19**). The majority of amphibian records were collected during our first surveys in late May, although an additional spike in amphibian mortality occurred during late July (**Fig. 20**). We had insufficient data from birds, mammals, and reptiles to discern meaningful spatial patterns. Amphibian mortality was dispersed along Route 8 (**Fig. 21**), although minor concentrations occurred in several places. Along the northern priority segment of Route 8 we studied, amphibian roadkill was concentrated in two locations:

- Mile marker 8.3—8.8
- Mile marker 7.6—7.9

Along the southern priority segment of Route 8 we studied, amphibian roadkill was concentrated in four locations:

- Mile marker 3.2—3.4
- Mile marker 2.5—3.0
- Mile marker 1.9—2.1
- Mile marker 1.6—1.8

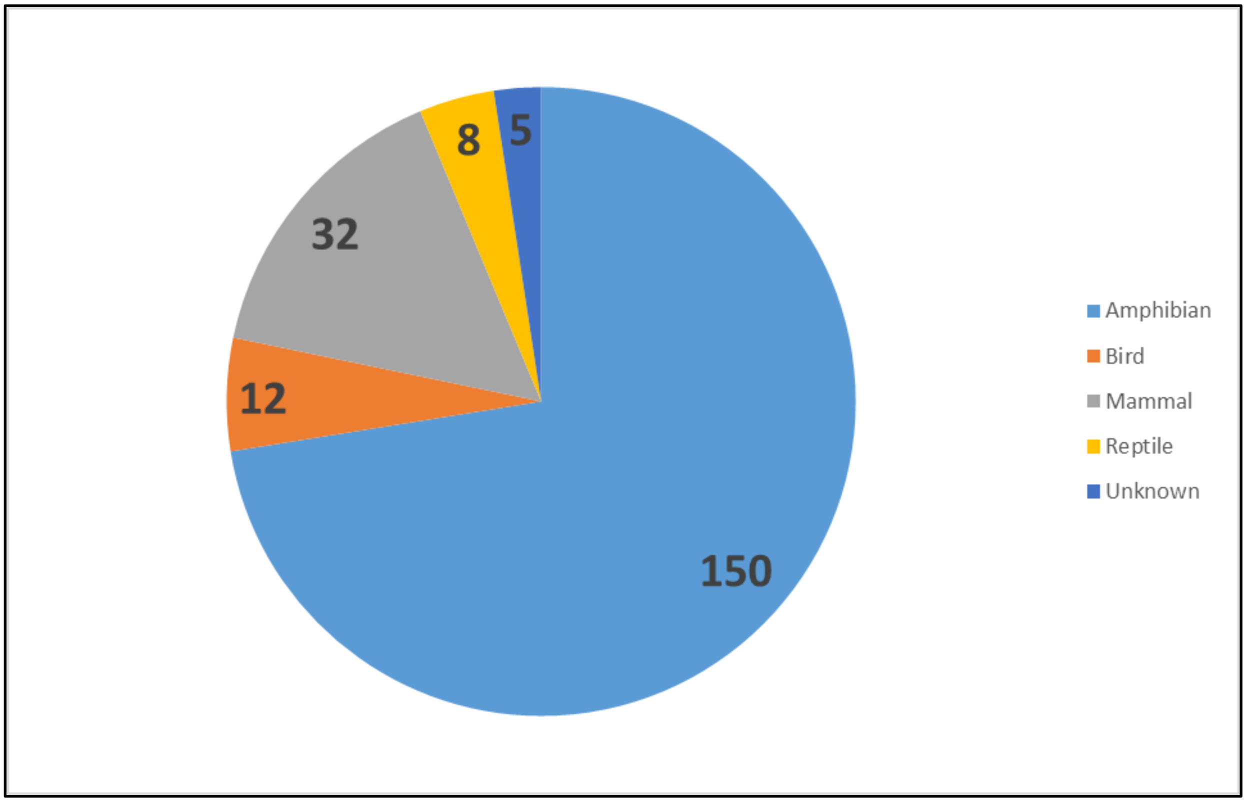

Figure 18. *Roadkill by taxonomic Class from Route 8 near Otis and Sandisfield, Massachusetts.*

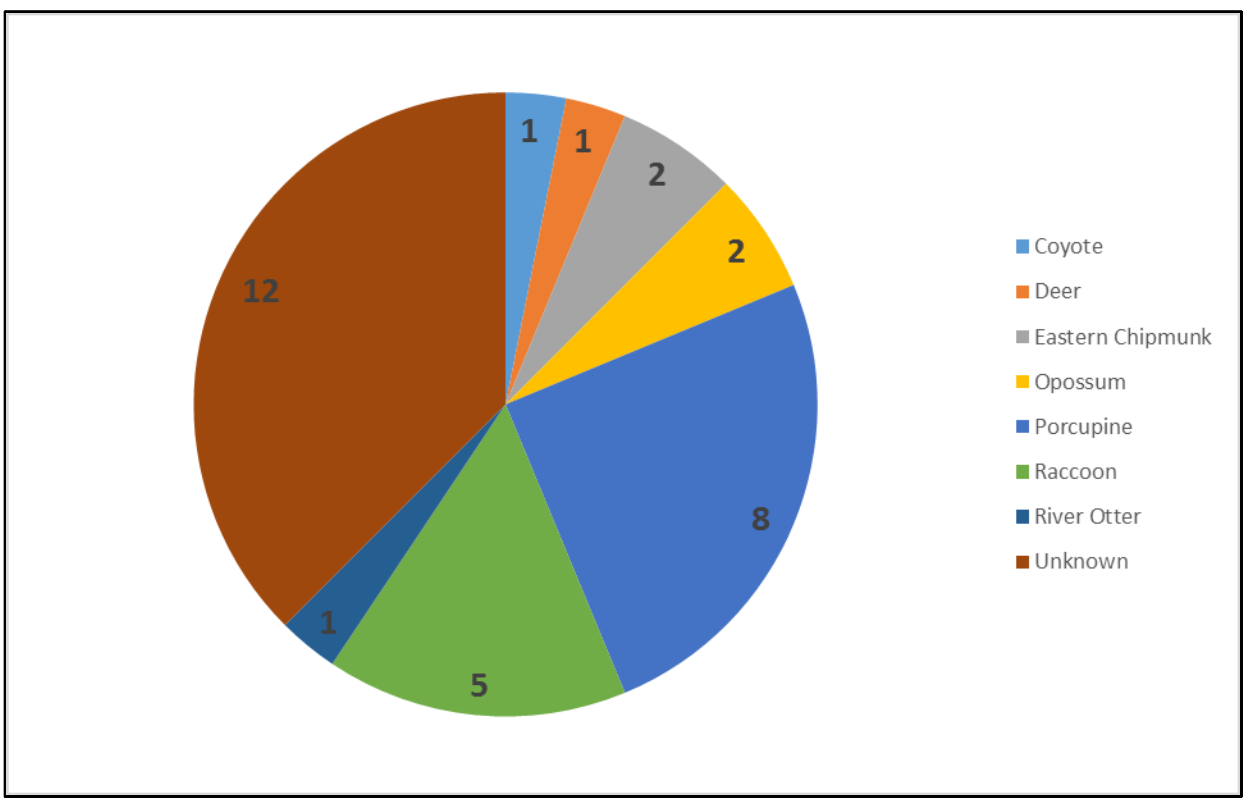

Figure 19. *Mammal roadkill by species from Route 8 near Otis and Sandisfield, Massachusetts.*

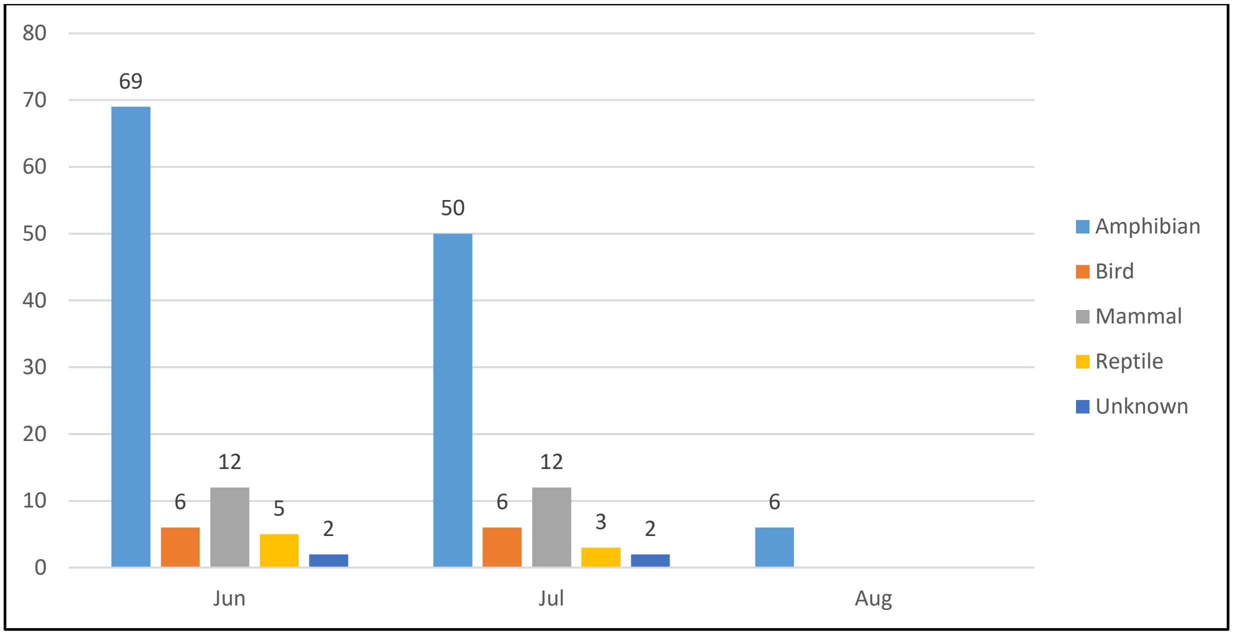

Figure 20. Roadkill by month and taxonomic Class from Route 8 near Otis and Sandisfield, Massachusetts. We exclude data from May, September, October, and November, since our sampling efforts differed substantially. Note that we only sampled the first two weeks of August.

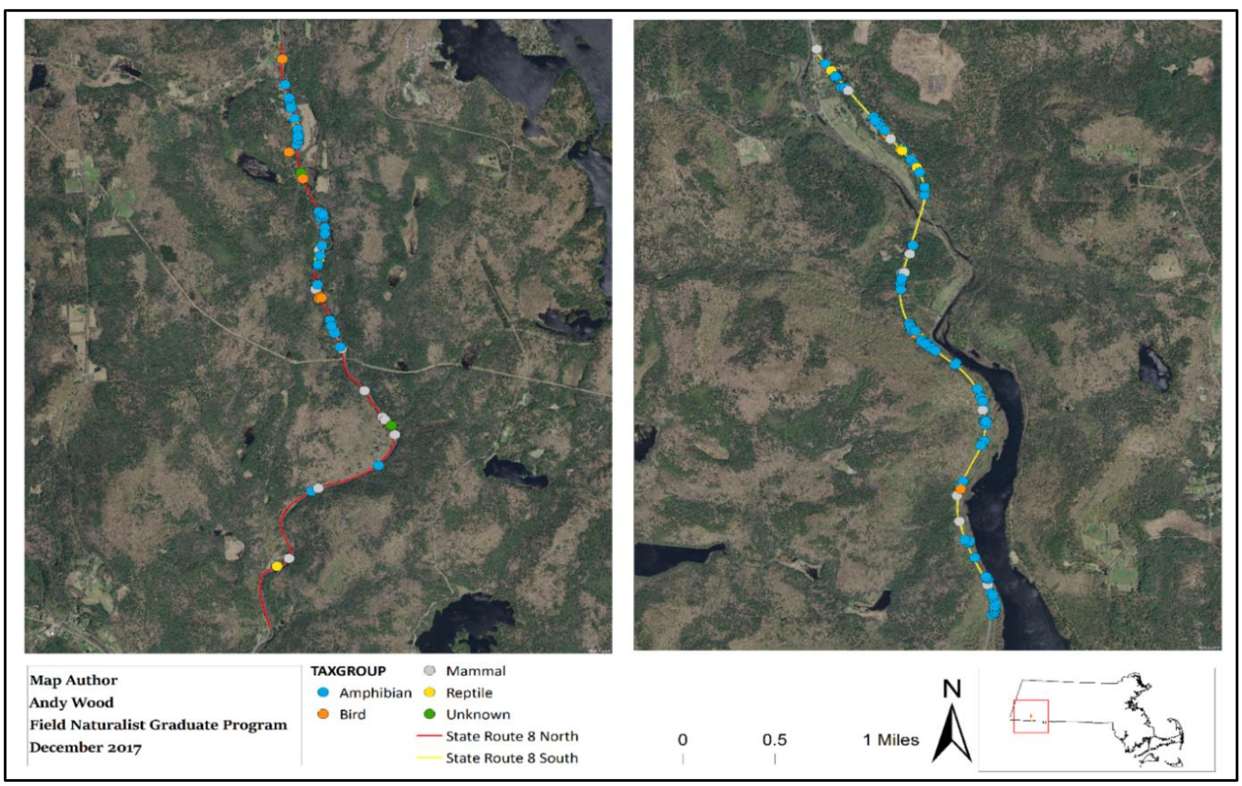

Figure 21. Roadkill distribution along Route 8 priority road segments near Otis (left) and Sandisfiel (right), Massachusetts.

DISCUSSION

Amphibian mortality

Amphibian mortality on roads is well-documented (Fahrig et al. 1995; Hels & Buchwald 2001). Our data suggest that amphibian mortality is common along Route 8, at least for one species: Eastern Newts (*Notopthalmus viridescens*), commonly known as *red efts* during their juvenile life stage*.* Eastern newts breed in slow-moving aquatic habitats. After several months in aquatic habitats, juveniles migrate to terrestrial habitats where they may spend 2-7 years before returning to aquatic habitats to breed. This movement from wetland to upland habitat often involves crossing roads, where mortality can be high. Previous research indicates that juveniles are unlikely to use terrestrial habitat more than 1000 meters from their aquatic habitat (Sousa 1985). The segments we studied along Route 8 run between wetlands and forested uplands, and amphibians migrating west to uplands must cross Route 8. We did not perform GIS analyses of amphibian roadkill spatial patterns; future work could compare the spatial distribution of roadkill to interacting variables, such as distance to a habitat feature.

We expect that our results underestimate the actual level of amphibian mortality. We observed that amphibian carcasses generally persist for one week or less. Since they disappear relatively quickly, we believe many more amphibians are killed and disappear between weekly sampling events. Additionally, our data do not account for large spring and fall migrations, when amphibians move in large numbers on warm, rainy nights. May, September, and October are often very active months for amphibians in New England, and our data do not cover those times. Note that the bright orange color of red efts may have increased our detection of this species.

Reptile mortality

We identified only two species of reptile roadkill: painted turtle (*Chrysemys picta*) and snapping turtle (*Chelydra serpentine*). With so few records, it is difficult to deduce any patterns. Fifty percent of all reptile roadkill occurred in June, which is consistent with other research indicating that most reptile movement and mortality occurs during May and June (Cureton & Deaton 2012; Garrah et al 2015; Langen et al. 2007).

Bird mortality

Similarly, with so few bird records, it is difficult to deduce patterns. We encountered several raptor carcasses near mile marker 0.5 on Route 8. This area coincides with a blind curve in the road after a relatively long and straight road section. Raptors frequently perch near roads to hunt or scavenge roadkill, so it is possible that collisions in this area relate to the speed of traffic, road layout, and driver reaction time.

Mammal mortality

Most mammalian roadkill were raccoon (*Procyon lotor*) or porcupine (*Erethizon dorsatum*). Both are slow-moving and common mammal species in western Massachusetts. Porcupine roadkill were commonly observed in other local research projects (L. Marx, personal communication 2017). Raccoons are highly adaptable to the urban environment (Gerht et al. 2010), and their mortality may relate to a willingness to use areas near roads and development. In our camera trapping work (**Chapter 3**), we frequently documented raccoons near roads.

The lack of other mammal species in the roadkill record could be explained by behavior and habitat use. First, many semi-aquatic mammals (*e.g*. mink, river otter, beaver) travel preferentially along stream and wetland corridors, and are consequently less likely to cross some roads. Our camera trap data detected river otter (*Lontra canadensis*) using a small culvert and a small bridge to cross Route 8. We found one dead juvenile river otter on Route 8, near a very small culvert, but this anecdote simply demonstrates that river otter can be killed on roads.

We believe that the lack of other carnivore species in the roadkill record can be explained by local abundance and behavior. Our work is consistent with a meta-analysis finding that carnivores were less commonly observed than herbivores in roadkill studies (Ford and Fahrig 2007). Many carnivore species use large areas, and so the likelihood of detection at any point or linear feature is low. When carnivores do approach roads, some may wait for openings in traffic before crossing. On Route 8, traffic is periodically sparse, and fast-moving species may cross with limited risk. We observed one black bear (*Ursus americanus*) cross Route 8 near mile marker 1.3. The bear was first observed moving parallel to the road, outside the guardrail. During a gap in traffic, the bear crossed the road heading west and climbed over the western guardrail. The whole encounter took less than a minute. Although we cannot estimate how frequently these crossings occur, lower-risk crossing opportunities exist on many rural roads.

Roads can be especially hazardous to moose (*Alces alces*) and white-tailed deer (*Odocoileus virginianus*), yet we detected neither species during our study. Moose are not abundant in this area of Massachusetts, and so it is not surprising that they are absent in the data. We presume that white-tailed deer are locally abundant in our study areas, so we expected to find more carcasses. The absence of deer in our roadkill data could have been confounded by DOT crews or other people removing carcasses quickly.

Data source comparisons

Data collected by MassDOT along Route 8 include only five mammal species: deer, porcupine, opossum, raccoon and coyote. These data suggest that DOT crews, which usually drive road segments, are more likely to record larger roadkill than smaller roadkill. Timestamps from GPS points also indicate that DOT crews often remove mammalian roadkill early in the morning before other research groups would have encountered it.

Similar projects in California indicate that hotspots identified by volunteer data do not overlap with hotspots identified by agency-collected data (Schilling & Waetjen 2015). Understanding patterns of roadkill removal by DOT crews in Massachusetts would be especially helpful in future studies. Currently, MassDOT is transitioning to a new data collection system with the goal of collecting more roadkill data from DOT crews. We anticipate that integrating research, citizen science data, and agency data will provide new insights into roadkill patterns.

Interpreting roadkill data

Understanding what roadkill data do and do not represent is critical for transportation planning. The heart of the issue is that we do not know how roadkill mortality will influence population dynamics. A variety of sampling issues also complicate data interpretation:

- *Unknown proportions*: Roadkill detections represent an unknown proportion of the true number of crossing incidents along a given road. For every dead porcupine we see, there is an unknown number of porcupines who made it safely to the other side of the road.

- *Current roadkill can produce future roadkill:* Roadkill attracts scavengers to roads, where they are at a greater collision risk. Thus, roadkill records may be not be independent of each other.

- *Distance-sampling effects:* The further from a transect walked or driven, the less likely observers are to detect roadkill. Dense vegetation and ditches may obscure roadkill from observers.

- *Injury versus mortality*: Not all collisions result in immediate death and some wildlife may die away from the road, undetected. Other wildlife may sustain only injuries. Thus, the amount of detected mortality probably underestimates the true impact on individuals and populations.

- *Detection biases:* Observers are more likely to report carcasses they are confident identifying (Boakes et al. 2016). Also, observers may be more likely to report only carcasses they feel are relevant (*e.g*. charismatic fauna), creating misleading detection patterns.

- *Carcass persistence:* Some carcasses disappear quickly without detection, while other carcasses persist longer, and may be repeatedly counted. Our observations indicate that amphibian carcasses have low persistence (<1 week) while mammal carcasses persist for 1-2 weeks, and occasionally 3 weeks. Guinard et al. (2012) also found higher persistence probabilities for larger bird carcasses during summer. Daily surveys would better quantify carcass persistence but require significantly more resources (Santos et al. 2011).

- *Survey biases:* Our mix of driving and walking surveys introduced another bias related to animal size. Driving surveys favor detection of larger animals. Walking surveys capture a wider range of animal sizes, but require more time and effort, which limits the amount of total area surveys can cover. Initially, we intended to walk all surveys, but time constraints and an injury in the late summer led us to switch to driving surveys.

- *Historical legacies of mortality:* Past mortality can depress local populations, and so current mortality trends may misrepresent the true longer-term impact of roads on wildlife populations (Eberhardt et al. 2013; Teixeira et al. 2017).

- *Weather influence:* Weather events influence wildlife activity. Amphibian and reptile roadkill relate strongly to warm, wet weather (Langen et al. 2007).

CONCLUSIONS

Slow-moving and common wildlife species experienced the greatest mortality along Route 8. Amphibians were killed more often relative to other taxonomic groups.

What level of roadkill warrants action? Our data, limited to one summer, simply cannot answer this question. When MassDOT repairs or upgrades crossing structures, slight modifications to funnel amphibians towards crossings should decrease road-top mortality. A significant body of literature is available for maximizing the effectiveness of crossings for amphibians (Merrow 2007; Woltz et al. 2008).

More data across seasons and years will increase the value of this dataset. Specifically, research to assess population abundance and distribution would help frame the impact of the WVC mortality we documented.

RECOMMENDATIONS

- To the degree possible, monitor roadkill mortality across all seasons and over multiple years.
- Collect roadkill data during warm, wet nights when amphibians are most likely to move across roads.
- Collect roadkill data along "control" road segments to gauge relative mortality across road types and locations.
- Develop relationships with DOT maintenance crews, who know road segments well, travel them regularly, and may be willing to collect roadkill data if given an easy system.
- Seek alternative data sources. One landowner mentioned that a local school bus driver frequently observes bear along the bus route. Strengthening relationships with local residents will yield additional place-based knowledge of wildlife activities.

CHAPTER 3
Camera Trapping

***Figure 22**. Bobcat (Lynx rufus) near Interstate 90 culvert.*

INTRODUCTION

Camera traps are powerful tools for remotely studying wildlife behavior and ecology (Cutler & Swann 1999; Wearn & Glover-Kapfer 2017). Many popular models on the market today rely on Passive Infrared (PIR) sensors, which automatically trigger the camera as animals pass through the sensor's detection field. The PIR sensor sends an electrical current to the camera, which then takes a picture based on pre-programmed settings (Welbourne et al. 2016). In most models, users can customize trigger speed, sensor sensitivity, and a variety of other settings. Price reductions in high-quality digital camera components and memory storage have greatly expanded the use of this technology.

Camera traps are used to answer a variety of ecological questions. The most basic application is using camera traps to explore a place and document local species. Results from these exploratory projects are useful precursors to more detailed question-based research (Meek et al 2014). Other applications include capture-recapture studies, occupancy analysis, long-term population monitoring, and behavioral studies. Camera traps are used extensively in wildlife transportation research to document wildlife use of road-crossings (Ng et al. 2004; Lapoint et al. 2003; Rodriguez et al. 1996; Villalva et al. 2013; Mata et al. 2008; Ascensao & Mira 2007; Wang et al. 2017; Donaldson 2011). Because camera traps can produce compelling animal photographs, many organizations also use camera trap images to engage community members.

We conducted a rapid species inventory and exploratory behavioral study in western Massachusetts using eighteen camera traps. Our primary goal was to document local wildlife species at sites along

Route 8, Route 2, and Interstate 90—sites where we also studied roadkill and crossing structures. Where possible, we placed cameras at culverts and bridges to learn about wildlife behavior those road features. Because we intentionally biased camera placement and did not consistently adhere to any particular sampling method, our data are not appropriate for rigorous quantitative analyses.

METHODS

Camera Trap Models

We used Bushnell Trophy Cam HD cameras and Reconyx HC-600 Hyperfire cameras. Both models are equipped with PIR sensors with a range up to 60 feet. To trigger the camera, an animal must cross the boundary of the camera sensor's detection zone. This limits false triggers from movement within detection zones by vegetation.

Array Design

We deployed 11 camera trap arrays opportunistically along three road segments in western Massachusetts (**Fig. 23**). We defined arrays as a group of one or more cameras deployed at a site of interest (*e.g*. around a bridge, along a trail). Our arrays used a variable number of camera traps (*n*=1-6). The number of camera trap units deployed was based on equipment availability, viable installation options, and what we thought the minimum number of traps would be to adequately "watch" an area. We dedicated more cameras to several arrays where we had permission to mount cameras directly on culverts. In total, we deployed cameras at 25 individual points in space within our 11 arrays (**Table 2**). Several locations were sampled only briefly because we relocated cameras that were malfunctioning or not performing well. No camera traps were baited.

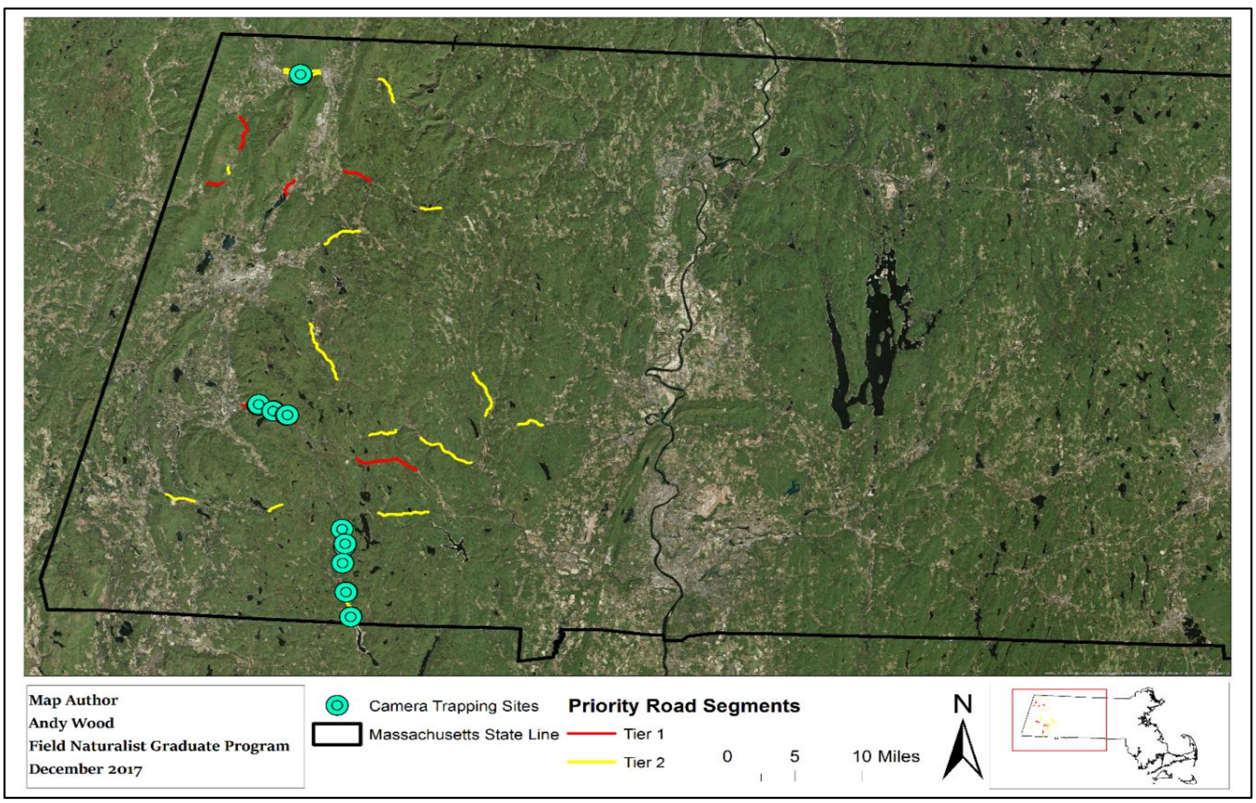

Figure 23. *Distribution of camera trap arrays on Route 2, Interstate 90, and Route 8 in western Massachusetts.*

*Table 2. Camera trap deployments. *Denotes ongoing trapping.*

CAMERA TRAP	FEATURE	DEPLOYED	RETRIEVED	TRAP NIGHTS
01-A	ATV Trail	6/15/2017	8/14/2017	60
02-A	Round Culvert	6/15/2017	8/14/2017	60
02-B	Round Culvert	6/15/2017	8/14/2017	60
03-A	Bridge	6/26/2017	10/11/2017	107
03-B	Bridge	6/26/2017	8/16/2017	51
04-A	Bridge	6/29/2017	10/6/2017	97
04-B	Bridge	6/29/2017	10/6/2017	99
04-C	Bridge	6/29/2017	10/6/2017	99
04-D	Bridge	6/29/2017	10/6/2017	99
05-A	Stream near culvert	7/3/2017	8/14/2017	42
06-A	Stream near culvert	7/5/2017	8/14/2017	40
07-A	Road	7/11/2017	8/14/2017	34
08-A	Box Culvert	7/27/2017	12/20/2017*	146
08-B	Box Culvert	7/27/2017	8/15/2017	19
08-C	Box Culvert	7/27/2017	8/15/2017	19
08-D	Box Culvert	7/27/2017	12/20/2017*	146
08-E	Box Culvert	8/15/2017	12/20/2017*	127
08-F	Box Culvert	8/15/2017	12/20/2017*	127
09-A	Box Culvert	7/27/2017	12/20/2017*	146
09-B	Box Culvert	7/27/2017	12/20/2017*	146
09-C	Box Culvert	8/15/2017	12/20/2017*	127
10-A	Appalachian Trail overpass	8/16/2017	10/16/2017*	61
10-B	Appalachian Trail overpass	8/16/2017	10/16/2017*	61
11-A	Appalachian Trail overpass	8/16/2017	10/16/2017*	61
11-B	Appalachian Trail overpass	8/16/2017	10/16/2017*	61
			Total Trap Nights	**2095**

Camera Installation & Security

We mounted most cameras on trees or concrete structures. On average, we mounted cameras 25 inches from the ground. We locked cameras inside metal security boxes secured with a 6mm cable lock looped around the tree or through a bolt drilled into concrete. To deter tampering and theft, we zip-tied laminated tags to each camera that included the project name, purpose, and our contact information.

Camera Settings & Metadata

Cameras were programmed to take bursts of three photographs, with a 10-second quiet interval between triggers to prevent SD cards from filling up too quickly. Other camera settings were initially programmed to default settings. At each installation, we collected information on site characteristics, array design, and camera settings (**Appendix C**).

Site Visits & Performance Tracking
We revisited cameras 1-2 weeks after installation to check on performance and make necessary adjustments. Although we intended to keep camera settings consistent across all sites, several cameras required changes in trigger sensitivity, flash, and other settings. During site visits, we adjusted angles, heights, and cleared vegetation to improve the line of sight to our intended trap location. We tracked clock accuracy, number of photos taken, and battery status. At each site visit, we replaced full SD cards with blank cards, and later downloaded images onto computers.

Photo Tagging and Processing
We tagged photos using the *Wild.ID* desktop program (http://wildid.teamnetwork.org/index.jsp). Graduate and undergraduate students identified all animals to species where possible. When animals were difficult to identify, we solicited input from other experts. We exported tagged files from *Wild.ID* to Excel spreadsheets for analysis.

RESULTS

From June 15 to December 20, 2017, we collected 37,177 photographs from 2,095 trap nights. In total, 3,957 images contained wildlife identified to species. Mammals and birds constituted 100% of all identified photographs; we detected no reptiles or amphibians. The number of photographs containing wildlife varied greatly among taxonomic families, with a high representation of deer, squirrel, chipmunk, and humans (**Fig. 24**). Since our sampling approach differed at each camera trap array, we review each array individually in the following sections.

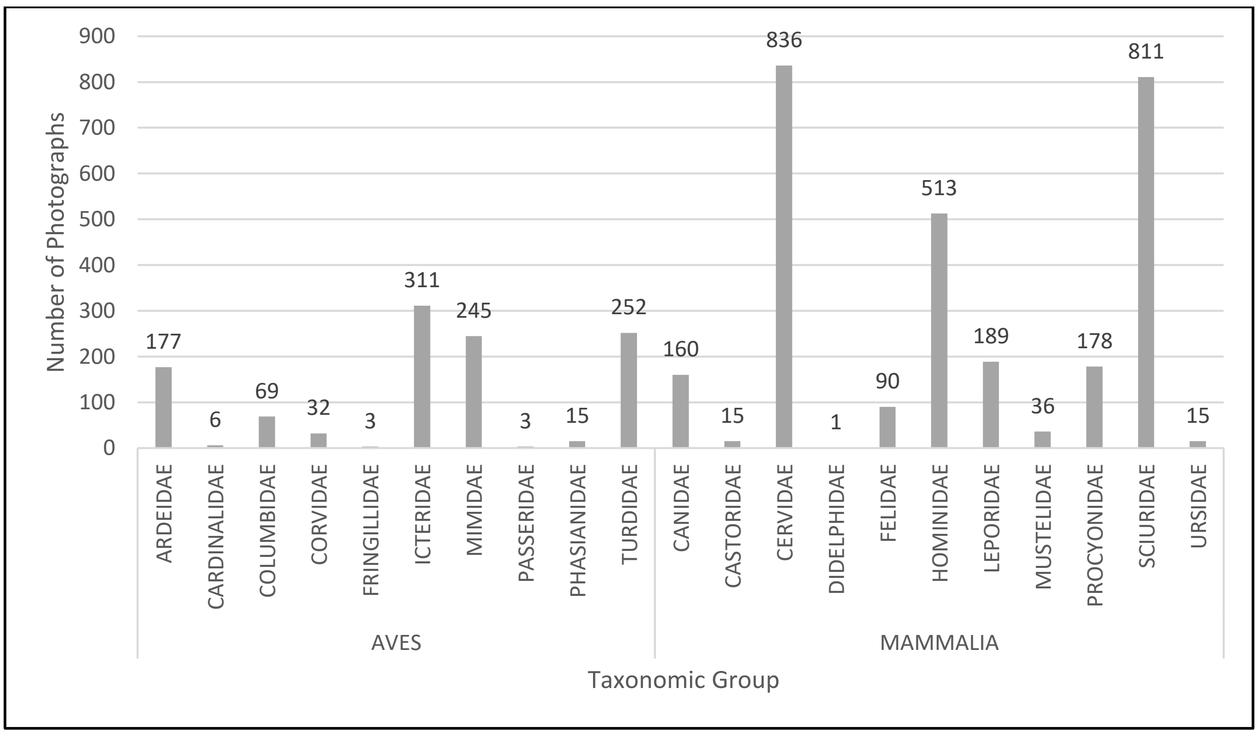

Figure 24. *Photographs by taxonomic family across all camera traps. Note the high representation of Cervidae (deer), Sciuridae (squirrels and chipmunks), and Hominidae (humans).*

CAMERA TRAP ARRAY 01

Route 8: Otis, MA

***Figure 25**. Location of Camera Trap Array 01 along the northern priority road segment of Route 8 near Otis, MA.*

Camera Trap	**01-A**
Deployed	June 15—August 14, 2017
Trap Nights	60
Feature	ATV Trail intersection with Route 8
Camera Position	45⁰ angle to ATV trail to capture approaches to and from the road, without triggering from passing vehicles.
Species Detected	• White-tailed deer *(Odocoileus virginianus)* • Coyote *(Canis latrans)* • Red Fox *(Vulpes vulpes)* • Raccoon *(Procyon lotor)* • Human *(Homo sapiens)*
Behavioral Notes	The most commonly observed behavior was wildlife approaching the road on the ATV trail and moving back into the forest. Because our camera was not able track wildlife if they moved onto the road, we cannot say for sure how many of these animals continued onto the road. We observed deer and red fox periodically at this site.

Comments	Wildlife commonly move along existing trails. We commonly observed animal track and sign along other trails in the region. While we were not able to camera trap extensively on this trail network, we believe that wildlife frequently travel along these linear features, which may influence how wildlife approach the highway in a variety of locations.

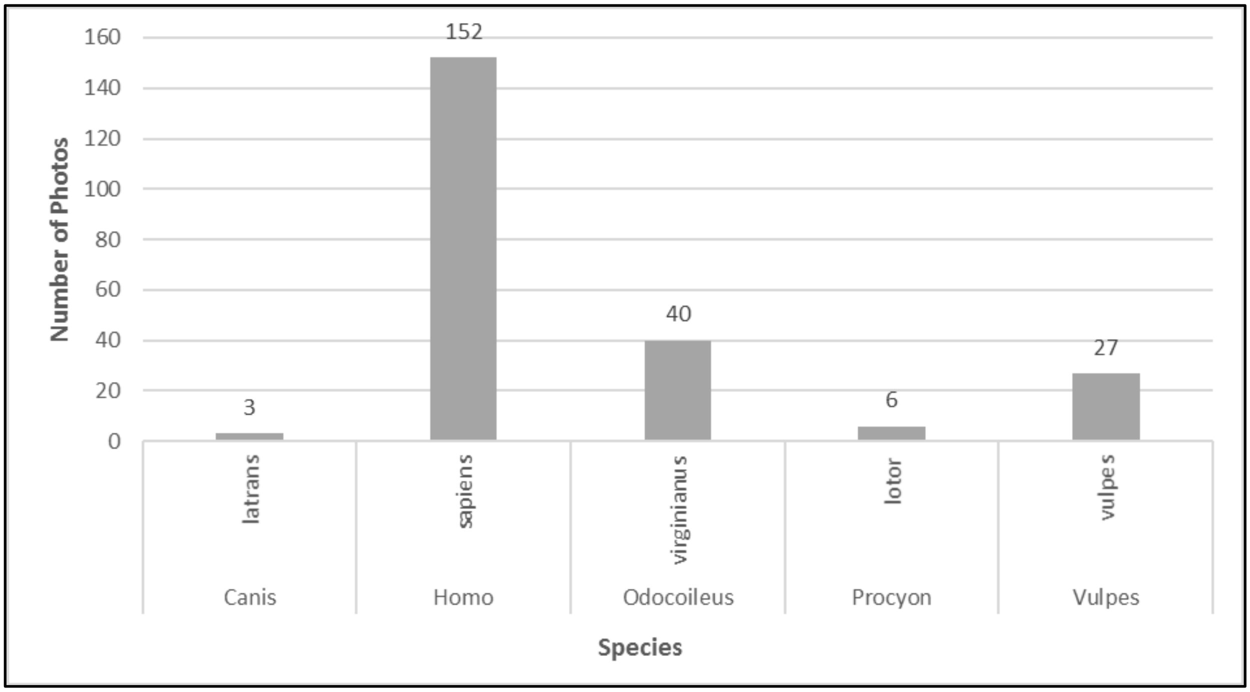

***Figure 26**. Photos by species from Camera Trap Array 01.*

***Figure 27**. White-tailed deer (Odocoileus virginianus) approaching Route 8 in Tolland State Forest near Otis, MA. Photograph from Camera Trap 01-A.*

CAMERA TRAP ARRAY 02

Route 8: Sandisfield, MA

Figure 28. *Location of Camera Trap Array 02 along the southern priority road segment of Route 8 near Sandisfield, MA*

Camera Trap	**02-A**	**02-B**
Deployed	June 15—August 14, 2017	
Trap Nights	60	
Feature	Culvert inlet	Culvert outlet
Camera Position	Facing entrances to a 5-ft diameter dry culvert.	
Species Detected	• Raccoon (*Procyon lotor*) • Wild turkey (*Meleagris gallopavo*) • Gray squirrel (*Sciurus carolinensis*) • Bobcat (*Lynx rufus*) • Human (*Homo sapiens*) • Cottontail (*Sylvilagus spp.*)	• Coyote (*Canis latrans*) • Raccoon (*Procyon lotor*) • Gray squirrel (*Sciurus carolinensis*) • Bobcat (*Lynx rufus*) • Human (*Homo sapiens*)

Behavioral Notes	One confirmed and two probable wildlife crossings. Looking at paired images, it appears that 1 bobcat and 1 raccoon passed through the culvert from west-to-east. We observed 1 gray squirrel cross through the structure from east-to-west during camera setup. We documented one human riding a motorbike through this culvert. Raccoon activity was frequent around the east side of this culvert. Coyotes passed by this culvert periodically moving north-to-south past the western entrance, but did not enter the culvert.
Comments	This dry culvert does not transport water underneath the road, and appears to offer continuous dry passage under Route 8. It is functionally large enough to pass most species of wildlife, excluding moose and some deer.

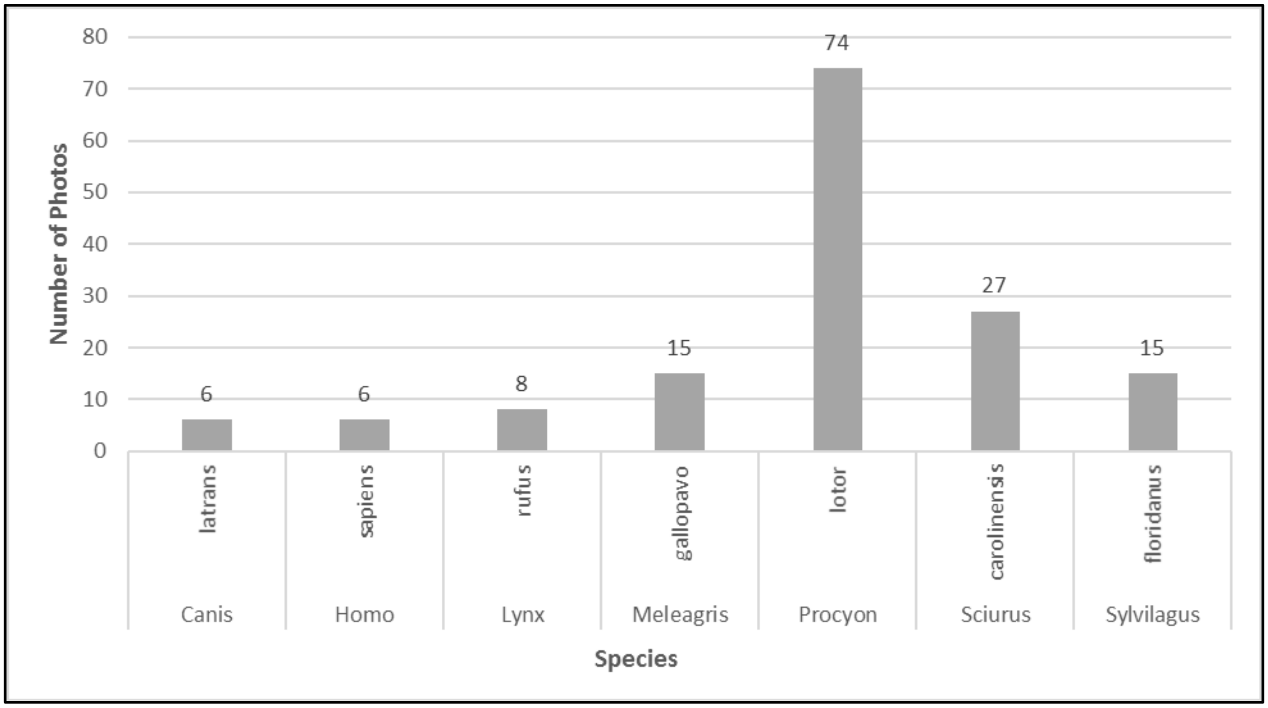

Figure 29. *Photos by species from Camera Trap Array 02.*

Figure 30*. Bobcat (Lynx rufus) entering culvert documented by Camera Trap 02-B (above). Under two minutes later, a bobcat was documented at the opposite end of the culvert by Camera Trap 02-A (below).*

CAMERA TRAP ARRAY 03

Route 2: North Adams, MA

Figure 31. *Location of Camera Trap Array 03 along the subsection of the Route 2 priority segment in North Adams, MA.*

Camera Trap	**03-A**	**03-B**
Deployed	June 26—October 11, 2017	June 26—August 16, 2017
Trap Nights	107	51
Feature	Upstream of inlet; west bank of river	Downstream of outlet; west bank of river
Camera Position	Top of wingwall, angled down to capture inlet approach	Perpendicular to game trail along western edge of streambank
Species Detected	• White-tailed deer (*Odocoileus virginianus)* • American robin (*Turdus migratorius*) • American goldfinch (*Carduelis tristis*)	• Beaver (*Castor canadensis*) • Bobcat (*Lynx rufus*) • Woodchuck (*Marmota monax*) • Mink (*Neovison vison*) • White-tailed deer (*Odocoileus virginianus)* • Raccoon *(Procyon lotor)* • Gray fox (*Urocyon cinereoargenteus*) • Cottontail (*Sylvilagus spp.*) • Small rodent *spp*.

Species Detected		• Green heron (*Butorides virescens)* • Northern cardinal (*Cardinalis cardinalis)* • American crow (*Corvus brachyrhynchos)* • Gray catbird (*Dumetella carolinensis*) • House sparrow *(Passer domesticus)* • Common grackle (*Quisculus quiscula*) • American robin (*Turdus migratorius*) • Mourning dove (*Zenaida macroura*) • Sparrow *spp.* • Warbler *spp*.
Behavioral Notes	Frequent deer movement along western streambank. Adults and juveniles regularly travel this area.	Frequent mammal movement along western streambank, including gray fox, mink, and woodchuck. Occasional visits by deer, and 1 single bobcat occurrence. Birds very active at this site.
Comments	We mounted cameras upstream and downstream of the bridge along the western bank; data from this array serves as an inventory of local species that *could* encounter the bridge while moving along the riparian corridor of the Hoosic River. Detection from CAM 03-A may be skewed towards large animals because it was placed high off the ground at an extreme downward angle.	

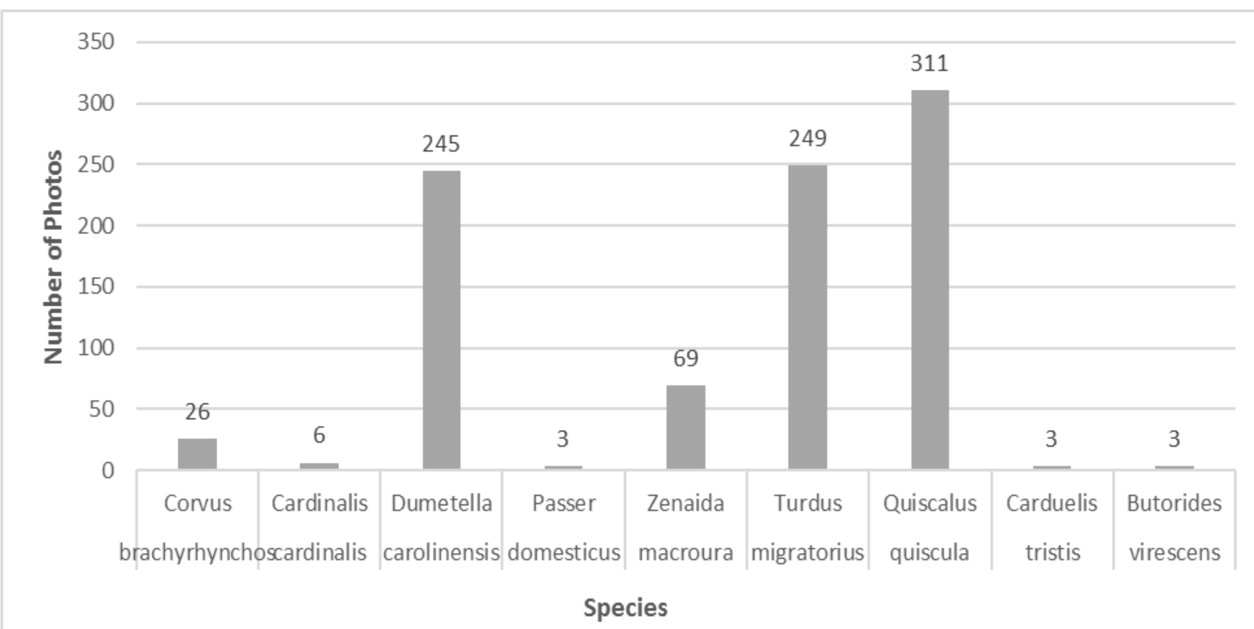

Figure 32*. Bird photos by species from Camera Trap Array 03.*

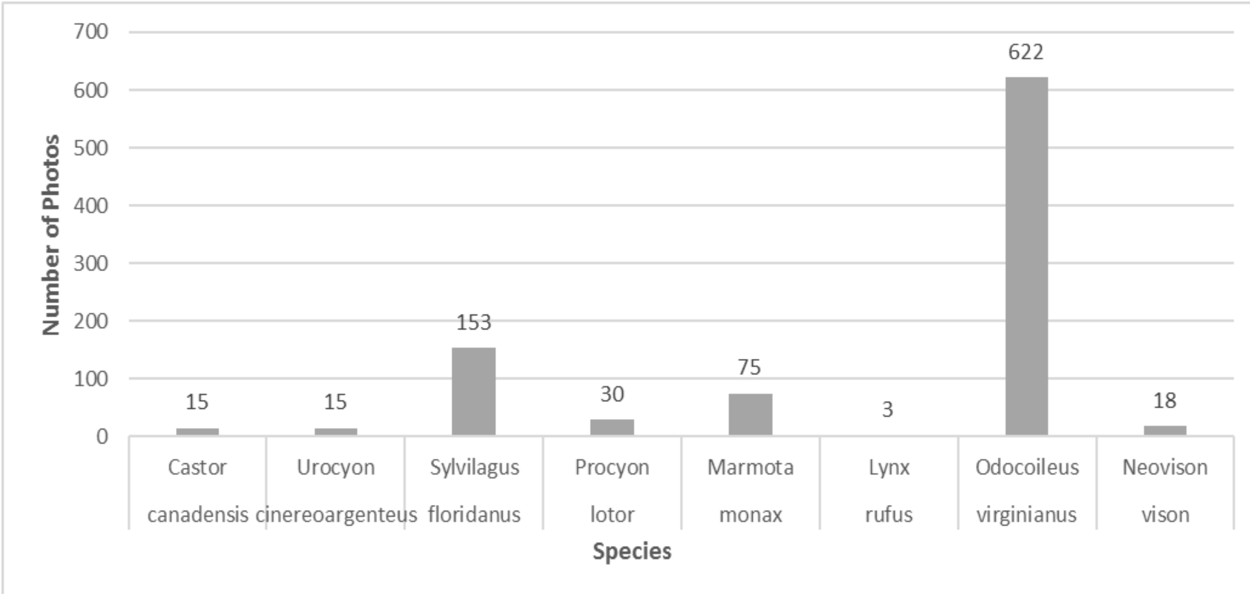

Figure 33. *Mammal photos by species from Camera Trap Array 03.*

Figure 34. *Bobcat detected at Camera Trap 02-B, downstream of the nearby bridge.*

CAMERA TRAP ARRAY 04

Route 8: Sandisfield, MA

***Figure 35**. Camera Trap Array 04, near the Connecticut-Massachusetts border along Route.*

Camera Trap	04-A	04-B	04-C	04-D
Deployed	June 29—October 6, 2017			
Trap Nights	97	99	99	99
Feature	Bridge Outlet, South	Bridge Inlet, South	Bridge Outlet, North	Bridge Inlet, North
Camera Position	Facing outlet & dry passage through bridge.	Facing inlet & dry passage through bridge.	Facing outlet & dry passage through bridge.	Facing streambank leading to dry passage through bridge.
Species Detected	• Coyote (*Canis latrans*) • Human (*Homo sapiens*) • Bobcat (*Lynx rufus*) • Raccoon (*Procyon lotor*)	• Gray squirrel (*Sciurus carolinensis*) • Human (*Homo sapiens*)	• Bobcat (*Lynx rufus*) • Gray squirrel (*Sciurus carolinensis*)	• Coyote (*Canis latrans*) • Human (*Homo sapiens*) • Gray squirrel (*Sciurus carolinensis*) • Chipmunk (*Tamias striatus*)

	• Gray squirrel (*Sciurus carolinensis*) • Chipmunk (*Tamias striatus*)			
Behavioral Notes	Frequent activity in the woods near the outlet, but relatively little activity into or out of the bridge.	Mainly squirrels foraging or humans walking down to the river.	One bobcat head enters the frame, but no subsequent detections.	Small rodents, squirrels, and chipmunks perching on upright rock.
Comments	This bridge should be very functional for terrestrial wildlife (2 meter-wide dry banks on each side), but overall use by wildlife was low during our study. Local DOT staff also report frequent roadkill in this area. Clearly, our data from camera trapping, roadkill, and crossing assessments do not capture the full picture of how wildlife interact with this bridge.			

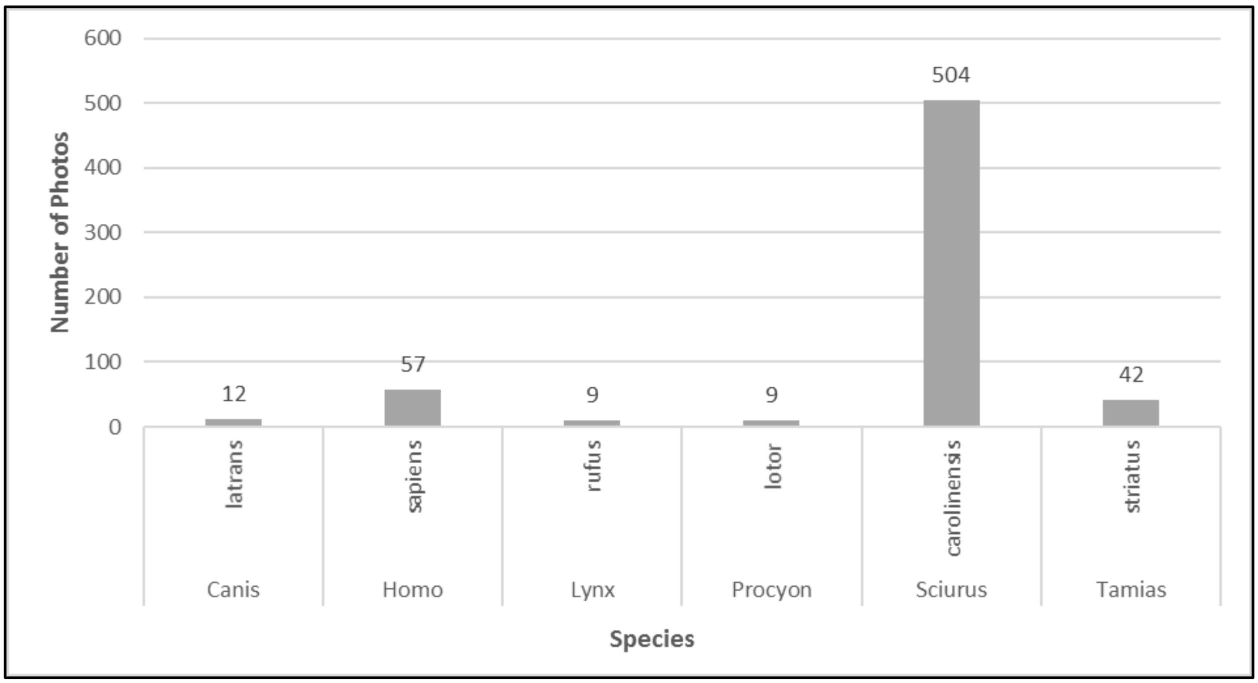

Figure 36. *Photos by species from Camera Trap Array 04.*

Figure 37. *Bobcat detected by Camera Trap 04-A. We did not confirm that this bobcat crossed through the bridge at Camera Trap Array 04, although its trajectory suggests it either passed under the bridge or skirted around the bridge outlet.*

Figure 38. *Bobcat detected by Camera Trap 04-C. It appears that this bobcat approached the bridge outlet, but did not proceed further.*

CAMERA TRAP ARRAY 05

Route 8: Sandisfield, MA

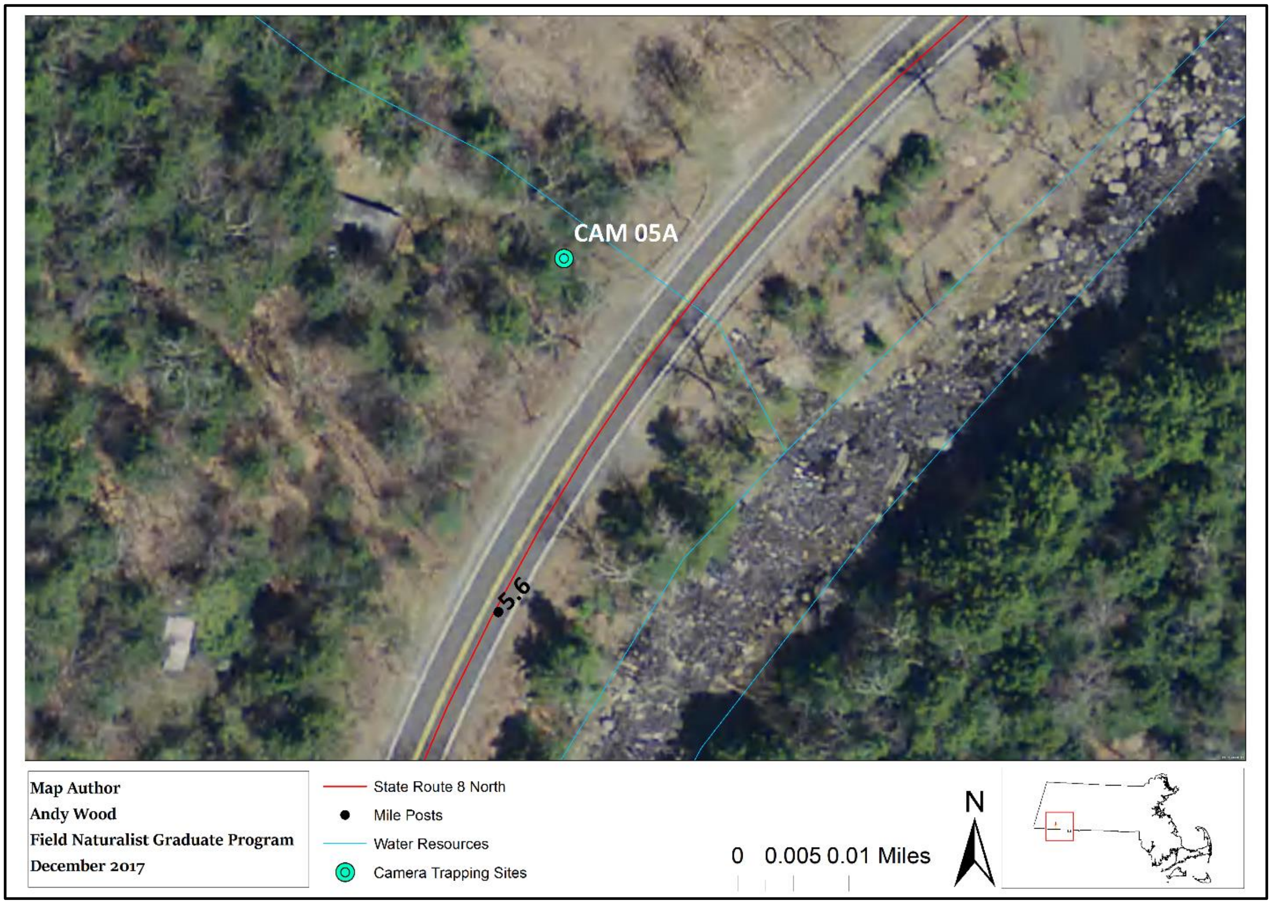

Figure 39. *Location of Camera Trap Array 05 near the northern priority segment of Route 8.*

Camera Trap	05-A
Deployed	July 3—August 14, 2017
Trap Nights	42
Feature	Tributary stream to Farmington
Camera Position	Upstream of a culvert above bankfull watching cross-section of stream.
Species Detected	• River otter (*Lontra canadensis*) • American crow (*Corvus brachyrhynchos*) • Raccoon (*Procyon lotor*)
Behavioral Notes	Raccoon moving through stream. Otter sliding down rock in stream. Crows perched on rocks in stream.
Comments	This small stream connects the Farmington River to upstream beaver-modified wetlands on state forest—an important habitat for river otter (Dubuc et al. 1990). Based on the surrounding habitat, we were surprised by our few detections. Tracking work shows that bear, coyote, and moose use trails on the adjacent parcel. The landowner reports a variety of wildlife species use this small tributary and consistent bobcat sightings over the last 50 years in the hills west of Route 8.

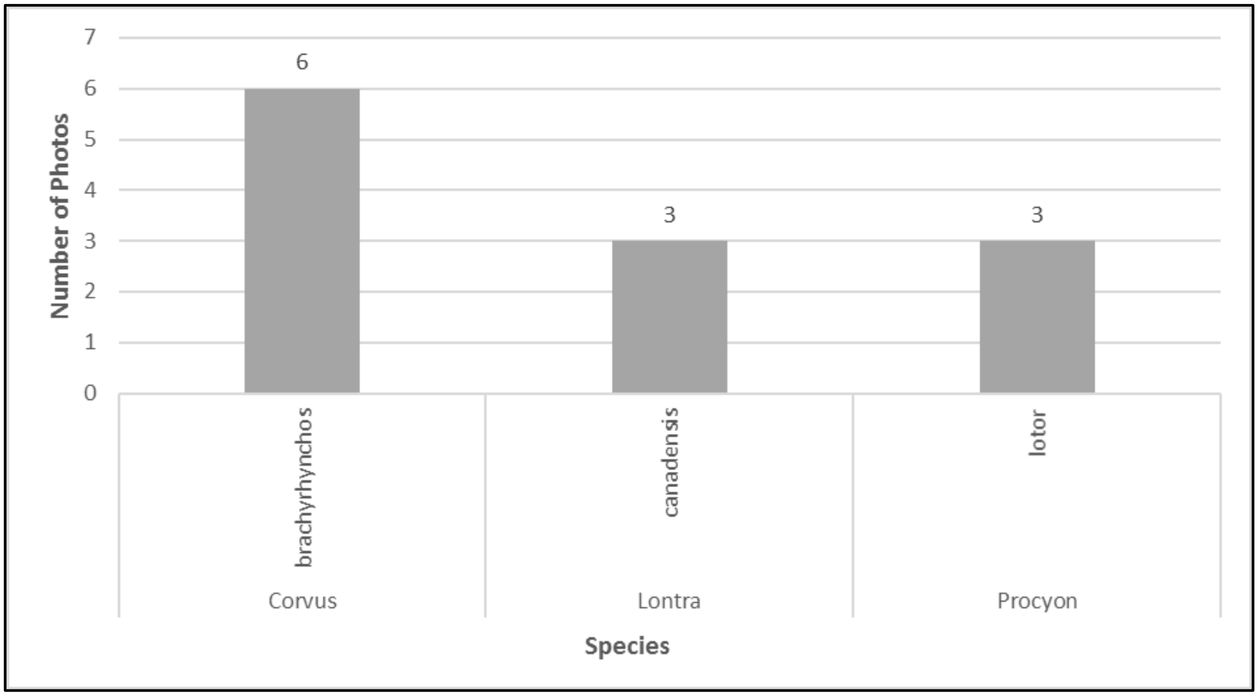

Figure 40*. Photos by species from Camera Trap Array 05.*

Figure 41*. River otter (Lontra canadensis) detected by Camera Trap 05-A, upstream of a culvert funneling this small tributary under Route 8 into the Farmington River.*

CAMERA TRAP ARRAY 06

Route 8: Otis, MA

Figure 42. *Location of Camera Trap Array 06 on the northern priority segment of Route 8 near Otis, MA.*

Camera Trap	06-A
Deployed	July 5—August 14, 2017
Trap Nights	40
Feature	Tributary stream to Farmington River
Camera Position	Upstream of inlet culvert. Near stream grade, facing a cross section of the stream.
Species Detected	• River otter (*Lontra canadensis*) • Gray squirrel (*Sciurus carolinensis*) • Great blue heron (*Ardea herodias*) • Raccoon (*Procyon lotor*) • Bobcat (*Lynx rufus*) • Mink (*Neovison vison*) • Human (*Homo sapiens*) • American robin (*Turdus migratorius*)
Behavioral Notes	Most wildlife moving upstream.

Comments	Our data suggest that the bridge downstream of the camera offers some functionality, since wildlife we documented moving upstream presumably would have passed through the bridge (steep topography between the bridge and the camera offer limited places for animals to enter the stream). The bridge is large enough to pass most mammals, except moose. Dry passage existed during low-flow conditions in 2017. Landowner reports black bear and coyote are common in the neighborhood, although we detected neither species at this array.

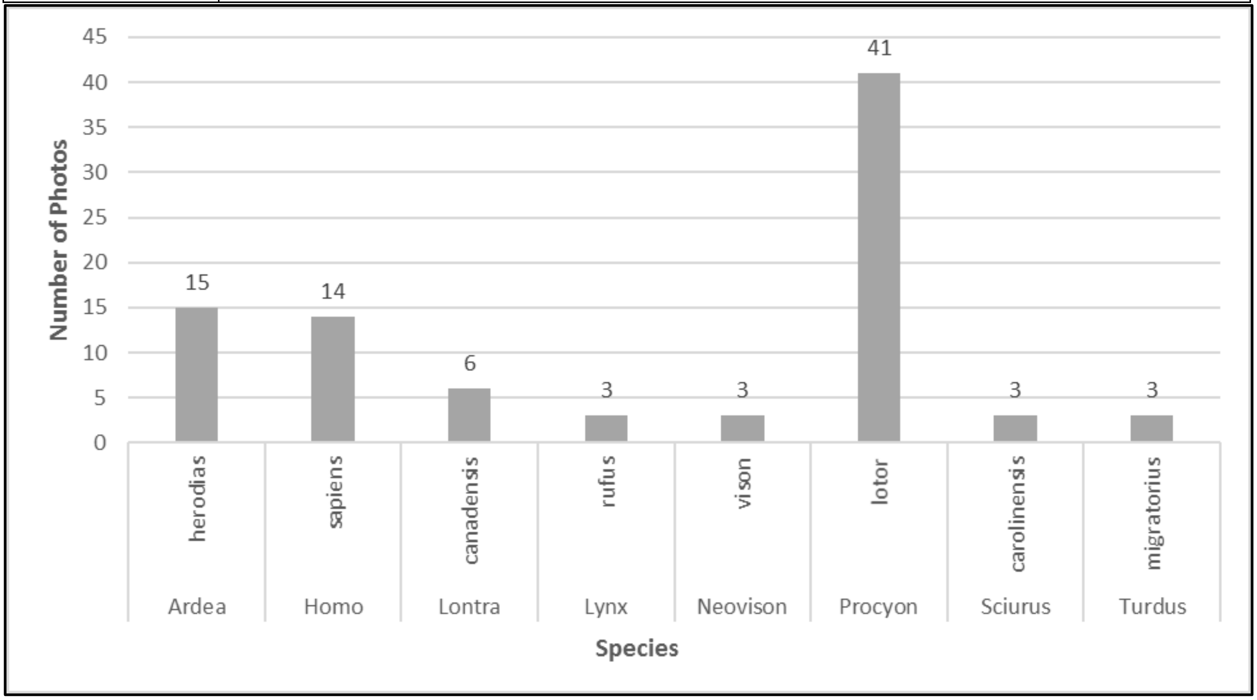

Figure 43. *Photos by species from Camera Trap Array 06.*

Figure 44. *Bobcat detected by Camera Trap 06-A, approximately 100 meters upstream of a bridge under which this small tributary passes and joins the Farmington River.*

CAMERA TRAP ARRAY 07

Route 8: Otis, MA

Figure 45. *Location of Camera Trap Array 07 along the northern priority segment of Route 8 near Otis, MA.*

Camera Trap	07-A
Deployed	July 11—August 14, 2017
Trap Nights	34
Feature	Road
Camera Position	Perpendicular to Route 8. Set back several meters in forest.
Species Detected	None
Behavioral Notes	None
Comments	This single unit array near Camera Trap 01A serves as a control: same habitat, similar topography, but no trail feature. Placing cameras where they are triggered by cars can quickly flood the dataset. This could be useful for characterizing roads where no AADT data exists, but may overwhelm researchers with marginally useful data relating to wildlife activity. Pairing traps 01-A and 07-A suggests that wildlife do not randomly move through forest habitat along this section of Route 8.

CAMERA TRAP ARRAY 08

Interstate 90: Lee, MA

***Figure 46**. Location of Camera Trap Array 08 at subsection of priority segment along Interstate 90 near Lee, MA*

Camera Trap	08-A	08-B	08-C
Deployed	July 27—December 20, 2017	July 27—August 15, 2017	July 27—August 15, 2017
Trap Nights	146	19	19
Feature	Culvert outlet	Culvert outlet; scour pool	Culvert inlet
Camera Position	Facing best approach to the structure.	Facing outlet drop and scour pool.	Near wingwall facing inlet cobble field.
Species Detected	• Coyote (*Canis latrans*) • Human (*Homo sapiens*) • Bobcat (*Lynx rufus*) • Fisher (*Martes pennant*) • Deer (*Odocoileus virginianus*) • Raccoon (*Procyon lotor*)	None	• Red Fox (*Vulpes vulpes*)

	• Gray squirrel (*Sciurus carolinensis*) • Gray Fox (*Urocyon cinereoargenteus*) • Black Bear (*Ursus americanus*) • Red Fox (*Vulpes vulpes*) • Small mustelid *spp*.		
Camera Trap	**08-D**	**08-E**	**08-F**
Deployed	July 27—December 20, 2017	August 15—December 20, 2017	August 15—December 20, 2017
Trap Nights	146	127	127
Feature	Culvert inlet	Culvert interior	Culvert interior
Camera Position	On top of inlet, facing down to inlet cobble field.	East side of structure near outlet. Facing dry ledge and water on west side of the culvert.	West side of structure near inlet.
Species Detected	• Coyote (*Canis latrans*) • Human (*Homo sapiens*) • Bobcat (*Lynx rufus*) • Woodchuck (*Marmota monax*) • Deer (*Odocoileus virginianus*) • Gray squirrel (*Sciurus carolinensis*) • Black Bear (*Ursus americanus*) • Red Fox (*Vulpes vulpes*)	• Great blue heron (*Ardea herodias*) • Human (*Homo sapiens*) • Bobcat (*Lynx rufus*) • Deer (*Odocoileus virginianus*) • Raccoon (*Procyon lotor*) • Cottontail (*Sylvilagus spp*.)	• Great blue heron (*Ardea herodias*) • Coyote (*Canis latrans* Human (*Homo sapiens*) • • Bobcat (*Lynx rufus*) • Fisher (*Martes pennant*) • Deer (*Odocoileus virginianus*) • Raccoon (*Procyon lotor*) • Gray squirrel (*Sciurus carolinensis*) • Black Bear (*Ursus americanus*) • Red Fox (*Vulpes vulpes*)

Behavioral Notes	**Bobcat:** Detected frequently from September to December. Several probable crossings documented, although our arrays did not capture complete sets images throughout the culvert. Bobcats used a dry ledge inside the culvert. **Deer:** Detected at the inlet, outlet, and inside the structure. At least one confirmed crossing. **Bear:** One confirmed crossing on October 28. No additional activity. **Fisher:** Detected inside the culvert on Aug 16 and August 18 near the inlet and near the outlet on August 17. No confirmed crossing. **Coyote:** Detected on six days at inlet, outlet, and inside culvert. No confirmed crossings. **Red Fox:** Detected on five days near inlet, outlet, and occasionally inside structure. **Gray Fox:** Detected on October 1 and December 8 near outlet.
Comments	This culvert was monitored by a four-camera array from late summer to early fall. In August we relocated Camera Traps 08-B and 08-C to new locations (08-E and 08-F). Overall, our array was able to capture several complete crossings, although additional cameras at this culvert would increase our monitoring capabilities.

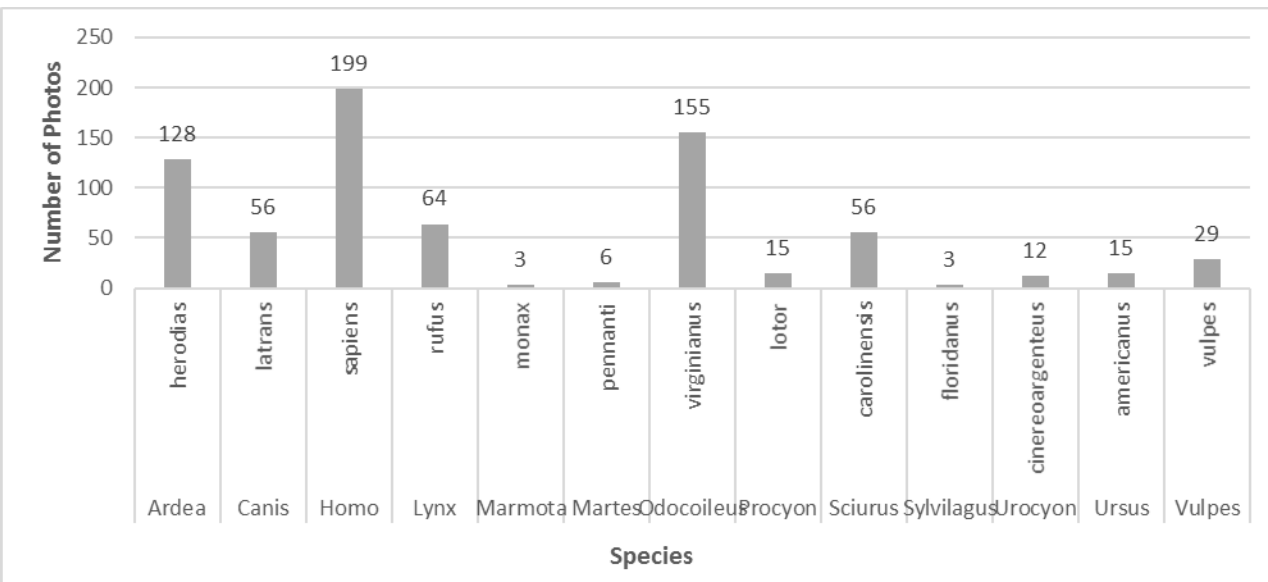

Figure 47*. Photos by species from Camera Trap Array 08.*

Figure 48. *Black bear (Ursus americanus) documented by Camera Trap Array 08 at culvert near mile 12.4 of Interstate 90. Pictures with corresponding time stamps from the outlet (top), interior (middle) and inlet (bottom) confirm this crossing.*

CAMERA TRAP ARRAY 09

Interstate 90: Lee, MA

***Figure 49**. Location of Camera Trap Array 09 along subsection of priority segment of Interstate 90 near Lee, MA.*

Camera Trap	09-A	09-B	09-C
Deployed	July 27—December 20, 2017	July 27—December 20, 2017	August 15—December 20, 2017
Trap Nights	146	146	127
Feature	Culvert Inlet	Culvert Outlet	Culvert Interior
Camera Position	Facing inlet entrance	Facing the outlet weir and scour pool.	Drilled into the eastern abutment, facing the west side of structure.
Species Detected	• Great blue heron (*Ardea herodias*) • Gray squirrel (*Sciurus carolinensis*) • Eastern chipmunk (*Tamias striatus*)	• Great blue heron (*Ardea herodias*)	• Great blue heron (*Ardea herodias*) • Gray squirrel (*Sciurus carolinensis*)
Behavioral Notes	We documented frequent activity of Great blue heron at this culvert, moving in and out of the culvert through the inlet and outlet. Gray squirrel entered the		

	culvert, but only from the inlet. Small rodents were active at the inlet of this structure. Other than great blue heron, we documented no animal approaches to the culvert outlet.
Comments	The weir in this structure limits wildlife access to this culvert from the south. The approach to the culvert inlet from the north appears functionally adequate, although camera trapping suggests low use of this culvert during our study.

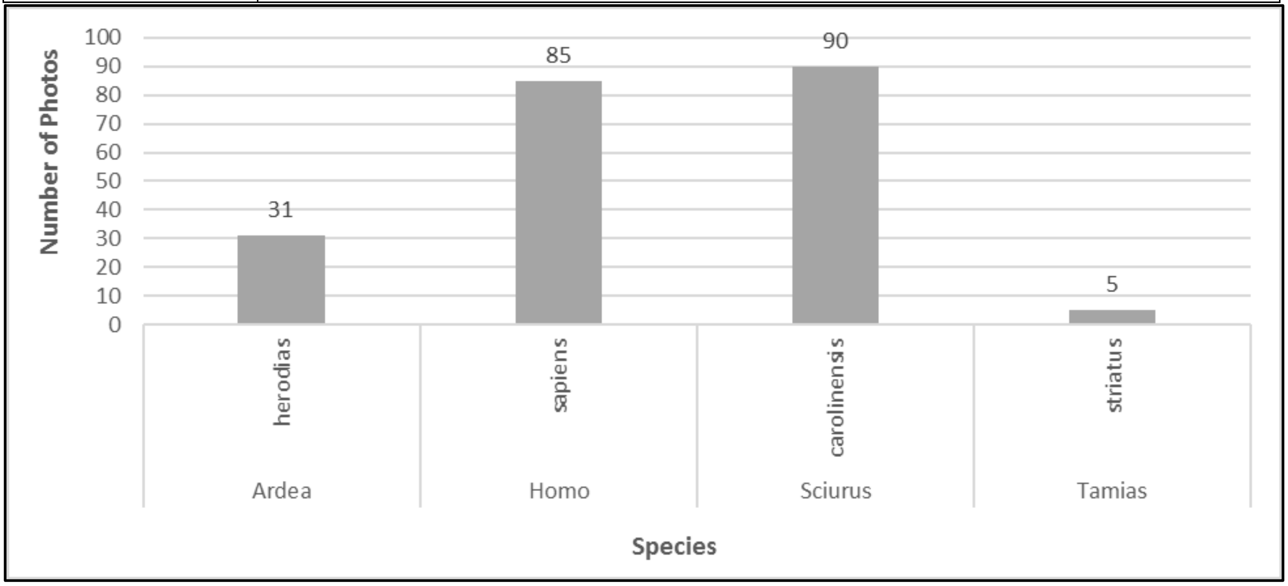

***Figure 50**. Photos by species from Camera Trap Array 09.*

***Figure 51.** Great blue heron (Ardea herodias) was a common traveler through this Interstate 90 culvert. Photograph from Camera Trap Array 09.*

CAMERA TRAP ARRAYS 10 & 11

Interstate 90: Becket, MA

Figure 52. *Location of Camera Trap Arrays 10 and 11 at Appalachian Trail overpass on priority segment of Interstate 90.*

Camera Trap	**10-A**	**10-B**
Deployed	August 16—October 16, 2017	August 16—October 16, 2017
Trap Nights	61	61
Feature	Appalachian Trail Pedestrian Overpass Eastbound Span - South	Appalachian Trail Pedestrian Overpass Eastbound Span - Median
Camera Position	Perpendicular to walkway	Perpendicular to walkway
Species Detected	• Virginia opossum (*Didelphis virginiana*) • Gray squirrel (*Sciurus carolinensis*) • Bobcat (*Lynx rufus*) • Human (*Homo sapiens*) • Domestic Dog (*Canis lupus familiarus*)	• Cottontail (*Sylvilagus spp.*) • Gray squirrel (*Sciurus carolinensis*)
Behavioral Notes	One documented bobcat crossings (by pairing with data from Camera Array 11)	

Camera Trap	11-A	11-B
Deployed	August 16—October 16, 2017	August 16—October 16, 2017
Trap Nights	61	61
Feature	Appalachian Trail Pedestrian Overpass Westbound Span - Median	Appalachian Trail Pedestrian Overpass Westbound Span - North
Camera Position	Perpendicular to walkway	Perpendicular to walkway
Species Detected	• Bobcat (*Lynx rufus*) • Cottontail (*Sylvilagus spp.*) • White-tailed Deer (*Odocoileus virginianus*)	• Cottontail (*Sylvilagus spp.*)
Behavioral Notes	One documented bobcat crossings (by pairing with data from Camera Array 10).	
Comments	Camera trapping work is ongoing at this site.	

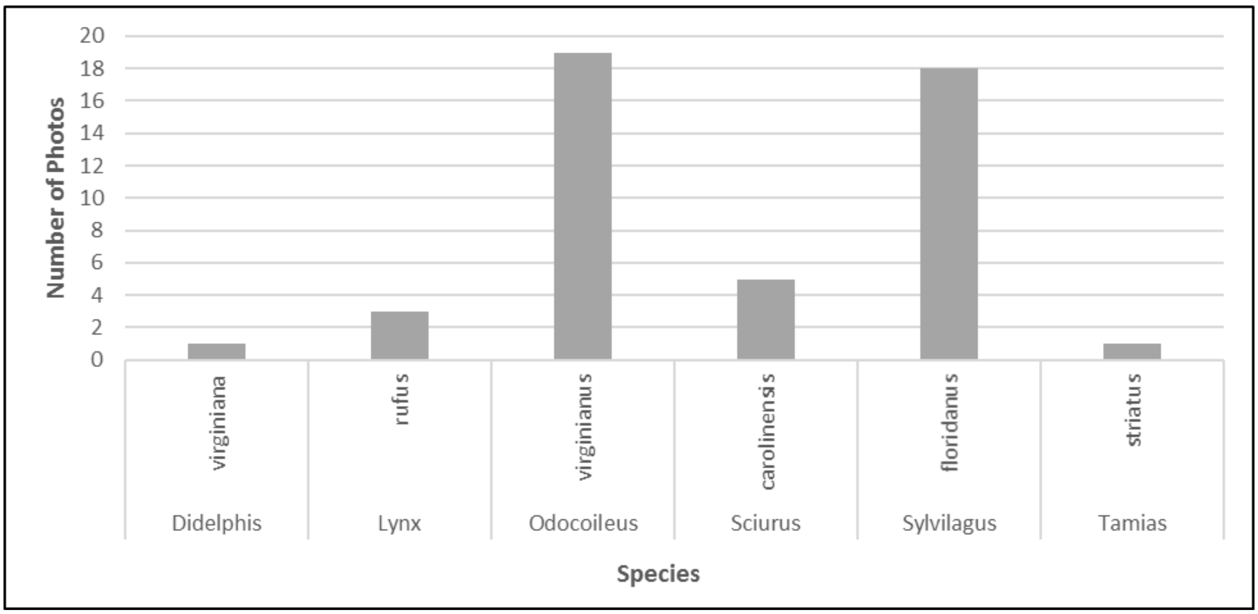

Figure 53. *Photos by species from Camera Trap Arrays 10 and 11.*

Figure 54. Bobcat detected by Camera Trap Arrays 10 and 11. Photographs with paired time stamps confirm that the bobcat crossed from south to north across I-90, crossing the eastbound span (top) and the westbound span (bottom).

DISCUSSION

Route 8

Our results demonstrate that several crossings are regularly visited and occasionally crossed by terrestrial wildlife. Overall, we were surprised by the low rates of use at the crossings where we camera trapped. At Camera Trap Array 04, the site we studied most intensively along Route 8, we expected more use of a large bridge with wide, dry banks underneath; however, during our 99 days of trapping we confirmed zero complete wildlife crossings.

Several species were notably absent at Route 8 sites: specifically moose, bear, fisher and gray fox. We observed moose track and sign on two parcels along Route 8, indicating that they are present to some degree. Similarly, we observed track and sign of bear along Route 8 in several locations. We observed one black bear cross Route 8 during early July, and local landowners report common sightings. For some reason, our traps did not detect these mammals. Gray fox are often found in mixed forest and field habitat, which is not common along this section of Route 8.

In general, it appears that substantial forest and wetland habitat is available along Route 8. We believe that our low levels of wildlife detections along Route 8 were mainly a function of limited sampling.

Route 2

Our camera trapping on Route 2 was limited to one site at a large bridge. Our results indicate that a number of species use the riparian corridor along the Hoosic River near this bridge. Technically, no dry passage was present through the structure in 2017, although water depth was as low as twelve inches during the summer. Our tracking work strongly suggests that adult and juvenile deer crossed through the bridge in shallow water. A sandbar in the middle of the river was also accessible through a shallow water crossing. Our tracking work indicates that deer used this sandbar frequently. We found track and sign of beaver and possibly river otter on the sandbar. Beaver and raccoon tracks were found near the inlet by Camera Trap 03-A.

It was difficult to find suitable trees to mount camera traps, and we recommend mounting cameras directly on the bridge to monitor wildlife passage. We believe wildlife are more likely to use the west cell of this bridge than the east cell.

Interstate 90

We documented many species near, inside, or moving through large box culverts. From the first four months of data, we documented wide-ranging carnivore species (fisher, black bear, and bobcat) crossing through one culvert near mile 12.4. However, we documented very little wildlife activity at a similar structure near mile 13.7. Although our data are preliminary, it appears that some wildlife can and do cross the Interstate using existing crossings, although we do not have sufficient data to ascertain the frequency of use.

Our data make a strong case for continued monitoring of these crossings. We strongly recommend dedicating more cameras to each site, which will provide data on crossing rates with higher certainty. Our design suggestions in **Appendix C** are based partly on our camera trapping experience underneath Interstate 90. Understanding the degree of permeability of Interstate 90 is essential to connectivity work in western Massachusetts.

Sampling
We intentionally biased our camera placement in order to maximize detections at features relevant to our study of roads, bridges, and culverts. This approach is appropriate for basic faunal surveys (Rovero et al. 2013), but it limits inference between camera trapping sites. Additionally, this type of sampling can create confirmation bias, where the data obtained convinces us that the areas we sample are the most important areas to study and mitigate. Despite these limitations, our approach was still useful, especially because so little was known prior to 2017 about wildlife use of our study areas.

Furthermore, we believe that animals do not cross roads at completely random intervals. Wildlife frequently travel through favorable habitats and along existing trails; the spatial arrangement of those features may pre-determine how much use a particular segment of road receives from wildlife. For example, Camera Trap 01-A and Camera Trap 07-A were placed close together similar hemlock-hardwood forests. We placed Camera Trap 01-A along an ATV spur trail, while Camera Trap 07-A was placed in the woods near the road where no active game trails were observed. Camera Trap 01-A had much more wildlife activity than Camera Trap 07-A.

Camera Performance
False triggers were much higher in Bushnell cameras than Reconyx cameras. This required more back-end work sorting through the photos for true detections of wildlife. The Bushnell cameras required more fine-tuning of settings: the first deployment was often filled with overexposed or underexposed pictures, as we did not correctly anticipate patterns of wildlife movement in front of cameras. The Reconyx units performed well on default settings, and consistently produced high quality images.

Fifty percent of Bushnell units lost time while deployed; no Reconyx units lost time while deployed. This was a minor issue for species inventory work, but problematic in locations where we intended to match images by time from paired cameras. Newey et al. encountered similar limitations using a variety of recreational camera trapping models (2015). Although we had issues with Bushnell cameras, collaborators we spoke to using similar models did not experience this issue. While we do not have the data to strongly endorse any particular model, a variety of published literature can help other groups select camera trap models most appropriate for their needs (Rovero et al. 2013; Swann et al 2004).

Data Management
Camera trap projects require skilled labor to catalogue, process, identify species, and archive the photos in meaningful ways. We estimate our relatively small project required 150 hours of data processing. Our methods of cataloguing, tagging, and exporting files greatly reduced processing time, and we strongly recommend developing data systems far in advance of fieldwork. Sound systems also increases the likelihood that other researchers will be able to use and interpret study results (Scotson et al. 2017; Forrester et al. 2016; Meek et al. 2014). We describe our approach in **Appendix C.**

CONCLUSIONS

Although our study was limited in scope, future work by collaborators can build on our knowledge of these road segments. Future groups working along roads will be well served by developing specific research questions (Meek et al. 2014; Meek et al. 2015).

RECOMMENDATIONS

- Field-test all camera units before deployment.

- Explore other camera options. Browning *Strike Force* cameras ($100-$150) work well in the Northeast, and appear to offer similar quality as the Bushnell cameras for a lower price (S. DeYoung personal communication 2017; G. Etter personal communication 2016).

- Dedicate sufficient staff time to camera trapping efforts.

- Monitor “control” sites with no crossing structures for comparison with camera trapping at sites with structures.

- Expand Interstate 90 camera trapping to include additional culverts and bridges.

- Expand camera trapping to span all seasons and multiple years.

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APPENDIX A
Road-Stream Crossing Resources

Road-Stream Crossing Resources

***Figure 55**. Dry culvert, providing passage for terrestrial wildlife underneath Route 8.*

Introduction

This resource guide is intended for organizations interested in assessing road-stream crossings for landscape connectivity. We do not provide a full suite of training materials, only a brief overview of our experience conducting Aquatic Organism Passage (AOP) and Terrestrial Wildlife Passage assessments as part of the North Atlantic Aquatic Connectivity Collaborative (NAACC). Readers should note that no consistent region-wide protocol currently exists for assessing Terrestrial Passage in the Northeastern United States. This resource guide provides information pertinent to creating such a guide.

NAACC Aquatic Organism Passage Surveys

The NAACC protocol works well with decentralized use; any group with adequate training can conduct NAACC surveys across a wide region. Other advantages of using NAACC aquatic surveys for connectivity planning include:

- Consistent terminology among collaborators.
- Offsite database storage.
- Publicly available data.
- Automated database scoring of records.
- Training programs that do not require previous experience in ecology or engineering.

NAACC AOP surveys have several limitations, including:

- Scoring that may not reflect the true connectivity value of crossing structures.
- Not suitable for non-aquatic taxonomic groups.
- Limited ability to address the influence of the surrounding landscape.

Efficient surveys require advance preparation. We scheduled field visits at least one week in advance with 2-3 people. We planned each day by first identifying a cluster of unassessed crossings. We prioritized surveying unassessed crossings, although we occasionally resurveyed crossings that needed updated information to account for storm damage or an incomplete previous record. We identified unassessed crossings by searching the NAACC database and assembling a list of target structures with GPS coordinates and local landmarks to guide the fieldwork. As we discovered, a critical error can occur during this planning phase. Currently, several regional and institutional sub-datasets exist in the NAACC database. On at least two occasions, our team surveyed crossings that we believed had not been assessed, only to discover we had searched only a subset of the entire database. While updated records are useful, we felt that our group should focus efforts on the numerous un-assessed structures.

Additionally, we discovered numerous unmapped crossing structures. In some cases, GIS models simply did not identify these structures. In other cases, these structures drained higher order ephemeral streams that likely run dry for much of the year. Finally, the distinction between a true road-stream crossing and a drainage structure is not always clear. This is important for budgeting field time; a field day planned around visiting eight crossing structures can easily turn into a 12-structure day, depending on how hard observers search for unmapped crossings.

In summary, we found NAACC AOP surveys relatively easy to conduct, appropriate for our team of staff and volunteers, and relevant to our associated wildlife connectivity research.

NAACC Terrestrial Passage Surveys

Assessing the impact of crossing structures on terrestrial wildlife is more complicated. Unlike fish that are obliged to stay in the stream, terrestrial wildlife interact with crossing structures in a variety of ways. The proposed survey protocol intends to assess structures primarily on their functional capabilities; in other words—is the structure physically capable of permitting terrestrial wildlife to pass through? During our field-testing of the survey protocol, we encountered a variety of issues, including logistical issues for field crews, clerical issues for data managers, and fundamental issues related to the complexity of animal behavior. Here, we review several issues:

Structure Size

Measuring physical dimensions of a structure appears straightforward, but its influence on wildlife is complex. One approach for interpreting structure dimensions is to combine width, height, and length into a composite index. Ng et al. (2004) used cross-sectional area (width *x* height), while others have used “Openness” (height *x* width / length) (Forman et al. 2003); however, note that different combinations of width, height, and length can generate the same index value. The effect may be profound on different species, which respond variably to the individual attributes of width, height, and length (Woltz et al. 2008). Kintsch and Kramer (2011) provide an excellent review of how taxonomic groups respond to structure size, although their study draws more from research in the western United States and Canada.

Substrate

Structure substrate is also important for wildlife. Our data and previous research documents bobcats using dry ledges to pass through culverts (Cain et al. 2003). Similar research in Europe suggests that small and medium-sized mammals frequently cross structures along dry ledges (Villalva et al. 2013). Deer and moose may avoid riprap or other footing unsuitable for hooves, although moose may be more willing to wade through deeper water than deer. It is straightforward to measure substrate size using a ruler or gravelometer, but in many structures, both concrete substrate and natural substrate are present

(**Fig. 56**). Some structures present ledges, artificial substrate, and natural substrate at different areas in the structure (**Fig. 57**). In cases where multiple passage options are present, field staff should assess the passage that provides the most possibilities for wildlife.

Figure 56. *Mixed substrate types of a dry ledge on bridge in Becket, MA.*

Figure 57*. Four dry passage options under bridge in Becket, MA. At the highest level, concrete and riprap passageways are available for wildlife use. Below, a narrow concrete ledge and nearby boulders also offer dry passage.*

Wildlife Behavior

Behavior around crossings varies widely among species. Our data and other anecdotes suggest that weasels and other mustelids regularly use crossing structures, whereas other taxa may be more reluctant to use crossings. Similar research in Vermont suggests that coyotes avoid all but the most open structures (large bridges), even though they certainly could fit through a small culvert (P. Marangelo 2017 personal communication). Black bear, on the other hand, appear to tolerate smaller structures. We found bear tracks through a rectangular 4.7x3 foot culvert in New Ashford, Massachusetts (**Fig. 58**). Black bear have been documented using structures as small as 3-foot diameter circular culverts (D. Paulson, 2017 personal communication).

Figure 58*. 4.7 foot tall culvert under Route 7 near New Ashford, MA. Black bear tracks filled this passageway.*

Temporal Variation

Wildlife may interact with crossing structures more during particular life stages, such as during juvenile dispersal (Beier 1995). Individual behavior also affects when wildlife use crossings. Some species may be willing to use improved crossings, but only after a time lag of months between installation and use (Villalva et al. 2013).

Landscape Context

Crossing structures are one piece of the landscape, and wildlife activity may be more related to the surrounding landscape context than to the attributes of the crossing structure. First, the presence of favorable habitats will influence the likelihood of structure use. However, the presence of good quality habitat alone does not necessarily lead to an increase in structure use by wildlife. For example, we found several crossings with active game trails nearby that did not pass through the actual crossing. Are animals avoiding the structure because of some unknown feature? Alternatively, alternatively, are they crossing over the road because there is no incentive to pass under, and no cost (measured in injury or mortality) to pass over the road? A successful assessment protocol for terrestrial passage through these structures will need to account for the surrounding landscape context.

Despite these complications, measuring and documenting structures is a good first step towards improving connectivity for both aquatic and terrestrial organisms. We rarely have the power to change the landscape context around a crossing, but we can improve crossings. Since funds and time are limited, comprehensively documenting structures in areas with high quality habitat will help transportation agencies prioritize projects.

To improve the efficiency of survey efforts, we recommend:

- Careful planning of field days by personnel familiar with the NAACC database.
- Generating detailed, printed, maps for field days to guide observers to unassessed crossings.
- Pre-labeling datasheets with XY coordinates, nearby features, and potential parking areas.
- Working in crews of two or more people. Crews of 3-4 people are more efficient, but two is an adequate number to survey most crossings.
- Using a camera that automatically labels photos with a serial number.
- Entering datasheets into the NAACC Database within 2-3 days. Many crossings are similar, nondescript structures, and it can be difficult to distinguish records from photographs.
- Prioritizing surveys in areas where mitigation projects are likely to happen.

Additionally, we recommend that the current NAACC Terrestrial Passage draft protocol incorporate the following eight recommendations into the next document draft.

1. Assume a Lower Level of Experience

Field staff have varying experience with wildlife biology and behavior. If we expect them to assess structures based on extensive knowledge of each species/group, we have to be prepared to work with highly variable and potentially unreliable data.

2. Use Teams of Two or More

Terrestrial Passage surveys will require a minimum of two people in the field. It is extremely difficult to measure large structures without a second person.

3. Update Equipment List

Most of the equipment used for aquatic passage surveys is adequate for terrestrial passage surveys; however, field staff should also bring:

- One small ruler for measuring tracks and scats
- Tracking and scat guides

4. Address Transition from *Bridge Adequate* Surveys

In the aquatic module, a bridge spanning the full channel and both banks may qualify as *Bridge Adequate* (**Fig. 59**), which frees the NAACC Observer from collecting the full suite of structure data. These structures may be relevant to researchers interested in terrestrial passage, but *Bridge Adequate* surveys do not capture basic dimensions or other structure data. To link the aquatic module with the terrestrial module, we will need to accommodate for this category.

Figure 59. *This bridge is classified as "'Bridge Adequate" in an AOP survey, leading to an abbreviated survey that does not collect essential information for assessment of terrestrial passage.*

5. Reconsider *Expected Percentage of Year that Functional Dry Passage is Present*

This is nearly impossible to determine based on one field visit. Dry passage is variable throughout the season, fluctuating with short-term precipitation trends. We can capture the width of dry passage in a moment, but it is less reliable to extrapolate to the rest of the season.

6. Clarify and Provide Examples of *Evidence of Human Activity At/Through the Crossing*

We recommend providing examples in a manual to help field staff choose the appropriate category (*Frequent/Daily, Occasional, None*). For example, how would one interpret graffiti? What amount of human tracks qualify as *frequent/daily use*? Clear guidelines and examples will help reduce variation across the sites.

7. Clarify *Vegetation Description*

Coordinators should clarify the goal in collecting this information to ensure its relevance to the overall assessment.

8. Clarify method for *Photos of Roadside Situation*

Where should NAACC Observers stand to take pictures? Perpendicular or parallel to the road? From the shoulder or the median? Currently, one could read the existing guidelines, take a picture of the shoulder and road, and end up with a picture that does not capture the true context of that road segment (**Fig. 60**). Explicit instructions may help standardize photographs entering the database.

Figure 60*. Photographs of the same crossing on Route 8 near the Connecticut border. Each perspective of the same crossing provides different context to the viewer.*

Useful Resources for Wildlife Track and Sign Identification.

<u>Mammal Tracks and Scat Life-Size Pocket Guide</u> Lynn Levine & Martha Mitchell. Heartwood Press. www.heartwoodpress.com (Pocket guide)

<u>Local Tracks of North America: "Quick Guide" to Commonly Seen Animal Tracks and Scats.</u> Local Birds Inc., 2010. www.Localbirds.com (Pocket guide)

<u>Mammal Tracks & Sign: A Guide to North American Species.</u> 2003. Mark Elbroch. Stackpole Books, Mechanicsburg, PA. (Large field guide)

APPENDIX B
Roadkill Survey Resources

Roadkill Survey Training Materials

Figure 61. A black bear crosses into the path of traffic along Route 8 in western Massachusetts.

Introduction

Thank you for your interest in surveying wildlife roadkill. Your data will help biologists, conservation organizations, and transportation agencies improve roads for wildlife *and* people. Please read this manual carefully before heading out to collect roadkill data.

What to Expect

- Walking, biking, or driving several miles of road.
- Identifying and photographing dead animals.
- Using a GPS unit and camera.
- Managing risk along busy roads.
- Submitting your data to an online database.

What to Wear and Bring

- Sturdy, comfortable footwear
- Long pants (for ticks & poison ivy)
- Sun hat
- Rain gear
- Reflective vest
- Clipboard
- Pencils/Pens
- Camera
- GPS unit
- Food and water
- Cell phone
- First aid kit

Getting Set Up to Survey

- Before starting your survey, place safety cones or "Survey Ahead" road signs on either end of your work zone so motorists know you are on the road.

- If you park your car in preparation for a survey, or during a driving survey, make sure you park in a safe, legal place. Public areas, such as a picnic area or city park are a good option. Avoid parking on private land, unless you have received permission from the landowner. Make sure your vehicle is completely off the road and not in the path of traffic. In all cases, use your judgement: if it seems like a bad place to leave a car, it probably is!

- Perform surveys in teams, or if you go out alone, make sure someone knows where you are and when you will return.

Walking the Road

Walking along roads can be hazardous. Follow these tips to stay safe.

Figure 62. This road has a wide shoulder, and is relatively safe to walk.

- Walk <u>against</u> the flow of traffic, so you can see oncoming vehicles in time to step far off the road. However, if the road shoulder is very narrow, walk whichever side of the road feels safer.

- Wear a reflective vest and bright-colored clothing.

- Only perform surveys during daytime and in good weather. Avoid surveying during low-visibility times: early morning, evening, foggy conditions, and heavy rain can all reduce drivers' ability to see you on the road.

- Step as far off the road as possible when you see oncoming traffic. Walk on the far side of guardrails where possible. If the road shoulder is narrow, survey from the safer side of the road, or walk along the outside of the guardrail. Avoid the inside lane of blind curves; drivers may not see you and have limited reaction time in these areas.

- Stay alert, and bring a friend to keep an eye out for oncoming cars.

- If it seems unsafe to walk, it probably is! Contact your project coordinator to discuss alternative options.

Driving the Road

Figure 63. Driving surveys are efficient, but miss smaller-sized roadkill.

- Conduct driving surveys in teams of two or more so one person can focus on driving while the other person scouts for roadkill.

- If you park your car to inspect a carcass, choose an area where you can pull your vehicle completely off the road.

- Make sure the speed you drive falls within a normal range of traffic speed for that stretch of road. Driving faster or slower than the average speed puts you at risk.

- On busy roads, the surrounding speed of traffic may prohibit you from driving at a slow enough pace to accurately record roadkill; in this case, this site may not be appropriate for a driving survey.

- Survey during quiet times, such as 10:00am or 2:00pm. Avoid surveying during rush hour and mid-day.

- If road conditions are unsafe, do not conduct driving roadkill surveys.

Collecting Data

Figure 64. Keep detailed notes from your surveys.

- For each survey, fill out a Roadkill Data Sheet (**Fig. 67**). Take special care to complete the box at the top of the data sheet. Capturing your **Name, Email,** the **Date, Road Name,** and **Start/End** times of your survey is important information.

- If you do not encounter roadkill during a survey, check the box in the top right-hand corner of the datasheet next to **I did not observe any roadkill.**

- Log the **Time** you encounter each roadkill. Note the hour, minute, and A.M. or P.M.

- Collect a GPS point and write the coordinates in the **Latitude** and **Longitude** fields.

- In most cases*, log each roadkill as a separate observation. First, circle the appropriate taxonomic **Group** (*Mammal, Bird, Reptile, or Amphibian*). Next, identify it to **Species**, if possible. If you are 100% sure of your identification, circle *High* in the **ID Confidence** field. If you are not 100% certain of the species, circle *Low* in the **ID Confidence** field. It is always better to be cautious about your identification than to be wrong.

- If it is the only carcass in the immediate area, write *1* in the **# of Animals** field. Note the **Sex** of the animal by circling the appropriate choice (*M/F*), or circle *Unknown* if you cannot tell. The form will ask: **Did it have a radio collar or tag?** Circle **Y** or **N** based on your observations.

- Describe your immediate surroundings in the **Location Description** box. Record nearby landmarks, such as bridges, intersections, driveways, or house numbers. Note anything else you think is relevant for describing the surrounding area.

- Take a photograph of each carcass to help project coordinators verify hard-to-ID roadkill. For each carcass you photograph, circle **Y** to note that you took a photograph**,** and note the file name from your camera settings next to **Photo #**. If you were not able to photograph the carcass, circle **N.**

If you encounter two of the same species very close to each other, you may record them in one observation box, and increase the **# of Animals to match the number of carcasses at that location. Since most GPS devices are only accurate to within a few meters, this will save you the trouble of entering numerous GPS coordinates for a cluster of same-species roadkill.*

Photographing Roadkill

- When photographing roadkill, include an object for scale reference. The best option is to place a small ruler or tape measure next to the animal (**Fig. 65**).
- If you do not have a tape measure or ruler, use another common object such as a pencil or car key. Some field notebooks contain printed rulers, which can be useful for photographing small animals (**Fig. 66**).
- Lay out the measuring device next to the roadkill (assuming it is safe to do so), and take the photo. This will make it easier for other people to determine the size of your roadkill, which can be important for determining the age and other biological information.
- You may need to move the carcass to get a better picture. Avoid handling roadkill: use a stick or your shoe to reposition the carcass.

Figure 65. *A tape measure is useful for photographing larger roadkill.*

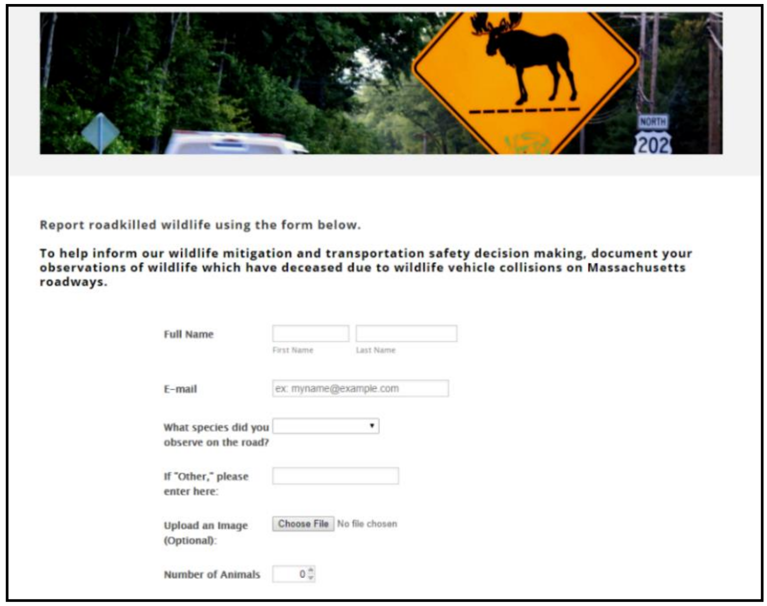
Figure 66. *A small turtle photographed next a reference ruler in a Rite-in-the-Rain field notebook.*

Entering Your Data

- Once you have completed your survey, carefully check your notes to make sure you completed all fields on the data sheet.

- Visit the online Massachusetts Department of Transportation's **Linking Landscapes Wildlife Roadkill Database** to upload your observations: http://www.linkinglandscapes.info/wildlife-roadkill-database.html

- Enter your data into the appropriate fields. Since there is currently no place to enter information about the animal's **Sex** or whether it had a collar or tag, enter that information into the **Comments** section.



Report roadkilled wildlife using the form below.

To help inform our wildlife mitigation and transportation safety decision making, document your observations of wildlife which have deceased due to wildlife vehicle collisions on Massachusetts roadways.

Full Name
First Name
Last Name
E-mail
ex: myname@example.com
What species did you observe on the road?
If "Other," please enter here:
Upload an Image (Optional):
Choose File No file chosen
Number of Animals
0

Figure 66. *Entering your data into the Linking Landscapes online database will ensure that your data goes directly to transportation planners.*

- Keep your survey data sheets in a safe place in case project coordinators contact you with questions about your data.

For Project Coordinators

These training materials are designed to help field staff conduct safe, efficient roadkill surveys. However, prior to sending staff into the field, project coordinators should spend time developing research questions and regional priorities. Your organization's needs may differ, and feel free to adapt these resources to your situation.

Walking vs. driving roadkill surveys

Organizations interested in conducting roadkill surveys will need to decide whether to walk or drive. An athletically fit person can walk a mile in 30 minutes on flat terrain. To increase roadkill detection, road walks should cover each lane of traffic. Under these circumstances, one mile of road will take an estimated minimum of 1 hour, assuming no roadkill and a brisk pace. However, documenting each roadkill may take several minutes. If the frequency of roadkill is high, a mile of survey work could take 1-2 hours. This time estimate does not include travel to and from the survey site. Our team found that walking roadkill surveys along ~8 miles of a rural highway regularly took 1-2 days per week, even with a group of interns available for work.

On walking surveys, observers are more likely to encounter a wide range of species sizes. Driving surveys are much faster than walking surveys, although this sampling favors detection of large animals: the larger the animal, the higher likelihood of encountering it during a rapid survey.

How should you choose a survey method? A good first step is determining which species are most relevant to your management goals. If physically small wildlife, such as reptiles or amphibians, are a high priority, walking surveys are most appropriate. If large mammals are the priority, driving surveys are probably adequate. Another useful approach is to determine the maximum amount of time available, and compare that value to the extent of roads you wish to survey. If managers wish to survey many miles of road at a higher frequency (*e.g*. weekly), but only have a few hours of staff time available, driving surveys are the most appropriate method.

A hybrid approach may work well in some situations. Driving surveys could cover long stretches of roads, with select sub-areas surveyed by walking. Comparing and analyzing data from this hybrid approach will require correcting for the different biases associated with each method.

Safety considerations

Working along roads is inherently dangerous. High traffic volume may jeopardize observer safety. Project managers should emphasize safety while training field staff. Managers should scout routes before they send people out, and be willing to modify plans if field staff feel unsafe. Permits are usually required to survey in the road right-of-way, and researchers should follow all safety conditions specified by the permit.

Data management

Managing roadkill survey data is relatively straightforward. Equipping technicians with printed datasheets and pre-set GPS units can standardize data formats and capture survey efforts. At the end of surveys, field staff can enter the data they collect directly into the online Linking Landscapes portal. Some people may prefer to use smartphones or tablets to collect data. Encourage staff to keep paper copies of datasheets on hand in case their devices run out of battery. Many field sites have limited cell service, and people new to the area may not be aware of this limitation.

Data sources

As more citizen scientists collect roadkill data, it will be important to distinguish between from incidental observations and more rigorous survey efforts. Inherent biases accompany this incidental data, although some researchers believe that high volumes of incidental data can supersede the quality problem. Because more people are interested in low-commitment efforts, more observers are available to submit data, and therefore more data is generated.

In an “adopt-a-road” model, volunteers regularly survey a pre-selected road segment. Project managers standardize the sampling and account for effort in data analyses. However, this model requires substantial coordination and volunteer dedication. Project managers will need to set up the study, scout appropriate sites, obtain permits, recruit observers, verify data, and finally, analyze data. It can be difficult to maintain sufficient people power and motivation to carry on a multi-year program.

However your organization chooses to incorporate citizen scientists, be sure to thank them for their efforts!

ROADKILL DATA SHEET

☐ I did not observe any roadkill

NAME: ____________ DATE: ____________ START TIME: ________

EMAIL: ____________ ROAD NAME: ____________ END TIME: ________

OBSERVATION #1

Group: Mammal / Bird / Reptile / Amphibian

Species: ____________

ID Confidence: High / Low

Animals: ________

Sex: M / F / Unknown

Did you take a photograph? Y / N

Photo #: ________

TIME: ____________

Latitude: ____________

Longitude: ____________

Did it have a radio collar or tag? Y / N

Location Description:

OBSERVATION #2

Group: Mammal / Bird / Reptile / Amphibian

Species: ____________

ID Confidence: High / Low

Animals: ________

Sex: M / F / Unknown

Did you take a photograph? Y / N

Photo #: ________

TIME: ____________

Latitude: ____________

Longitude: ____________

Did it have a radio collar or tag? Y / N

Location Description:

OBSERVATION #3

Group: Mammal / Bird / Reptile / Amphibian

Species: ____________

ID Confidence: High / Low

Animals: ________

Sex: M / F / Unknown

Did you take a photograph? Y / N

Photo #: ________

TIME: ____________

Latitude: ____________

Longitude: ____________

Did it have a radio collar or tag? Y / N

Location Description:

Please enter your data into the Linking Landscapes Wildlife Roadkill Database
http://www.linkinglandscapes.info/wildlife-roadkill-database.html

Figure 67. Sample datasheet for roadkill surveys.

APPENDIX C
Camera Trapping Resources

Camera Trapping Training Materials

Figure 68. Gray fox (Urocyon cinereoargenteus) near culvert under Interstate 90 in western Massachusetts.

Introduction

So you want to do a camera trapping study? Perhaps your colleagues are using camera traps, you've seen the captivating photos, and you've decided your organization can afford a few cameras. The good news is that many quality camera trap models are available for $100-$1000. With a relatively modest investment, you can acquire these powerful tools and use them to investigate various questions. However, keep in mind that using camera traps effectively to answer your questions requires careful planning, clear objectives, time, and other resources.

This guide we provides a brief overview to planning and executing a camera trapping project. Since camera traps can be used to answer a variety of research questions (occupancy, species inventory, mark-recapture, *etc*.) this guide provides general advice. Whether you are a land trust learning about a new property or a transportation agency studying wildlife use of culverts, this guide can help you plan for success and avoid common pitfalls.

Stage 1: Planning What to Do

Before you begin, consider: *what do I want to know?* It can be tempting to install cameras and figure out the rest later, but this approach rarely (if ever) provides the right answer. Your question could be as simple as "Which species raid the compost bin?" or "What time of day are bobcats active?" Whatever you want to know, be sure to take the time to clearly articulate your question. Once you settle on a question, you can develop the rest of your study design. If you are not sure how to design a study, find colleagues who have that kind of experience, and read about other camera trapping studies. While you design your project, consider these factors:

Time

How much time am I willing to invest? How much time will I need to answer my question?
Thinking about these questions will help you appropriately scale the scope of your project. Keep in mind that a single season study will not capture how wildlife behave from year to year.

Money

How much money am I willing to invest?
Equipment, travel, and staff time add up quickly. Establishing a budget will help you appropriately scale the scope of your project.

Expertise

How much expertise do I have on hand?
Make sure that you have trained staff or volunteers for fieldwork and for sorting through photographs. Identifying some species can be difficult, so plan to have someone around with experience identifying local species.

Equipment

What equipment should I use? How much will I need?
Our basic equipment list:

- Cameras
- SD memory cards
- Straps or brackets for mounting cameras
- Cable locks (basic security)
- Metal lock boxes (extra security)
- Zip ties
- Labels with contact information
- Multi-tool
- Folding handsaw
- Waterproof, padded bag or container for transporting equipment

Choose cameras based on your budget and recommendations from colleagues conducting similar work. You may not need the most advanced model on the market, but make sure you purchase equipment with a reputation for reliability in your local ecosystem.

Data Management

What will my data management system look like? What programs will I use? Where will my data be stored? Which computers will we use?
At minimum, you will need a decent computer, a way to download images from SD cards, and a system for backing up files (external hard drive or cloud-based drive). These days, you can download open source software designed to handle camera trapping project. These programs take extra time to learn, but will save you many hours of tedious data entry. We used *Wild.ID*, a desktop-based program developed by the Tropical Ecology Assessment & Monitoring (TEAM) Network (http://wildid.teamnetwork.org/index.jsp).

Stage 2: The Test-Run

You may be tempted to jump into the real study, but it is always a good idea to do a test-run. You do not want any nasty surprises further down the road.

Figure 69. *Testing camera trap equipment in western Massachusetts.*

Test your equipment: Do the cameras work as expected? Do the cameras perform well in the local climate? How quickly do your SD cards fill up? Is your computer screen big enough to view the photos effectively? Which settings on your cameras work best at your field sites?

Test your people: Are they comfortable using the equipment? Are they familiar enough with the project objectives? Do they know the local terrain?

Test your field site: What is your field site like? Are the local landowners receptive to your work? Can you access the area where you intend to trap?

Test your subjects: Are you getting photos of your target species? Are you getting pictures from the right height? Are you getting the right light conditions? Tweak the settings (assuming your sampling design permits it) to get the best pictures of your target species.

Test your data outputs: Once you have a bit of data, run your intended analyses (if any). Does the data actually help you answer your question? If not, you may need to revisit Stage 1 to re-examine your questions and study design.

The Test-Run provides valuable information for your project. It is not a waste of time, so do not skip it! You might learn about an interesting feature on the landscape or an unexpected animal behavior. All of this local knowledge can be leveraged towards the future success of your project, and may provide the basis for new studies.

Stage 3: The Real Study

This is the part where you take what you learned from the Test-Run, and run your study. Inevitably, issues will come up, but hopefully fewer issues than if you had skipped the Test-Run.

Stage 4: Communicating your Results

Hopefully you have answered your initial question, or perhaps you have new questions that were generated during Stage 2 or Stage 3. Now you can share what you learned along the way. Remember that your colleagues may be interested in your specific results, but they may also be looking for advice on your methods, or on how you processed your camera trap data. Share what you have learned—what worked well, what flopped, what your thoughts on equipment are, *etc*.

Other Tips for Success

Develop a Workflow

Create workflow diagrams for managing the diverse tasks associated with a camera trapping project. If you are working on a team, a workflow diagram can help staff follow procedures consistently throughout the project. This diagram can provide almost as much information as a training manual, but in a condensed visual (**Fig. 74-75**). Feel free to adapt and modify our examples as needed.

Design Multi-Camera Arrays

In some cases, you may need to deploy multiple cameras in one location to answer your research question. For example, monitoring wildlife use of a 150-foot culvert simply cannot be done comprehensively with only one camera unit, since no camera can effectively monitor the entire structure. For monitoring culverts, a two-camera array provides useful, but not conclusive data about wildlife passage through a culvert; a third camera inside the culvert provides more certainty. Larger structures may require numerous cameras. Once you have identified the features you wish to set traps at, spend time designing the ideal array. Think about how many cameras you would dedicate to this array in an ideal world. Once you have designed the ideal array, consider the resources you have on hand. It may be worthwhile to study fewer features comprehensively rather than many features a bit. See **Figures 76-77** for array design ideas.

Mount Cameras for Success

Mounting your camera well is the key to getting good photos, but not every site will present ideal characteristics. The successful camera mount requires a combination of creativity and diligence. In the northeast, one commonly available option is to mount cameras to trees. If your area is treeless, get creative. Cameras can be mounted on rock cairns, drilled into concrete, or mounted on brackets attached to various other substrates. See **Figure**s 78-80 for a step-by-step guide to mounting cameras on trees, and other camera mounting resources. Once you have settled on a mounting location, take the time to thoroughly test your setup's angle, height, and detection zone. This process can easily take an hour or more; don't skimp on the time, or you may end up needing to make adjustments later, when you wish you had better data.

If you use locks with keys, make sure to equip all staff with a key set, which will enable team members to independently visit sites.

Capture Metadata

Metadata is information about data. Documenting different aspects of your project helps you to track camera performance and project logistics. At minimum, plan to collect:

- Site name
- Start date
- End date
- GPS coordinates
- Land cover
- Nearby features and location description
- Camera ID#
- Memory card ID#
- Details of your trap setup
- Camera angle and height from ground
- Initial battery status
- Lock codes
- Photographs of your setup.

Creating datasheets with your desired metadata will help your team consistently track whatever it is you want to track. For reference, see our datasheets (**Fig**. **81).**

Streamline Data Management

Develop a consistent system for the entire project, for both field and office work.

Managing Data in the Field

We found that having two SD cards per camera was essential. Out team could visit cameras, retrieve the SD card, insert the second card, and complete file work back in the office. We brought a tablet and SD card reader to check incoming photos for quality while we were in the field. This helped us adjust camera settings in real time.

Figure 70*. Retrieving SD cards from the field and capturing metadata.*

Managing Data in the Office

Keeping your data organized will help you navigate through files. Keep in mind that as your project grows in size, your ability to remember where certain photos are kept will diminish. You can address this by using a database. If your project includes collecting charismatic photos of wildlife, you may want to copy photos into a folder labeled "Marketing" as you sort through images. It will be easier to do this as you process photos, rather than doing it later on in the project. Creating a flowchart for the data management process can help your staff consistently process camera trap data **(Fig. 82).**

We downloaded camera files from SD cards onto computers, and kept our data backed up in three locations. We grouped images into folders, following our internal naming convention. For example, our folder labeled *CAM01A_B1_B1A_06152017_07152017* contained photos from array *CAM01* at camera trap *A*. The camera and SD cards used were *B1* and *B1A*, respectively. The start date was *June 15, 2017*, and the end date was *July 15, 2017*. Within our file directory, each camera array included a series of folders, labeled by the dates when our team visited the array.

Tagging Photos

A number of camera-trapping-specific software applications exist, and many are open source. The benefit of using these software is that they are tailored to the needs of camera trappers. For a good review of available software, see Wearn and Glover-Kapfer (2017). We used the TEAM Network's Wild.ID platform because of TEAM's reputation in the camera trapping research community. Wild.ID is desktop-based, a useful trait for working in field sites with limited internet access. Wild.ID allows users to batch export results and metadata to Excel and other file formats.

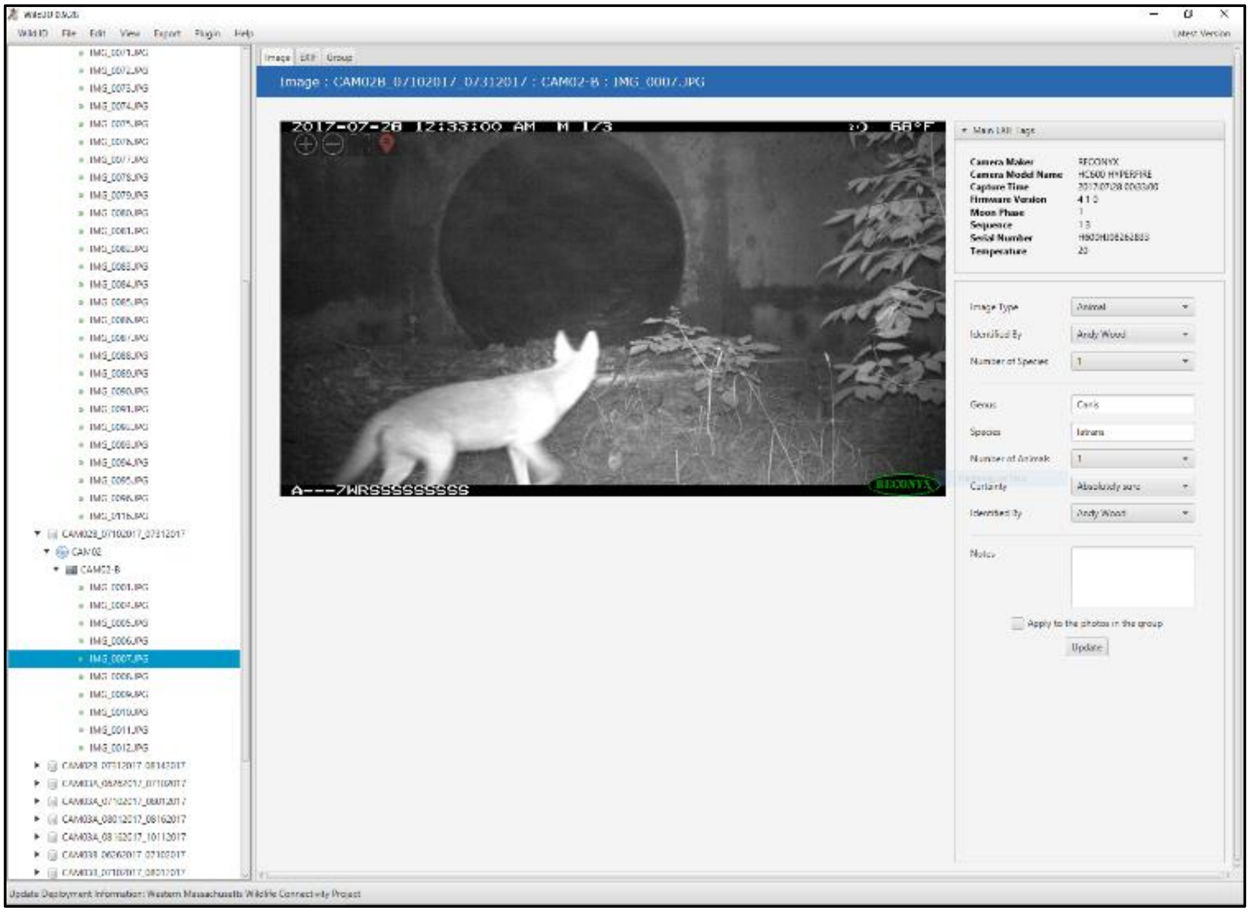


***Figure 71**. Wild.ID tagging interface. Users import project metadata and files into Wild.ID, then tag photos by species.*

Photo Type	Photo Date	Photo time	Raw Name	Class	Order	Family	Genus	Species	Number of Animals	Person Identifying the Photo	Camera Serial Number
Setup/Pickup	2017-07-27	10:49:25	IMG_0021.JPG								R4
Blank	2017-07-27	10:49:29	IMG_0024.JPG								R4
Blank	2017-07-27	10:49:27	IMG_0022.JPG								R4
Blank	2017-07-27	10:49:28	IMG_0023.JPG								R4
Blank	2017-08-01	18:46:12	IMG_0025.JPG								R4
Blank	2017-08-01	18:46:14	IMG_0027.JPG								R4
Blank	2017-08-01	18:46:13	IMG_0026.JPG								R4
	2017-08-10	01:09:26	IMG_0028.JPG								R4
	2017-08-10	01:09:27	IMG_0029.JPG								R4
	2017-08-10	01:09:28	IMG_0030.JPG								R4
Blank	2017-08-11	05:21:52	IMG_0031.JPG								R4
Blank	2017-08-11	05:21:54	IMG_0033.JPG								R4
Blank	2017-08-11	05:21:53	IMG_0032.JPG								R4
Setup/Pickup	2017-08-15	12:52:29	IMG_0035.JPG								R4
Animal	2017-08-17	05:28:31	IMG_0001.JPG	MAMMALIA	CARNIVORA	MUSTELIDAE	Martes	pennanti	1	Andy Wood	R4
Blank	2017-08-17	05:28:32	IMG_0002.JPG								R4
Blank	2017-08-17	05:28:33	IMG_0003.JPG								R4
Blank	2017-08-30	10:25:26	IMG_0004.JPG								R4
Blank	2017-08-30	10:25:27	IMG_0005.JPG								R4
Blank	2017-08-30	10:25:28	IMG_0006.JPG								R4
Animal	2017-09-04	09:20:35	IMG_0007.JPG	MAMMALIA	RODENTIA	SCIURIDAE	Sciurus	carolinensis	1	Andy Wood	R4
Animal	2017-09-04	09:20:36	IMG_0008.JPG	MAMMALIA	RODENTIA	SCIURIDAE	Sciurus	carolinensis	1	Andy Wood	R4
Blank	2017-09-04	09:20:37	IMG_0009.JPG								R4
Animal	2017-09-08	15:53:10	IMG_0010.JPG	MAMMALIA	RODENTIA	SCIURIDAE	Sciurus	carolinensis	1	Andy Wood	R4
Animal	2017-09-08	15:53:12	IMG_0011.JPG	MAMMALIA	RODENTIA	SCIURIDAE	Sciurus	carolinensis	1	Andy Wood	R4
Animal	2017-09-08	15:53:13	IMG_0012.JPG	MAMMALIA	RODENTIA	SCIURIDAE	Sciurus	carolinensis	1	Andy Wood	R4
Animal	2017-09-08	16:02:12	IMG_0013.JPG	MAMMALIA	RODENTIA	SCIURIDAE	Sciurus	carolinensis	1	Andy Wood	R4

***Figure 72**. Excel spreadsheet created from Wild.ID export. Wild.ID merges the project metadata with the individual species record created by tagging.*

Analyzing Data

Using Microsoft Excel *Pivotchart* functions is an easy way to summarize camera trap data **(Fig. 73).** More advanced analyses may require other software, but this approach is adequate for basic, preliminary data exploration.

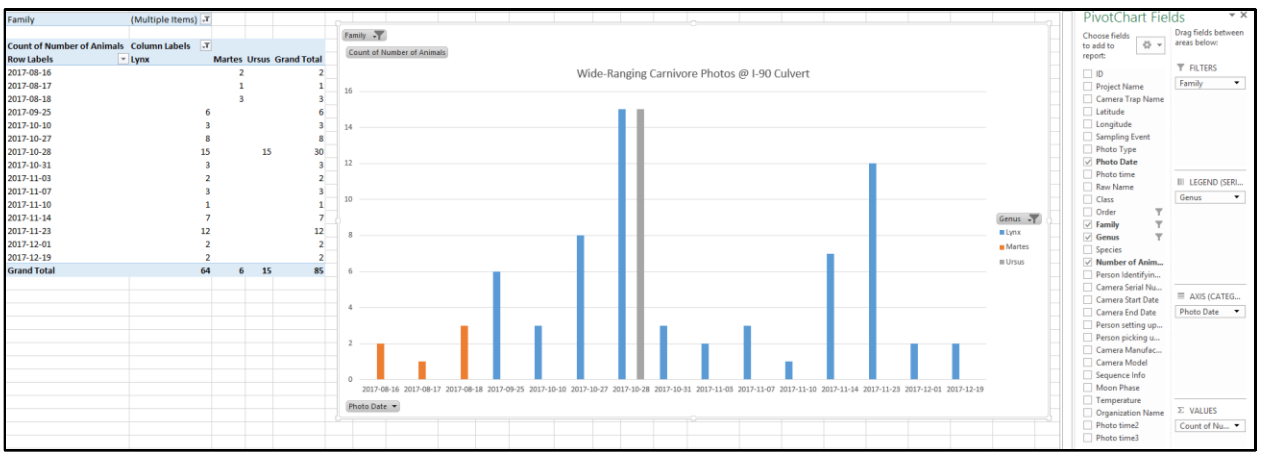


***Figure 73**. Pivotchart tools in Excel allow users to drag and drop different variables into charts and tables. This approach saves considerable time sorting through the massive spreadsheets generated by camera trapping projects.*

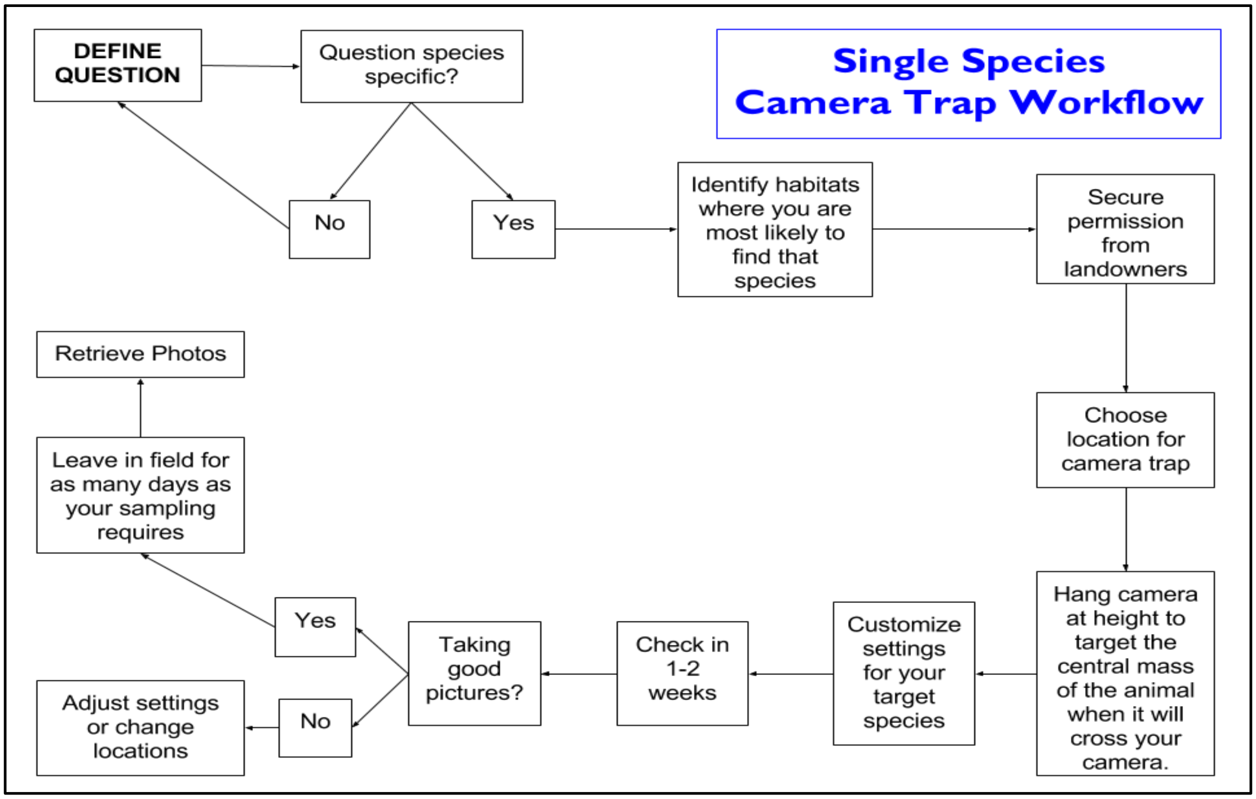


Figure 74. *Sample workflow for a single-species camera trap study.*

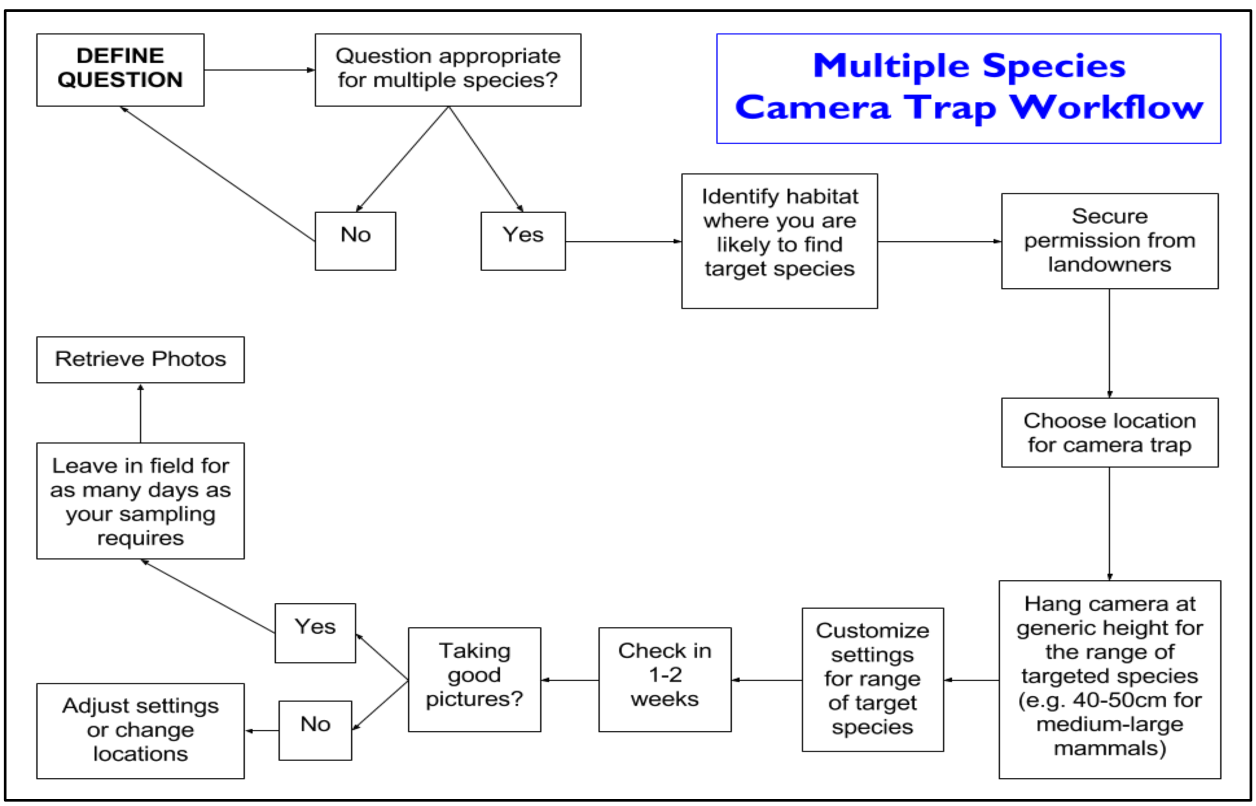


Figure 75. *Sample workflow for a multiple-species camera trap study.*

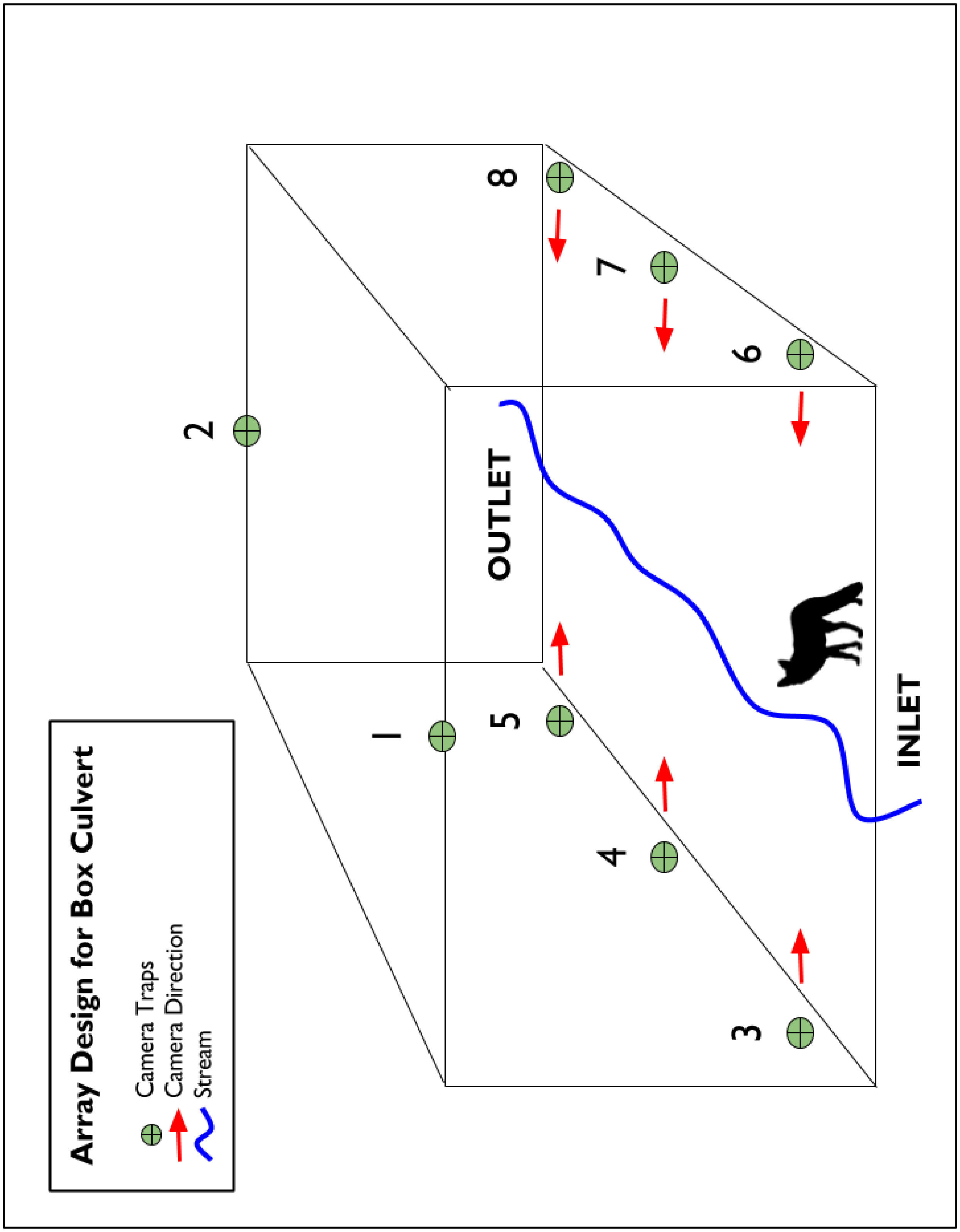


Figure 76. *Example camera trap array design for monitoring wildlife passage through a box culvert. Cameras #1 and 2# monitor approaches to and exits from the culvert inlet and outlet, respectively. Cameras #3-5 are paired with cameras #6-8 to monitor the culvert interior.*

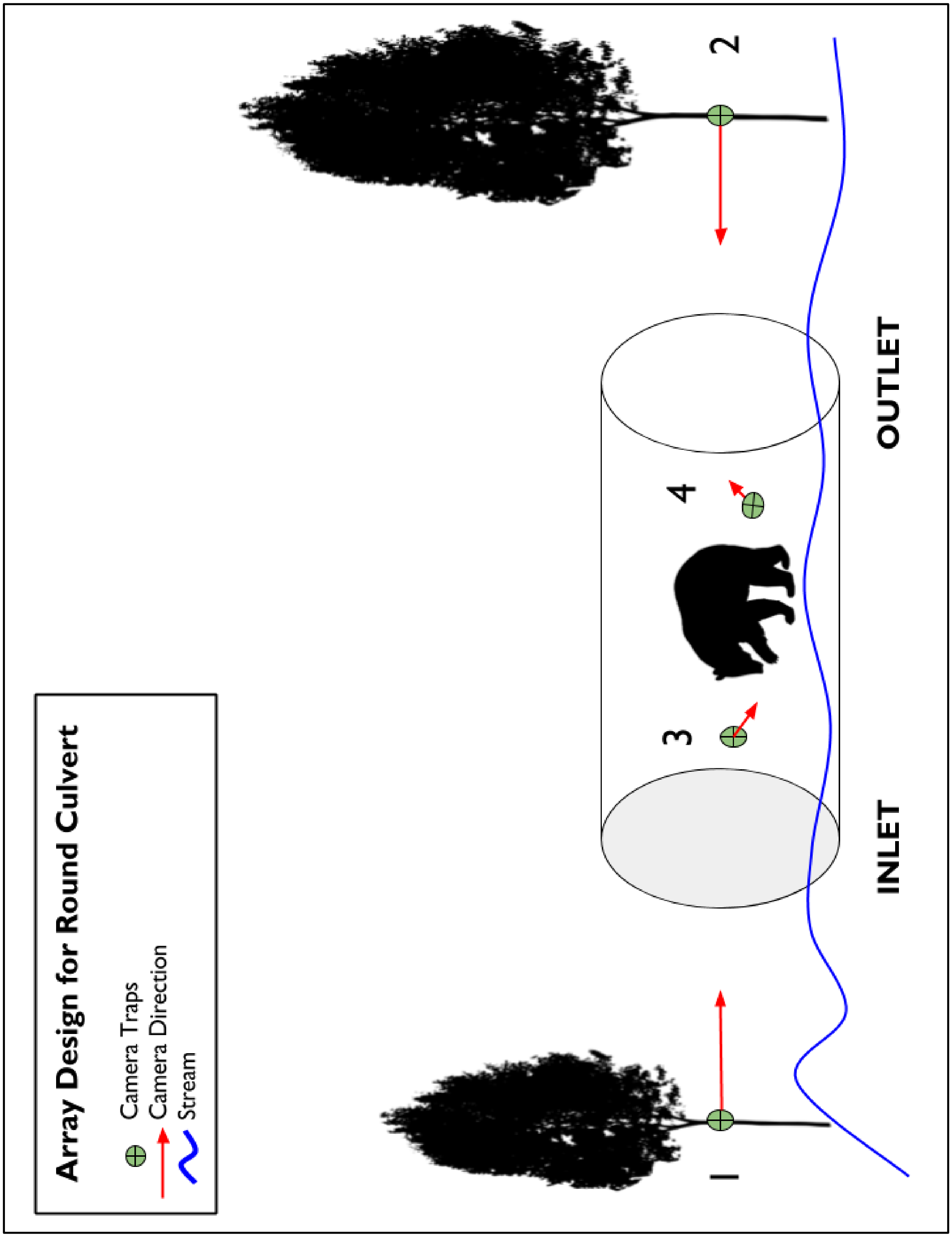


Figure 77. *Example camera trap array design for monitoring wildlife use through a round culvert. Cameras #1 and #2 monitor the inlet and outlet, respectively. Cameras #3 and #4 are mounted inside on opposing walls to monitor the culvert interior.*

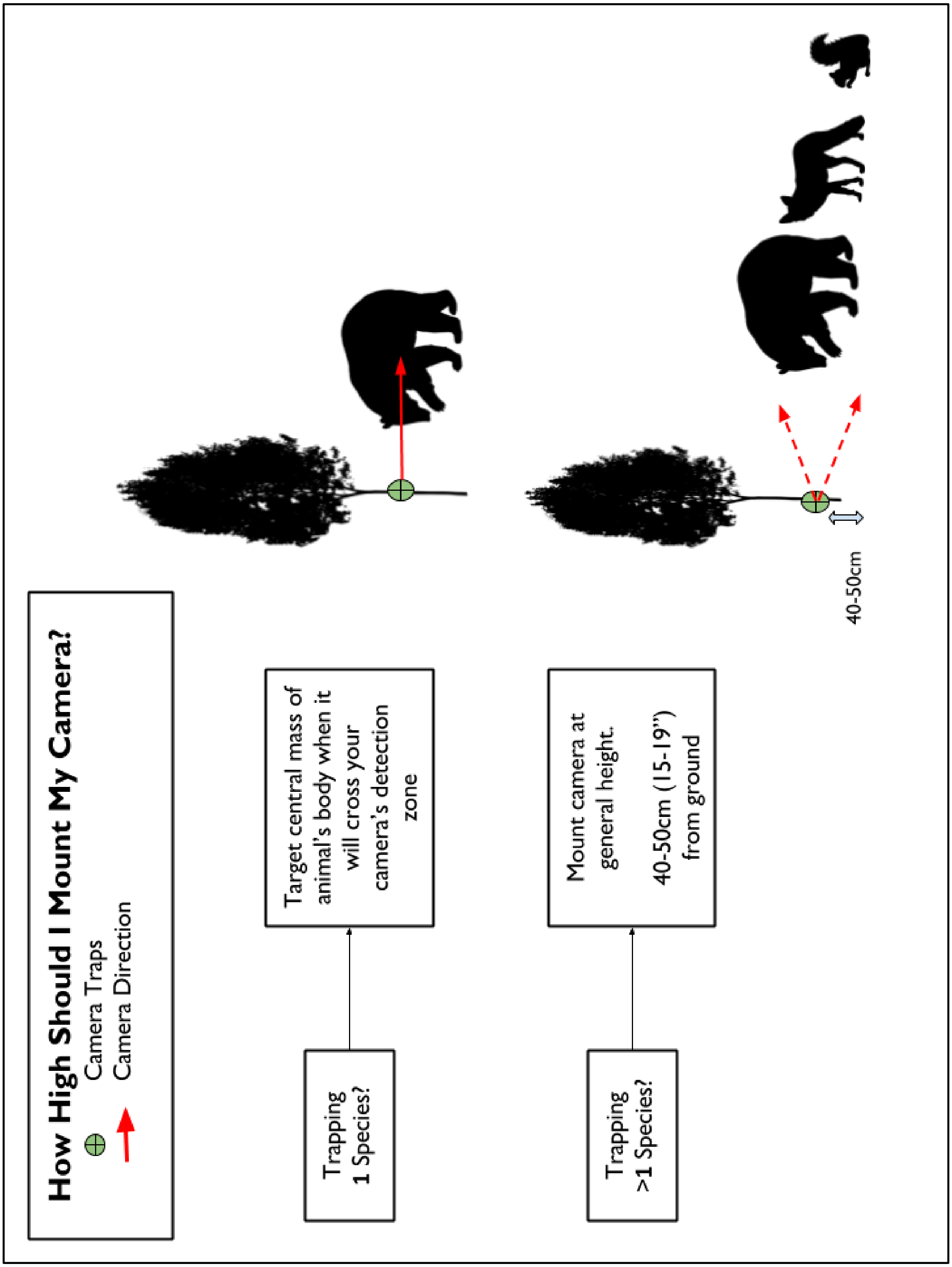


Figure 78. Tips for mounting cameras at an appropriate height.

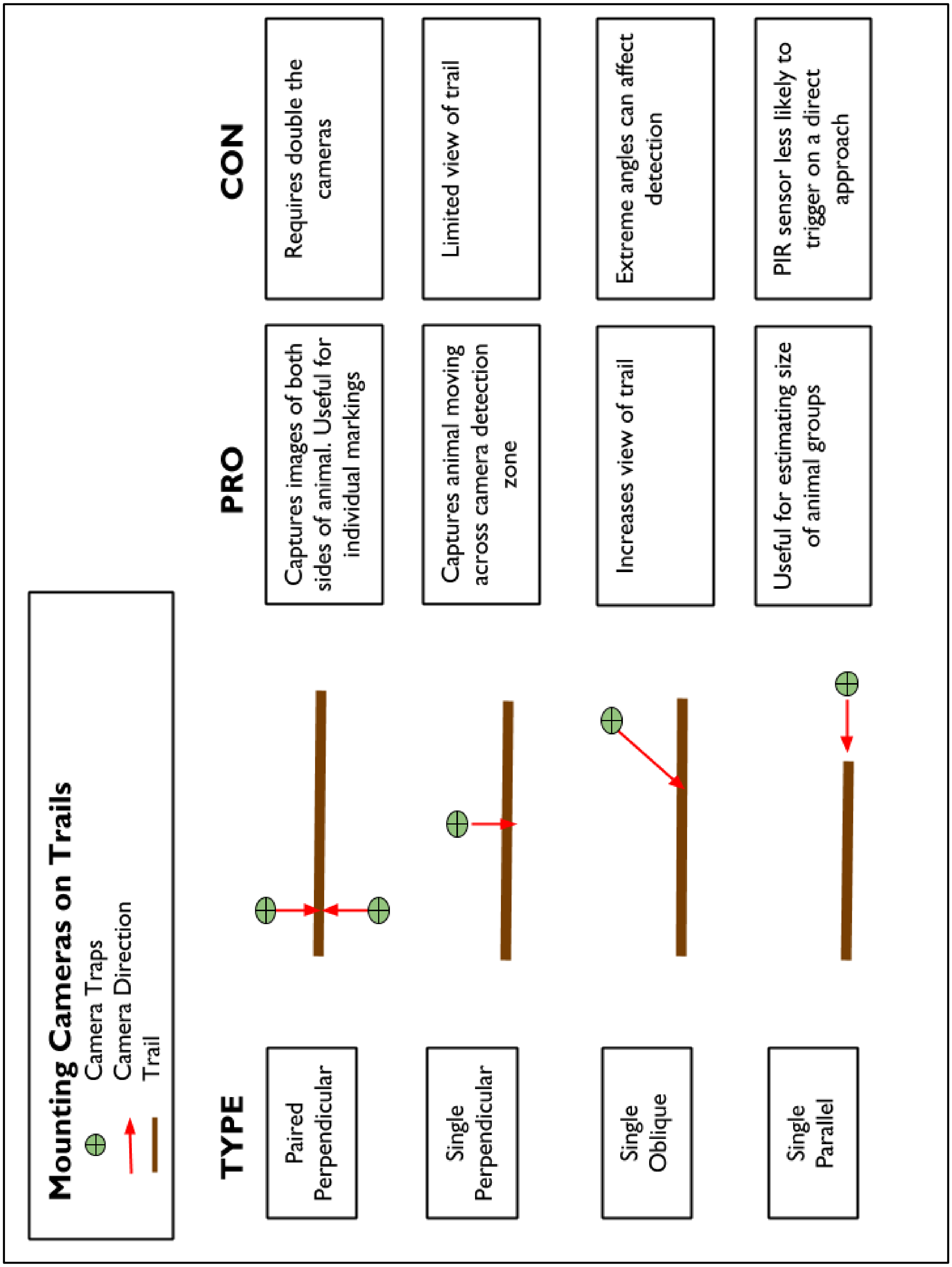


Figure 79*. Example designs for setting cameras along trails and other linear features.*

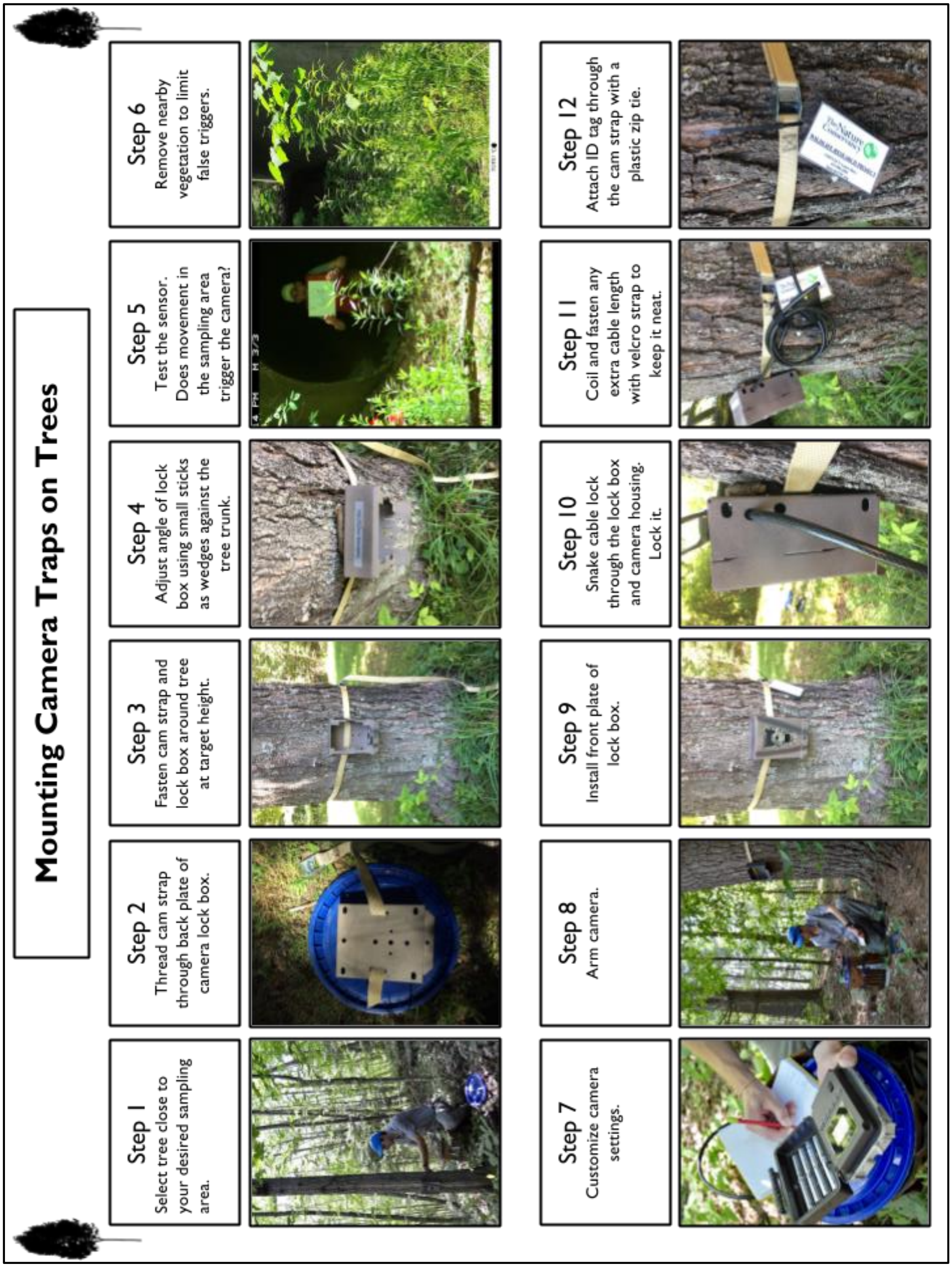


Figure 80. *Step-by-step guide to mounting cameras securely on trees.*

SITE DATA	SITE SETUP
Site: Location Description: GPS Coordinates: Structure: □Y □N Type: Height: Width: Length: Water in Structure? □Y □N Depth: Canopy Cover: Layout Description:	Camera #: SD Card #: Hang Type: Angle From Vertical: Height from Ground: Battery Status: Detection Zone Tested? □Y □N Camera Armed? □Y □N Camera Locked? □Y □N Photo of Setup? □Y □N Malfunction/Damage: GPS Unit & Waypoint #: Code Lock #: Notes:

SITE VISIT

Location:____________________________	Detection Zone Tested? □Y □N
Last Visit:___________________________	Camera Armed? □Y □N
Camera:______________________________	Camera Locked? □Y □N
# Pictures: ___________________________	Malfunction/Damage: __________________
Battery Status:________________________	Temperature:__________________________
SD Card # Out:________________________	Weather:______________________________
SD Card # In:_________________________	Notes:_______________________________

Figure 81. *Sample field data sheets for camera trapping setup and site visits.*

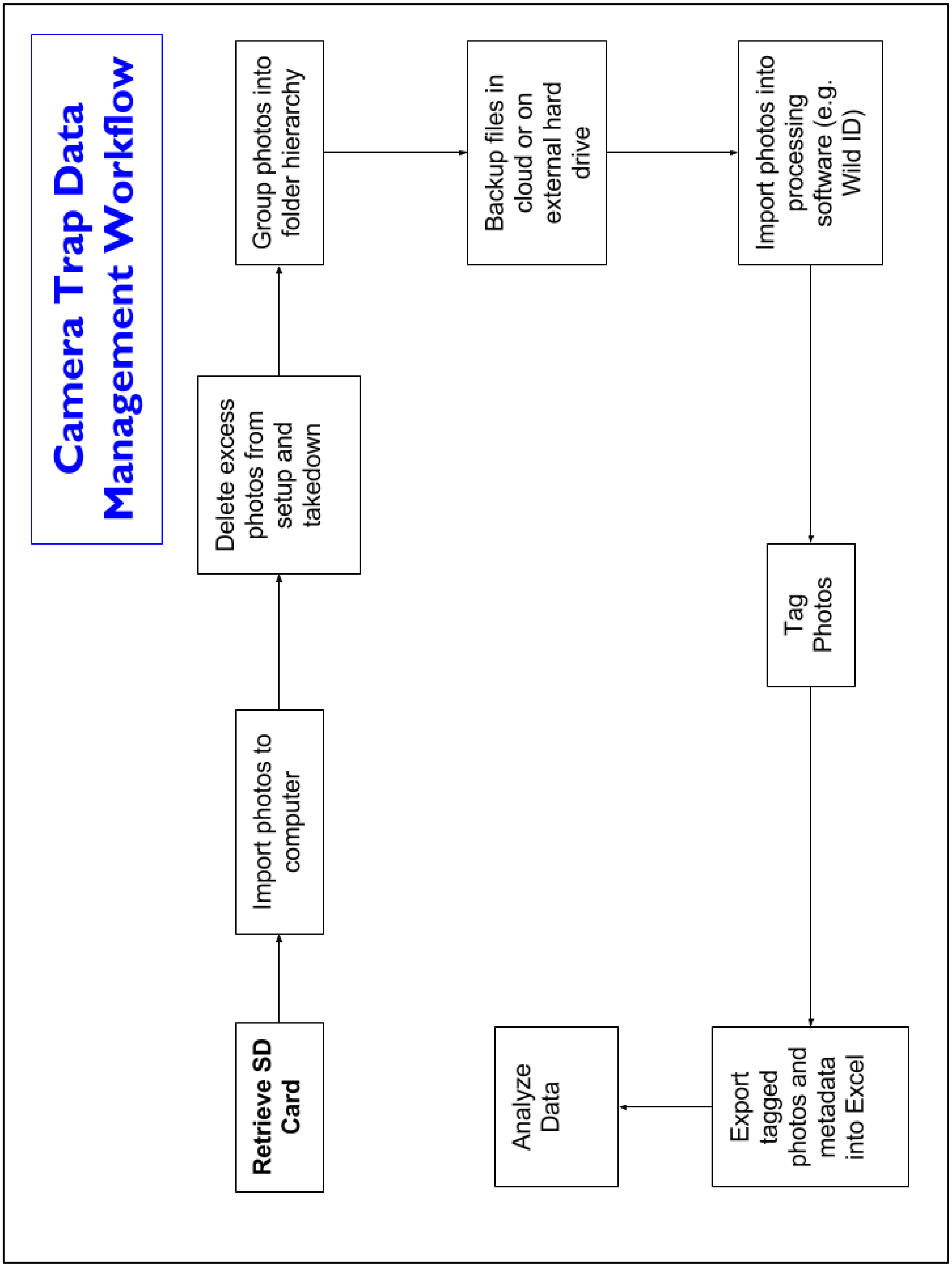


Figure 82. *Sample workflow for camera trap data management.*

USEFUL GUIDES FOR CAMERA TRAPPING & WILDLIFE RESEARCH

Camera Trapping for Conservation: A Guide to Best-Practices**.** Oliver R. Wearn & Paul Glover-Kapfer. 2017. World Wildlife Foundation. WWF Conservation Technology Series 1(1). WWF-UK, Woking, United Kingdom.

Camera Trapping for Wildlife Research. Editors: Francesco Rovero & Fridolin Zimmermann. 2016. Data in the Wild. Pelagic Publishing. Exeter, United Kingdom.

Wildlife Cameras in the Northern Appalachians: Uses and Lessons Learned. 2017. Staying Connected Initiative. White Paper Summary from 2016 Northeastern Transportation and Wildlife Conference.

Terrestrial Vertebrate (Camera Trap) Monitoring Protocol Implementation Manual. V.3.1. Tropical Ecology Assessment and Monitoring Network (TEAM). 2011. Center for Applied Biodiversity Science, Conservation International. Arlington, VA.

Camera Traps in Animal Ecology: Methods and Analyses. Editors: Allan F. O'Connel, James D. Nichols, and K. Ullas Karanth. Springer. New York, New York.

Non-Invasive Survey Methods for Carnivores. 2008. Editors: Robert A. Long, Paula MacKay, William J. Zielinski, and Justina C. Ray. Island Press, Washington, D.C.

Designing Field Studies for Biodiversity Conservation. 2001. Peter Feinsinger. The Nature Conservancy. Island Press, Washington, D.C.

APPENDIX D
Landowner Relations Resources

Landowner Relations Resources

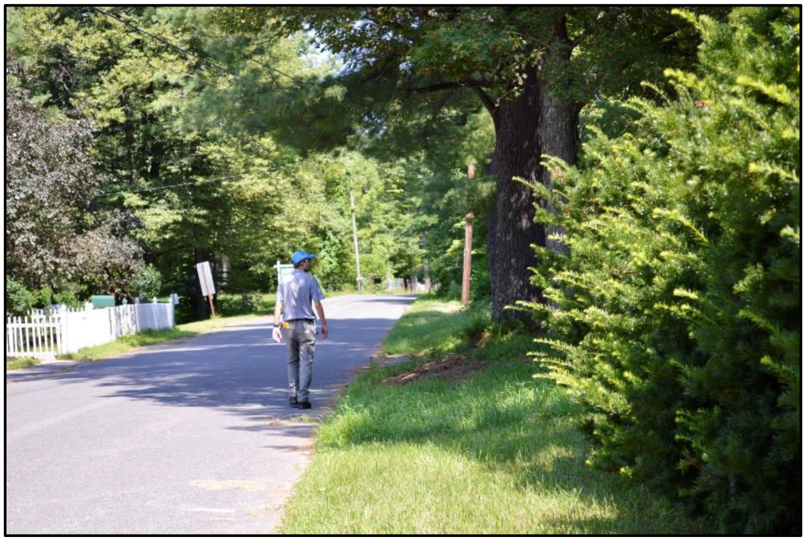


Figure 83. *Visiting landowners in southwestern Massachusetts.*

Introduction

Working with private landowners is essential for wildlife research and conservation, especially since the majority of Massachusetts land is privately owned. Securing access to private lands can dramatically increase the available land for research. Additionally, interactions with landowners can yield valuable local knowledge about wildlife activity. Interviews with local residents can be combined with other research methods to catch information that may be missed (Riggio & Caro 2017). In this guide, we outline our general approach to working with landowners used during the 2017 field season.

Stage 1 – Securing Permission

Most roads are buffered from adjacent parcels by a right-of-way (ROW) corridor. Assuming you obtain the appropriate permits from transportation agencies, many aspects of wildlife-transportation research can occur within the right-of-way. However, any work involving adjacent habitats will require obtaining landowner permissions. In cases where public land abuts the ROW, land managers may require formal research permits Permissions from private landowners are typically less formal, and sometimes faster to obtain. Whatever the land ownership structure, it is essential to obtain permission to access land and respect the terms given in the permission.

We requested access from each landowner along two segments of Route 8 in the Massachusetts towns of Otis and Sandisfield. Print mailings were sent to forty landowners in May 2017. Throughout the summer, we also encountered several landowners in person during field work. In cases where the landowner seemed interested in our work and receptive to our presence, we verbally requested access to their land. In other cases, we requested access to cross their land to reach neighboring parcels. During our work on Route 2 and Interstate 90, we similarly encountered landowners and verbally requested access.

In total, we received permission to access private land from six landowners along Route 8; three along Route 2; and three near Interstate 90. Our response rate from the Route 8 mailings was 15%. Several factors may have contributed to this low rate of response. First, many residences along Route 8 are not occupied year round, and may not have received our mailing. Second, because we had sufficient land available for research, we did not proactively follow up with most landowners who received our initial mailing.

When we spoke with collaborators about our low rate of return, we found that other groups with higher rates of return had focused more on getting landowners to participate in research, whereas ours focused only on granting our team access to the land. We include our letter (**Fig. 85**) as well as letter used in the Tug Hill region of New York (**Fig. 86)** with the hope that other groups can develop more effective outreach materials to send to private landowners.

Stage 2 – Building Relationships

Receiving access to work on private land is only a piece of the long-term relationship between landowners and your organization. While your research project may have an expiration date, the relationship between your organization and the landowner should not. Keep in mind that even a minor conversation about your project may influence a landowners' impression of an entire organization. Researchers should be cognizant that expertise in the subject matter may be less important than the ability to gracefully interact with landowners.

Local perceptions of conservation organizations and government agencies can influence interactions wildlife researchers have with landowners. We found that most landowners were very willing to discuss local wildlife, although we avoided topics related to land conservation and politics. Along Route 8, controversy over a pipeline project influenced some of our interactions with landowners. Project managers should prepare field staff with talking points prior to field work, but also encourage staff to develop authentic relationships with landowners and other people they meet on the job.

Here are several tips we recommend for building positive, long-lasting relationships with landowners:

Meet people
Take the time to have conversations with the people you meet, even if you are on a tight schedule.

Respect landowner privacy
Some people simply do not want you on their land. Don't take it personally—it may have nothing to do with your work. Be respectful of landowner privacy while working on private lands, especially around residences.

Recognize landowner expertise
Assume that landowners know more about their land than anyone else.

Use landowner time efficiently
Keep your interactions brief, unless invited to talk more.

Prioritize relationships over data
The long-term relationship is more important than your data. Do not jeopardize the relationship for a short-term gain on any project.

Stage 3 – Sharing results with landowners

Once you finish the project, make sure to share your findings with landowners—a simple act of reciprocity. A small token of appreciation, such as a thank-you card, or a printed photo from a camera trap, can go a long way. Many landowners will be curious to hear about your project results, and may share your work with other people in their community.

Stage 4 – Preserving relationships and local knowledge

Since the goal is to build a strong relationship, make sure your local connections are documented for the future. Documenting landowner interactions can keep all staff abreast of potential issues, and help preserve relationships that individuals build. Preserving this institutional knowledge is essential for long-term success in wildlife research and conservation. When possible, longer-term staff should introduce newer field staff to landowners.

We tracked all staff and volunteer landowner interactions using *Trello* project management software (https://trello.com), which allowed multiple users to log interactions and stay abreast of other staff interactions (**Fig. 84**).

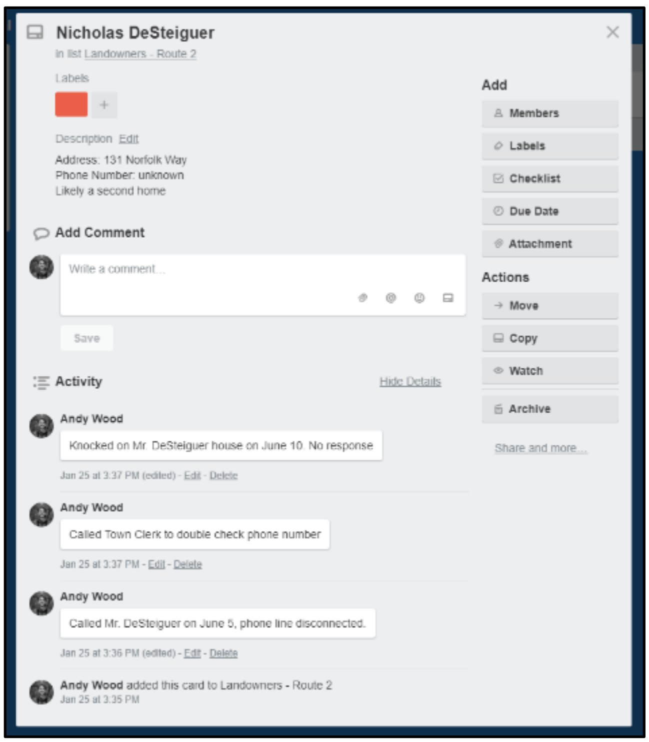


Figure 84*. Trello interface with a fictional landowner. Each comment is time-stamped, allowing multiple users to track the status of landowner relations in real time.*

USEFUL GUIDE FOR LANDOWNER RELATIONS

The Land Trust Standards and Practices Guidebook: An Operating Manual for Land Trusts. Vol 2. Bates, S.K. and T. Van Ryn (Eds). 2006. Land Trust Alliance. Washington, DC.

The Nature Conservancy
Protecting nature. Preserving life.™

The Nature Conservancy in Massachusetts
136 West Street, Suite 5
Northampton, MA 01060

tel (413) 584-2596

nature.org/massachusetts

May 23, 2017

Dear

I am writing to you and your neighbors to introduce myself and the Nature Conservancy's work on wildlife corridors in Western Massachusetts. The Nature Conservancy is a private, non-profit conservation organization that has been working for over 60 years to protect the lands and waters on which all life depends. We have protected 119 million acres of land and thousands of miles of river around the globe in 35 countries. We work in all 50 states, and operate three offices in Massachusetts. One of our projects is to identify and maintain wildlife corridors throughout Massachusetts that link the forests of Northern New England with the forests of the Central and Southern Appalachians. Maintaining these connections through the state will allow animals to travel safely between habitats. Your land is part of this interconnected landscape, and may provide important habitat for a variety of animals.

During 2017-2018, we will conduct wildlife surveys along Route 8 near Sandisfield and Otis. Our team of graduate students and volunteers will monitor roadsides for roadkill, evaluate culverts and bridges, and deploy wildlife cameras to determine how roads and other obstacles impact animal movement. To collect enough quality data, we need access to both public and private lands. **Will you grant permission for our team to access your land for wildlife research?**

Our activities may include:

- Documenting relevant plants and land features alongside roads (stone walls, streams, *etc.*)
- Setting up motion-detecting cameras along roads or wildlife trails (deer paths, *etc.*)

In the event that our cameras capture photographs of people, we will immediately delete those photos. Our interest relates primarily to wildlife, and respecting your privacy is one of our highest priorities.

All Conservancy staff are covered by our liability insurance, and all volunteers and contractors fill out a liability release form. Andy Wood, our graduate student coordinating this research, will be the primary person accessing private lands along Route 8.

The Nature Conservancy *always* obtains landowner permission before accessing private property, so we cannot and will not cross your land until we hear back from you. **If you are willing to grant permission for Conservancy staff/contractors/volunteers to access your land, please return the attached form.**

Thank you for your consideration of my request for access to your land. If you need more information to make your decision, please contact me by email/phone (below) or at the mailing address above.

Sincerely,

Laura Marx

Laura Marx, Forest Ecologist ● lmarx@tnc.org ● 413-584-2596

Figure 85. *Page 1 of a letter mailed to landowners requesting access for research. This letter received a relatively low response rate.*

I, ____, grant permission for Nature Conservancy staff/contractors/volunteers to access my land to conduct wildlife surveys and collect wildlife camera images. This permission expires on June 1, 2018.

The address of my land is: ____.

___________________________________ Signature

___________________________ Date

☐ Please call me to discuss, at the following number _____________________________.

Please return this form in the enclosed envelope to The Nature Conservancy, 136 West Street, Suite 5, Northampton, MA 01060.

Figure 86. *Permission form for private land access accompanying the letter on the previous page.*

TUG HILL TOMORROW LAND TRUST

The Nature Conservancy Adirondacks

WILDLIFE CONSERVATION SOCIETY

7/13/15

Dear xxxx,

Have you seen bobcat, moose, bear, fisher, marten or otter in your neighborhood? Would you like to use a wildlife camera to see for yourself what animals are in your own backyard, while contributing to an important study? If so, we would love to hear from you!

We are launching a new wildlife monitoring project led by the Tug Hill Tomorrow Land Trust, the Adirondack Chapter of The Nature Conservancy, the Wildlife Conservation Society, and the NYS Tug Hill Commission. Our team has been working together in the Black River Valley, between the Adirondacks and Tug Hill, since 2006. This work is part of a regional effort to facilitate the movement of wide-ranging mammals between large blocks of protected forests across the Great Northern Forest (for more information, please visit www.stayingconnectedinitiative.org).

With grant funding through New York State Department of Environmental Conservation and the Land Trust Alliance's Conservation Partnership Program, we will be working with landowners in the Black River Valley to explore these key questions:

- What types of wildlife are moving through the valley and where?
- What opportunities exist for landowners to enhance habitat for different species of wildlife?

We have 25-30 wildlife cameras to distribute throughout the valley, and are looking for

Figure 87*. Page 1 of a letter mailed to landowners in New York requesting access for research. This letter received a relatively high response rate. Note the engaging visuals.*

landowners who are interested in helping us collect some fun and valuable wildlife images. Property access and camera placement will of course be at each landowner's discretion. It is very important to us that these surveys are conducted with utmost respect for private landowners. Cameras will be pointed away from homes and staff will closely adhere to any access instructions provided by the landowner. We will not reveal your name or the location of your property in association with our findings. We invite you to participate in this collaborative project at whatever level is of interest to you, whether it's joining us in the field, helping to sort through pictures or simply allowing access.

No technical expertise is required, just an interest in wildlife and willingness to help.
If you are interested in participating in this study, or would like to learn more about our work, we encourage you to join your neighbors for an informational session on *September x*. The Black River Outdoor Education Program has kindly offered their Black River Forest Campus as a meeting space, located at- *address.* RSVP for the meeting by *x date* via email or telephone to the contact below.

Linda Garrett
Tug Hill Tomorrow Land Trust
Email: thtomorr@northnet.org
Phone: (315) 779-8240

We appreciate your consideration, and we hope to hear from you soon.

Sincerely,

Figure 88. *Page 2 of a letter mailed to landowners in New York.*

APPENDIX E
Data Transfer Summary

Data Transfer Summary

Accompanying data from this project were transferred to the Massachusetts Chapter of the Nature Conservancy via a shared TNC Box account.

File or Folder Name	File Type	Contents	Destination in TNC Box Account
BerkshireWildlifeLinkage_March2018	ESRI *.gdb*	Camera Trapping Metadata; Road Segments Surveyed; Roadkill Data; Camera Trapping Data	*Deliverables* Folder
LandownersContacted_2017	Microsoft Excel *.xlsx*	Records of landowners contacted by mail in May 2017	*Deliverables* Folder
Marketing Photos	Folders with *.jpeg* files	Charismatic photos of wildlife; photos of field staff; photos of field sites	*Marketing Photos* Folder
Background Project Information	Folder with assorted file types	Reports and files providing project context	*Project Context* Folder
Camera Trap Photographs	Folders with *.jpeg* files	Photos from 2017 camera traps. *Note: grouped by folder and not processed*	*Camera Trapping* Folder
Roadkill Photographs	Folders with *.jpeg* files	Photos of 2017 roadkill	*Roadkill* Folder
NAACC Terrestrial Passage	Folders with assorted file types	Records of 2017 NAACC crossings	*NAACC Aquatic Passage* Folder
NAACC Aquatic Passage	Folders with assorted file types	Records of 2017 crossings	*NAACC Terrestrial Passage* Folder