New Hampshire DOT

Research

Wildlife Vehicle Collisions Data Gathering and Best Management Practices

Final Report

Prepared by Plymouth State University, Center for the Environment, for the
New Hampshire Department of Transportation, in cooperation with the
U.S. Department of Transportation, Federal Highway Administration

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16. Abstract

Currently the scope or cost of wildlife vehicle collisions (WVCs) in New Hampshire is not understood. Citizens die every year in New Hampshire in collisions with wildlife. There is also a cost in terms of emergency response and property damage from the collisions. Records of collisions with wildlife are not held in one easy to access central location. A better understanding of where these collisions are happening and how often could allow future projects to incorporate more wildlife crossing structures during project development and design to reduce wildlife vehicle conflict.

The research included a review and analysis of available sources of information about WVCs in NH from the NH Department of Safety data that is shared with the NHDOT Highway Design Bureau, the roadkill and accident data collected by the various NHDOT Districts, and the NH Department of Fish and Game roadkill data. The results supported the project deliverables that include a mapping interface that identifies hot spots of WVCs, a review of mitigation measures, and a summary of best management practices found to effectively reduce WVCs in the Northeast. Communication materials were developed to highlight the importance of WVC data collection, analysis, and mitigation.

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Wildlife Vehicle Collisions Data Gathering and Best Management Practices

Amy M. Villamagna, Ph.D.

Eric Laflamme, Ph.D.

Hyun Joong Kim, Ph.D.

Plymouth State University
Department of Environmental Science and Policy Center for the Environment
17 High Street, MSC #48
Plymouth, New Hampshire 03264

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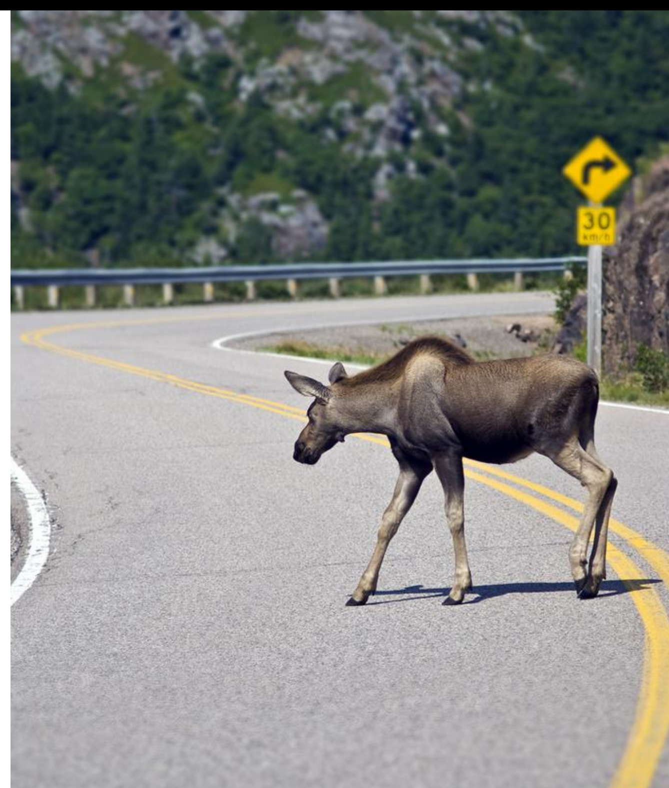

Final report to
New Hampshire Department of Transportation in fulfillment of project SPR 42372I
19 May 2021 – 30 September 2023

Amy M. Villamagna, Ph.D.
Eric Laflamme, Ph.D.
Hyun Joong Kim, Ph.D.
Plymouth State University
3/18/2024

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PROBLEM STATEMENT

The Research Suggestion Form that sparked this project described the problem as follows. "Currently we do not understand the scope or the cost of wildlife vehicle collisions (WVCs) in New Hampshire. The records of collisions with wildlife are not held in one easy to access central location. Additionally, the Safety Section in the Highway Design Bureau does not have the person power or funding to address this issue. Citizens die every year in New Hampshire in collisions with wildlife. There is also a cost in terms of emergency response and property damage from collisions. An idea that wildlife vehicle collisions are unavoidable has been commented on by NHDOT staff; however, other New England states do find efforts to incorporate more wildlife crossing structures during project development and to improve driver education are worthwhile. Review of the Huijser et al. paper 'Cost–Benefit Analyses of Mitigation Measures Aimed at Reducing Collisions with Large Ungulates in the United States and Canada: a Decision Support Tool' indicates that the breakeven point of installing effective mitigation measures for preventing deer collisions is 3.2 collisions per kilometer per year."

SUGGESTED RESEARCH

The same Research Suggestion Form stated that research should be funded to gain "a better understanding of where these collisions are happening and how often, could allow future projects to include wildlife passage in design to reduce wildlife vehicle conflict". The project proposes a review of the sources of information available about WVCs in NH including the Department of Safety data that is shared with the Highway Design Bureau, the roadkill and accident data collected by the various NHDOT Districts and the NH Fish and Game roadkill data. Data from the NHF&G wildlife sightings database might also be found to be pertinent. Based on this data, the project proposes a mapping interface that would identify hot spots of WVCs. Additionally, the project proposes a review of WVC mitigation measures and a summary of BMPs that have been found to effectively reduce WVCs in the Northeast. If specifics are available about these BMPs, such as detail sheets, they would be gathered as part of the project. Lastly, the project recommends the development of some type of educational material for NHDOT staff about the cost and prevention of WVCs. A GIS story map might be a good tool for this education.

ANTICIPATED PRODUCTS/OUTCOMES

- A database/map, such as ArcGIS, that portrays the WVC in NH and that can be easily maintained/updated.
- A list of recommended effective BMPs and details as available.
- An educational component (GIS story map, flyer, webpage or video) describing the costs of WVCs (generally) and benefits of mitigation.

EXPECTED BENEFITS

- Increased productivity and work efficiency
- Enhanced safety
- Reduced user cost

PROJECT PERIOD: 19 May 2021 - 30 September 2023* (extended from 12/31/2022)

PROJECT TEAM: Dr. Amy Villamagna (PI), Dr. Hyun Joong Kim, Dr. Eric Laflamme, and 2 undergraduate research assistants (O. Boyer & S. Debisschop), Plymouth State University

FUNDED PROJECT OBJECTIVES

1) Synthesize literature regarding wildlife-vehicle collisions (WVC) and the efficacy of mitigation strategies
2) Compile WVC, animal carcass, wildlife tracking, hunting tags in NH into database for cross-agency use
3) Map WVC and animal carcass data, develop "hotspot" maps
4) Analyze WVC and animal carcass to build predictive models to identify mitigation priorities
5) Develop communication materials to highlight the importance of data collection, analysis and mitigation

SCOPE OF WORK

In the subsections that follow, we describe the methods, results, and/or products associated with the project objectives. Links to web-based resources are provided where appropriate.

1) Synthesize literature regarding wildlife-vehicle collisions (WVC) and the efficacy of mitigation strategies.

Methods. We conducted an extensive literature search during the first two quarters of the project. The review focused largely on: data collection (by whom and how) and types (animal carcass, wildlife-vehicle collision [WVC], wildlife tracking; Data analysis (e.g., hotspot mapping, statistical predictive analysis); mitigation strategies to reduce WVC; efficacy of mitigation strategies. All references were organized in a Mendeley Online Reference Manager. We established a working group for collaboration and anyone with a Mendeley Online account (free) can request access (from A. Villamagna) to the online library. Many studies and reports were annotated in Mendeley to facilitate collaboration and sharing. Appendix A provides a list of all references included in the online library. Our review included Huijser et al. (2007), an extensive synthesis of animal-vehicle collision data collection in the US and Canada, Rytwinski et al. (2016) who furthered the research effort by evaluating the effectiveness of road mitigation efforts at reducing WVC, the Huijser et al. (2018) Wildlife-Vehicle Collision Reduction Study prepared for US Federal Highway Administration, and Steckler (2019) "Connect the Coast" report that provided an overview, reference to wildlife corridor models created by NH Dept of Fish and Game for the Seacoast region of NH, and described process for identifying priority road segments as those within prioritized habitat blocks and predicted wildlife corridors, as well as many other studies and reports. We also contacted representatives from state transportation and wildlife agencies in the northeast US, including NY, ME, MA, CT, and VT to assess commonly employed WVC strategies (Table 1). Information from this review was synthesized and an ArcGIS Online StoryMap developed largely as an "in-reach" tool to share information within DOT. The Wildlife -Vehicle Collisions Storymap was organized into four focal areas (tabs).

Wildlife Vehicular Collisions - a call for connection This section provides an overview of the problem - one to two million collisions occur between vehicles and wildlife every year in the US, costing more than US$ 8 billion annually (Huijser et al. 2018). Using estimates of the average cost of a deer collision range from US$ 2,451 (Huijser et al. 2018) and $ 4,418 (Huijser et al. 2022) and WVCs reported in NH between 2002-2019, the total cost of WVCs ranged between US$ 65 – 117 million.

NH WVCs Analysis and Maps This section provides map visualization of WVC data in NH as well as interpretive text to support the issue in NH.

WVC Reduction Strategies This section summarizes a variety of WVC reduction strategies, organized into the following four categories: motorist behavior, fencing and wildlife corridors, landscape modification, and animal behavior. We describe the strategy and evaluate its efficacy based on published studies. Dynamic (active or seasonal) signs in conjunction with a reduction in speed limit are more effective than permanent signage without speed reductions (Riginos et al. 2022) but assessing the overall effectiveness is challenging when the locations of signs are not accurately documented. In summary, motorist behavior alterations (such as signs) may only be effective when used for short periods of time and when dynamic or attention grabbing. Unfortunately, wildlife signs in NH are not cataloged in an asset manager, which makes it impossible to assess their efficacy or review for revision in this State. An opportunity exists to assess signs and redistribute as needed in seasonal hotspot areas.

Supporting Resources. This section provides a summary and direct access to the most helpful resources, including the 2018 Wildlife Vehicle Collision Reduction Study, the 2011 Wildlife Crossing Structure Design Handbook, and information for requesting Mendeley WVC library access.

Products.

- Mendley Online Reference Manager WVC Group Library
    - Resources are tagged for easy searching
    - PDFs and/or URLs included where possible
    - Free access with Mendeley Online account and request to amvillamagna@plymouth.edu

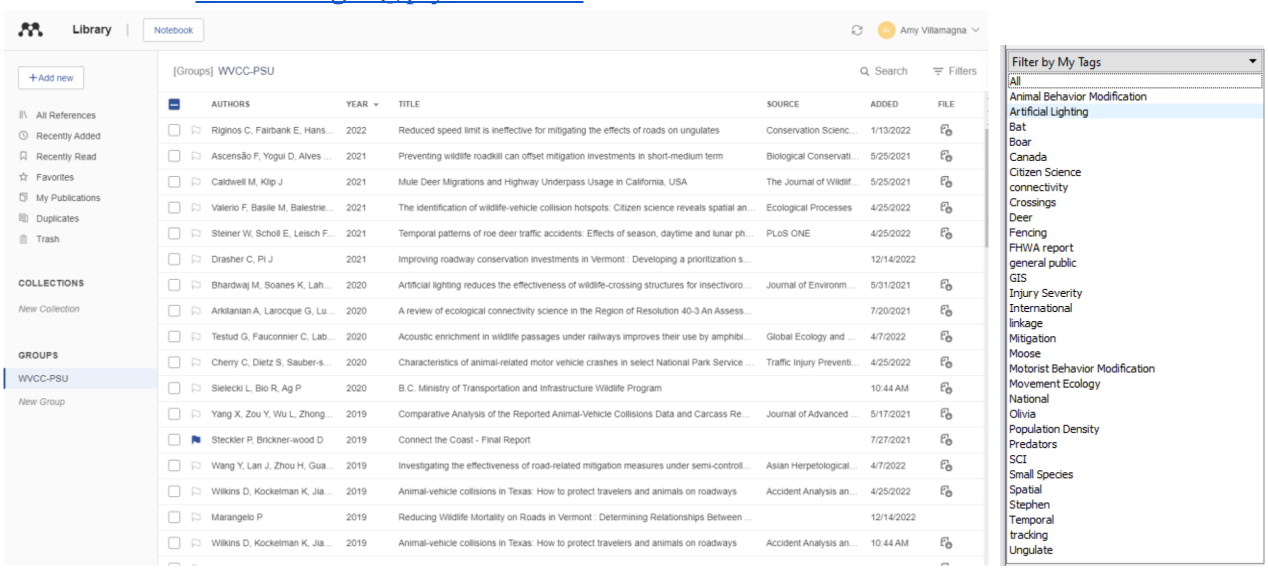


Figure 1: Mendeley Online Reference Manager WVC group with filter by tag option

- Wildlife Vehicle Collision - Literature Synthesis Outline
- Wildlife-Vehicle Collisions in New Hampshire StoryMap

Figure 2: Opening screen of the Wildlife-Vehicle Collisions in New Hampshire StoryMap, created in ArcGIS Online and hosted by Plymouth State University.

2) NH Data compilation. Maps alongside spatial analysis of WVC events and wildlife movement patterns provide powerful decision-support tools that can increase the cost-effectiveness of mitigation measures (Diaz-Varela et al. 2011). The first step toward such is compiling data that exists, identifying data gaps, attempting to fill those gaps in the short and long-term, and analyzing patterns. As noted in the Research Project Suggestion Form and reinforced by Huijser et al (2007), data relevant to the threat of WVCs is gathered and maintained by a variety of entities. In NH this includes NHDOT, NH Fish and Game, NH Dept of Safety. Additional data regarding wildlife crossings (that have not resulted in collisions) may be found in published and unpublished reports focusing on biological field research (e.g., wildlife tracking [WT]; Scarpitti et al. 2005), wildlife sightings, and game harvest registration and check station reports. Our intent was to develop a consolidated database that included data source, date of record, data type, location, and spatial resolution.

Methods.

Figure 3 below provides a visual representation of the workflow from data compilation, combination to spatial analysis and data integration, to statistical analysis, and finally with our main project products.

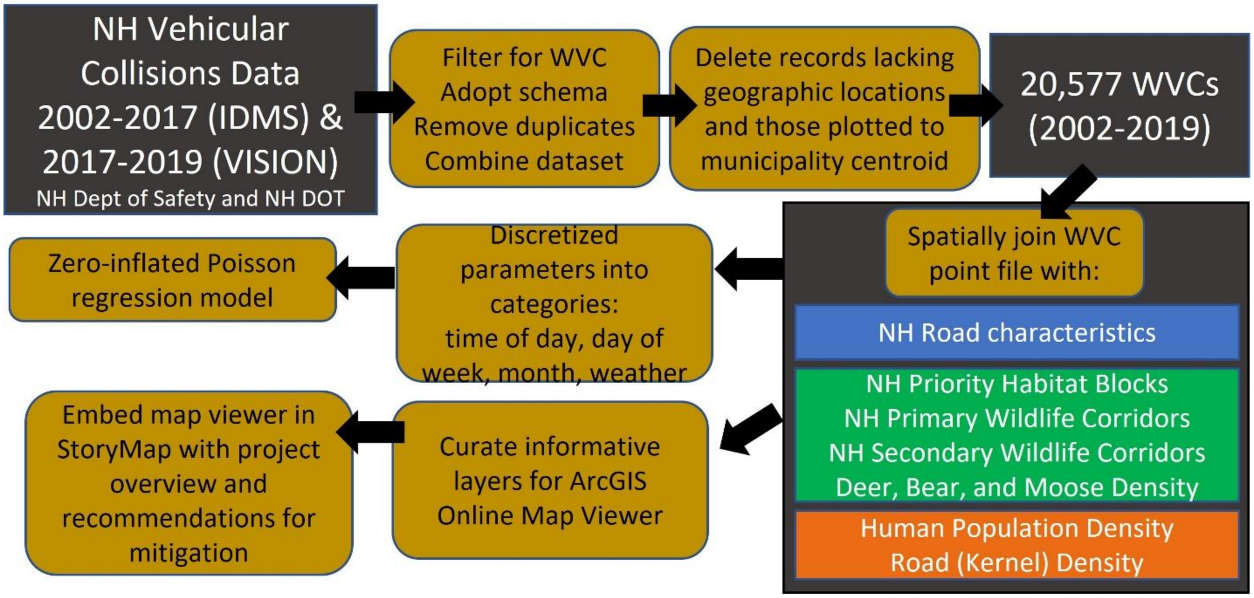


Figure 3: Visual overview of the project process.

Vehicle Collisions: Relevant collision data was requested from the NH Department of Safety. Two distinct vehicular collision datasets, 2002-2017 IDMS and 2017-2019 VISION, were available. However, variations in data formats for a given attribute were apparent between datasets. Challenges may arise during subsequent analysis due to differences in field names and data formats. The WVC point datasets exhibit problems with duplicate entries and instances where points recorded at municipality centroids rather than actual collision sites. Our methods to address these challenges are described in the WVC Mapping section below.

Roadkill Data: NH Dept Fish and Game maintains a wildlife sighting database in which "roadkill" is an attribute. Wildlife sighting records are voluntary. NH Dept of Fish and Game shared their reported roadkill data from 2006-2021 with this project. It included 519 records with spatial accuracy ranging from "within 10m" to greater than "1000m", with 390 records "within 100m". These records did not detail the species involved and only 23 records specified "mammal", which are largely responsible for wildlife-vehicle collisions that would be recorded by Dept of Safety. This dataset is considered a severe underestimate of roadkill and was not included in the statewide assessment of hotspots.

Wildlife Population Density: NH Dept of Fish and Game shared population density estimates for moose (6 regions; 2020-2021), bear (6 regions; 1998-2021), and deer (20 management units; 2020 pre-hunt). This data was included in the statistical analysis described in Objective 4, but its coarse spatial resolution did not lend well toward identifying problem areas. Moreover, studies have shown that population densities are not strongly correlated with WVCs, despite popular thought (Jones, 2022). Phase II of the project will incorporate emerging analytical results from camera trapping statewide (Moll per comm).

Wildlife Tracking: There were few published studies of animal movement in NH at the start of this project (Scarpitti et al. 2005), however more are forthcoming through the research lab of Dr. Rem Moll, University of New Hampshire. Phase 2 of this project integrates Moll's lab efforts into monitoring wildlife activity near WVC hotspots identified from the vehicle collision record.

WVC reduction strategies: At the start of this project, there were few examples of WVC reduction and wildlife connectivity projects in the state. We requested the locations of underpasses and wildlife warning signs. At the time of our request, there was no clear way to identify WVC reduction project locations within a NHDOT database. Likewise, the locations of signs were not attainable for spatial analysis. We recommend NHDOT assess the location of such signs and wildlife-motivated features in projects moving forward to evaluate success and adapt as needed.

Existing road crossing structures: Through our research and conversations with NHDOT and our project TAG, it became apparent that retrofitting existing road crossing structures held the most promise for statewide WVC reduction in the near future. To locate the existing crossings and access data about aquatic organism passage and crossing size, we downloaded the 2022 NH Stream-Road Crossing database, maintained by the New Hampshire Stream Crossing Initiative and included this data in our online mapper and our site prioritization process.

Wildlife Priority Habitats and Corridors: NH Dept of Fish and Game shared the results of the statewide priority habitat and predictive wildlife corridors analysis with us. We integrated the location of priority habitats and wildlife corridors into the WVC record by means of a Spatial Join. WVC locations within 400 feet of a priority habitat block, wildlife corridor, or secondary corridor were noted as such (binary: 1= within 400 feet; 0 = not within 400ft) within the amended attribute table of the master (2002-2019) WVC point layer. Between 2002 and 2019, 5801 WVCs of were recorded within 400 feet of a priority habitat block, Y within 400 feet of primary wildlife corridor, and 8226 within 400 feet of secondary wildlife corridor.

Products:

- Data described above was integrated into the statistical and spatial analyses described in Objective 4.
- Data were included as supportive layers in the NH Wildlife Vehicle Collision (online) mapper created in ArcGIS online and hosted by Plymouth State University.
- Data is included as supportive information toward WVC reduction and prioritization in the Wildlife-Vehicle Collisions in New Hampshire StoryMap.

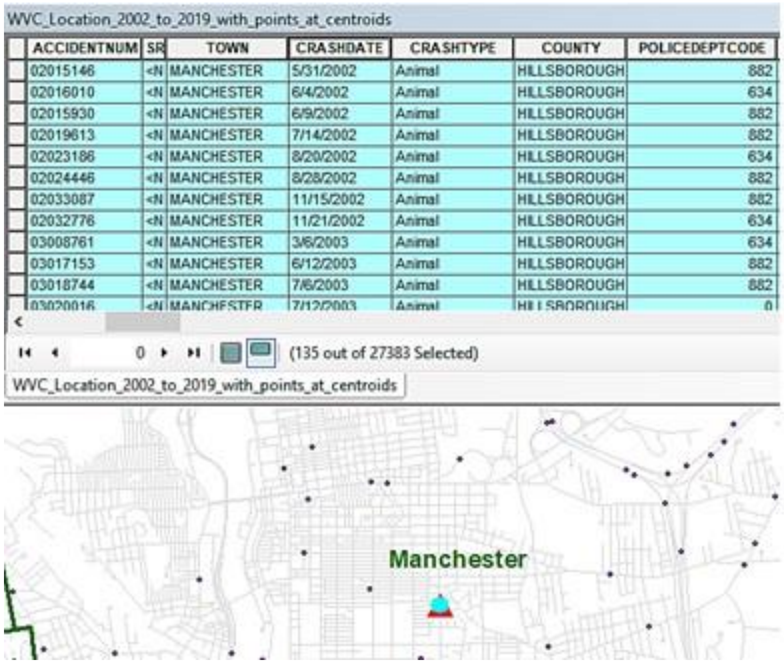
3) WVC Mapping. We intended to spatialize WVC data and developed an online ArcGIS Map application that would enable the user to quickly identify hotspots (i.e., areas of reoccurring WVCs) and to visualize how patterns of WVC change over space and time. The envisioned WVC web mapper was intended to be used by various agencies and organizations to view the data.

Methods.

Data consolidation: Our analysis began with consolidating two vehicular collision datasets (2002-2017 IDMS and 2017-2019 VISION) curated by the NH Department of Safety and shared with the NH Dept of Transportation. Following comprehensive data quality assessments, various concerns emerged, encompassing data overlaps, discrepancies in data point locations, dissimilar field names across databases, and different data formats between the IDMS and VISION databases. Therefore, we first developed a new schema for the wildlife-related vehicular collision data. This schema was designed to retain essential fields of information documented in both datasets. The process is outlined as follows.

First, we cleaned up data by identifying WVC records and eliminating duplicate records within WVC data. The state of NH transitioned its data recording in 2017 so once combined we needed to remove duplicates. Where duplicates existed (n= 444) we retained the VISION record and deleted the IDMS record. There were a few IDMS records (n=16) that were included in the 2017 IDMS but not VISION datasets. The combined collision dataset from 2002-2019 contained 605,390 records. We used the crash type field to exclude non-WVC records. Collisions recorded as Animal (other), Animal (Bear), Animal (Deer), Animal (Turkey), and Animal (Moose) were retained for subsequent analysis. Nearly all WVC were recorded as Animal (Other), with only some records in 2017 that carried a more specific crash type description. We cannot explain why only some records from 2017 include species specific information. We have inquired with NHDOT and NHDOS with no clear answer. In total, there were 27,383 WVCs recorded by the state during the 2002-2019 timeframe.

Among these data points, we found that a significant portion of points were located at the centroids of municipalities (see Figure 4). During early consultations with regional planners that use the NH collision dataset, we learned that the NH Collision data included records that were not spatially explicit. Records without latitude and longitude data are included as well as collisions that map to the centroid of the corresponding municipality. Given the project’s objective to identify potential roadway characteristics that might influence the probability of a WVC, we decided to remove records that did not plot close to a roadway. We used ArcMap and ArcGIS Pro to identify and remove points that were placed at the centroid and distanced over 200 feet from a roadway in the NH DOT 2021 roadways data layer. Finally, a total of 20,577 records were retained for subsequent spatial and statistical analyses.

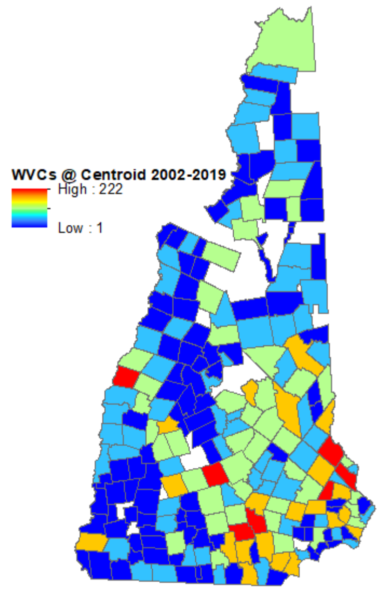

WVC_Location_2002_to_2019_with_points_at_centroids

ACCIDENTNUM	SR	TOWN	CRASHDATE	CRASHTYPE	COUNTY	POLICEDEPTCODE
02015146	<N	MANCHESTER	5/31/2002	Animal	HILLSBOROUGH	882
02016010	<N	MANCHESTER	6/4/2002	Animal	HILLSBOROUGH	634
02015930	<N	MANCHESTER	6/9/2002	Animal	HILLSBOROUGH	882
02019613	<N	MANCHESTER	7/14/2002	Animal	HILLSBOROUGH	882
02023186	<N	MANCHESTER	8/20/2002	Animal	HILLSBOROUGH	634
02024446	<N	MANCHESTER	8/28/2002	Animal	HILLSBOROUGH	882
02033087	<N	MANCHESTER	11/15/2002	Animal	HILLSBOROUGH	882
02032776	<N	MANCHESTER	11/21/2002	Animal	HILLSBOROUGH	634
03008761	<N	MANCHESTER	3/6/2003	Animal	HILLSBOROUGH	634
03017153	<N	MANCHESTER	6/12/2003	Animal	HILLSBOROUGH	882
03018744	<N	MANCHESTER	7/6/2003	Animal	HILLSBOROUGH	882
03020016	<N	MANCHESTER	7/12/2003	Animal	HILLSBOROUGH	0

(135 out of 27383 Selected)

WVC_Location_2002_to_2019_with_points_at_centroids

***Figure** 4 (Left) The recording of 135 points at the centroid within the City of Manchester. The original WVC dataset comprises 6,806 point records (from 2002 to 2019) placed at the centroids of corresponding municipalities. (Below) Summary of WVCs mapped at the municipality centroid between 2002 and 2019.*



Second, during the comprehensive integration of data into the 2002-2019 database to facilitate spatial and statistical analyses, we encountered variations in attributes. These differences ranged from disparities solely in field names to discrepancies encompassing both field names and data formats. For these fields, we adopted the field name and format that was present in the most recent data collection efforts (VISION 2017-2019). The data within the databases underwent manipulation and modification to establish uniformity among data fields within the geodatabase, as the IDMS and VISION databases possessed distinct data formats. To ensure enhanced consistency, field names were standardized using the VISION formatting approach within the geodatabase table for effective analysis (see Figure #).

Figure 5: Standardized field names within the consolidated geodatabase (2002-2019 dataset).

Finally, we utilized SQL tools to manipulate and establish a proper database from two distinct data sets due to their disparate data formats. For instance, identical data and information were recorded in databases using diverse formats such as text, date, or numeric representations, posing challenges for subsequent analysis. It was necessary to create new datasets with uniform data formats.

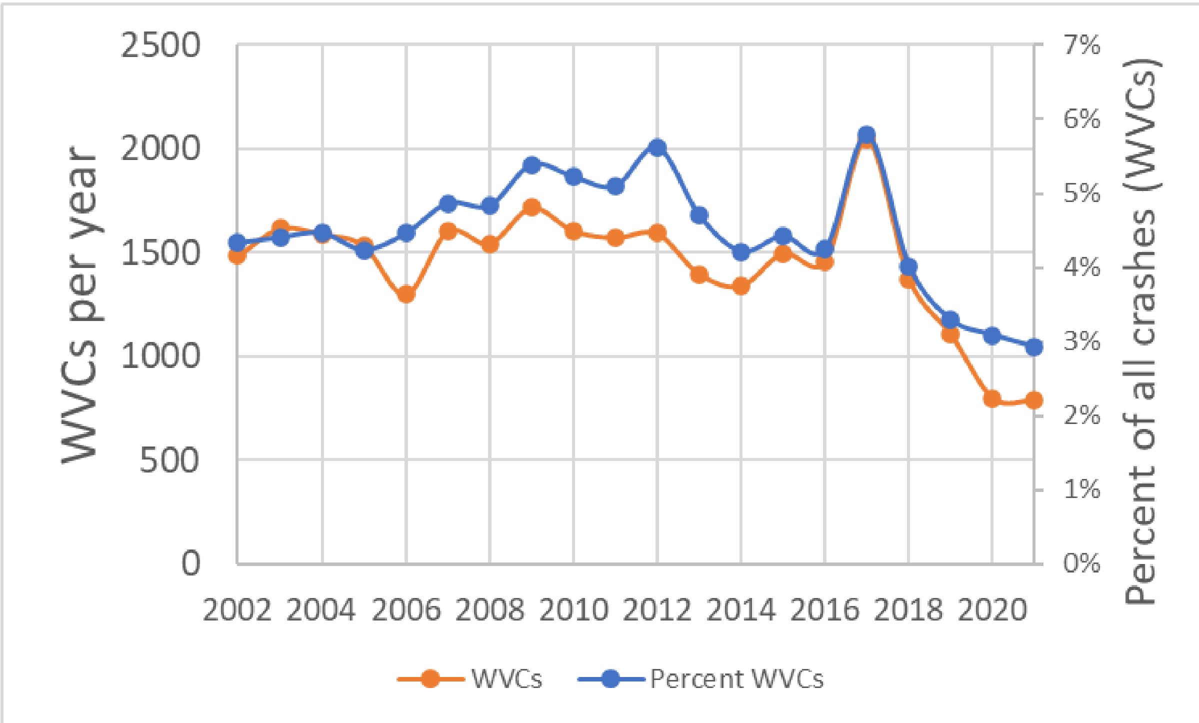


Figure 6: Total WVCs per year and their percent of all collisions in NH between 2002 and 2021.

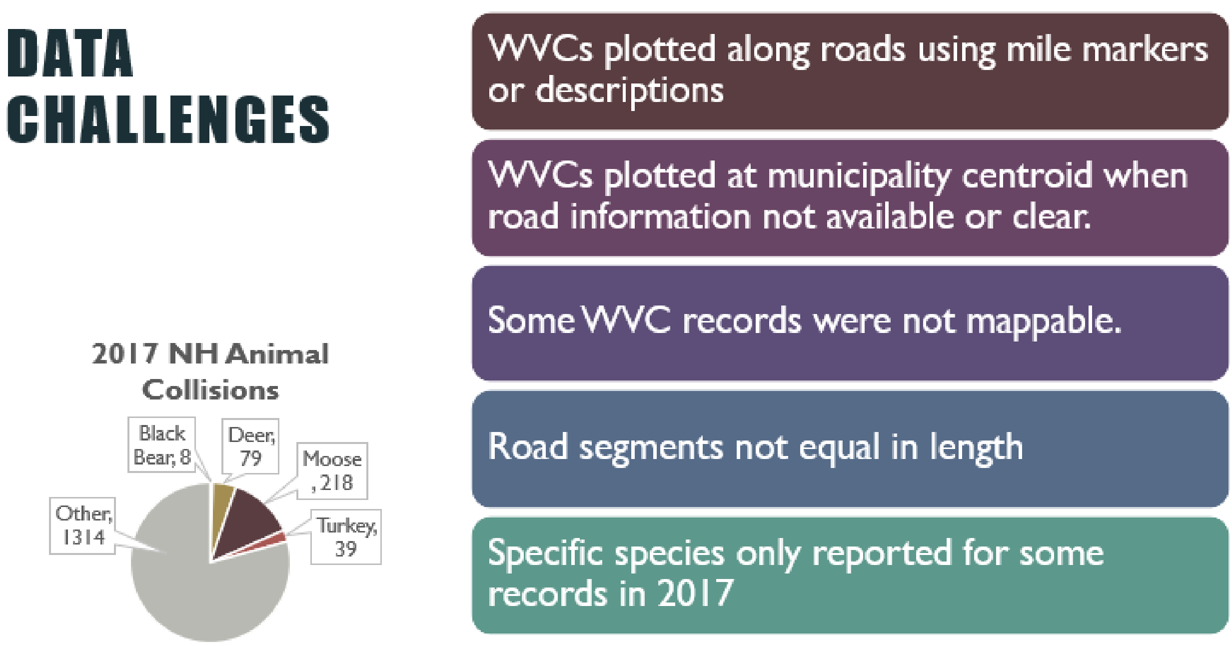


Figure 7: Summary of data challenges encountered during the project.

WVC Analysis and Integration with Supporting Data: In order to associate WVC location with potentially influential factors that vary spatially (Figure 8), we conducted a series of spatial joins in ArcMap 10.8 between WVC point data and supporting GIS data layers. We then aggregated all WVCs within defined times periods to facilitate their use for long-term assessment and future planning. WVC point location data was summarized by the following time periods: 2002-2019, 2015-2019, 2010-2014, and 2002-2009. The subsections below describe the spatially explicit GIS processes for integrating road characteristics, habitat and wildlife corridor data with the WVC locations (point data).

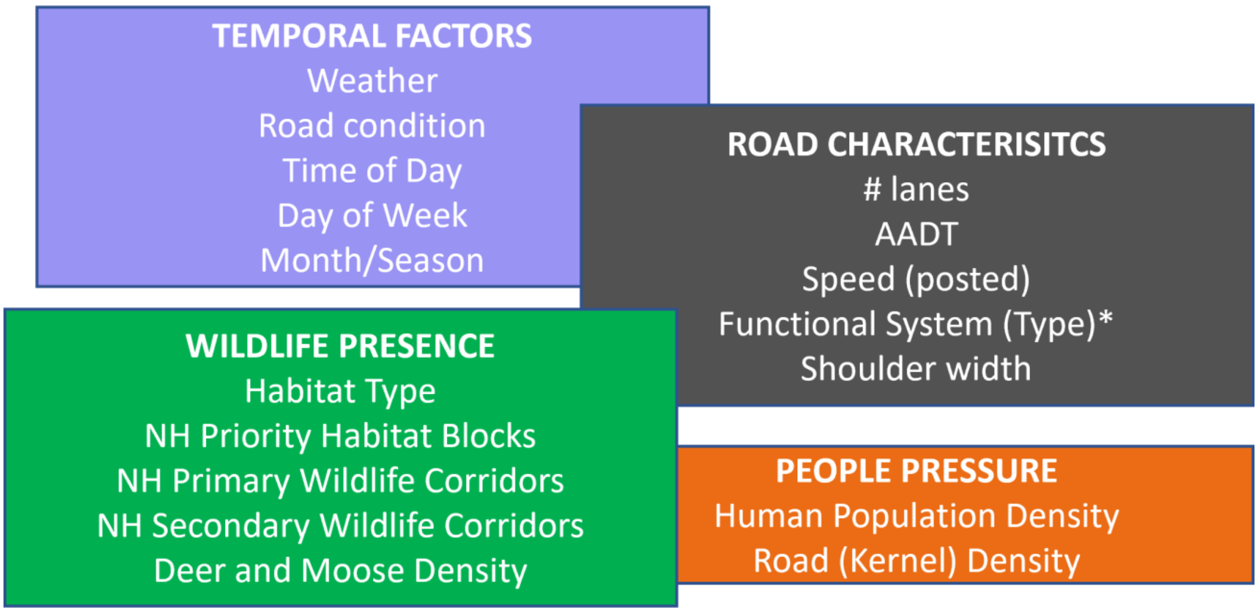


Figure 8: Factors potentially influencing the probability of a WVC.

Roadway characteristics. The WVC dataset provided to the project team from Dept of Safety includes some road attributes described at the time of the accident (e.g. road design, road alignment, road surface) but it did not include all roadway attributes found in the NH Dept of Transportation Roadways GIS layer. To resolve this, we used ArcGIS to spatially join the WVC points to the NH Roads GIS layer (*Join Operation*: one to one; *Match Option*: Closest with *Search Radius* of 100 ft). This linked each WVC record with additional roadway information such as Annual Average Daily Traffic volume (AADT), number of lanes, road width, shoulder width, functional system tier, road surface (paved/unpaved), and direction. The NH Roads GIS layer does not include posted speed limits, so we used the functional system as a proxy (Table 2). AADT data was not available for all roadways included in the 2022 NH Roads layer, so we appended 2021 NH Roads data with AADT data recorded in the 2015 NH roads layers.

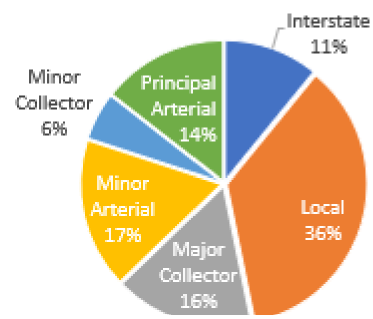
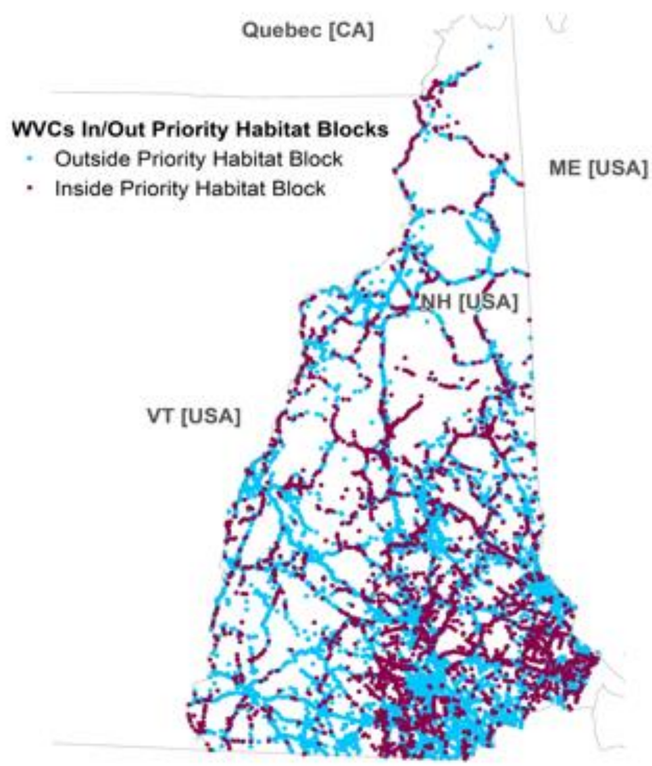


Figure 9: Proportional abundance of WVCs by road functional system classification

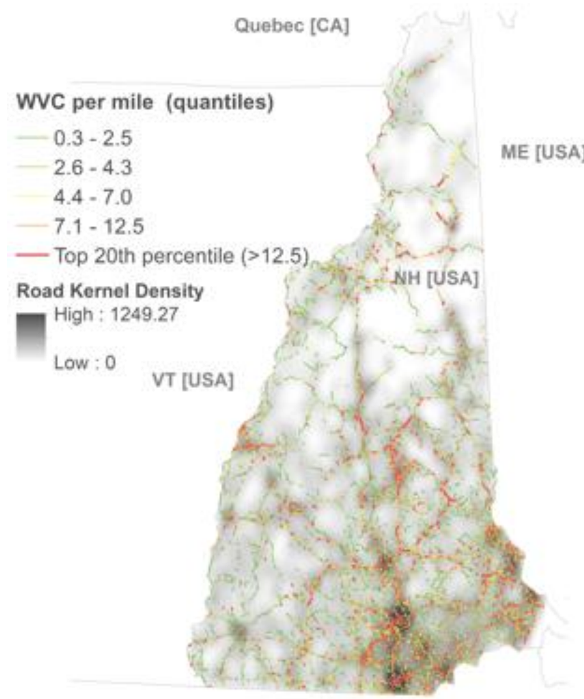
Table 1: Speed estimates based on Functional System attribute assigned to all NH roads.

Functional System Code	Functional System Name	Proxy speed
7	“Local”	30
0	“No Func”	50
4	“Minor Arterial”	50
6	“Minor Collector”	40
5	“Major Collector”	40
3	“Principal Arterial-Other”	60
2	"Principal Arterial- Other Freeways and Expressways"	55
1	“Interstate”	65

Priority Wildlife Habitat and Corridors. In 2022, NH Department of Fish and Game released three statewide GIS data layers that map high probability areas of priority wildlife habitat blocks, primary wildlife corridors, and secondary corridors. We integrated information from all three layers (polygons) into the WVC dataset through a series of spatial joins using ArcMap 10.15, each with a search radius of 400 ft from the WVC point (*Join Operation*: one to one; *Match Option*: Within distance of 400 ft). The data is included in the WVC dataset as binary factors (within 400ft: Y or N). In addition, we integrated regional deer, bear, and moose population estimates for 2020 derived from NH Dept. of Fish and Game through a spatial join with WVC points.



Human Population and Road Density. To complement the regional wildlife population densities, we calculated road density using Kernel Density approach in ArcMap 10.5 and then extracted values to WVC points. Human population density was calculated using Block Group population data from 2015-19 ACS survey and dividing by the Block Group land area. This data was then spatially joined (*Join Operation*: one to one; *Match Option*: Intersect) in ArcMap 10.5 with the WVC point layer.



Road-level aggregation: To identify problematic road segments, those with multiple WVCs, we summarized WVC data by roadway segment using the NH DOT roads layer Unique Road Id attribute. The Unique ID is a unique number given to a single roadway segment. Segments vary in length. The table below describes the summary metrics calculated. Each metric was added as an attribute in the master WVC point layer which enables the user to specify symbology for the focal metric.

To perform summary calculations, we added a field to the master WVC point layer named "counter" and populated all records with a "1" (this is an analyst's preference and not absolutely needed to calculate the sum of WVCs per roadway). Data was summarized using the Summary Statistics tool (*Statistics Field*: counter; *Statistics Type*: Sum; *Case Field*: Unique_ID).

Table 2: Summary of calculations applied and the time periods over which the WVC data was analyzed and aggregated.

Metric description	Calculation	Time Period
Total WVCs	Sum of all WVC points spatially joined to a given road segment by Unique ID	2002-2019, 2015-2019, 2010-2014, 2002-2009, *2020-2021
WVC Density (WVCs per mile)	"Total WVC" for corresponding time period divided by the length of the roadway segment in miles	2002-2019, 2015-2019, 2010-2014, 2002-2009, *2020-2021
Annual Average WVCs	"Total WVC" for corresponding time period divided by the length of the time period in years	2002-2019, 2015-2019, 2010-2014, 2002-2009, *2020-2021

A description of the GIS data products from analysis and supporting GIS data is provided below. These GIS databases are also seamlessly shared within the Mapper.

- Individual reported Wildlife-Vehicle Collision locations aggregated by time period breaks into three time period datasets:
  - **WVCs 2015-2019** includes all mappable collisions associated with animals during 2015-2019 period.
  - **WVCs 2010-2014** includes all mappable collisions associated with animals during 2010-2015 period.
  - **WVCs 2002-2009** includes all mappable collisions associated with animals during 2002-2009 period.
- Aggregated measures of WVCs for every unique road segment in the NH Dept of Transportation Roads layer
  - ***Total WVCs****:* sum of WVCs over a specified time period within each unique road segment
  - ***Density*** *(WVC per mile)*: Total WVCs over a specified time period *divided by* the length of a unique road segment

- Wildlife and Human Influences
  - ***Prioritized Habitat Blocks***: Core areas of wildlife habitat are areas over 50 acres in size that are a priority in the New Hampshire Wildlife Action Plan. Highest Ranked Habitat in NH and/or Highest Ranked Habitat in Biological Regions. (learn more about this layer and the two corridor layers from the NH Wildlife Corridors Mapper website)
  - ***Primary Wildlife Corridors***: The top-scoring linkages between habitat blocks for all focal species combined that may benefit multiple wildlife species with a variety of dispersal behaviors.
  - ***Secondary Wildlife Corridors****:* The top-scoring linkages between habitat blocks for each focal species considered individually.
  - ***NH Stream Crossings****:* locations of stream crossings reported in the 2021 SADES data available through the NH Stream Crossing Assessment
  - ***NH Municipality boundaries****:* Available from NH DOT GIS Data Quarterly Snapshots
  - ***NH Regional Planning Commission boundaries****:* Available from NH DOT GIS Data Quarterly Snapshots
  - ***NH DOT Projects***: road segments with projects currently in the design and planning phase. These are available from NH DOT GIS Data Quarterly Snapshots

Products.

- Summary of roadway level trends over time.

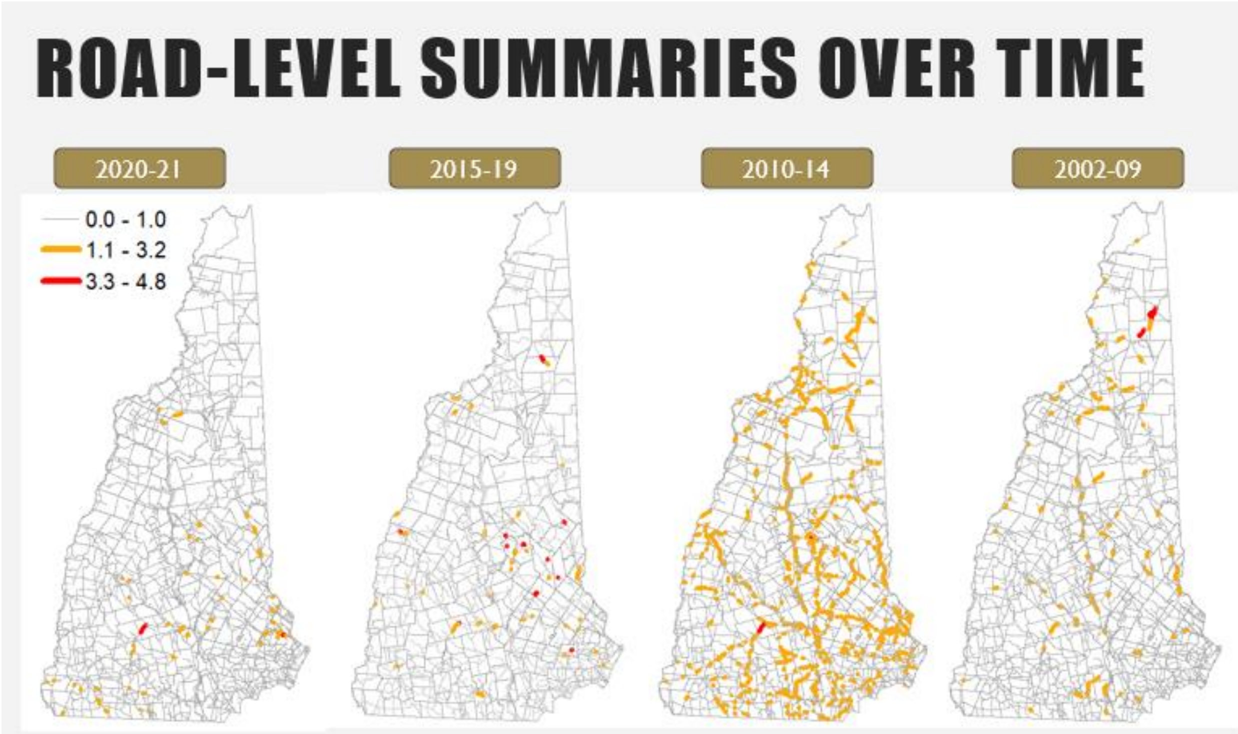


Figure 10: Visual pattern in total WVCs over time in NH presented at the 2023 International Conference on Ecology and Transportation in Burlington, VT.

- A GIS project folder of data layers created during this project and supporting data layers downloaded from sources described above.
- ArcGIS Online Web Mapper - NH Wildlife Vehicle Collisions 2002-2019
  We established a web portal to facilitate the dissemination of WVC map data, analytical outcomes, and pertinent information. Leveraging ESRI's web platforms, ArcGIS Online and ArcGIS Web AppBuilder, we designed and constructed the website dedicated to hosting WVC resources and analytical findings (see Figure 3).

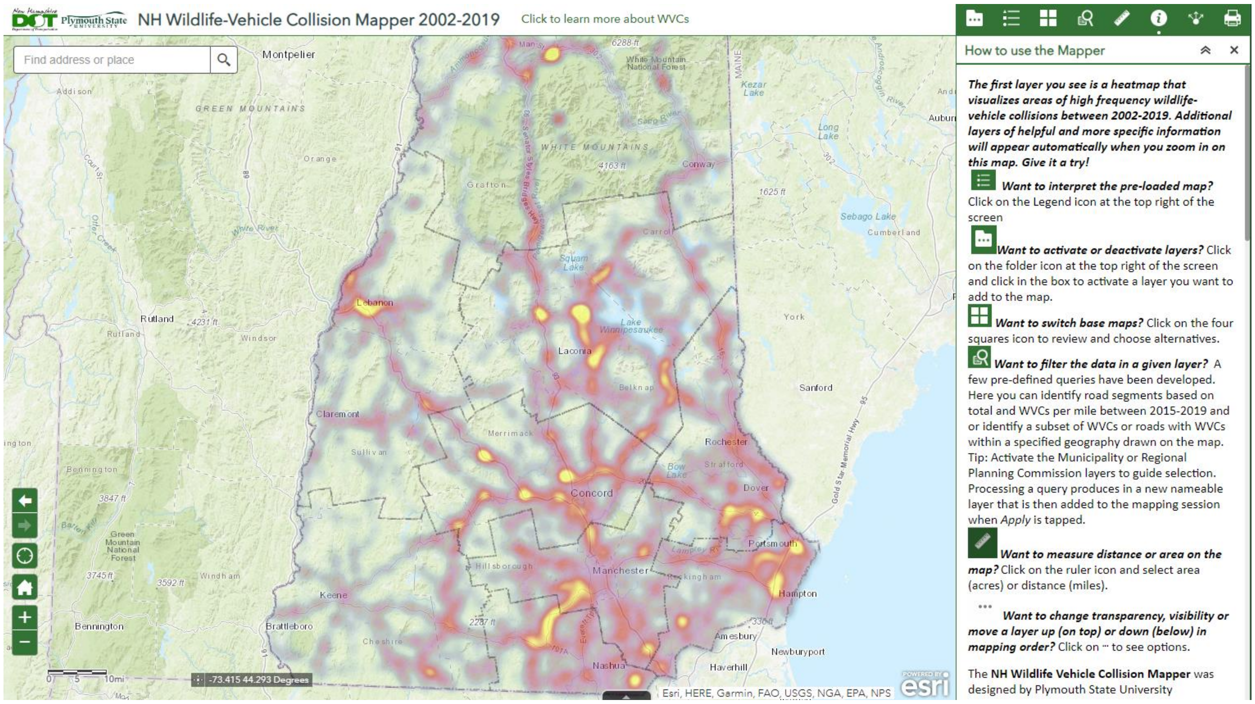


Figure 11: NH Wildlife Vehicle Collision Mapper 2002-2019 opening screen with "How to use the Mapper" information pinned to side panel.

4) WVC Data analysis. Mapping alone provides a snapshot of where WVC has occurred and their frequency, but analyzing spatial patterns can provide greater insight that enables us to predict areas of high WVC probability. Additional factors may influence this probability their identification will likely influence the effectiveness of mitigation strategies (Figure 11 above). Such factors include traffic volume, posted or prevailing speed, wildlife population density, wildlife movement patterns (Holthorn et al. 2015), driver awareness, time of year/day, road attractiveness, adjacent habitat, roadside vegetation, and integration of mitigation into the landscape (Litvaitis and Tash, 2008). Identifying the influence and interplay (interaction) of such factors can enhance our ability to predict and mitigate WVC. Using the data compiled, we will pursue several modelling approaches that may help explain the frequency of WVC and thereby predict/identify areas of high WVC probability based on roadway characteristics (number of lanes, posted speed, sinuosity), adjacent habitat/land cover/land use data, and seasonality (Found and Boyce 2011, Gunson et al. 2011, Lao et al. 2011, Holthorn et al. 2015, Kusta et al. 2017). The results of these analyses are reported via figures, tables, interpretation of fitted models, and predictive maps. We evaluate and report the performance of predictive models for use in decision-making and to inform future data collection efforts.

<u>Methods.</u>

Variable Identification: For this analysis, we aimed to investigate the effect of a variety of factors on wildlife vehicle crashes, or WVCs. Thus, WVC counts are considered the variable of primary interest, the response. After considering all other data available to us, we decided to focus on several features/conditions that are logically or likely (based on current literature) associated with WVCs. These explanatory variables included temporal designations (time-of-day, day-of-week, month), weather conditions, roadway information (number of lanes, posted speed limit, AADT, shoulder width, number of lanes) and geographic information (presence of primary/secondary animal corridor, wildlife area, deer/moose concentration, human concentration, and road concentration).

We then discretized several variables into broad categories. Specifically, we simplified time-of-day into morning, evening, and other categories; we simplified month into fall, spring, and summer/winter (or "other") categories; we simplified day-of-week into just weekday and weekend categories; and we simplified weather into just clear and inclement categories. Most other continuous variables were scaled (normalized) to facilitate future model fitting.

Data Preparation: Next, we created a dataset by counting the number of WVCs recorded along each route and at each unique level of time-of-day, day-of-week, month, and weather condition. Since there were more than 9,500 routes and 36 unique levels of time-of-day, day-of-week, month, and weather, we had more than 300,000 combinations (categories), each with an associated number of WVCs. For each of these categories, we also identified corresponding roadway features such as roadway length, number of lanes, posted speed limit, AADT, shoulder width, roadway alignment, proximity to wildlife corridor, human concentration, and wildlife (deer, moose) concentration.

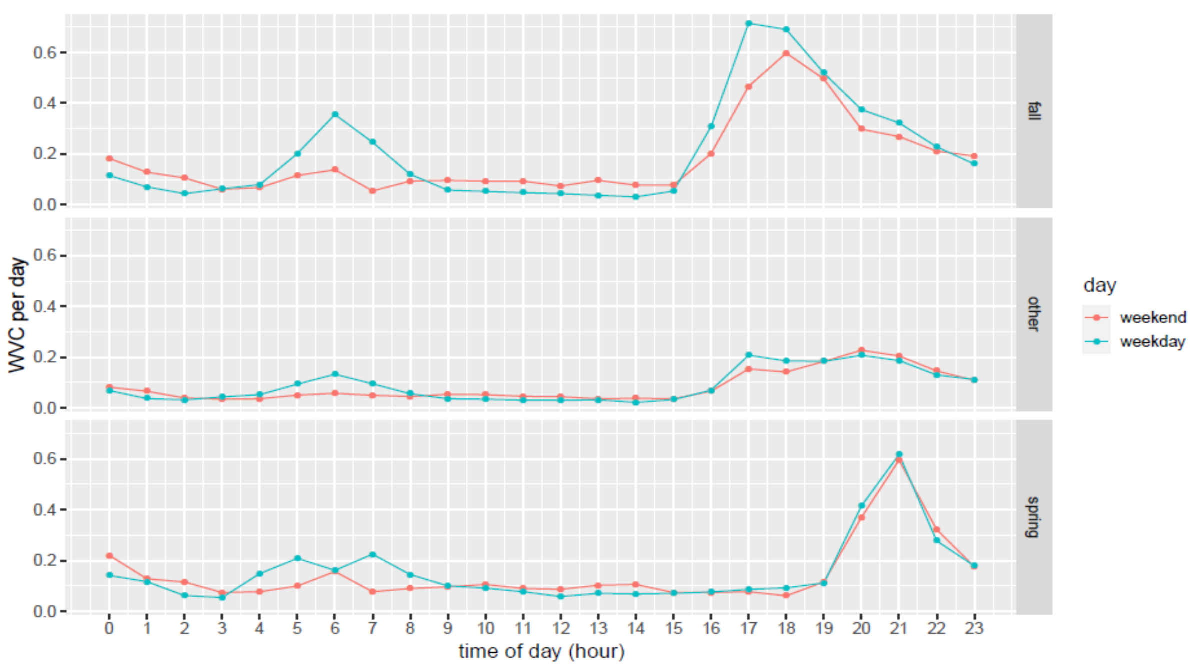


Figure 12: WVCs in NH by day of week and time of day 2002-2019.

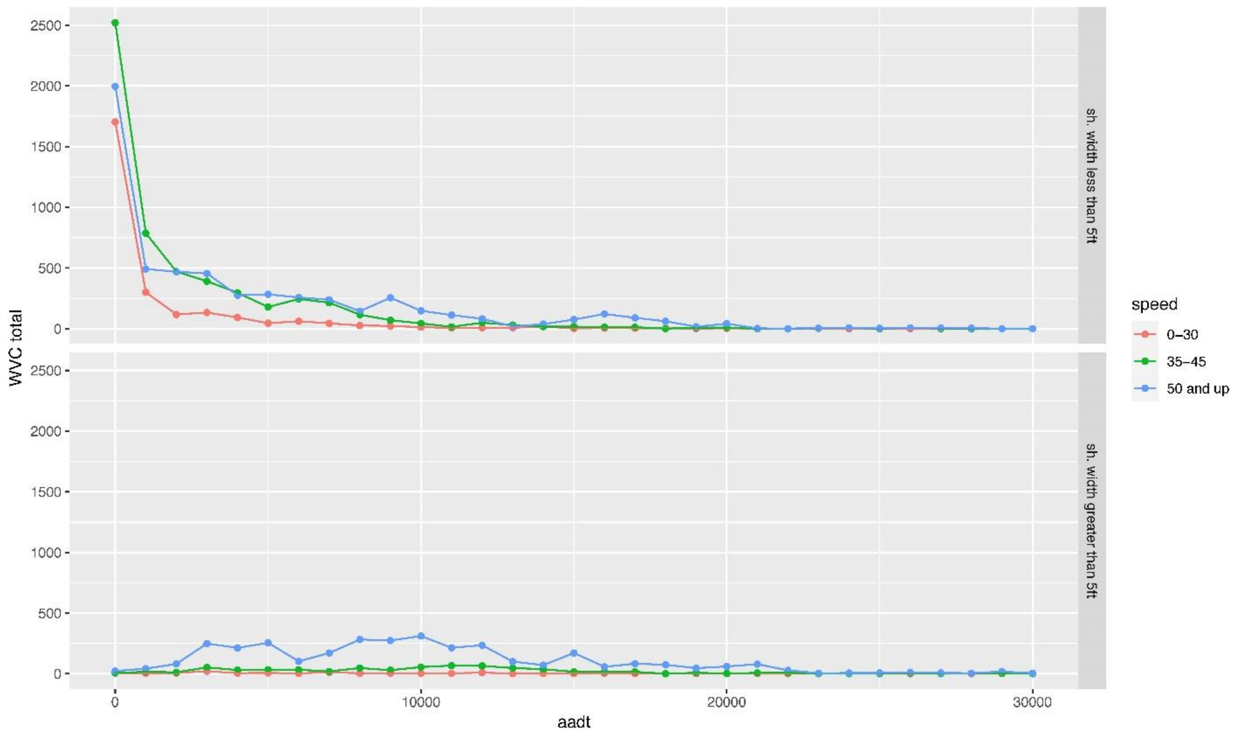


Figure 13: WVCs in NH by speed, shoulder width, and annual average daily traffic (2002-2019)

Statistical Model: The model chosen for the analysis was primarily based on the nature of the data. Since we have WVC counts per roadway as our response, we pursued count-based regression forms such as the Poisson regression and Negative Binomial regression models. After an initial investigation, the simpler Poisson regression form was pursued as there was no evidence to support the use of the more complicated NB form. Next, after inspecting the response variable, the accident counts, we observed a large proportion of categories with zero observed accident counts, or routes where no accidents occurred at the given combination of time, day, month, and weather condition. To properly account for this, we pursued a zero-inflated version of the Poisson regression model. This type of model form essentially conditions the distribution (Poisson) on the non- zero counts and some portion of the zero counts.

Model Fitting: All model fitting was performed using R statistical software. Model fitting identified several statistically significant (based on p-values) terms, both main effects and interactions, as well as 'practically' significant terms, or effect sizes (exponentiated regression parameters) that are larger than 2 or 3. Chief among the practically significant terms was the interaction between weather and time-of- day. The fitted results suggest that for the morning hours, 5AM to 8AM, compared to inclement weather conditions, there is more than a 7-fold multiplicative effect on WVC count for clear weather conditions; for the evening hours, 4PM to midnight, there is about a 10-fold multiplicative effect for clear conditions; and for the "other" hours, there is about an 11-fold multiplicative effect for clear conditions. This effect is also evident from the plot below. Here, we can see the increase in WVCs (y-axis) at the different times of day, increases that correspond to the interpretation of the model parameters above. We can conclude that there are many more WVCs during clear weather conditions, as expected, but the precise increase depends on the time-of-day.

Shortcoming of results: A major challenge of our analysis is the large number of roadway segments (over 9,500) and the size of our resulting dataset. This is challenging because, even after discretizing our variables (weather, season, time, etc.), the number of WVCs are scattered very sparsely across the combinations of variables. Despite using an appropriate model, a zero-inflated Poisson model, our model predictions fail to improve upon a null model that would simply predict zero WVCs for any case. In fact, there is no evidence that our full model is significantly more accurate than the null model in terms of predicting the number of WVCs. One potential remedy we pursued was to use roadways themselves instead of individual roadway segments. This reduced the number of unique locations (from over 9,500 to around 2,700), but WVCs were still sparsely dispersed among these locations and predictions were still poor.

Products.

- Insight into the temporal variability associated with collisions and the lack of a strong spatial or road characteristic influencing collisions. This analysis has strengthened our belief that wildlife are crossing where they want and need to and that we need to address barriers to safe wildlife passage across our roadways by better understanding wildlife movement patterns.
- Forthcoming manuscript documenting the statistical analysis and results.

5) Develop communication materials to highlight the importance of data collection, analysis and mitigation. We initially proposed to develop the following. All have been achieved and described above.

- online map application as described in Obj 3.
- a StoryMap that integrates our findings from Objectives 1-4.
- presentation at regional or national conference focusing on transportation and/or wildlife
- manuscript preparation and submission for peer review

6) Analyze WVC data from 2020-2021. This objective was added opportunistically due to extension in project period and remaining funding since the project was able to utilize funding from other sources as match. The objective was to conduct the same analyses described above on two additional years of data.

Methods.

We followed the same methods described above to integrate supporting data into the WVC point data and to summarize collisions at the road level. Rather than reassign time periods and reanalyze the full data record, we calculated total WVCs, WVC density, and annual average WVCs per road for 2020-2021. The annual average metric enabled us to compare across time periods.

Products.

- Data aggregations were completed and will be included in the GIS database provided to NHDOT.
- Products from spatial analysis and aggregation were used in, opportunistically added, objective 7 site prioritization analysis described below.

7) Identify WVC hotspots for on-the-ground wildlife monitoring (Phase II). This objective was added opportunistically as the project progressed and serves as a bridge between Phase I and Phase II. It was the focus of second and third quarter of 2023.

Methods.

To prepare for Phase II of this project in which on-the-ground wildlife monitoring will occur in partnership with Rem Moll (UNH), we ranked sites based on the aforementioned road-level aggregate metrics. We explored variety of prioritization approaches that differed in the metrics included and the weights given to each. Prior to receiving and processing the 2020-21 data, we used normalized values of Total WVCs and WVCs per mile to identify subset of road segments. There is no federally established threshold for the number of WVCs that are considered problematic or should be targeted for change. Instead, we explored a variety of thresholds to yield 27-58 sites priority sites across the state. The NHDOT and PSU project leads and Phase II UNH project lead discussed the process and agreed to give greater weight to 2015-2019 and 2020-21 data. To use 2020-2021 and 2015-2019 data, we averaged the WVCs per year in each period and normalized the total WVCs to score between 0-1 where road segments scoring a 1 representing the highest annual average of WVCs observed. Results were presented to NHDOT project lead via an ArcGIS online map (Figure 14).

Figure 14: Wildlife Corridor Field Site Selection map shared for prioritization discussions in summer 2023.

We found that the annual average alone was not informative enough because there was little variability in the maximums across time periods and each time period was heavily influenced by roadways with no WVCs, making the means extremely similar.

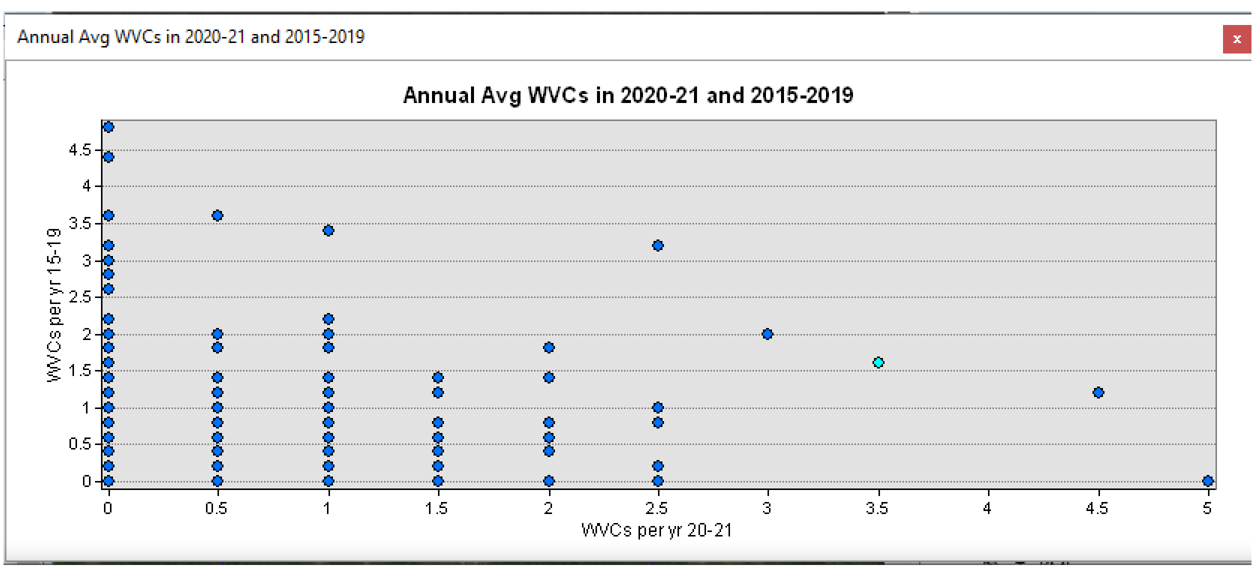


Figure 15: Example of annual average WVC data used to determine thresholds for site selection.

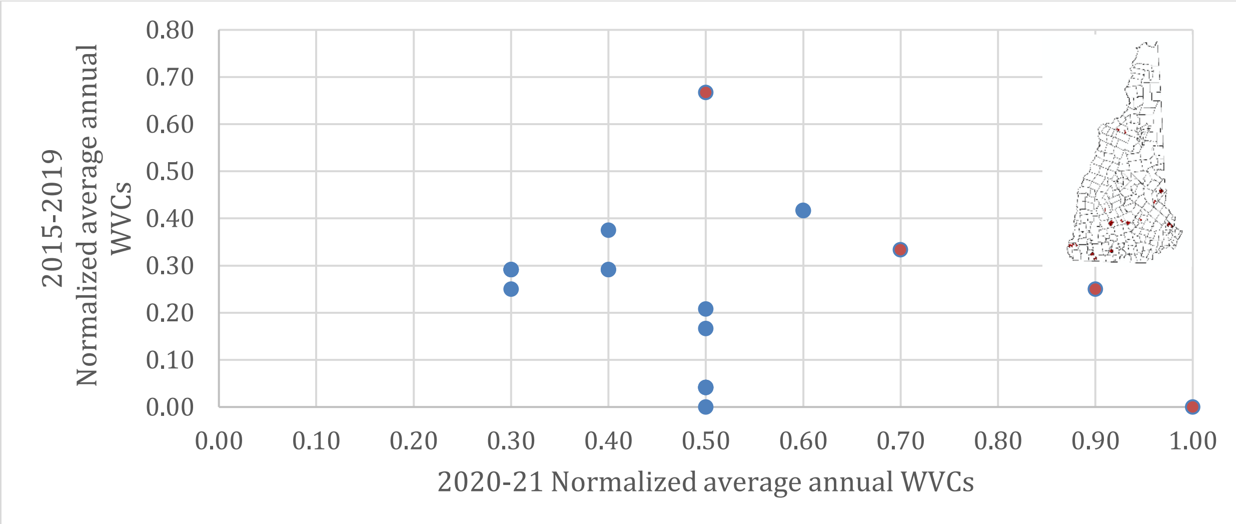


Figure 16: Roads where the normalized annual average was ≥0.5 in 2020-21 OR normalized annual average was ≥ 0.25 in 20-21 AND normalized annual average was ≥ 0.25 in 2015-19 yielded 19 roadways mapped.

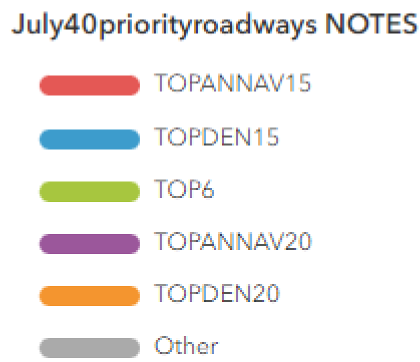
After many additional analyses, a sensitivity analysis of the selection parameters revealed that the resulting priorities were highly sensitive to changes in the parameters (metrics included) and the thresholds chosen. The lack of federal guidance on thresholds and the variability across states led us to take a comprehensive approach. We decided to identify the top 25-30 roads for each of the following criteria (parameters and thresholds) and then assess for overlap among criteria:

- 2015-29 annual avg WVCs
- 2015-19 avg WVC density*
- 2020-21 annual avg WVCs
- 2020-21 avg WVC density*

*high density values must also meet minimum WVC criteria (2020-2021 ≥ 1 per yr; 2015-19 ≥ 0.6 per yr).

None of the prioritized roadways that met a single criterion above met all four criteria. One met three of the four criteria and four met two of the criteria. These were considered the TOP 6 roadways for site selection. Additional sites were selected using the following framework and mapped with corresponding symbology. An additional 4 sites were added based on their nearness to another site and their high values, although below the stated threshold, because they were recognized as part of a regional problem. This resulted in 40 sites that could be further investigated and prioritized based on proximity to stream crossing, wildlife corridors, terrain, etc.

- 10 highest roads not already included for 2015-19 avg WVCs (n=10)
- 10 highest roads not already included for 2015-19 density (n=10)
- 5 from the 2020-21 avg WVCs (n=5)
- 5 from the 2020-21 density (n=5)



Each of the 40 sites were individually reviewed to evaluate nearby conditions related to wildlife corridors, existing crossings, neighborhood hotpot, and persistence of problem from 2015-2021 (i.e., their promise as potential sites for mitigation) (Figure 17). Based on discussions with NHDOT project lead and conversations at the International Conference On Ecology and Transportation (ICOET), higher priority was given to sites with existing stream crossing structures nearby that might, with infrastructure change, facilitate terrestrial wildlife movement under roadways. Eighteen (18) of the 36 sites prioritized have a documented stream crossing within 600 feet of the roadway. We then identified the stream crossing infrastructure that was associated with these roadways, which summed to 39 stream crossings. Some of these were greater than 600 feet away from the roadway but identified as part of a neighborhood/regional problem.

Finally, to ensure we were not missing larger areas of concern in which a single roadway may not have had enough WVCs to meet the aforementioned criteria, but a cluster of roadways suggested a larger concern, we rasterized the WVC data and identified additional areas of concern. This yielded another six (6) road segments and twenty-two (22) stream crossings.

Figure 17: Overview of data used in site prioritization process.

Products.

- ArcGIS Online Field Site Selection map
- Prioritized list of sites and detailed notes about their potential as wildlife monitoring sites and future sites for mitigation

SUMMARY OF RECOMMENDATIONS

- **Enhance data collection at the scene of collisions. Make species a required field in electronic forms when animal-related is selected for collision type.** As the state shifts to a digital, online platform for accident reporting, making the animal-related field a requirement for submission could result in more detailed data for future analysis. Unidentifiable can be an option as needed. Photo guides can be included in the mobile app as well as an opportunity for photo upload. In addition, more driver information could be recorded at the site of a collision, including likelihood of speeding, whether the driver was impaired or distracted, driver age, and driver's perceived reason for crash. All this information could help us better identify populations of drivers that may be most affected by WVCs and better understand the influences, given the result from our analysis that road characteristics are not strong influencers.

- **Enhance monitoring and data collection regarding WVC statewide. This includes requiring the reporting of roadkill using a GPS-enabled roadkill reporting app for mobile devices.** All NHDOT road crew vehicles/personnel should be equipped with GPS-enabled mobile devices on which roadkill can be reported (e.g. ROaDs mobile app or Utah Roadkill Reporter). This data should be assessed monthly, alongside WVC collisions, and shared via an easy-to-use platform like an ArcGIS dashboard. This data should be shared between NH Dept of transportation and NH Dept of Fish and Game to inform decision-making.

Enhance existing stream crossing structures near WVC hotspots and within predicted wildlife corridors (NH Fish & Game) to facilitate safe passage of terrestrial wildlife, especially those that use riparian corridors for movement. The lack of statistically significant spatial or road predictors of WVCs suggest that most is likely attributed to the movement patterns of resident wildlife, with temporal factors such as time of day, year, and human behavior such as speeding or distracted driving. Thus, the best course of action is to better understand wildlife habitat use and movement in areas of high WVC frequency. The wildlife corridor maps integrated into the prioritization analysis and the web WVC mapper are the results of habitat suitability and landscape connectivity model conducted by NH Fish and Game. Mapped wildlife corridors do not reflect locations of known wildlife corridors. Thus, it is strongly encouraged that users incorporate best available local data sources and ground-truth results of corridor analyses, which is essential for identifying critical connectivity zones. Phase II of this project is designed to collect animal movement activity near hotspots using active trigger wildlife cameras. Data from Phase II should help us better understand these WVC patterns and further prioritize areas when NHDOT and partners can invest in mitigation.

- **Conduct an asset inventory of wildlife warning signs statewide.** Research suggests that wildlife crossing signs are often ignored because they are static, common along U.S. roads and are not always accompanied by a reduction in speed limits (Riginos et al. 2022). Moreover, many signs have been installed at the request of the community with little scientific assessment or correlation to WVCs. Sign location should be analyzed alongside WVC and roadkill data to confirm their need. Those lacking clear justification should be removed to avoid driver apathy.

- **Install "Wildlife – Vehicle Collision Zone" signs** (or something similar) in statewide WVC hotspots identified in this project. These are different than the traditional wildlife crossing signs and would be intended to draw greater attention to the risk to human and wildlife safety. Where appropriate, more dynamic signage and speed reductions should be enforced (Riginos et al. 2022). With data from WVC, roadkill, and site surveys, speed reductions could be seasonal and therefore more likely to be adhered to.

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