Linking Landscapes for Massachusetts Wildlife: 2010-2017 Road Mortality Summary Report
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Acknowledgments

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Abstract

Initiated in 2010, the Commonwealth of Massachusetts' Linking Landscapes for Massachusetts Wildlife (LLMW) project objectives are to document wildlife road mortality and identify locations with high wildlife mortality rates. The information generated will inform transportation infrastructure planning so that roadway improvements can be designed to mitigate the impacts of roads on wildlife, by improving connectivity and reducing animal-vehicle collisions. Reducing animal vehicle collisions can also improve public safety for the motoring public. The project combines expertise from various state agencies and information from the public. The LLMW websites provides three data entry portals to the public, one for general wildlife road mortality, one for vernal pool amphibian crossing road mortality, and one for turtle road mortality data entry. These three separate data entry portals can be accessed by anyone. LLMW also coordinates a systematic turtle mortality monitoring program. Citizen scientists conduct repeated surveys during the nesting season at selected locations and enter their data into the turtle mortality data portal. From January 2010 to September 2017, 528 volunteers have participated in one or more of these projects, resulting in the documentation of over 6,450 mortalities, representing 82 species at 2,301 locations throughout the state. For this report, LLMW data were summarized and mapped to identify locations with high rates of mortality for general wildlife, vernal pool amphibians, and turtles. Twenty-one locations where 11 or more mortalities were reported within a one-mile stretch of roadway for general wildlife, 48 locations were vernal pool amphibians cross roads, and 483 total locations with turtle mortalities were observed. The general wildlife and vernal pool observations were opportunistic, while the turtle observations consisted of a mix of opportunistic observations and systematically chosen survey locations. Additionally, wildlife mortality data collected by MassDOT maintenance personnel and animal-vehicle crash data from MassDOT's Crash Portal were also summarized, and used to identify hotspots for wildlife mortality around the Commonwealth.

1. Introduction

1.1 General Overview of Linking Landscape for Massachusetts Wildlife

In 2008, the Massachusetts Division of Fisheries and Wildlife (MassWildlife), and its Natural Heritage and Endangered Species Program (MA NHESP) entered into a formal interagency service agreement (ISA) with the Massachusetts Department of Transportation (MassDOT), Highway Division to improve the efficiency of state-level environmental project review. A significant benefit to the agreement was the ability to share resources that otherwise would be limited. The combined effort facilitated the agencies ability to take a science-based approach to understand the impacts of roads on wildlife and their habitat (as it relates to conservation and public safety). Further, the agreement has facilitated the agencies' ability to become activity engaged in the field of road ecology. The success of the agreement led to additional collaboration between the agencies outside of the regulatory realm, on wildlife and transportation issues.

Initially, based on reports of potential turtle mortality hotspots the agencies received from the public in 2008 and 2009, and some improvements were made at specific locations to reduce future mortality. Moving forward, both agencies realized that a statewide dataset documenting wildlife mortality issues was needed in order to categorize and prioritize locations for improvements for the safety of both wildlife and the motoring public. Therefore, in 2010, the agencies partnered with the University of Massachusetts, Amherst, and launched Linking Landscapes for Massachusetts Wildlife (LLMW).

LLWM is a proactive, non-regulatory transportation-ecology program to mitigate the impact of Massachusetts' road network on wildlife and their habitats, and to improve public safety. The Commonwealth contains 16,534 km (10,274 mi) of highways and other major roads and 62,101 km (38,588 mi) of minor roads. Road densities are greatest in the eastern region due to urban expansion from Boston and Worcester and coastal development, and in areas of high population densities within portions of the Connecticut River Valley in Franklin, Hampshire, and Hampden Counties (Figure A-1, Appendix A). This transportation infrastructure affects wildlife through direct mortality due to vehicle collisions, and by fragmenting and degrading habitats. In addition, wildlife in and near roadways can cause collisions, either directly or as motorists try to avoid wildlife, potentially resulting in property damage and personal injury.

The objectives of LLMW are to: enhance, protect, and restore habitats impacted by roads; reduce wildlife-vehicle collisions and improve public safety; incorporate conservation priorities into transportation planning; and, implement wildlife and transportation research. By implementing this objectives, the agencies will further their ability to preserve rare species populations and enhance the safe passage of wildlife across roads. To help achieve these goals in as cost effective method as possible, a citizen science research program was developed to collect data that could them be used to inform decision-making.

The LLMW team identified three central research focuses for the statewide assessment of wildlife/transportation conflicts: 1) species subject to road mortality which are of the highest conservation priority (e.g. rare turtles); 2) species subject to road mortality due to life histories that may result in seasonal crossings of roads (e.g. vernal pool breeding amphibians); 3) other species subject to road mortality, with an emphasis on larger animals that may be more of a public safety issue (e.g. moose, bear, deer). To address these three themes, three separate databases and a monitoring program were designed to meet research needs. The data collected will be used for environmental planning purposes in the context of the state Transportation Improvement Program, in conjunction with other spatial and modeling resources such as BioMap2 from the MA NHESP and the Conservation Assessment and Prioritization System (CAPS) from the UMass Extension.

LLMW provides a data collection platform that allows users to record their observations of wildlife road mortality. Online data forms available on the LLMW website use a Google Map interface that allows users to mark the exact location of an observation and enter associated data, including species and numbers of animals observed, date of the observation, observer name, contact information, and additional comments. Over time, accumulated observations collected through the LLMW will identify potential wildlife crossing hotspots and quantify the types animals associated with each hotspot and their rate of mortality. The public has been invited to submit road mortality observations to the LLMW website through the MassWildlife newsletter, through conservation organization listservs, and during presentations at conferences and other professional meetings. Program participants have included state and independent biologists, members of conservation and watershed organizations, and the general public (citizen scientists).

The data generated through the LLMW program will contribute important information and allow MassDOT to categorize and prioritize roadway segments for safe wildlife passage. As transportation improvement projects are proposed along roads with documented wildlife crossing hotspots, considerations for wildlife-friendly designs can be incorporated at the earliest planning phases, and the improvements can be targeted to benefit the species at greatest risk. As highway reconstructions, bridge replacements, and other transportation infrastructure improvement projects are planned, LLMW data will be used to select priority locations for wildlife-friendly enhancements, such as signage, barrier fencing, wildlife tunnels, and bridges and culverts that meet Massachusetts stream crossing standards. The information generated by LLMW can also be used by conservation organizations, watershed associations, or other groups interested in conducting their own wildlife conservation/ transportation infrastructure projects. LLMW welcomes opportunities to assist and collaborate on such efforts.

The data summarized in this report represents submissions to the LLMW website from the beginning of the program in 2010 through September 2017. These data are augmented with and compared to roadkill locations collected by MassDOT maintenance personnel and data regarding animal/vehicle collisions collected by law enforcement and accessed through MassDOT's Crash Portal (https://services.massdot.state.ma.us/crashportal/). These three data sources present a substantial amount of information from which to identify and prioritize locations where wildlife/roadway conflicts occur and mitigation should be considered.

1.2 LLMW Initiatives

1.2.1 General Wildlife Road Mortality Database

LLMW's Wildlife Roadkill data entry portal allows anyone to document any wildlife mortality observed on a road in Massachusetts. This portal on the LLMW website prompts users to enter their name, e-mail, species observed, and number of animals observed, then provides the user with a mapping tool to record the location of their observation. Users may include environmental practitioners, highway personnel, law enforcement, as well as the general public.

1.2.2 Amphibian Crossing Road Mortality Database

Vernal pool breeding amphibians require a matrix of upland and wetland habitat, and roads and development often fragment and isolate these landscape features. Each spring, as amphibians move from upland overwintering habitat to vernal pools to breed, many of these mass migration events involve the crossing of roads. When large numbers of individuals must cross roads, excessive mortality may threaten local populations. In Massachusetts, two of the species that depend on vernal pools are listed as Special Concern, the Jefferson salamander, and the blue-spotted salamander. Three other species, spotted salamander, spring peeper, and wood frog, are also recognized as vernal pool dependent breeders.

The LLWM Amphibian Crossing data entry portal is the tool for users to document locations where they observe amphibians crossing roads to access vernal pools. This data entry portal on the LLMW website prompts users to enter their name, e-mail, date of observation, describe the location of observation, enter the town of observation, and provides the user with a mapping tool to record the location of their observation. A list of amphibian species is provided for users to select and enter a count for.

The goal of this database is to identify and document high-use amphibian crossings, and this summary report provides an inventory of the crossing locations and the number of amphibians reported at them since 2010. LLMW is interested in using these data to assist conservation commissioners, conservation organizations, planners, and highway departments to determine where conservation efforts such as amphibian tunnels, drift fencing, and temporary road closures, will have the greatest benefit.

1.2.3 Turtle Mortality Database and Monitoring Program

Turtles are of conservation concern worldwide, as they have low reproductive success and slow population growth rates. Population persistence relies on the reproductive contribution of individuals over a long lifetime, and the annual removal of just a few adults from a population due to unnatural causes, such as road mortality, can have dramatic effects on population viability. Similar to other species, turtles may cross roads in order to access multiple resources needed for survival. For example, some freshwater turtle species are known to move from overwintering to foraging habitat in early spring, which may require moving across roads to access another wetland or move within a single wetland bisected by a road. In addition, adult females often must cross roads to reach suitable habitat for laying their eggs each spring. Additionally, road shoulders are known to attract nesting turtles since sunny areas with loose gravel are desirable for nesting.

In Massachusetts there are 11 species of listed turtles, five of which have life histories that put them at risk of crossing roads. The wood turtle and the eastern box turtle are listed as Special Concern, the Blanding's turtle and the diamond-backed terrapin are listed as threatened, and the northern red-bellied cooter is listed as endangered. Massachusetts' other listed turtles, the bog turtle and five species of marine turtle, are unlikely to encounter roads. Massachusetts non-listed turtles, the painted, snapper, spotted, and musk also have life histories that put them at risk of crossing roads.

The LLMW Turtle Roadkill data entry portal is the tool for users to document locations where they observe turtles on the roadway, either opportunistically or as part of the structure monitoring program described below. The goal is to identify and document high-use turtle crossings, and this summary report provides an inventory of the crossing locations and the number of turtles reported since the inception of LLWM in 2010. The Turtle Roadkill data entry portal on the LLMW website prompts users to enter their name, e-mail, date of observation, describe the location of observation, enter the town of observation, and provides the user with a mapping tool to record the location of their observation. A list of turtle species is provided for users to select and enter a count for. The data form provides entry fields to submit the results of up to three repeated surveys/observations at the same observation point.

LLMW also established a structured research program to more rigorously evaluate sites for high rates of turtle mortality. This program recruits volunteers to conduct three repeated surveys at pre-selected locations of interest during the turtle nesting season. These standardized surveys allow for a more accurate comparison of sites in order to prioritize locations for measures including turtle passages and fencing, to reduce turtle mortality. The focus of these surveys is on freshwater turtle populations and survey sites are located on causeways and other roads that bisect wetlands, and roads adjacent to both wetland and turtle nesting habitats. Volunteers are provided training and specific locations to monitor, chosen by MA NHESP personnel.

Initially, in 2009 LLMW selected 190 potential survey sites by consulting with local biologists, conservation organizations, and the general public, as well as through aerial photograph interpretation and field reconnaissance to identify locations where multiple turtles are known to be or might potentially be killed each year on roads. In 2011, LLMW identified 7,075 road segments throughout Massachusetts as having significant interactions with wetlands and likely to contain a freshwater turtle road crossing hotspot through a statewide model based on proximity to a wetland, presence/absence of wetlands on both sides of the road, traffic volume, road width, and priority habitat for rare turtle species. In 2010, LLMW solicited volunteers to initiate the monitoring program, assigning 70 potential hotspots to volunteers. Additional sites identified independently were also surveyed by volunteers. Surveys followed a standardized protocol, consisting of a survey during the last week of May, second week of June, and last week of June. These three sampling periods fall within the typical spring nesting period for freshwater turtles in Massachusetts. During each survey, volunteers collected all carcasses present on the road and road shoulders and recorded the number, species, and age classes (i.e., adult, juvenile, or hatchling) observed. Collected carcasses were removed from the road after each survey and discarded nearby to prevent re-collection during subsequent surveys. Volunteer recruitment and training by NHESP is on-going.

1.3 Other Data Sets Considered

To identify locations with high rates of mortality, roadkill data collected by MassDOT maintenance personnel and animal-vehicle-collision (AVC) data from the MassDOT Crash Portal were considered as well as the LLMW data. These two additional data sets are described below.

1.3.1 MassDOT Mortality Data

MassDOT maintenance personnel pick up road-killed animals as part of their general duties. Although they have not collected information about roadkill in a systematic fashion to date, they do keep logs of the general maintenance activities they conduct. From these records, roadkill location information can be drawn. For this report, MassDOT provided LLMW with roadkill information collected from 2012 through August, 2017. These reports are limited to larger animals, consisting of the following species: bear, bobcat, coyote, deer, fisher, fox, moose, other, and otter. For each report of an animal carcass picked up, maintenance personnel fill out a roadway description field, which contains the roadway, starting mile marker, ending mile marker location, town, and direction (northbound, southbound, etc.) if applicable. Note however, that because roadkill were not collected systematically, the amount of data available from this reports varied between MassDOT regions.

1.3.2 MassDOT Crash Portal Data

MassDOT compiles vehicle crash information, and makes this information publically available for analysis. As described on the MassDOT Crash Portal homepage (https://services.massdot.state.ma.us/crashportal/), crash data are compiled by the MassDOT Registry of Motor Vehicles, based on crash reports submitted by State and local police, and other police departments. MassDOT cautions that some information in the reports may have aggregated, or incorrectly or incompletely reported. Additionally, jurisdictions with limited budgets and manpower may under report, especially non-severe crashes. Therefore, MassDOT makes no representation as to the accuracy or completeness of the crash records or the data collected from them. For the purposes of this report, all crashes from 2007 through 2014 where the first harmful event was marked as "collision with animal" were considered. The collision with animal category had two sub-categories, "deer' and "other". The most recent year for which Crash Portal data are available is 2014, and we chose the 2007-2014 time period to match the duration for which LLMW General Wildlife data are available.

2. Methods

2.1 Overview of Data Management and Mapping

LLMW Data Sets

The data entered in to the three on-line LLMW data portals resulted in three separate datasets, hereafter referred to as General Wildlife, Amphibian Crossing, and Turtle Mortality. For all three databases, we started by cleaning the data, which allowed us to focus in on variables of importance (species, observation date, count, etc.), and use the data more efficiently with other software. All three data entry portals were updated in 2014. Adjustments to the data entry forms resulted in some difference between data recorded from 2010 through 2014 and data recorded from 2015 through September 2017. Additionally, although the intent of the on-line data forms was to standardize data entry, users sometimes filled out the forms incompletely, or used the “comment” and/or “location” boxes to record their observations in a narrative fashion. We interpreted omissions and comments to maximize the number of usable records.

The first step in data cleaning was to standardize all variables between the two time periods/datasets. Next, coordinates were checked for consistency among coordinate system (latitude longitude versus MA state plane, etc.). For every record, observation date was examined and split into date and year. Not all records provided a date of mortality observation. For these records, the time stamp was used to generate ‘year’. For records that reported a range of dates (i.e., From 5 May through 1 June I saw…) the first date mentioned was used as the observation date. Comments that the observed animals was alive or dead were not separated out, as the location reported is assumed to reflect a wildlife crossing regardless of success, and all observations are generically referred to as “mortalities” throughout this report.

Many records reported several species within the same report entry, so these records were duplicated and each species listed became its own data entry. Additionally, many of the counts entered into the “Count” field of the data entry form did not match narrative information provided in the comment field. If no count was entered into the “Count” field or comment box, the count was assumed to be one individual animal. If count provided was 1 and comment read ‘Saw three turkeys dead’ then count was adjusted to match the count given in the comments. Other assumptions made in determining counts include assigning a numerical value to quantity descriptors; the following was assumed: ‘dozens’=24, ‘few’ or ‘some’=3, ‘endless’=50, ‘a lot’=10, hundreds=’200’, ‘numerous’ or ‘several’ or ‘many’ = 5, ‘multiple’=2. Lastly, in the Amphibian Crossing dataset, count data reported prior to 2015 formatted as a date in the output dataset. We assume that observers were reporting count live/count dead or vice versa, and excel assumed a date based on the entry format (i.e. excel reads 3/21 as March 21). These entries were adjusted by adding the first and second numbers together for a total count value (e.g., 3/21/2010 = 3+21 = 24).

After cleaning the data, several additional modifications were made to finalize the three LLMW datasets for analysis. Initially, nearly half of the records reported in the Amphibian Crossing dataset were missing spatial locations, so coordinates were estimated using GoogleMaps based on street names and other location data provided. (A geographic position was unattainable for only one record using this method.) Additionally, the following types of records were removed from the datasets:

- Data with observation dates prior to 2007 were deleted (four records)
- Data with fields marked as 'TEST' were deleted
- Data reported for insects was deleted
- Duplicate records, based on identical observer, location, species, count, and comments, were removed. (Duplicates between datasets were assumed not to exist.)
- Records with a count of 0 were removed.
- Species submitted to the Vernal Pool Amphibian and Turtle Mortality datasets that did not belong to the respective category were moved to the General Wildlife dataset

MassDOT Mortality and Crash Portal Datasets

The MassDOT Mortality and Crash Portal datasets, described in Sections 1.3.1 and 1.3.2, respectively, were also processed for analysis, including basic quality control. We removed duplicate records and records, and generated a locational tag for the MassDOT Mortality data derived from the mile marker, town, and direction (northbound, southbound, etc.) information provide in the record. Each Crash Portal data record included a location defined by State plane coordinates.

Mapping

Each data record with a valid location tag from all data bases was mapped based on its x, y coordinates using ArcView 10.4. Roughly four percent of all General Wildlife records, about eight percent of all Turtle Mortality records, and about two percent of all Amphibian Crossing records did not have an adequate locational tag and could not be mapped. Any record that fell outside of the state of Massachusetts was deleted. About 22% of the MassDOT Mortality records included sufficient information to generate a location tag and could not be mapped, but nearly all (99% +) of the Crash Portal data could be by mapped

Subsequent mapping tasks varied by dataset, but included creating visuals displays of results aggregated by town, mapping actual locations of observed mortalities and creating surface to show distribution of mortalities along roadways. These surfaces were created using ArcView's Point Density tool, which divides a map into cells, then calculates the density of point features (mortalities for the purposes of this analysis) around each cell. The user defines the cell size, as well as the size of the "neighborhood" around each cell that should be search for features. Conceptually, after the neighborhood is defined around each cell center, the number of points that fall within the neighborhood is totaled and divided by the area of the neighborhood. For the maps generated for this report the cell size was 0.25 miles square, and the neighborhood was 0.5 miles. All maps are included in Appendix A, and referenced as figures in Section 3.0.

2.2 LLMW General Wildlife, MassDOT Mortality, and Crash Portal Data

To summarize the General Wildlife data, the 79 unique wildlife species (including 34 species of bird) reported from 2010 to 2017 (Table B-1, Appendix B) were combined into 31 categories based on higher taxanomic orders and general similarity, consisting of: amphibian, bear, beaver, bird, bobcat, canine, coyote, deer, domestic dog, fisher, fox, frog/toad, housecat, mink, moose, muskrat, opossum, otter, porcupine, rabbit/hare, raccoon, salamander, skunk, small mammal (rodents, mice, voles), snake, squirrel/chipmunk, turtle, unidentified mammal, unknown, weasel, and woodchuck (Table B-2, Appendix B). These groupings assume that observers accurately identified the species reported, unless the reports species was improbable for the state, based on its known range and distribution (e.g., badger, wolf). Improbable species were modified to 'Unknown'. 'Unknown' was also used when no species was provided or when a species was selected but overwhelming uncertainty was presented when discussing the observation in the comment field.

The MassDOT Roadkill reports were limited to larger animals and consisted of the following species: bear, bobcat, coyote, deer, fisher, fox, moose, other, and otter. The Crash Portal data was reported as either "deer" or "other", and were divided in to these two categories. After the data were processed for each of these three datasets, we calculated basic summary statistics regarding the number of species, animals, and reports by year.

To identify hotspots, we used ArcMap to assign all the records from the LLMW General Wildlife, MassDOT Roadkill, and Crash Portal datasets to the nearest roadway mile post. Mile posts are a logical way of locating hotspots, as MassDOT uses mile markers to locate all types of roadway infrastructure and projects. Mortalities were assigned to the nearest mile marker based on their location tag and a one-half mile buffer merge. Any record outside of the one-half mile buffer was deleted. All of the MassDOT mortality data, about 72 percent of the Crash Portal data, and about 70 percent of the General Wildlife data met the one-half mile buffer standard. We assigned each record to its closest whole mile post, (e.g., 1.0, 2.0, 3.0, etc.), ignoring the tenth of a mile posts (e.g., 1.1, 1.2, 1.3, etc.). The data in each dataset were maintained separately, not combined. We obtained the mile post locations from MassGIS. The mile post locations are a statewide point data layer, developed by MassDOT's Office of Transportation Planning GIS Services group, and represents milepost locations on numbered routes (Interstate, US and state highways) throughout the state. After each record was assigned a mile marker, the number of animal observations associated with each mile marker was counted, and the mile markers with highest number of records were identified, for each of the three datasets. The hotspot locations identified by the MassDOT Mortality and Crash Portal datasets were then compared.

2.3 Vernal Pool Amphibian Road Mortality Database

After all the records were cleaned and standardized, we calculated basic summary statistics regarding the number of species, animals, and reports by year, then mapped each location where amphibians were reported on a roadway. We symbolized the mapped locations to reflect the number of animals reported.

2.4 Turtle Road Mortality Database and Monitoring Program

After all the records were cleaned and standardized, we calculated basic summary statistics regarding the number of species, animals, and reports by year, then mapped each location where amphibians were reported on a roadway. We symbolized the mapped locations to reflect the number of animals reported.

2.5 Volunteer Participation

In addition to analyzing the mortality data, we looked at volunteer participation by dataset and across years. We calculated basic summary statistics regarding the number of volunteers participating and the number of reports per volunteer, by database. We also summarized the distribution of volunteers by town for each database so that information on rates of reporting can be inferred, and mapped the number of volunteers by town to visually illustrate the effect of volunteer participation on the amount of data collected.

3. Results

3.1 LLMW General Wildlife, MassDOT Mortality, and Crash Portal Data

Summary Statistics and Species Summaries

From 2010 through September 2017, 2,036 reports of 2,665 individual animals observed on Massachusetts roads were submitted by 312 different volunteers. The reports included 79 different species, assigned to 31 species groups, and are summarized in Table 1. From 2012 through August 2017, MassDOT personnel submitted records of 2676 animal carcasses, consisting of nine animal categories (Table 2). From 2007 through 2014, 13,521 collisions with animals (11,892 deer, and 1,629 'other animal' collisions) were reported to the Crash Portal database (Table 3). The distribution of all wildlife-road mortalities along primary roadways, based on each of these three data sources, is illustrated in in Figures A-2, A-3, and A-4 (Appendix A) for visual comparison. The locations where mortalities of species of medium to large sized mammals, excluding deer, were reported in the LLMW General Wildlife and MassDOT Mortality datasets are illustrated in Figures A-5, and A-6 (Appendix A), respectively.

Table 1. General Wildlife data - summary of species and mortality counts reported, by year. Species of interest to MassWildlife are highlighted in gray. Includes all records, including those that could not subsequently be mapped due to insufficient locational information.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	Totals	Percent
Amphibian		37	262	33	2					334	12.5 %
Bear		1	1	1	3		2	1	1	10	0.4 %
Beaver	1	28	17	6	9	2	4	5	2	74	2.8 %
Bird		43	44	45	30	17	14	15	65	273	10.2 %
Bobcat		2	3	1		1		2	2	11	0.4 %
Canine				2						2	0.1 %
Coyote		5	12	3	4			2	3	29	1.1 %
Deer		9	22	10	7	2	8	2	13	73	2.7 %
Domestic dog			1	2						3	0.1 %
Fisher		6	8	5	2		1		8	30	1.1 %
Fox		16	16	7	5	1	2	1	5	53	2.0 %

	2009	2010	2011	2012	2013	2014	2015	2016	2017	Totals	Percent
Frog/Toad	2	102	28	28	30	24	27	0	3	244	9.2 %
Housecat		1	4	3	3	1				12	0.5 %
Mink		8	10	4	2	1	9	2	8	44	1.7 %
Moose		2		1						3	0.1 %
Muskrat		13	3	3	4		3			26	1.0 %
Opossum		23	16	51	34	8	3	5	4	144	5.4 %
Otter	1	2	3	3	1			2	2	14	0.5 %
Porcupine		11	6	4	7	3	1	2	3	37	1.4 %
Rabbit/Hare	2	5	9	43	22	4	6	6	4	101	3.8 %
Raccoon		47	26	36	27	2	10	10	10	168	6.3 %
Salamander		1	4	1		2			11	19	0.7 %
Skunk		17	7	9	13	1	7	4	4	62	2.3 %
Small mammal		15	5	5	4	2	1	1	3	36	1.4 %
Snake	3	24	35	31	10	6	5		5	119	4.5 %
Squirrel/Chipmunk		57	44	186	57	21	20	34	5	424	15.9 %
Turtle	5	32	17	15	19	1	7	10	31	137	5.1 %
Unidentified mammal		13	2	7	1		2			25	0.9 %
Unknown		6	34	39	24	8	1		6	117	4.4 %
Weasel		10	1	3	1		1		3	19	0.7 %
Woodchuck		2	1	8	5	1	2	1	2	22	0.8 %
Total	14	538	641	595	326	108	136	105	202	2665	100 %

Table 2. MassDOT Mortality data, number of carcasses recorded by year. Species of interest to MassWildlife are highlighted in gray. Includes all records, including those that could not subsequently be mapped due to insufficient locational information.

	2012	2013	2014	2015	2016	2017	Total	Percent
Bear	3	5	5	9	13		35	1.3%
Bobcat	1				4		5	0.2%
Coyote			15	33	52	2	102	3.8%
Deer	22	130	237	306	366	9	1070	40.0%
Fisher			2		2		4	0.1%
Fox	2	2	8	18	24	1	55	2.1%
Moose		2	5	3	4	2	16	0.6%
Other Animal	39	260	302	319	428	39	1387	51.8%
Otter					2		2	0.1%
Total	67	399	574	687	895	52	2,676	100%

Table 3. Crash Portal data, number of animal vehicle collisions, by year. Essentially all data had a valid location tag and could be mapped.

	2007	2008	2009	2010	2011	2012	2013	2014	Total	Percent
Collision with animal – deer	975	1,218	1,286	1,317	1,500	1,621	1,941	2,084	11,892	88%
Collision with animal - other	160	184	170	193	206	228	241	252	1,629	12%
Total	1,135	1,402	1,456	1,510	1,706	1,849	2,182	2,336	13,521	100%

Distribution of Mortalities

As illustrated in Figures A2, A3, and A4, all three of these datasets show high crash densities around Boston but not within Boston, in the Pioneer Valley, and in the Southeastern part of the State, but even within these broad similarities, there is substantial variation. The General Wildlife data shows high densities of mortality along Route 3/495, Route 202, and Interstates 90 and 91. The towns with the highest mortality counts include Northampton, Franklin, and Barnstable. As discussed in Section 3.4, the number of volunteers making reports in a town or along a particular section of road likely has a strong influence on the number of mortalities reports at a particular location.

DOT Mortality data show high rates of mortality along I-495 and I-95, I-91 near Chicopee, and on SR 202 near Athol. Towns with the highest mortality counts include Southampton, Dedham, and Wellesley. The Crash Portal data mapping shows AVCs primarily in the central, and especially the eastern extent of the state. The towns with the highest mortality counts during the study period were Middleton, Westport, and Rehoboth. The towns with the highest crash count from animals other than deer were in Fall River, Worcester and Blandford.

Mortality Hotspots

Wildlife mortality hotspots along roadways may represent locations where roads interfere with landscape connectively for wildlife and /or locations with an elevated risk of wildlife-vehicle collisions. Because the General Wildlife data represents the widest variety of wildlife species, including many smaller species, the hotspots identified by this data set may be more representative of connectivity conflicts, rather than safety conflicts. To understand connectivity issues that the General Wildlife data set hotspots might represent, further examination of the species represented in the hotspot, and the features of the surrounding landscape (e.g., streams, valleys or ridgelines that can act as travel ways, habitat types) would be necessary. This type of analysis was beyond the scope of this report.

The MassDOT Mortality data and the Crash Portal data reflect mortality of larger species, and while these data may represent connectivity conflicts, these two data sets also represent safety conflicts. We identified this type of potential hotspot by examining the number of mortalities along roadway segments throughout the Commonwealth. Roadway segments were defined by town boundaries, as the MassDOT Mortality data was recorded in this fashion. Future data collection efforts by MassDOT maintenance personnel will include a more precise locational tag, which will allow these data to be tied to specific mile markers, as can be currently done with the Crash Portal data.

The definition of a hotspot is somewhat arbitrary in nature, as discussed in Section 4.1. For this example, we wanted to consider the information provided by both data sets. We used a definition of 11 or more mortalities recorded for a MassDOT Mortality road segment, where that roadway segment also contained a mile marker with a count of 11 or more recorded Crash Portal mortalities. Mile marker counts are the number of mortalities within 0.5 miles of either side of the mile marker. Sixteen roadway segments meet both standards, with four high mortality areas identified on I-495, and two on SR 2 (Table 4). Choosing a different definition would produce different results. Examining roadways for hotspots using and comparing multiple approaches is recommended, especially when information from multiple data sets is available.

Table 4. High mortality areas, defined as town roadway segments with 11 or more mortalities recorded for the MassDOT Mortality data set, and containing a mile with 11 or more Crash Portal mortalities. Total mortality per segment from each data set is reported.

Route	Town	Mortality Count (Crash Portal, MassDOT Mortality)
SR70	Boylston	28, 13
I95/SR128	Dedham	31, 12
SR146	Douglas	16,16
SR30	Framingham	32, 13
SR2	Gardner	31, 13
I91	Greenfield	48, 13
I495	Hopkinton	30, 29
I495	Marlborough	28, 11
I495	Milford	35, 11
I395	Oxford	43, 18
SR2	Templeton	40, 16
SR9	Wellesley	40, 13
I495	Westford	33, 15
SR110	Westford	34, 12
SR109	Westwood	38, 15
US20	Wilbraham	39, 16

3.2 Amphibian Crossing Mortality Database

From 2010 through 2017, 1,920 individual vernal pool amphibians were observed crossing or deceased on Massachusetts roads, at 48 separate locations. The number of individuals observed at each location ranged from 1 to 379 (average = 22), and these reports were submitted by 35 different volunteers. The reports included four different amphibian species, and are summarized in Table 5. The overall effort applied to amphibian monitoring and results are summarized in Table 6. The locations of reported vernal pool amphibian mortality are illustrated in Figure A-7 (Appendix A).

Table 5. Summary of amphibian species reported in the Amphibian Crossing database, by year. Listed species are highlighted in gray. Includes all records, including those that could not subsequently be mapped due to insufficient locational information.

Group	Species	2009	2010	2011	2012	2013	2014	2015	2016	2017	Totals
Frog/Toad	Spring Peeper		11		23	3		178	5	138	358
	Wood Frog		161	509	89	11		76		42	888
Salamander	Jefferson-Blue spotted salamander	1	6	71	1					4	83
	Spotted salamander	41	205	225	39	14	3	31	12	51	621
	Total	42	383	805	152	28	3	285	17	235	1,950

Table 6. Summary of Amphibian Crossing reporting effort.

	Number of Locations	Number of unique Species	Number of Individual animals	Number of People Submitting Reports
2009	1	2	42	1
2010	15	4	383	13
2011	15	3	805	11
2012	2	4	152	2
2013	5	3	28	4
2014	2	1	3	1
2015	4	3	285	4
2016	1	2	17	1
2017	3	4	235	2
Total	48	4	1,950	35

3.3 Turtle Mortality Database and Monitoring Program

Overall Summary

From 2010 through 2017, 1,775 individual turtles were observed crossing or deceased on Massachusetts roads, at 483 separate locations. The number of individuals observed at each location ranged from 1 to 53 (average = 2), and these reports were submitted by 229 different volunteers. The reports included ten different turtle species, and are summarized in Table 7. The locations of reported turtle mortality are illustrated in Figure A-7 (Appendix A).

Table 7. Summary of turtle species reported in the Turtle Mortality database by year. Species of interest to MassWildlife are highlighted in gray. Includes all records, including those that could not subsequently be mapped due to insufficient locational information.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	Totals	Percent
Blanding's turtle			12	1			1	4		18	1.0%
Diamondback terrapin			5							5	0.3%
Eastern box turtle		19	4	20	1				1	45	2.5%
Musk turtle		8	10	7	4		1			30	1.7%
Painted turtle		330	360	122	43		68	34	3	960	54.1%
Red-bellied cooter			1							1	0.1%

	2009	2010	2011	2012	2013	2014	2015	2016	2017	Totals	Percent
Red-eared slider turtle		2		7						9	0.5%
Snapping turtle	2	101	127	99	44		9	2	1	385	21.7%
Spotted turtle	1	25	38	16	15		3	3		101	5.7%
Unidentified turtle		57	98	44	3		1			203	11.4%
Wood turtle	1	7	4	1	3		2			18	1.0%
Total	4	549	659	317	113	0	85	43	5	1,775	100%

Summary of Structured Monitoring

The online data form provided by the Turtle Mortality data entry portal does not include a tag/field to differentiate between a record entered for an opportunistic one-time observation, as compared to a single survey made at a location assigned for the structured monitoring program. Based on coordinate locations for records submitted to the Turtle Mortality database, less than twenty percent of total sites reported had repeat visits (Table 8). Furthermore, only twelve locations were surveyed two years in a row. Of these twelve, three locations were visited two times total over two years, five sites were visited three times over two years, two locations were visited four times over two years, and two locations were visited five times over two years. No locations were visited more than two years. Eight of the twelve sites had sequential year visits that occurred in 2011 and 2012.

Table 8. Summary of turtle monitoring efforts by coordinate location.

Year	Number of locations with 1 visit	Number of locations with 2 visits	Number of locations with 3 visits	Total number of locations monitored	Percent of locations with repeat visits
2009	4	0	0	4	0%
2010	102	15	2	119	14%
2011	178	27	18	223	20%
2012	82	13	6	101	19%
2013	32	2	3	37	14%
2014	0	0	0	0	0%
2015	11	8	4	23	52%
2016	8	0	1	9	11%
2017	1	0	1	2	50%

3.4 Volunteer Participation

The public has been invited to submit road mortality observations to the LLMW website through the MassWildlife newsletter, through conservation organization listservs, and during presentations at conferences and other professional meetings. Program participants include state and independent biologists, members of conservation and watershed organizations, and citizen scientists.

Volunteer participation is summarized in Table 9 by year and by dataset. Participation was highest across all citizen science datasets in 2010 and 2011. Across all analysis years, each dataset had a few key volunteers who contributed a large percent of total data. In the General Wildlife dataset, two individuals contributed over 20 percent of all data (15 and 7 percent, individually). Although more equally distributed in level of effort, the Amphibian Crossing dataset had three observers who contributed about 30 percent of overall data (10-11 percent individually). The Turtle Mortality dataset had one individual who contributed about 10 percent of all data submitted. Two additional volunteers contributed an additional 11 percent (six and five percent, individually. All datasets had a lag in participation in 2014. Across all three citizen science datasets, 526 volunteers contributed data. Thirty volunteers reported information to two of the three datasets, and three observers contributed to all three. The number of participants by town, for each dataset, and the influence number of volunteers may have on number of mortalities reported, are visually depicted in Figures A-9 though A-11 (Appendix A).

Table 9. Volunteer participation by database and year.

Year	General Wildlife	Amphibian Crossing	Turtle Mortality	Grand Totals
2009	6	1	4	11
2010	72	13	71	156
2011	72	11	121	204
2012	64	2	62	128
2013	44	5	25	74
2014	6	1	0	7
2015	28	4	7	39
2016	24	1	2	27
2017	40	2	2	44
Total	**312**	**36**	**235**	**689**

4. Discussion

4.1 Data Limitations

While all the data sets examined for this report provided valuable information about wildlife/roadway conflicts, the limitation of these data should be kept in mind when considering the results, and comparing between them. First and foremost, these data sets were each generated from different levels of effort. The LLMW data were largely collected opportunistically and in a non-random, non-systematic fashion, although some systematic effort applied to the Turtle Mortality data set. Additionally, the volunteer effort varied substantially between data sets and across years (Table 9). The effect of this data collection approach on the distribution of data across the State us illustrated in Figures A-9, A-10 and A-11 (Appendix A). However, despite its limitations, the LLMW data provides valuable insight into specific locations, and for uncommon species that are overlooked in the other two data sets.

MassDOT maintenance personnel drive roads in a more systematic fashion the general public, but their coverage may be influenced by other the need to conduct other maintenance activities, and to date, their reporting effort has also varied.

The Crash Portal data is systematically collected across the entire state, and provides almost eight times more data than all LLMW data combined, and about six times more data than the MassDOT Mortality dataset. Because of the wealth of data and because the reporting structure for this data set is the most standardized, it likely provides the most accurate reflection of wildlife/roadway conflicts across the state. However, nearly 90% of the data represents deer, which may or may not be a good proxy for other species, as discussed below. Additionally, reporting rates may also be somewhat inconsistent across the Commonwealth, as smaller police forces, more common in the western part of the state, may be less likely to submit reports for non-severe animal vehicle collisions due to manpower and budgetary issues.

Additionally, although Crash Portal dataset is the most comprehensive data currently available, it is not free from biases. Table 3 shows an increasing trend in deer mortalities from 2007 to 2014; however this trend is likely a function of improved reporting practices, as during this time period more jurisdictions likely placed technology in law enforcement vehicles, allowing officers to make immediate reports, and communications coverage likely improved to cover the state more evenly. Also, the incidents reported to the Crash Portal system are only those severe enough to require the involvement of law enforcement. Many animal-vehicle collisions do not generate a police report, as evidenced by comparisons to insurance reports. State Farm Insurance publishes an annual report of deer vehicle collision claims made to it (https://newsroom.statefarm.com/deer-collision-damage-claim-costs-up), reporting 10,750 claims in 2014/15 and 7,500 claims in 2015/16 for the Commonwealth. Even though they are from different years, the claim numbers clearly appear to represent an order of magnitude difference from police reports. It is also noteworthy that the 2015-2016 report for deer collisions is 30.2% less than the 2014-2015 report. Also of note, the State Farm report compares the number of claims filed to the number of licenced drivers, by state, and based on this comparison, Massachusetts has one of the lowest risks of deer-vehicle collisions in the United States.

4.2 LLMW General Wildlife, MassDOT Mortality, and Crash Portal Data

Comparisons among Data Sets

The General Wildlife, MassDOT Mortality, and Crash Portal databases all show high mortality rates around Boston, but not within Boston itself. This pattern is expected as development in the Boston area has consumed most wildlife habitat, while the surrounding landscapes are a mix of suburban and exurban development that continues to support habitat suitable for a variety of wildlife species, especially deer. Additionally, the roads in the Boston area experience high traffic volumes. All three databases also show high mortality rates in the Pioneer Valley and in the Southeastern part of the State, but there is substantial variation within these areas as well as in the rest of the state. This variation is expected as the level and type of effort (random vs. systematic) used to collect data for the three datasets is different, as discussed above, and the species of animals represented are also different (Table 1, 2 and 3).

The General Wildlife dataset is dominated by smaller wildlife species including opossum, squirrels, and chipmunks (28% of records), and 10% of records are avian species, which are not represented at all in the other two datasets. Additionally, only 2.7% of the General Wildlife records are deer while 88% and 40% of the Crash Portal and MassDOT Mortality data are deer, respectively. It is not surprising that the General Wildlife dataset is biased towards smaller species, and potentially towards more uncommon species as well. Safety or maintenance personnel are likely to rapidly remove large and/or common species (e.g., moose, deer, coyotes) from the roadway, so they are not available for citizen volunteers to observe, and citizen volunteers may make a special effort to report smaller or rare species to keep them from being overlooked.

The level and type of effort that MassDOT maintenance personnel engage in to remove road-killed animals from the roadway needs to be defined in order to determine the completeness of the MassDOT Mortality dataset. However, for the animals which maintenance personnel identify to species, this dataset may be the best representation of true location and species distribution of road-killed wildlife (Figure A-6, Appendix A). Intuitively, the distribution of species in the MassDOT Mortality dataset seems to match the relative numbers of those species expected across the landscape. Additionally, because maintenance personnel remove road-killed animals from the roadway, they have the best opportunity to record all carcasses, which is likely the reason that this dataset is a better source for moose mortality locations than the LLMW General Wildlife dataset (compare Figures A-5 and A-6, Appendix A).

Nearly 90% of the Crash Portal records represent collisions with deer. Deer may or may not be a good proxy for other species of wildlife. While other wildlife species may follow similar landscape features (e.g., streams, forest edges) to the roadway as deer, they do not necessarily have the same habitat preferences, and may use the landscape, including roadway crossings, differently. However, if the goal of reducing roadway/wildlife conflicts is also to improve human safety, mortality hotspots identified by the General Wildlife data set could be matched to hotspots identified by the Crash Portal data, particularly because the General Wildlife dataset includes so few deer.

Identifying Hotspots and Decision Making

Identifying a mortality hotspot is a complicated problem, as a 'hotspot' is based on perception and therefore has no objective definition. While a metric of comparison can be objectively defined (e.g., a "spot" with more mortalities than average or expected), there is still the issue of defining the size of the area that should be considered for analysis. Any approach that is used must approximate how someone would define a reasonable area of analysis, and is therefore subject to interpretation. Hotspot analysis falls into four broad categories, visual analysis of mapped data, density based measures, model based analysis, and spatial analysis methods. All approached have their pros and cons. No approach is inherently right or wrong, and applying multiple approaches is recommended by many authors.

For the purposes of this summary report, the hotspots listed in Table 4 (Section 3.1) were identified using an intuitive, but arbitrary, definition of a "high" number of mortalities (11 or more per mile). Mile-long segments of observation were chosen because they could conveniently be matched to mile markers. However, because hotspot identification is a complex task, additional consideration should be given to both the process of identifying hotspots, and how the hotspot information will be incorporated into transportation planning. For example, some mitigation measures (e.g., an underpass or expanded culvert) by their nature will be much shorter than a mile. Should this consideration change the size of hotspots analyzed? Or, should the mitigation be extended (e.g., by adding fencing) to cover the entire hotspot? Additionally, to help define both the size of the hotspot and the best type of mitigation, any hotspots identified needs further analysis to determine why they are "hot". Is there a large wildlife population at that location because of high quality adjacent habitat? Is there a landscape feature (e.g., stream, forest edge, ridgeline) that brings animals to the road side? Is there a combination of good habitat and high traffic volume? A holistic view of hotspot identification and understanding the area surrounding the hotspot will set the stage for designing the most effective mitigation measures.

Mortality data as an x,y coordinate location only provides partial information to determine the best locations to mitigate wildlife/roadway conflicts and reduce mortality. Complete information to support good decision making also requires understanding how animals are using the landscape to approach the roadside, and if there are key resources in the landscape that create extra incentive for animals to cross the roadway at certain locations. To support decision making, identified hotspots should be examined in the context of habitat characteristics and topographic information at the roadside scale and at a broader scale. This type of information can be collected initially using aerial imagery and other desktop data sources, followed by on-site observations in the field.

4.2 Amphibian Crossing Mortality Data Base

A total of 48 vernal pool amphibian crossing locations throughout Massachusetts were reported to the LLMW website over nine years. The number of animals observed at each location ranged from 1 to 379 (average = 22). This is a relatively small sample size upon which to draw conclusions from, especially considering the size of the Commonwealth. Given the small sample size and the non-systematic approach to collecting these data, it is difficult to determine how best to define an "important" crossing that should be prioritized for mitigation measures to facilitate crossing. Locations with listed species may be inherently of greater concern, but more information on the numbers of animals that are killed, and the variability in those numbers is needed in order to draw conclusions based on the number of animals observed.

However, all of these locations caught the attention of a volunteer who subsequently made the effort to report it to LLMW, which implies some level of uniqueness, compared to the surrounding landscape. All of these locations may warrant further investigation to examine the features that surround the crossing locations and the barrier effect created by the roadway to determine if mitigation is warranted in these locations. Over time, as more amphibian crossing data is collected and the variability surrounding reported numbers is better understood, this database may also provide a basis for understanding the importance of a crossing based on the number of animals observed.

4.3 Turtle Road Mortality Data Base

More information regarding MA NHESP's overall effort to identify turtle mortality hotspots through modeling and other evaluation efforts is need to understand how the data collected through the LLMW website can contribute to prioritizing locations for mitigation measures to reduce mortality. Additionally, to understand these data, it is essential to be able to differentiate between opportunistic "one-time" observations versus observations made and entered as part of the systematic survey program, even if only one visit to an assigned survey area was made.

5.0 Next Steps

The Linking Landscapes team is very grateful for the dedication and efforts provided by its contributors. The success of the partnership would not be possible without their support. The Summary Report has allowed us to review and analyze the data collected over the last seven years. During this time public awareness of the citizen science projects have grown and additional sources of data have become available. The most exciting aspect of the Summary Report is proposing actions and goals for the next seven years of Linking Landscapes for Massachusetts Wildlife.

An obvious need and interest is to create a more comprehensive data collection process that reduces bias. Therefore, MassDOT is currently working to deploy a wildlife collision collector application for smartphones/tablets, to reduce bias, simplify the reporting process, and improve reporting by District Maintenance personnel.

In addition to the development of the application, continued and increased public engagement will occur. This engagement will raise awareness of the citizen science projects as well as increase reporting and its distribution across the commonwealth.

Further evaluation of identified wildlife road morality "hotspots" is necessary. Given limited resources, research needs to be completed in a deliberate and efficient manner. The first step is to conduct a desktop level review of the "hotspots" that is then paired with rapid field assessments of existing site conditions and constraints. If warranted, the field assessments can include the deployment of remote wildlife cameras, tracking, and/or intensive road morality surveys. These efforts will allow us to determine if and what short/long term improvements are possible. Examples of short-term improvements can include signage to increase public awareness and fencing (where feasible). Long-term improvements conducted as part of future roadway improvement projects could include increased upland passage at stream and wetland crossings, installation of wildlife passage structures, and other road design measures that can increase public safety and habitat connectivity.

Where long term options exist, a dataset of locations will be created an entered into the MassDOT Project Intake Tool so that future MassDOT projects in the area can investigate improvements at the identified "hotspots". As new, less biased data become available in the future, the agencies will reassess the dataset(s) to identify and investigate any new potential hotspots.

Finally, we will continue to propose and implement road ecology research projects. The results from these projects will expand our understanding of transportation and wildlife interactions in Massachusetts. In order for this to be successful we will need to continue to work collaboratively towards the dual goal of improving public safety and the conservation of wildlife.

Appendix A – Figures

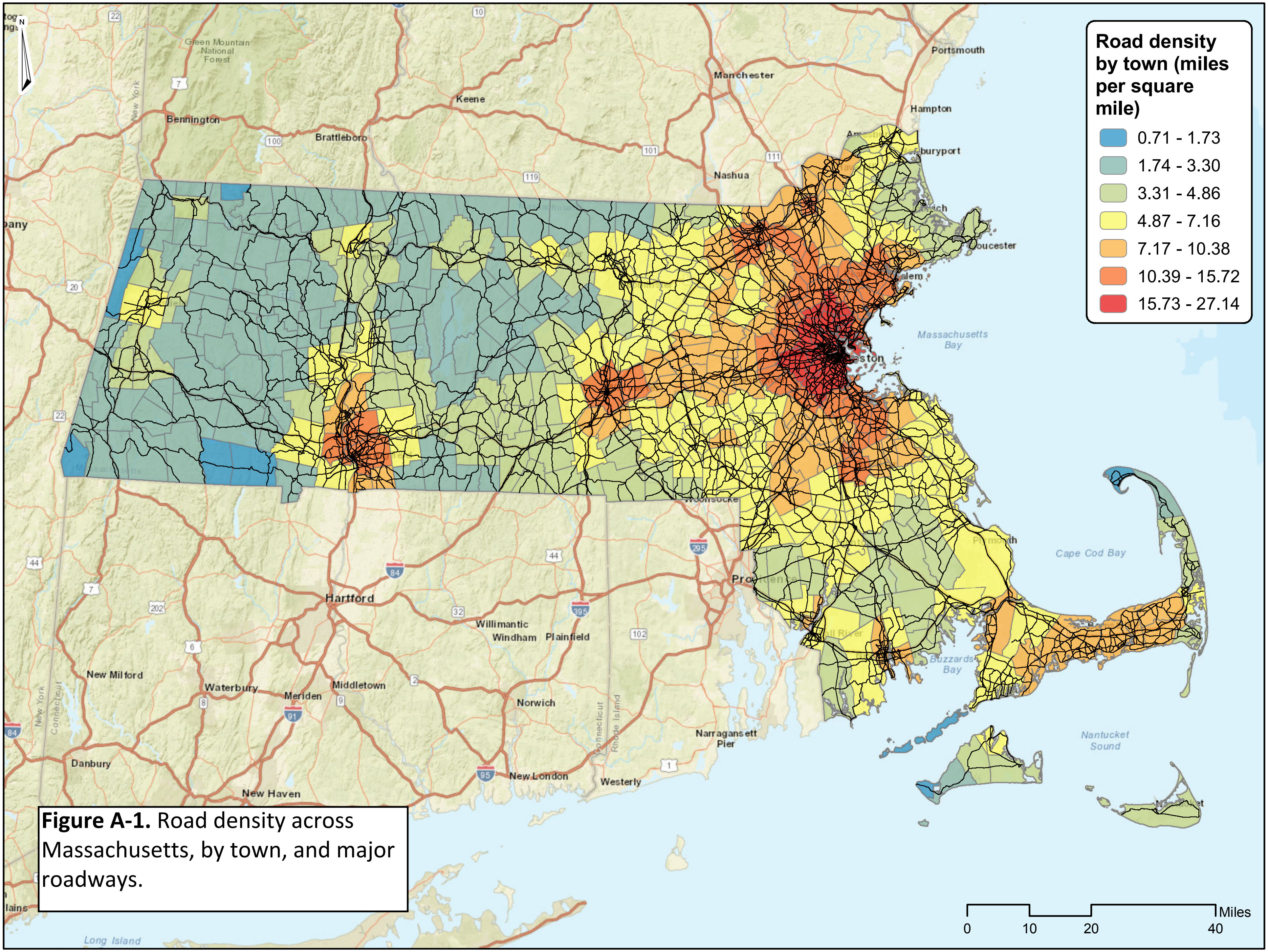

Figure A-1. Road density across Massachusetts, by town, and major roadways.

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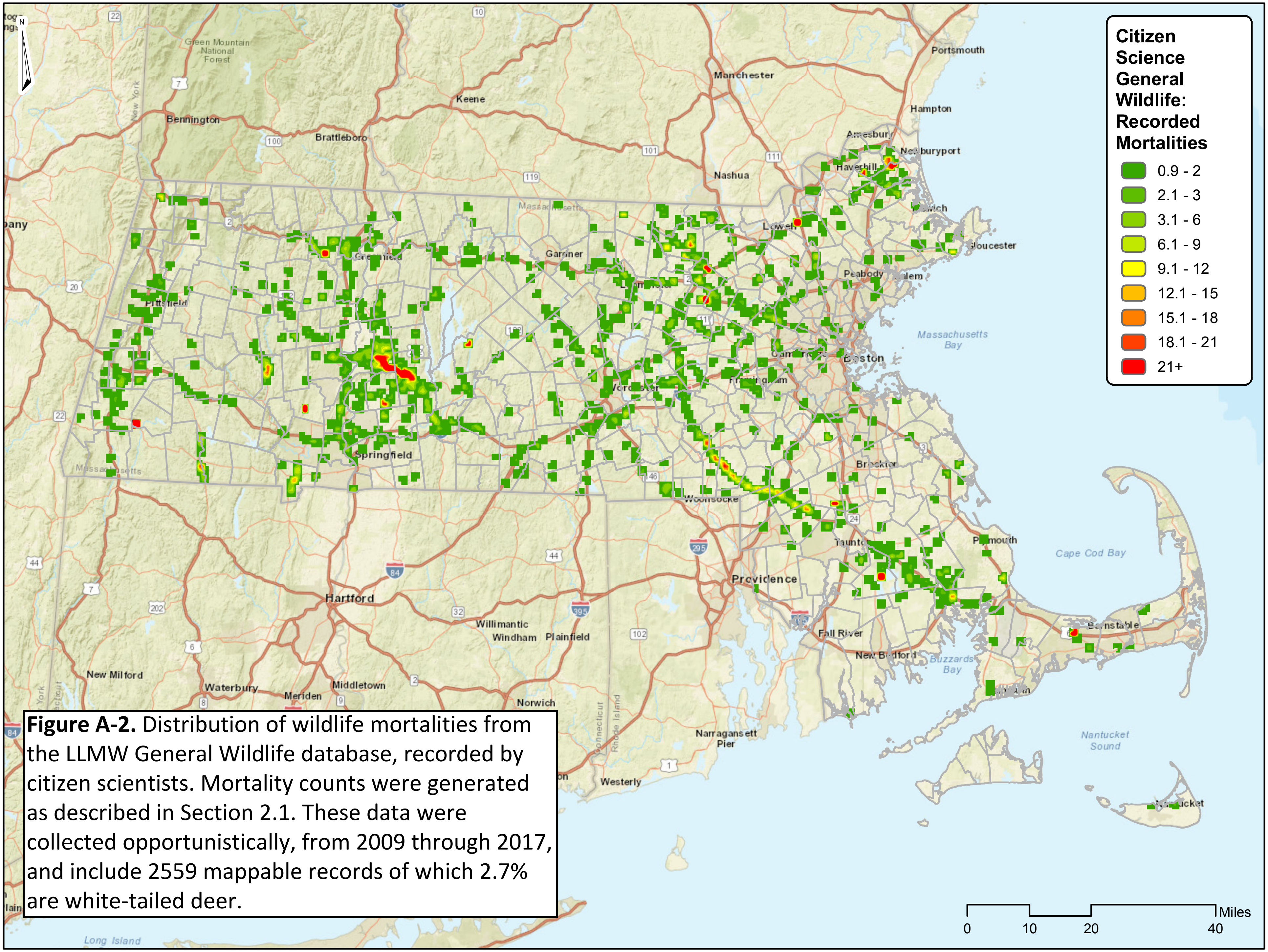

Figure A-2. Distribution of wildlife mortalities from the LLMW General Wildlife database, recorded by citizen scientists. Mortality counts were generated as described in Section 2.1. These data were collected opportunistically, from 2009 through 2017, and include 2559 mappable records of which 2.7% are white-tailed deer.

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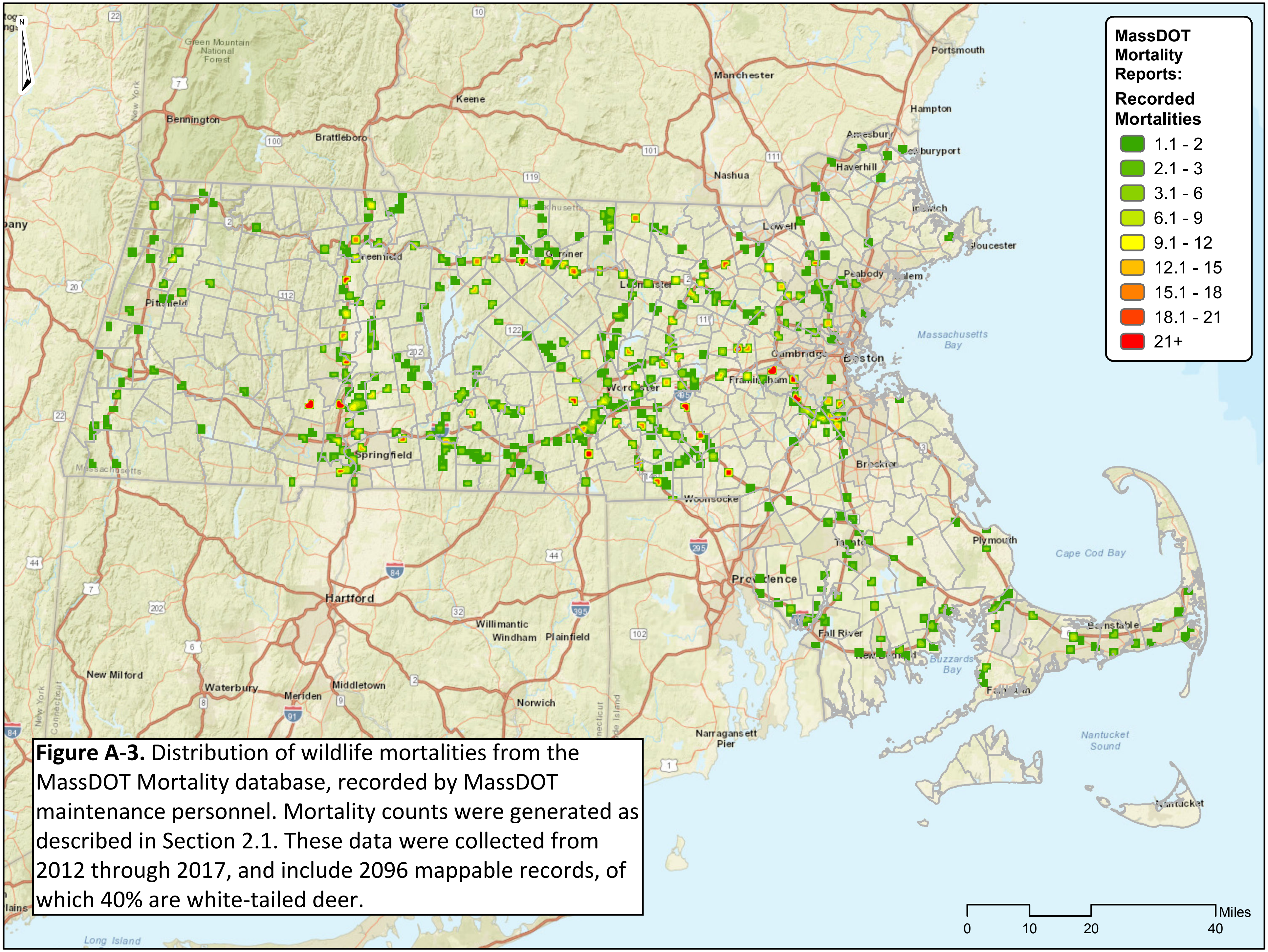

Figure A-3. Distribution of wildlife mortalities from the MassDOT Mortality database, recorded by MassDOT maintenance personnel. Mortality counts were generated as described in Section 2.1. These data were collected from 2012 through 2017, and include 2096 mappable records, of which 40% are white-tailed deer.

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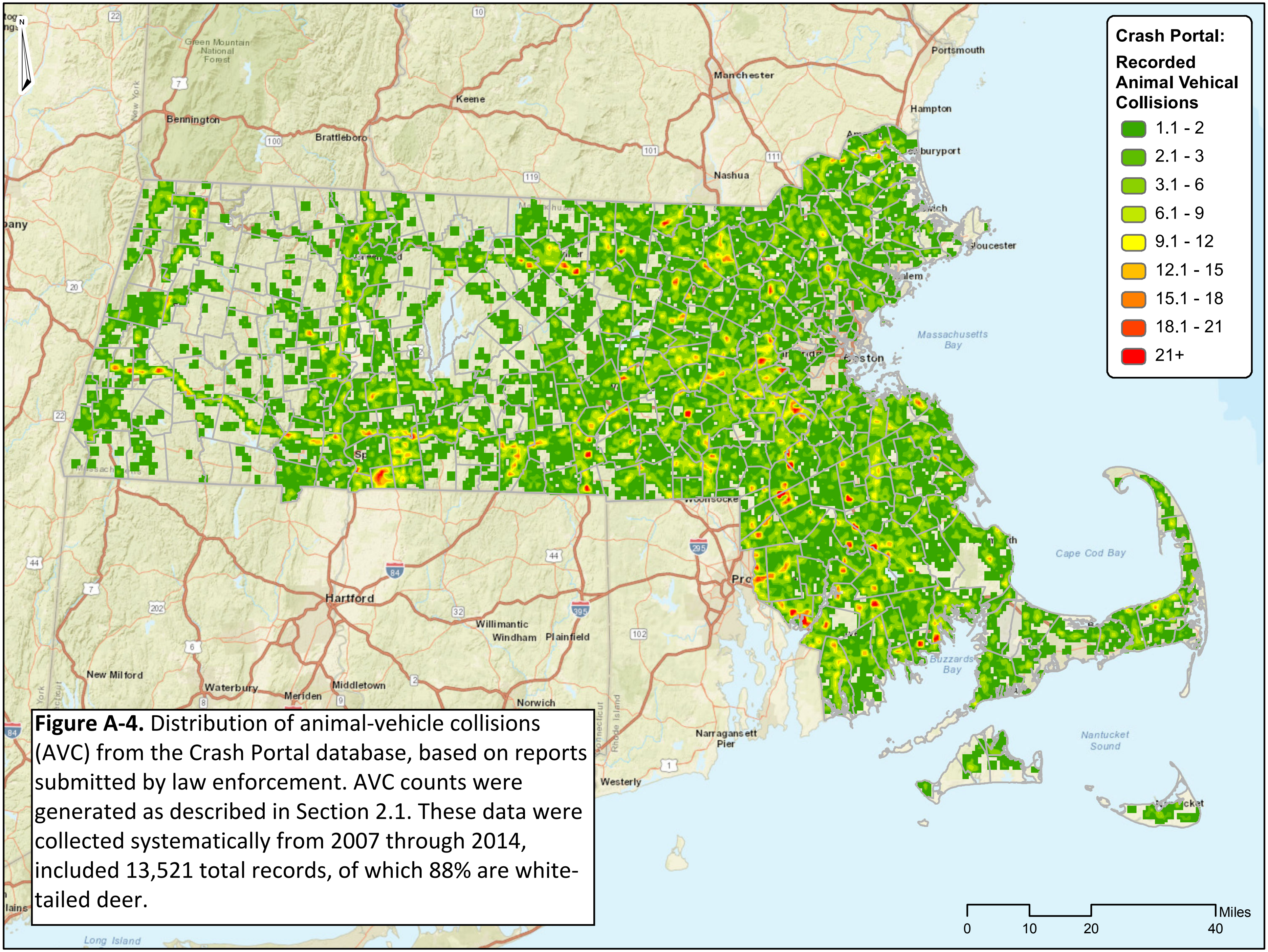

Figure A-4. Distribution of animal-vehicle collisions (AVC) from the Crash Portal database, based on reports submitted by law enforcement. AVC counts were generated as described in Section 2.1. These data were collected systematically from 2007 through 2014, included 13,521 total records, of which 88% are white-tailed deer.

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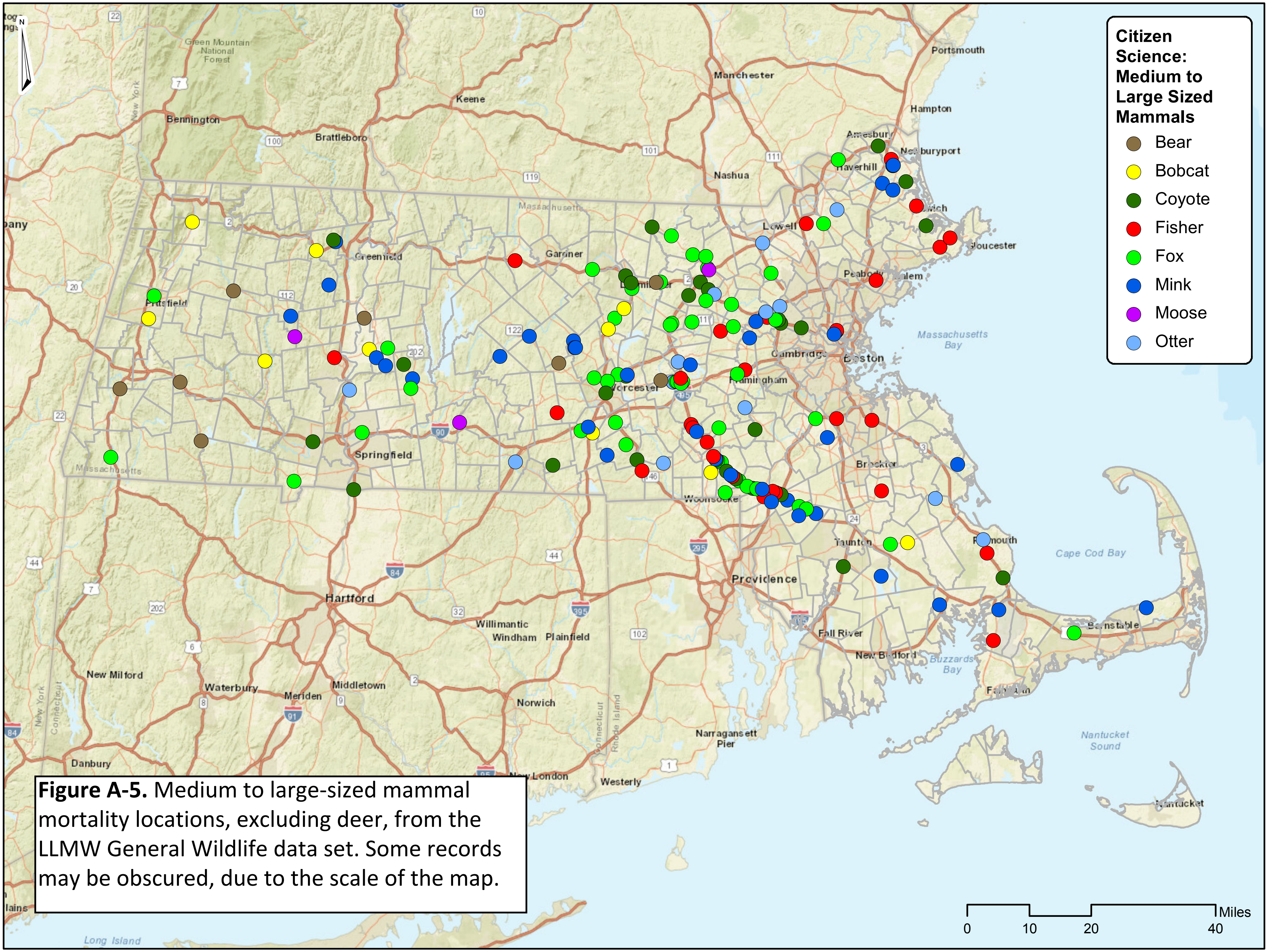

Figure A-5. Medium to large-sized mammal mortality locations, excluding deer, from the LLMW General Wildlife data set. Some records may be obscured, due to the scale of the map.

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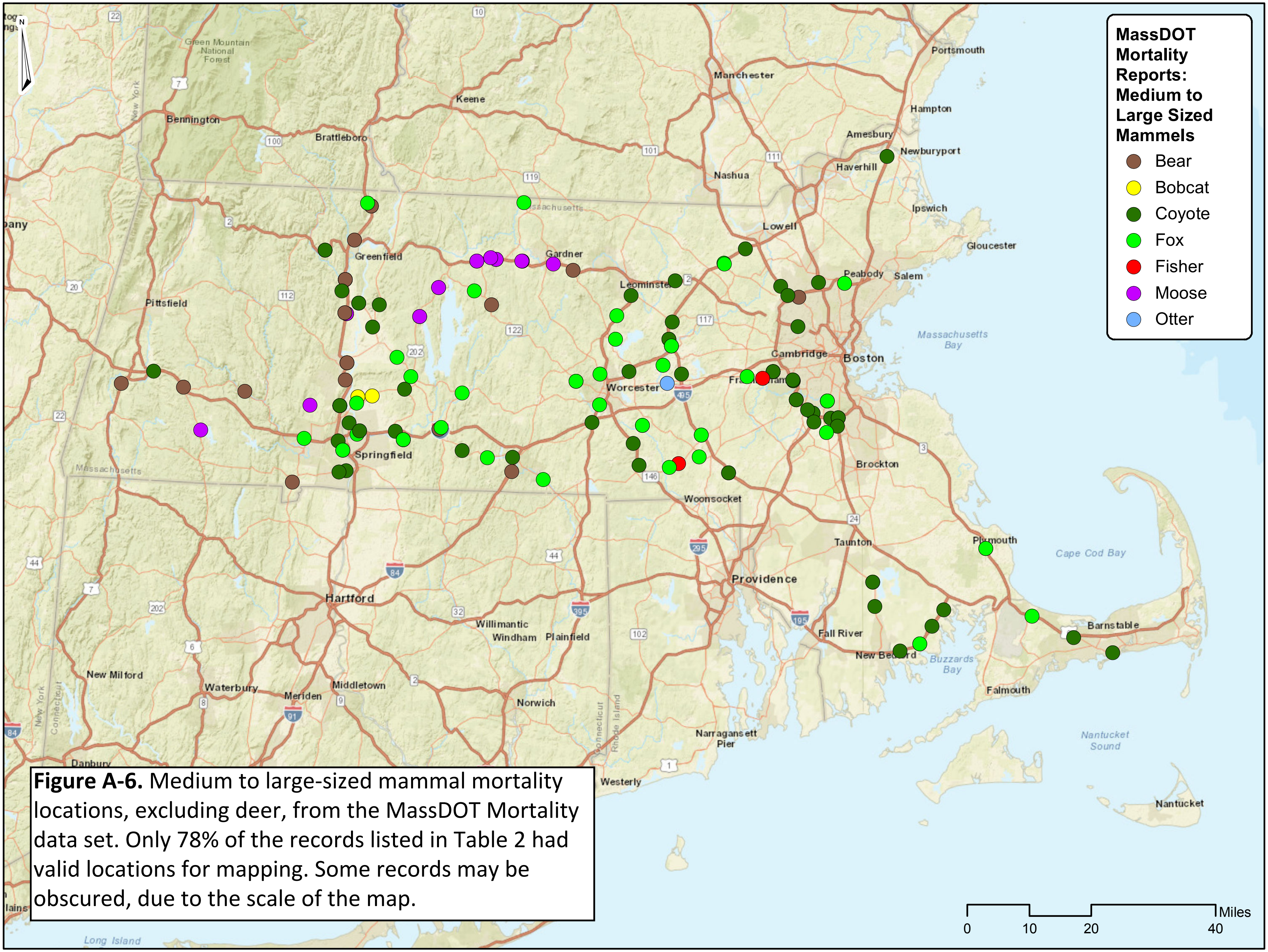

Figure A-6. Medium to large-sized mammal mortality locations, excluding deer, from the MassDOT Mortality data set. Only 78% of the records listed in Table 2 had valid locations for mapping. Some records may be obscured, due to the scale of the map.

G:\Projects\GIS_Projects_2017\MA_LinkingLandscapes\MXD\REV4\MA_DOTMortality_WildlifeLocations_121117.mxd

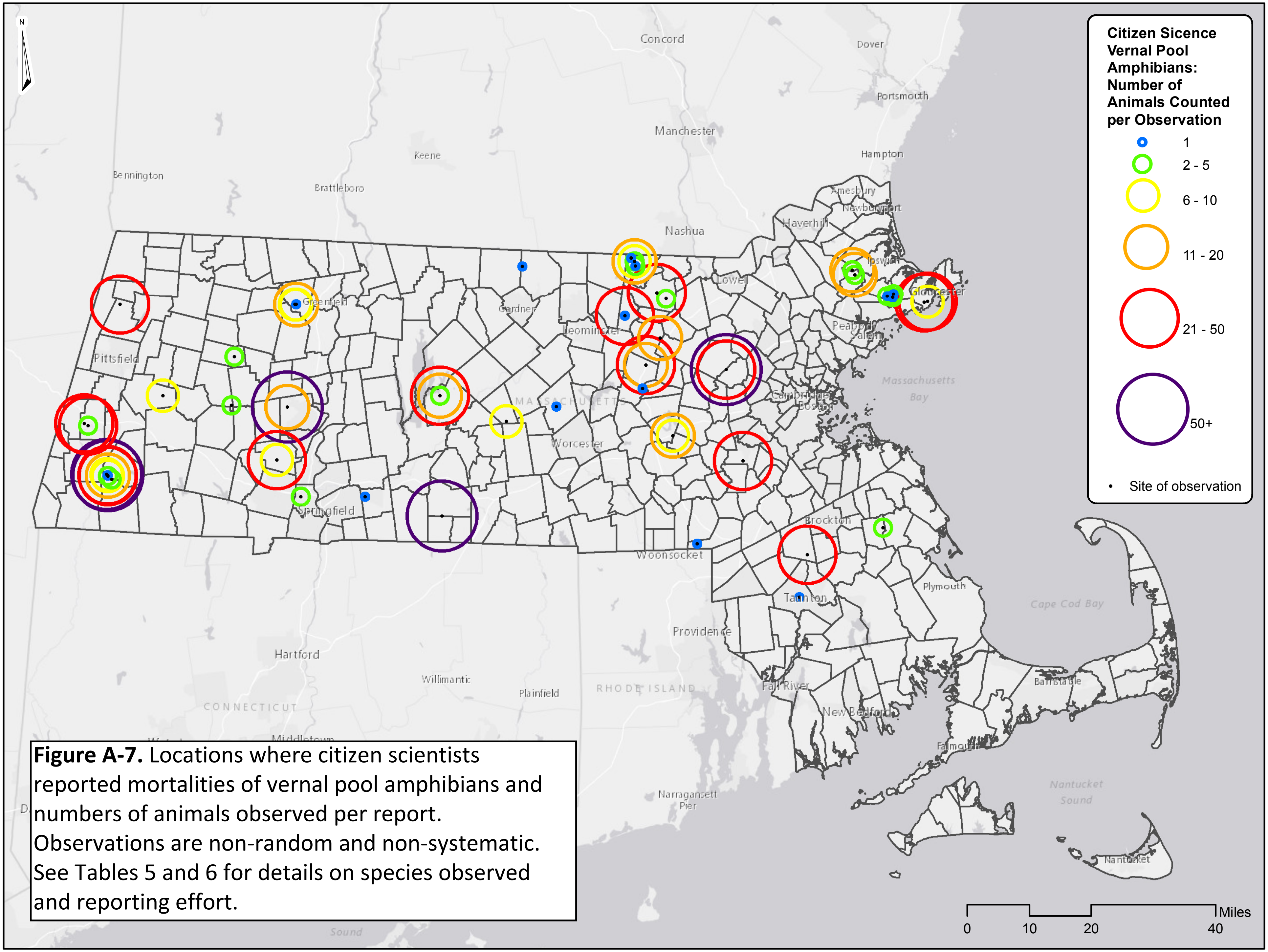

Figure A-7. Locations where citizen scientists reported mortalities of vernal pool amphibians and numbers of animals observed per report. Observations are non-random and non-systematic. See Tables 5 and 6 for details on species observed and reporting effort.

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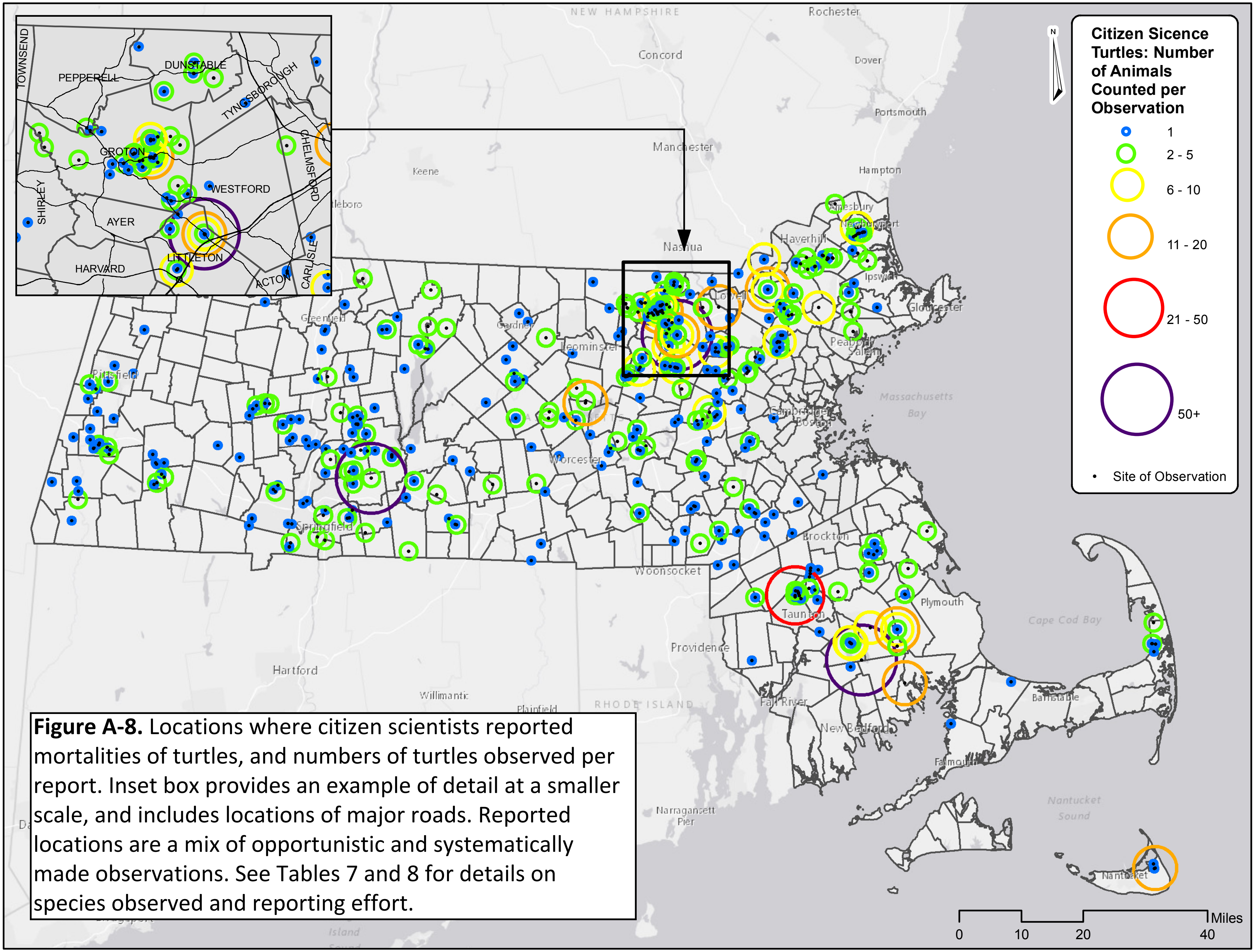

Figure A-8. Locations where citizen scientists reported mortalities of turtles, and numbers of turtles observed per report. Inset box provides an example of detail at a smaller scale, and includes locations of major roads. Reported locations are a mix of opportunistic and systematically made observations. See Tables 7 and 8 for details on species observed and reporting effort.

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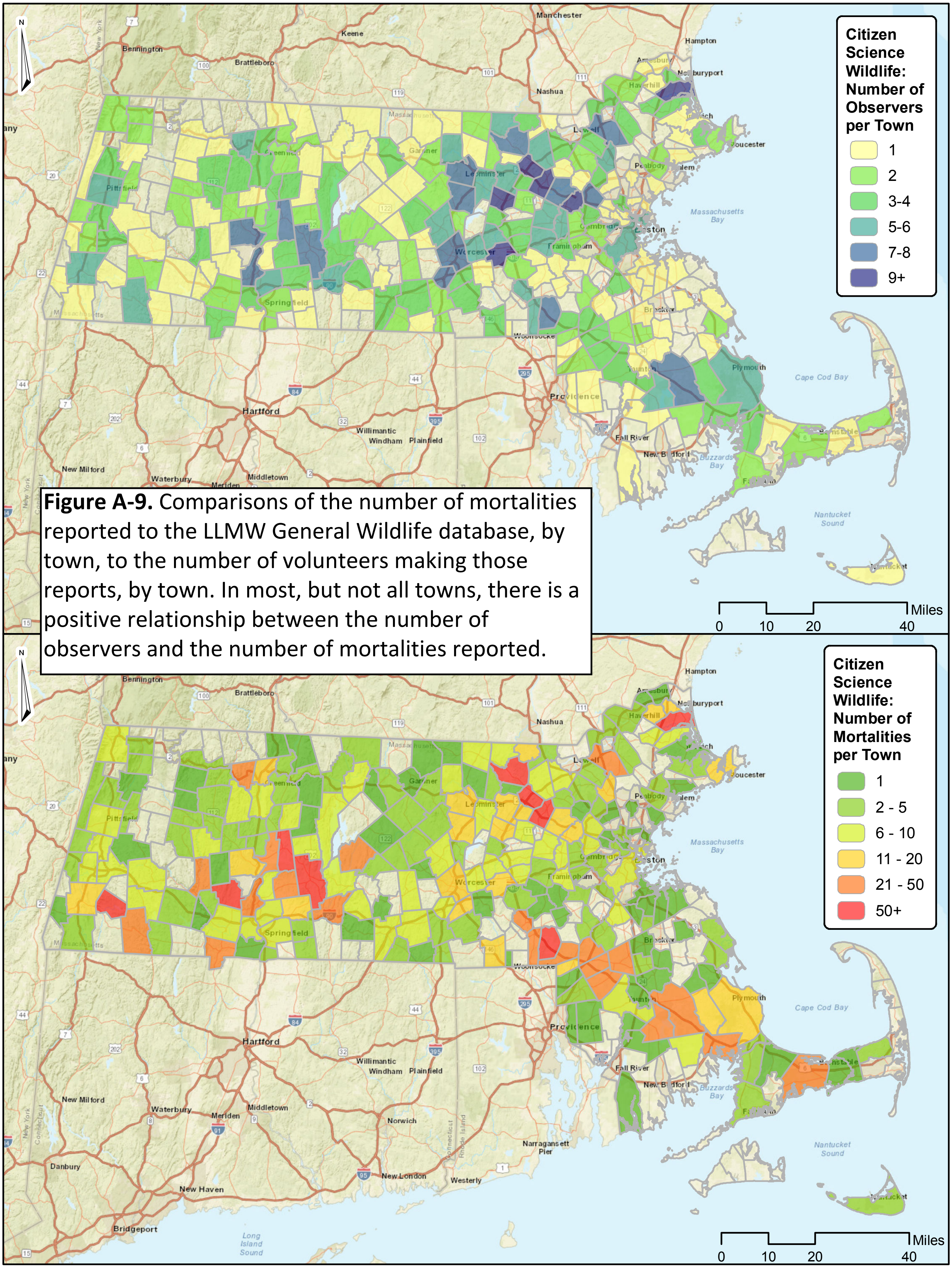

Figure A-9. Comparisons of the number of mortalities reported to the LLMW General Wildlife database, by town, to the number of volunteers making those reports, by town. In most, but not all towns, there is a positive relationship between the number of observers and the number of mortalities reported.

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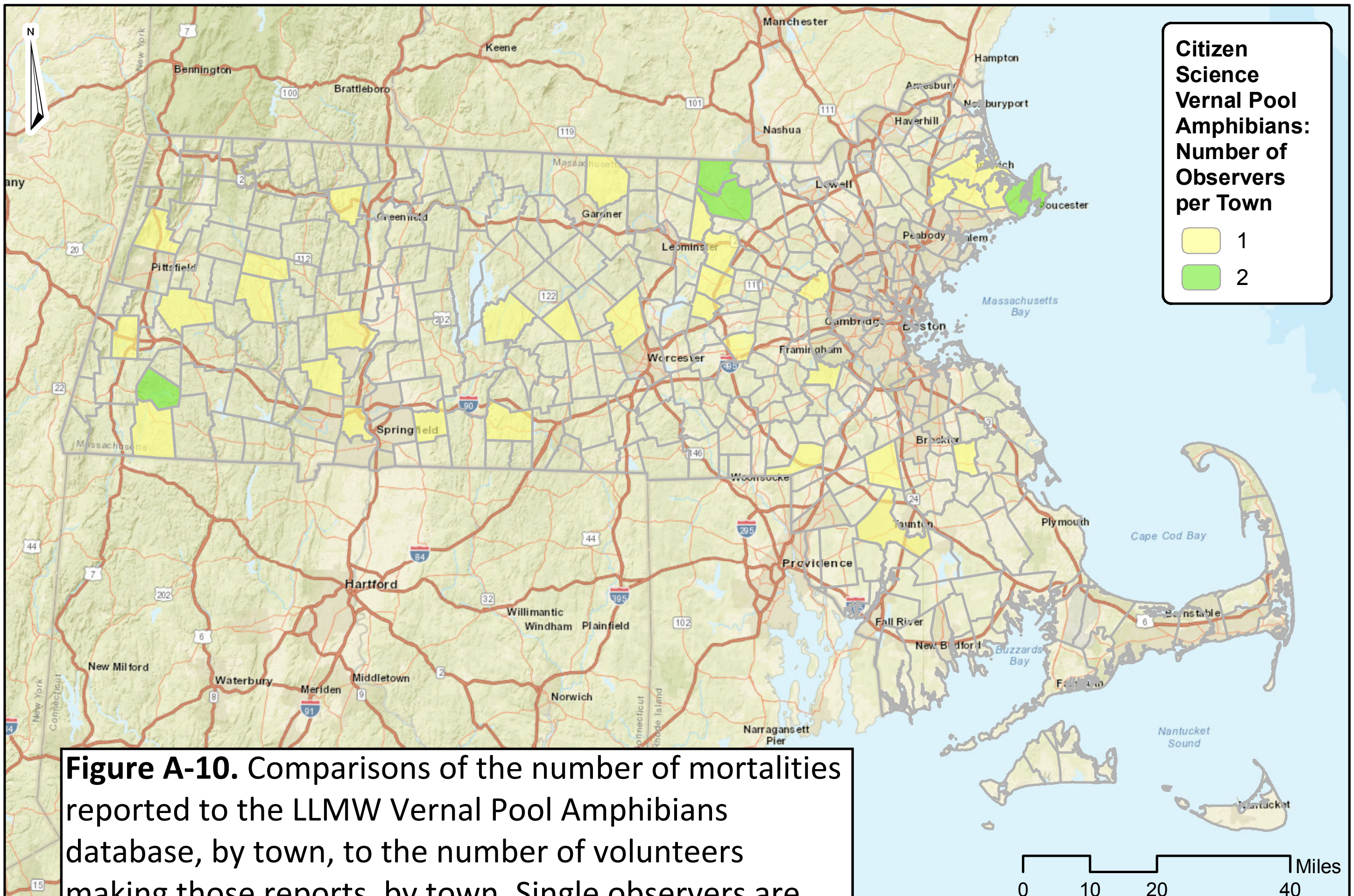
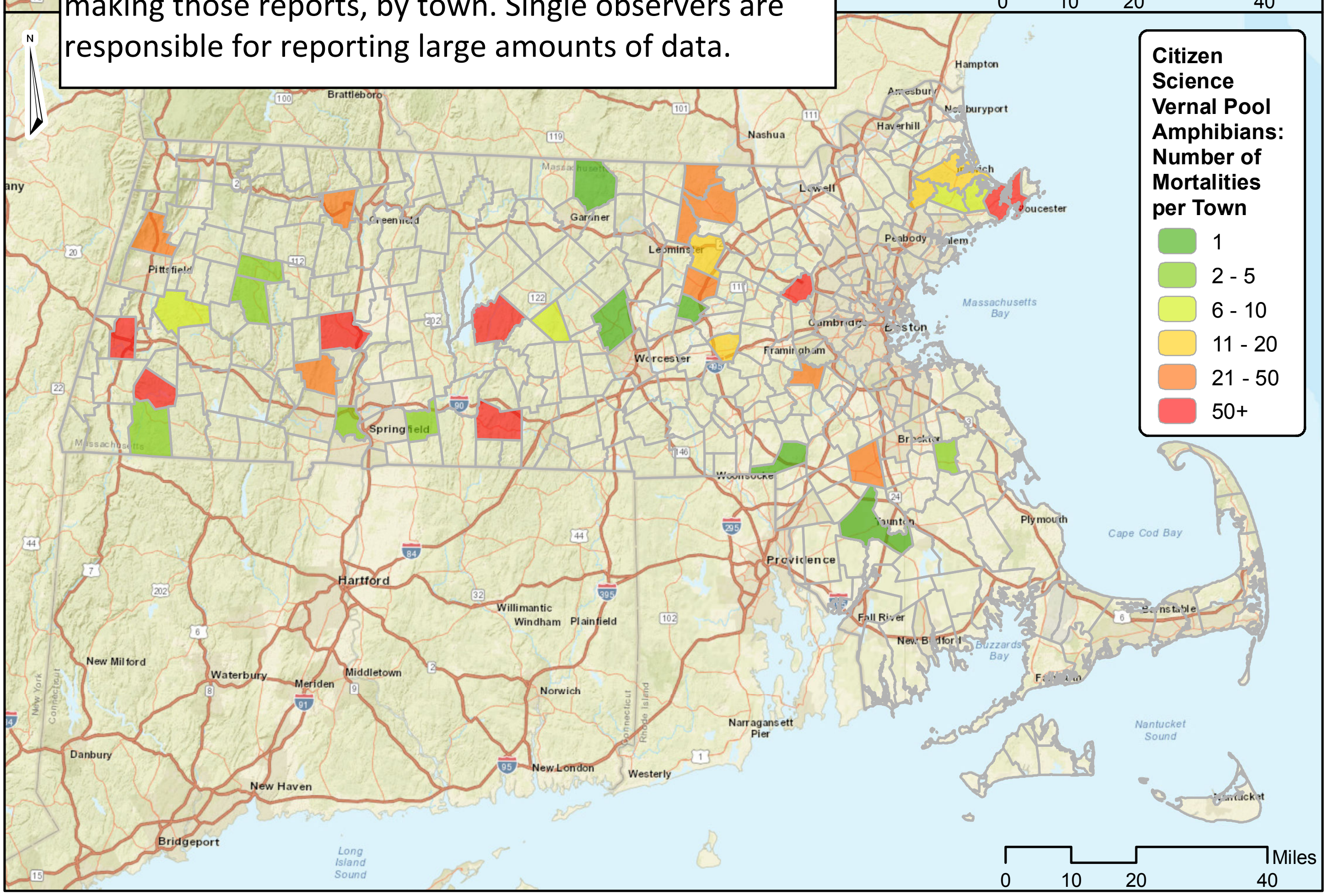


Figure A-10. Comparisons of the number of mortalities reported to the LLMW Vernal Pool Amphibians database, by town, to the number of volunteers making those reports, by town. Single observers are responsible for reporting large amounts of data.



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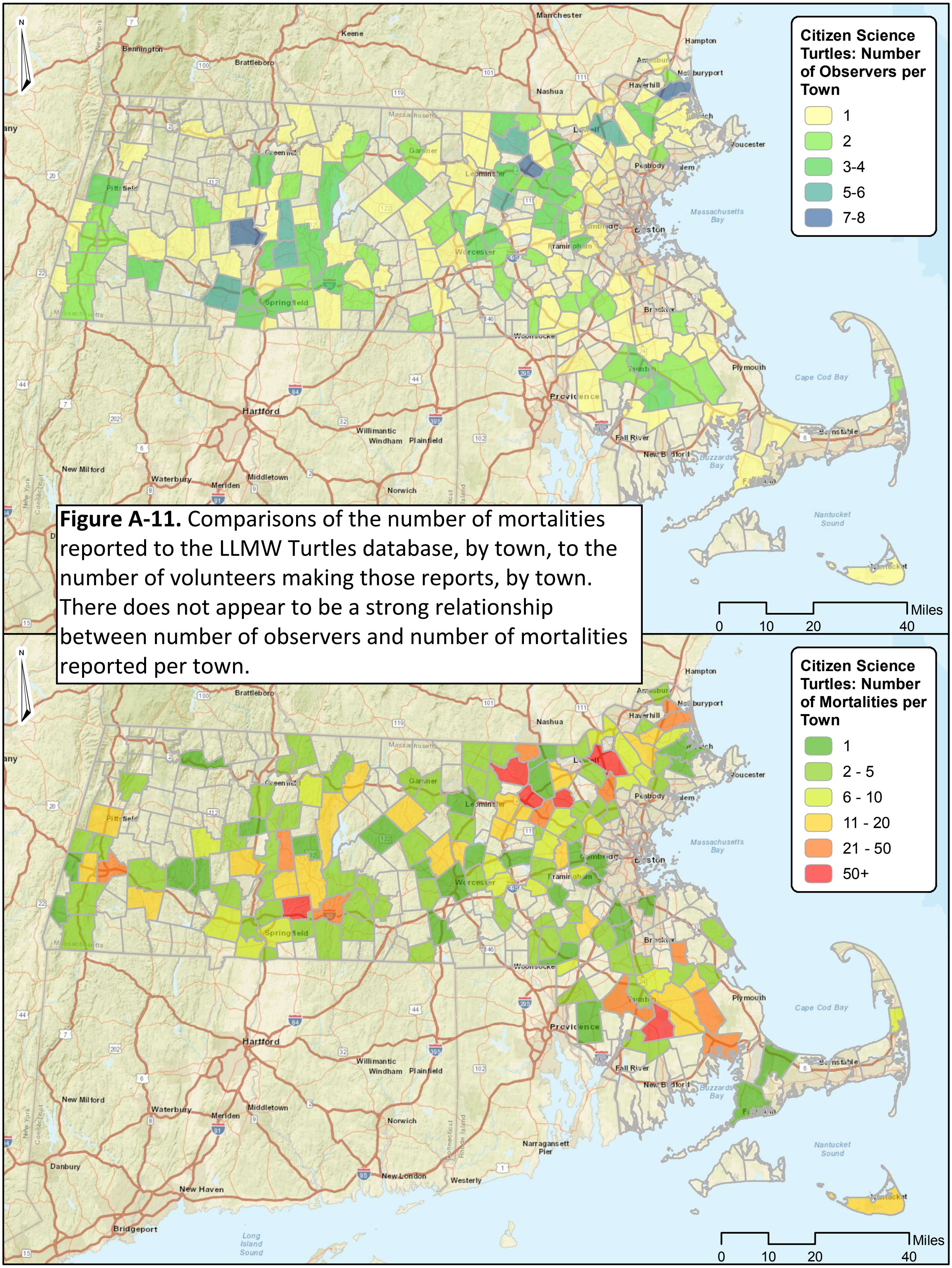

Figure A-11. Comparisons of the number of mortalities reported to the LLMW Turtles database, by town, to the number of volunteers making those reports, by town. There does not appear to be a strong relationship between number of observers and number of mortalities reported per town.

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Appendix B – Species Tables

Table B-1. Listing of unique species reported in the LLMW amphibian crossing, turtle mortality, and general wildlife datasets. Species of interest to MassWildlife are highlighted in gray. Species submitted to the Turtle Mortality dataset and Vernal Pool Amphibian datasets that do not belong to that respective group were moved to the General Wildlife dataset for analysis.

Common Name	Scientific Name	Dataset		
		Wildlife	Turtle	Amphibian
Mammals				
Black bear	*Ursus americanus*	X		
Beaver	*Castor canadensis*		X	
Bobcat	*Lynx rufus*	X		
Chipmunk	*Tamias striatus*	X	X	
Cottontail rabbit	*Sylvilagus floridanus*	X		
Coyote	*Canis latrans*	X		
Eastern gray squirrel	*Sciurus carolinensis*	X	X	
Fisher	*Martes pennanti*	X		
Fox*	Canidae	X	X	
Gray fox	*Urocyon cinereoargenteus*	X		
Hairy-tailed mole	*Parascalops breweri*	X		
Long-tailed weasel	*Mustela frenata*	X	X	
Mammal*	Mammalia		X	
Mink	*Neovison vison*	X	X	
Mole*	Talpidae		X	
Moose	*Alces americanus*	X	X	
Mouse*	Dipodidae or Cricetidae	X	X	
Muskrat	*Ondatra zibethicus*	X	X	
Porcupine	*Erethizon dorsatum*	X		
Raccoon	*Procyon lotor*	X	X	
Red fox	*Vulpes vulpes*	X		
Red squirrel	*Tamiasciurus hudsonicus*	X	X	
Rodent*	Rodentia		X	
Short-tailed shrew	*Blarina brevicauda*	X		
Short-tailed weasel	*Mustela erminea*	X	X	
Small mammal*	Mammalia		X	
Squirrel*	Sciuridae	X	X	
Striped skunk	*Neovison vison*	X	X	
Virginia opossum	*Didelphis virginiana*	X	X	
Weasel*	Mustela	X	X	
White-tailed deer	*Odocoileus virginianus*	X		
Woodchuck	*Marmota monax*	X		
Birds				
American crow	*Corvus brachyrhynchos*	X	X	
American goldfinch	*Spinus tristis*		X	
American robin	*Turdus migratorius*	X	X	
American woodcock	*Scolopax minor*		X	
Bird*	Aves	X	X	
Baltimore oriole	*Icterus galbula*	X		
Barred owl	*Strix varia*	X		
Canada goose	*Branta canadensis*	X	X	

Common Name	Scientific Name	Dataset		
		Wildlife	Turtle	Amphibian
Cedar waxwing	*Bombycilla cedrorum*		X	
Common grackle	*Quiscalus quiscula*	X	X	
Duck*	Anatidae	X	X	
Eastern screech owl	*Megascops asio*	X		
European starling	*Sturnus vulgaris*	X		
Gray catbird	*Dumetella carolinensis*	X		
Great horned owl	*Bubo virginianus*	X		
Gull*	Laridae	X		
Heron*	Ardeidae		X	
Hawk*	Accipitridae	X		
Mallard	*Anas platyrhynchos*		X	
Mourning dove	*Zenaida macroura*		X	
Northern bobwhite	*Colinus virginianus*	X		
Northern flicker	*Colaptes auratus*	X		
Owl*	Strigidae	X		
Raptor*	Accipitriformes	X		
Red-tailed hawk	*Buteo jamaicensis*	X		
Red-winged blackbird	*Agelaius phoeniceus*		X	
Rock pigeon	*Columba livia*	X		
Ruffed grouse	*Bonasa umbellus*	X		
Sparrow*	Passeridae		X	
Tufted titmouse	*Baeolophus bicolor*	X		
Warbler*	Parulidae		X	
Waterfowl*	Anseriformes		X	
Wild turkey	*Meleagris gallopavo*	X		
Yellow warbler	*Setophaga petechia*			
Reptiles				
Blanding's turtle	*Emydoidea blandingii*	X	X	
Box turtle	*Terrapene carolina carolina*	X	X	
Diamondback terrapin	*Malaclemys terrapin*		X	
Eastern garter snake	*Thamnophis sirtalis*	X	X	
Milk snake	*Lampropeltis riangulum triangulum*	X	X	
Musk turtle	*Sternotherus odoratus*	X	X	
Northern black racer	*Coluber constrictor constrictor*	X		
Northern brown snake	*Storeria dekayi dekayi*		X	
Northern water snake	*Nerodia sipedon sipedon*	X	X	
Painted turtle	*Chrysemys picta*	X	X	X
Red-bellied cooter	*Pseudemys rubriventris*		X	
Red-eared slider	*Trachemys scripta elegans*		X	
Ring-necked snake	*Diadophis punctatus edwardsii*	X	X	
Smooth green snake	*Opheodrys vernalis*		X	
Snake*	Serpentes		X	
Snapping turtle	*Chelydra serpentina*	X	X	
Spotted turtle	*Clemmys guttata*	X	X	
Wood turtle	*Glyptemys insculpta*	X	X	
Amphibians				
American Bullfrog	*Lithobates catesbeiana*	X		X
American toad	*Anaxyrus americanus*	X		
Amphibian*	Amphibia		X	

Common Name	Scientific Name	Dataset		
		Wildlife	Turtle	Amphibian
Four-toed salamander	*Hemidactylium scutatum*			X
Frog*	Anura	X	X	
Green frog	*Lithobates clamitans melanota*	X		X
Jefferson-blue spotted salamander	*Ambystoma jeffersonianum/A. laterale*			X
Leopard frog	*Lithobates pipiens*	X		
Pickerel frog	*Lithobates palustris*			X
Red-backed salamander	*Plethodon cinereus*			X
Red eft	*Notophthalmus viridescens*		X	X
Salamander*	Urodela	X		
Spotted salamander	*Ambystoma maculatum*	X		X
Spring peeper	*Pseudacris crucifer*			X
Toad*	Bufonidae	X	X	
Wood frog	*Lithobates sylvatica*	X		X

*=Species unknown

Table B-2. Mortality Count by Species Groupings for Animals Reported in the General Wildlife Dataset. Species of interest to MassWildlife are highlighted in gray.

Species Group	Frequency reported	Number of Mortalities
Bear	10	10
Beaver	71	73
Bird	156	200
Bobcat	10	11
Canine	2	2
Coyote	29	29
Deer	73	73
Domestic dog	2	3
Fisher	30	30
Fox	51	52
Frog/Toad	49	97
Housecat	12	12
Mink	35	39
Moose	2	2
Muskrat	17	18
Newt	107	156
Opossum	137	140
Otter	14	14
Porcupine	37	37
Rabbit/Hare	99	101
Raccoon	161	167
Salamander	11	18
Skunk	58	58
Small mammal	19	24
Snake	26	29
Squirrel/Chipmunk	380	387
Turtle	116	136
Unidentified mammal	10	10
Unknown	106	107
Weasel	15	15
Woodchuck	22	22