Investigation of Northern Long-Eared Bat Roosting Sites on Bridges

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16. Abstract

Populations of several non-migratory bat species have declined significantly in New England due to White-nose Syndrome, resulting in several species, including the Northern Long-Eared Bat (*Myotis septentrionalis*), being listed as threatened or endangered at the federal or state level. While bats are known to roost in bridges in other regions, it was not known whether bridge roosting was utilized in New England. The project initiated with a literature review and interviews with personnel involved in tracking bat populations, inspecting bridges and researching bridge roosting. The project team then conducted rapid visual screenings of 191 bridges throughout New England, and selected eighteen bridges for further in-depth study. Further study included visual inspection, acoustic monitoring, thermal imaging and evening monitoring of structures for emergence. A supplemental visual survey form was developed to supplement the Programmatic Biological Assessment for Transportation Projects in the Range of the Indiana Bat and Northern Long-Eared Bat (U.S. DOT). Comparisons and recommendations are included for evaluation methods including visual inspections, staining characteristics, acoustic monitoring and guano identification, with examples provided for each of the eighteen bridges.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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1.0 Introduction

1.1 Project Objectives and Overview

The main objective of the originally proposed research project was to develop a screening tool and to demonstrate its accuracy in determining the presence of northern long-eared bats roosting in New England bridges. Additional information was to be collected and disseminated related to preferred structural types for bat roosting, New England bat population distributions, and evaluation of existing public data already collected by State Fish and Wildlife Departments and Transportation Agencies throughout New England. As the project progressed the objectives were modified to address ongoing national efforts in this area in order to avoid redundancy with those efforts. Evaluation of developed national screening tools for their application to the New England region and development of a New England specific supplemental bridge screening form became primary objectives, along with the evaluation of regional bridge characteristics and inspection methods. These were added to the original objectives.

It is known and documented that bats can use bridges for a range of roosting activities, though the prevalence of bridge use in New England is not well documented or understood. In the absence of this data, environmental protection laws could be applied broadly, requiring bridge inspections, time of year restrictions for bridge construction and maintenance, and/or criteria to provide roosting habitat when designing replacement structures. The burden will most likely be placed on State Transportation Agencies to ensure that construction and maintenance activities do not require protection measures for protected species. A survey tool to assess the likelihood of bat presence prior to any construction or maintenance activities would greatly aid conservation efforts and focus efforts toward those structures that have higher likelihood of being utilized for bat roosting.

This project was a proactive means to develop a survey tool to assess the likelihood of bat presence in bridges, develop a regional knowledge base of bats for New England Transportation Agencies, and provide demonstrations of field observations of bridges to verify the usefulness of the survey tool.

1.2 Benefits of Bats

Bats are essential organisms for maintaining ecological processes. They consume large quantities of insects, including agricultural pests (Keeley and Tuttle 1999, Smith and Stevenson 2013a, SDBWG 2004), assist in pollination and seed dispersal (Smith and Stevenson 2013a, SDBWG 2004), and provide cultural benefits (Smith and Stevenson 2015). In many places, bats contribute a large portion of mammalian diversity (Smith and Stevenson 2013a and 2015) with bats accounting for a quarter (Keeley 2007) to a third (Aughney 2008) of Ireland's mammalian fauna. With about 1,300 species worldwide (BCI 2015), bats contribute about a fifth of worldwide mammalian species (Bradford 2014). Bats are beneficial to advances in medicine as anticoagulants in their saliva have been utilized, and studying bats has led to development of navigational aids to assist the blind (SDBWG 2004). They also do not pose any negative environmental impacts as large colonies have been shown to have negligible effects on water quality (Keeley and Tuttle 1999).

1.3 Human Impacts on Bat Populations

Globally, bat populations are declining due to several factors. The greatest threat to hibernating bats in North America and the greatest source of current population declines observed in these species is White-Nose Syndrome (WNS). WNS is a fungal disease that affects hibernating bats species and has already resulted in the death of millions of bats in the northeast U.S. (Froschauer and Coleman 2012), which makes this threat of particular interest in the current project. Other causes of bat population declines have been attributed to habitat destruction and modification (Keeley and Tuttle 1999, Smith and Stevenson 2013a, 2014 and 2015, Hendricks et al. 2005, Shiel 1999, SDBWG 2004), disturbance during critical life phase of hibernation and/or maternity periods (Smith and Stevenson 2013a, SDBWG 2004), pesticide usage (Shiel 1999, Smith and Stevenson 2013a, 2014 and 2015, SDBWG 2004), climate change, pollution, disease, human development including urbanization, increased development and operation of wind turbine facilities (Smith and Stevenson 2013a, 2014 and 2015), poor regulatory measures, and a lack of public awareness (SDBWG 2004). Additionally, bats have a slow reproductive rate, which is suggested as another reason bats are receiving legal protection (Keeley 2007), and why bat populations are particularly susceptible to threats (Smith and Stevenson 2013b, Gore and Studenrogh 2005, Szewczak 2011). Young bats have a higher mortality rate than adults, as young bats more frequently experience accidents during first flights, are more susceptible to predation, and may be more susceptible to the elements during their first hibernation (SDBWG 2004).

Roadway construction can have negative impacts on bats (Christensen et al. 2015, Keeley and Tuttle 1999) as roads placed along rivers and rock faces or through riparian zones have permanently destroyed tree roosts and increased human accessibility to roosts (Keely and Tuttle 1999). Roadways can also cause mortalities due to collisions, habitat patchiness, population fragmentation, and barrier effect causing restrictions on animal movement (Christensen et al. 2015, Smith and Stevenson 2013a). As natural roosts are destroyed, bat usage of manmade infrastructure, including culverts, bridges, buildings, and mines, has been observed to increase (Cleveland and Jackson 2013, Smith and Stevenson 2013b). Manmade structures utilized as roosts typically have similar thermal and physical characteristics as natural roosts. It also may be more beneficial for bats to roost in bridges as many bridges are typically located near waterbodies (Christensen et al. 2015, Smith and Stevenson 2013a) which often serve as food sources for bats, offering shorter commutes to foraging sites than bats that roost in caves (Arnett and Hayes 2000, Smith and Stevenson 2013a). It has sometimes been reported that bridges and buildings are used as roosting sites 'of last resort' when natural habitats are reduced. However, there are many cases of vibrant bat colonies in the U.S. utilizing bridges and efforts to design features both removable and permanent that are conducive to bat roosting to attract colonies (Keeley and Tuttle 1999).

For all threatened, endangered or candidate (proposed for listing) species, it is of utmost importance to understand their roosting habits, habitat, range and population densities, and to avoid disturbances that could further deplete the populations.

1.4 Bats and Bridge Construction

It is notable that the most vulnerable period of potential bat roosting in bridges corresponds with the prime construction and maintenance season throughout New England (May through August). Requirements of State Transportation Agencies to provide assurance that construction and maintenance activities do not require protection measures for protected species could therefore affect the majority of roadway and bridge projects. Bats that utilize bridges are susceptible to injury or death by bridge maintenance or repair work and demolitions, which is regrettable since these threats can be prevented through exclusion from work zones (Keeley and Tuttle 1999, Hendricks et al. 2005, Shiel 1999). While there are guidelines for procedures, each bridge should be assessed individually (Shiel 1999).

The most impactful and significant effect to bats from construction is destruction and removal of natural vegetation. Impacts due to disturbances caused by construction can vary depending on the timing of such disturbances in relation to the lifecycle of bats (Smith and Stevenson 2014). Possible dangers to bats during construction include death and injury from abandonment of volant (able to fly) or nonvolant (not able to fly) young (Smith and Stevenson 2014), entombment (Smith and Stevenson 2014, Keeley 2007), suffocation, and crushing (Keeley 2007). Construction can also cause bats to abandon roosts due to excessive vibrations, noise pollution, and modifications to the roost's thermal conditions. Night time construction can also discourage emergence due to lights, noise, and unfamiliar odors (Smith and Stevenson 2014) which can lead to health problems if normal feeding patterns are discouraged. It is important to recognize that bats can be in a state of torpor when roosting, making them vulnerable to disturbance. In the torpor state they will be unable to react to disturbances and may be dislodged and injured before being able to emerge from the roost (Szewczak 2011).

Basic utility of bridges and minor work on bridges can sometimes be completed when bats inhabit bridges. Bats are accustomed to the noise and vibrations of traffic and bridge construction, and typically ignore workers. Disturbance to bats utilizing crevices in bridges can be minimized when working on bridges if there is definitive confirmation for the absence of bats in the specific areas in which work is completed, and the bridge work is not specifically targeting the crevices used for roosting. Any construction work that impacts areas used for roosting, including the potential of materials filling the area, significant vibration or noise in the area, or major construction work staging, can have great impact on bats using the bridge. Bats that utilize larger open areas are easily disturbed, but work schedules can be shifted to accommodate times that are less likely to have bats occupying the area (Keeley and Tuttle 1999). This may be more difficult to accomplish in northern states where the construction season has significant overlap with times of year that bats would be actively roosting in bridges.

When any construction activities are scheduled for a bridge when there is the possibility of bat usage, or suspected or confirmed bat usage, personnel from the Departments of Natural Resources, Fish and Wildlife agencies, or other relevant consultants or qualified biologists should be included in the construction process to evaluate the situation (Cleveland and Jackson 2013, Gore and Studenrogh 2005). If it is possible and safe, any bridges scheduled for decommission, especially if they are known or suspected roost bridges, should be abandoned rather than demolished (Cleveland and Jackson 2013, Geluso and Mink 2009). If construction activities are scheduled over the winter months when bats are hibernating, it may be important to note distance to hibernacula as excessive vibrations from construction within 0.5 mi (0.8 km) from hibernacula sites can cause arousal from hibernation and deplete bats' fat reserves (Smith and Stevenson 2015). Szewczak (2011) mentions that schedules for construction and maintenance activities can change unpredictably, and stresses the importance of open communication between parties responsible for bat management and parties responsible for bridge construction and maintenance.

1.5 Bat Species of Interest

The primary species of interest in this project are the northern long-eared bat (*Myotis septentrionalis*) (MYSE), also known as the northern *Myotis*. Four additional species are of general interest in this project: the Indiana bat (*Myotis sodalis*) (MYSO), also known as the Indiana *Myotis*; the little brown bat (*Myotis lucifugus*) (MYLU), also known as the little brown *Myotis*; the tricolored bat (*Perimyotis subflavus*) (PESU), formerly known as the eastern pipistrelle (*Pipistrellus subflavus*); and the big brown bat (*Eptesicus fuscus*) (EPFU). MYSE is listed as threatened in 38 states including all of New England under the Federal Endangered Species Act (Federal Register 2015), and MYSO has been a federally endangered species since 1967. MYLU and PESU are also being evaluated by the U.S. Fish and Wildlife Service (USFWS) for listing under the Endangered Species Act. Current listings of bat species in each New England state, as well as federal listings are provided in **Table 1-1**. The newer listings can be attributed to WNS, which has drastically reduced the populations of these bat species since 2006, in some cases reducing populations by over 90 percent (estimated deaths of over 6 million bats) (Turner et al. 2011). Other regional bat species, such as EPFU whose populations have not been as drastically reduced, are worth monitoring and collecting data to use as a baseline for future studies, especially since EPFU and MYLU are two bat species in New England that preferentially roost in structures during the summer (SDBWG 2004, NatureServe 2015). Migratory bat species (eastern red bat, silver-haired bat and hoary bat) populations have not been affected by WNS (Bennett 2015) and are not specifically studied in the project. The Eastern Small Footed Bat (*Myotis leibii*) (MYLE), was initially excluded from this project as it was expected to be less likely to utilize bridges. However, based on the wide use of masonry and rock components in bridges (which may be similar to their natural roost features) along with being a listed species in most of the region, MYLE should also be considered.

The primary focus of this project was MYSE, although data was collected on MYLU, PESU, and MYSO. Data on EPFU, other non-migratory species and MYLE was collected when encountered as it required minimal additional effort. State Fish and Wildlife Departments are leading efforts to track threatened, endangered, and candidate bat species in New England, but data collected pre-WNS may not be a reliable source to predict current habitat occupancy. It is not known if bat population reductions are evenly distributed or have resulted in the complete loss of colonies in certain regions, or how the reduced colony sizes have affected bats' behavior.

Table 1-1: State and Federal Bat Species Listings

Latin Name	Abbre-viation	Common Name	Species of Greatest Conservation Need (no further listing)	Special Concern	Threatened	Endangered
Myotis leibii	MYLE	Eastern small footed *Myotis*	RI[a]		ME, VT	CT, MA, NH
Myotis septentrionalis	MYSE	Northern long-eared bat	RI[a]		Federal US	CT, ME. MA, NH, VT
Myotis sodalis	MYSO	Indiana bat				Federal US, CT, MA, VT
Myotis lucifugus	MYLU	little brown bat	RI[a]			CT, ME, MA, NH, VT
Perimyotis subflavus	PESU	Eastern pipistrelle (tri-colored bat)	RI[a]	ME		CT, MA, NH, VT
Lasiurus borealis	LABO	Eastern red bat	MA, RI[a]	CT, ME, NH		
Eptesicus fuscus	EPFU	big brown bat	MA, NH, RI[a]	ME		
Lasionycteris noctivagans	LANO	silver haired bat	MA, RI[a], VT	CT, ME, NH		
Lasiurus cinereus	LACI	hoary bat	MA, RI[a], VT	CT, ME, NH		

Note [a]: Rhode Island is currently revising their state threatened and endangered species listings

2.0 Literature Review

Relevant literature on life cycle and roosting behaviors of bats in general were reviewed. All found documentation of bats roosting in bridges was also reviewed, regardless of species encountered or geographic location, to get a sense of general roosting behavior. Literature focused on the general region or species of concern for the project were further investigated. Searches were completed using Web of Science and Engineering Village databases through the University of Massachusetts library system, Google Scholar and general internet based search engines.

2.1 General Roosting Needs

Roost structures are of immense importance as roosts are where bats raise their young and spend the majority of their lives. Having suitable roosting areas is seen to be an integral factor relating to the distribution, abundance, and dynamics of bat populations (Feldhamer et al. 2003, Smith and Stevenson 2013a). Roosting needs vary throughout the year and are tied to the species life cycle.

This chapter aims to provide basic information on roosting needs of bats in general. It is also important to note that previous information gathered on bat species is pre-WNS, with current ongoing studies determining the long-term impact of WNS on bats. Previous research on bats' use of bridges has been focused in various locations throughout the U.S. and Ireland. Table 2-1 summarizes the locations of previous research as well as bat species studied and encountered. Both climatic conditions and species composition vary widely within these studies. In general, these conditions do not match the combination of climate and species found in New England, necessitating specific bat studies in New England. For example, in southern U.S. states with warm ambient conditions, there is concern for choosing cooler roosting locations (Ferrara and Leberg 2005, Smith and Stevenson 2013b) but in the northeast U.S., bats tend to choose warmer roost locations since ambient temperatures fluctuate and are cooler. Table 2-1 summarizes the species identified in and locations of the studies cited for this literature review.

Table 2-1: Summarized details on bat bridge roosting studies cited

Author	Bats Encountered in Study	Location
Adam and Hayes (2000)	MYLU, EPFU Townsend's big-eared bat (*Corynorhinus townsendii)* California myotis (*Myotis californicus*) long-eared myotis (*Myotis evotis*) fringed myotis (*Myotis thysanodes*) long-legged myotis (*Myotis volans*) Yuma myotis (*Myotis yumanensis*)	Oregon Coast Range, USA
Arnett and Hayes (2000)	N/A, local species in the area (unspecified, EPFU pictured)	Western Oregon Cascades, USA
Aughney (2008)	brown long-eared bat (*Plecotus auritus*) Daubenton's bat (*Myotis daubentonii*) eastern pipestrelles (*Pipistrellus pipistrellus*) Natterer's bat (*Myotis nattereri*) whiskered bat (*Myotis mystacinus*)	Ireland

Table 2-1: *continued* Summarized details on bat bridge roosting studies cited

Author *continued*	**Bats Encountered in Study** *continued*	**Location** *continued*
Bennett et al. (2008)	PESU, EPFU Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) southeastern myotis (*Myotis austroriparius*) Brazilian free-tailed bat (*Tadarida brasiliensis*) unidentified *Myotis* species	South Carolina, USA
Cleveland and Jackson (2013)	N/A, local species in the area (unspecified, MYLU pictured, bridge utilized by *Tadarida brasiliensis* colony pictured)	Georgia, USA
Feldhamer et al. (2003)	MYSE, MYLU, PESU, EPFU	Southern Illinois, USA
Ferrara and Leberg (2005)	MYSE, PESU, EPFU Rafinesque's big-eared bats (*Corynorhinus rafinesquii*)	North-central Louisiana, USA
Geluso and Mink (2009)	EPFU Arizona myotis (*Myotis occultus*) Yuma myotis (*Myotis yumanensis*) Brazilian free-tailed bat (*Tadarida brasiliensis*) pallid bat (*Antrozous pallidus*) silver-haired bat (*Lasionycteris noctivagans*) California myotis (*Myotis californicus*) fringed myotis (*Myotis thysanodes*)	Rio Grande Valley, New Mexico, USA
Gore and Studenrogh (2005)	EPFU free-tailed bats (*Tadarida brasiliensis*) southeastern myotis (*Myotis austroriparius*) evening bats (*Nyteceius humeralis*)	Florida, USA
Hendricks et al. (2005)	MYLU, EPFU hoary Bat (*Lasiurus cinereus*) western Small-footed Myotis (*M. ciliolabrum*)	Montana, USA
Keeley (2007)	Daubenton's bat Natterer's bat brown long-eared bat Leisler's bat (possibly, not confirmed)	County Laois and County Offaly, Ireland
Keeley and Tuttle (1999)	MYSE, MYSO, MYLU, PESU, EPFU big free-tailed bat (*Nyctinomops macrotis*) California leaf-nosed bat (*Macrotus californicus*) cave myotis (*Myotis velifer*) evening bat (*Nycticeius humeralis*) fringed myotis (*Myotis thysanodes*) gray myotis (*Myotis grisescens*) long-eared myotis (*Myotis evotis*) long-legged myotis (*Myotis volans*) Mexican free-tailed bat (*Tadarida brasiliensis*) Mexican long-tongued bat (*Choeronycteris Mexicana*) pallid bat (*Antrozous pallidus*) Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) silver-haired bat (*Lasionycteris noctivagans*) small-footed myotis (*Myotis leibii*) southeastern myotis (*Myotis austroriparius*) Townsend's big-eared bat (*Corynorhinus townsendii*) western small-footed myotis (*Myotis ciliolabrum*) Yuma myotis (*Myotis yumanensis*) western Pipistrelle (*Pipistrellus Hesperus*)	Southern and western USA (has map of where surveyed)

Table 2-1: *continued* Summarized details on bat bridge roosting studies cited

Author *continued*	**Bats Encountered in Study** *continued*	**Location** *continued*
Perlmeter (1996)	MYLU long-legged myotis (*Myotis volans*)	Willamette National Forest, Oregon USA
Shiel (1999)	Daubenton's bat (*Myotis daubentonii*) Natterer's bat (*Myotis nattereri*) whiskered bat (*Myotis mystacinus*) long-eared (*Plecotus auritus*) pipistrelle (*Pipistrellus pipistrellus/pygmaeus*)	County Leitrim and County Sligo, Ireland
Smith and Stevenson (2014)	N/A, general guidelines about bats, speaks to several species	USA
Smith and Stevenson (2013a)	N/A, general guidelines about bats, speaks to several species	New Mexico, USA
Smith and Stevenson (2013b)	*Myotis lucifigus occultus* *Myotis velifer* *Myotis yumanensis* *Tadarida brasiliensis*	North central New Mexico, USA
Smith and Stevenson (2015)	N/A, general guidelines about bats, speaks to several species	USA
SDBWG (2004)	N/A, general overview, speaks to species local to South Dakota	South Dakota, USA
Timpone et al. (2010)	MYSE, MYSO	Northeastern Missouri, USA
Trousdale and Beckett (2004)	Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)	Southern Mississippi, USA

2.1.1 Life Cycle

The life cycle of non-migratory bat species and species that migrate shorter distances to hibernation areas for the winter in New England includes a fall swarm period when bats breed at or near hibernation sites, a hibernation period during the cold winter months, a spring emergence period when bats travel to summer foraging areas, and a summer maternity season. The distance between hibernation and maternity roosts may range in proximity from 20 to 200 mi (3.2 to 320 km) (NatureServe 2015). In New England, bats hibernate through the cold winter months, with approximate hibernacula locations reported in eastern New York, Vermont, and western Connecticut and coastal areas of Rhode Island. After bats emerge from hibernation in the spring the females ovulate and use stored sperm from mating in the fall breeding season to initiate pregnancy. While there are different reproductive strategies among bats, the five species of interest use delayed fertilization. Pregnant females separate in the spring into maternity colonies ranging from ten to several hundred bats depending on the species, although colony sizes tend to be smaller post-WNS. Most bat species have one pup per year including MYSE, MYLU, and MYSO (NatureServe 2015), although some species can have two (SBDWG 2004) including PESU and EPFU, with pups born in the late spring (NatureServe 2015). In some years, reproductive rates can be low with only 25 to 50 percent of the reproductive-aged females producing offspring (SDBWG 2004). The pups are nonvolant for about three to four weeks (NatureServe 2015) and are completely reliant on their mothers for food and warmth. Maternity colonies are therefore very vulnerable throughout their three to four month duration, starting from initializing the colony in the spring through the pups' birth, maturing, and finally leaving the maternity roost late summer/early fall. Disturbance can result in direct mortality or cause the mothers to abandon their young, especially in earlier stages before the pups are volant. Once the pups are volant, bats may use several roosting sites in close proximity with one being dominant, though this behavior and number of roosting locations will vary from species to species and among colonies (Bennett 2015). These bat species can live for 15 to 20 years or more, but rarely make it to these older ages, and stay reproductive until about 12 years of age (NatureServe 2015).

2.1.2 Roost Types

The main purposes of roosts utilized through a bat's life cycle are to provide protection from predators and shelter from the elements. Bats roost in a variety of natural locations and human-made structures including trees, caves, abandoned mines, cliffs, houses, barns, churches, and bridges. Bats can be selective on roost choice, and selection is based on various characteristics depending on the species. Location of roosts relative to foraging areas, other roosts, other bat populations, and distance between day- and night-roosts are all likely considerations.

Roosts are where bats congregate for a variety of activities including social interactions, mating, energy conservation, and shelter and protection from weather and predators or disturbance (Gore and Studenrogh 2005). Bats can be selective in roost choice as energy conservation is of particular importance and is related to reproductive success and overall survival of bats (Gore and Studenrogh 2005, Ferrara and Leberg 2005). Different microclimates are preferable for different roost types, as well as for different weather conditions. No single roost will be beneficial in all weather conditions or during all stages of life or reproductive phases (Arnett and Hayes 2000, Smith and Stevenson 2013a, 2013b). Typically bats will roost in rock crevices or cavities, such as abandoned mines or caves, in cliffs or talus piles, in trees both living and dead (snags), underneath the bark or within hollows, or in structures such as buildings, bridges, dams, or artificial bat houses. Locations need to have high humidity and limited air movement to conserve water as bat wings are thin membranes, and bats are subject to dehydration due to evaporation (SDBWG 2004). Being nocturnal, roosts need to be dimly lit inside as bats prefer dark locations utilizing cavities of roost sites not illuminated by direct sunlight or artificial light, and that do not have illuminated exits and entrances. Lighting cannot be used to rule out certain locations, however, as bats will utilize roost sites with non-ideal conditions if there is a need (Keeley 2007).

2.1.2.1 General Hibernacula Needs

Winter roosts or hibernation roosts provide stable environments with no airflow, humid conditions, and low, stable temperatures between 30 and 50^{o}F (-1 to 10^{o}C) (TBGNWCS 2015, WDFW 2015). These roosts are shared by males and females, and are typically located in caves, mines, attics, walls, basements, and building lofts. Crevices and locations utilized for hibernation vary by species. MYSE, for example, tends to roost high up in deep crevices in hibernacula, so is difficult to get accurate hibernacula counts, whereas other species of interest tend to cluster and hibernate in groups, making it easier to estimate hibernating populations (Bennett 2015). Hibernation roosts are highly susceptible to disturbance because interruptions leading to arousals that take bats out of torpor during hibernation use up crucial fat reserves, lowering a bat's chance of survival through the winter (SDBWG 2004, FHWA FRA 2015). Hibernation roost colonies are also susceptible to disturbance because bats are concentrated in these locations. In the northeast U.S., bats are not expected to hibernate in bridges (VDOT Environmental Division 2014) due to cold winter temperatures prohibiting appropriate conditions for hibernation.

2.1.2.2 Day-Roost (Diurnal)

Since bats are nocturnal, day roosts, or diurnal roosts, are used for extended periods of rest. Day-roost locations can be utilized as maternity roosts, summer male roosts, or transient roosts, and are selected for protection from predators and weather when rearing young, resting, or sleeping (Keeley and Tuttle 1999, Hendricks et al. 2005, Ferrara and Leberg 2005). Day-roosts typically have more stable conditions than night-roosts (SDBWG 2004) though preferable microclimates, temperatures, and levels of darkness for day-roosting vary depending on species and time of year (Ferrara and Leberg 2005). Bats tend to congregate in specific locations within day-roosts that have appropriate microclimates, and will shift within roosts to maintain those conditions. Day-roosts can range in usage size from a maternity colony with over a million pups and mother bats, to a single male (Keeley and Tuttle 1999). Occupancy in day-roosts typically lasts about one month at a specific location (Hendricks et al. 2005) though bats typically switch roots locations every one to ten days (Bennett 2015, Baldwin et al. 2017).

2.1.2.3 Night-Roost (Nocturnal)

Night-roosts, or nocturnal roosts, are places where bats congregate between nightly feedings to digest their food in areas protected from wind. Night-roosts are also used for other reasons such as regulating body temperature and social functions (Keeley and Tuttle 1999, Perlmeter 1996) including maintaining close relationships with the group, especially for mothers and pups, and providing information centers to enhance foraging trips. Thermoregulation is achieved by choosing night roosts with favorable microclimates, and/or forming clusters to maintain body temperatures and minimize energy loses (Perlmeter 1996, Gore and Studenrogh 2005). Night-roosts are used at various times throughout the night depending on location, species, and time of year. Some studies have noted bats most often utilizing night-roosts from approximately 10PM until midnight (Hendricks et al. 2005, Keeley and Tuttle 1999, Perlmeter 1996), with other studies noting night-roost utilization occurred throughout the night, peaking between 3:00AM to 4:30AM, with infrequent use an hour to an hour and a half after sunset (Adam and Hayes 2000). Perlmeter (1996) also notes that there are different timings of peak night-roosting as different bat species have different foraging habits (Perlmeter 1996).

2.1.2.4 Maternity Roost

Maternity roosts are found in locations that provide insulation from ambient temperature and humidity extremes (Smith and Stevenson 2013a) and tend to be larger congregations of reproductive females and pups. Larger colony sizes may serve to make thermoregulation more efficient, as roosts with larger groups can be 9 to 18^{o}F (5 to 10^{o}C) warmer than roost with smaller groups. This is critically important as an energy saving mechanism as female energy demands increase during pregnancy (Smith and Stevenson 2013a) and warmer roosts are needed when mothers leave their pups for feeding bouts in the evenings (Bennett et al. 2008, Gore and Studenrogh 2005). Maternity roosts are utilized for at least three months (approximately June through August) (Hendricks et al. 2005), but may be occupied intermittently from the time of spring emergence in April or May through the time when bats leave for the fall swarm in August or September, depending on the location and species. Maternity roosts are susceptible to disturbance and necessitate protective efforts. It is of utmost importance that maternity roosts are not disturbed (Gore and Studenrogh 2005, Keeley 2007), especially in the months of June and July (Keeley 2007).

2.1.3 Roost Fidelity

Roost fidelity decreases energy expenditures from searching for appropriate roosts, provides roost familiarity, facilitates social relationships in colonies and populations, and provides colony stability (Smith and Stevenson 2013a). Bats are known to exhibit roost fidelity, seasonally and annually returning to the same roosts (Keeley 2007), but predicting roost fidelity or roost switching patterns and behavior is considered impossible (Smith and Stevenson 2013b) as bats may switch roost locations and structures seasonally and/or annually (Gore and Studenrogh 2005, Geluso and Mink 2009). Bennett et al. (2008) found bats exhibit high short-term fidelity to bridge roosts, and found indications of strong fidelity year-to-year as well (Bennett et al. 2008), but variable levels of fidelity exist both annually and seasonally for bat usage of certain bridges as day-roosts. Fidelity of roosts within a year tends to be during a shortened period of time, such as July and August, or August and September (Hendricks et al. 2005). Fidelity of roosts between years is lower for day-roosts utilized by bachelor bats and/or non-reproductive female bats than for maternity roosts (Hendricks et al. 2005). Roost fidelity can also be related to roost permanency. Bats exhibit lower fidelity to ephemeral, short lived, roosts that occur in numerous locations such as dead and aging trees, or trees with exfoliating bark (Smith and Stevenson 2013a, Bennett et al. 2008). Bats exhibit higher fidelity to permanent structures that are rare in occurrence, including caves and manmade structures such as bridges and buildings (Smith and Stevenson 2013a, Bennett et al. 2008). Each roost has its own microclimate that varies throughout the year, and since bats with different metabolic demands (males, pregnant or lactating females, bats of different species) have different needs, roost fidelity varies both within and among species (Keeley 2007, Smith and Stevenson 2013a). While alternative roosts are chosen as backups for loss of a primary roost (Smith and

Stevenson 2013a) and may be continued to be used, drastic changes such as illuminating or disrupting a bridge that has served as a roost site for numerous years will cause abandonment of the roost site (Keeley 2007).

2.2 Species of Interest Information

Depth of information provided in this section is dependent on the extent each species has been studied. Documentation on certain species is sparse as studying species characteristics and population dynamics due to the threats of WNS has only recently allowed resources to be devoted to research on some of these species. More current research on MYSE has been presented at conferences such as the North American Society for Bat Research Annual Symposium in October 2016 (Craven et al. 2016, Curry and Farrell 2016, Johnson et al. 2016, Karsk et al. 2016, Kaupas 2016, Rogers and Kurta 2016, Rojas et al. 2016, Rusk et al. 2016), and the Northeast Bat Working Group Annual Meeting in January 2017 (Bailey et al. 2017, Baldwin et al. 2017, Dermody et al. 2017, Dowling et al. 2017, Lout and Ketterling 2017, Ritzert et al. 2017, and Silvis et al. 2017).

2.2.1 Anatomy Similarities and Differences

Table 2-2 summarizes general physical/anatomical facts about the five species of interest. Information was used from the following sources: Caceres and Barclay (2000), Fujita and Kunz (1984), Thomson (1982), Fenton and Barclay (1980), Kurta and Baker (1990), Hamilton (1943), NatureServe (2015), USFWS (2015), SDBWG (2004) TNBWG (2013), MN DNR (2015).

MYSE ears are mouse-like, and the species can be distinguished by its ear length and tragus shape, which is long, narrow, and pointed. MYSE also has a balder face mask than the other *Myotis* species (SDBWG 2004). MYLU has similar coloration as the MYSE, but its fur is glossy along its back and buffy along its belly (SDBWG 2004), and has shorter ears than MYSE (Hamilton 1943, SDBWG 2004, NatureServe 2015). MYSO is very similar to MYLU, although it has different coloration, smaller more delicate feet, and a smaller skull than MYLU (Hamilton 1943, NatureServe 2015). This species also has shorter ears than MYSE, and can be distinguished by its keeled calcar (NatureServe 2015). PESU is one of the smallest eastern North American bats (Hamilton 1943, NatureServe 2015), and EPFU is the largest of these species with a broader head and snout compared to other *Myotis* species (SDBWG 2004).

Guano size, when combined with other behavioral, visual, and habitat clues, may help to narrow down species identification. Guano for all the *Myotis* species, as well as PESU, is, on average, the size of an uncooked grain of rice. EPFU guano is noticeably larger in comparison, about the size of a cooked grain of rice (Bennett 2015). There also are molecular classifying tools that allow for species identification based on DNA testing of guano samples (Walker et al. 2016, Clare 2011, Larsen et al. 2012, Nadin-Davis et al. 2012, Patrick and Stevens 2014, and Miller-Butterworth et al. 2014).

Table 2-2: Species Differentiation

Species	Body Length *in (mm)*	Wingspan *in (mm)*	Forearm length *in (mm)*	Body weight *g*	Coloration/Patterns	
					Fur	**Membrane**
MYSE	3 - 3.7 (77 - 95)	9 - 10 (228 - 254)	1.3 - 1.5 (34 - 38)	5 - 8	Back: dark brown Belly: light brown Buffy shoulder patches	dark brown
MYSO	3 - 4 (75 - 102)	9.5 - 10.5 (240 - 267)	1.4 - 1.6 (36 - 41)	5 - 8	Back: dull greyish chestnut Belly: cinnamon pinkish	blackish-brown
MYLU	2.5 - 4 (64 - 100)	8.5 - 11 (216 - 280)	1.4 - 1.7 (35 - 42)	4 - 8	Above: dark brown Below: buffy to pale grey Glossy tipped hairs	dark brown
PESU	2.9 - 3.5 (75 - 90)	8.3 - 10.2 (210 - 260)	1.2 - 1.3 (31 - 33)	3.5 - 6	Back: yellow/grey-brown to red-brown Belly: paler	lighter, can appear pinkish
EPFU	4.2 - 5 (106 - 127)	11 - 13 (280 - 330)	1.8 - 1.9 (45 - 48)	13 - 18	Chocolate brown Long and silky	dark brown to blackish

2.2.2 Echolocation Characteristics

Bats use echolocation for spatial perception and navigation and to search for prey for feeding. Search phase calls are emitted when flying and searching for prey. Other calls include feeding buzzes where bats rapidly echolocate to hone in on prey, and emergence chatter emitted as bats exit roost locations. Bats tend to emit more call variety when they are flying near roosts as compared to the more recognizable and consistent calls emitted during open air flight (Szewczak 2011).

Particular bat calls, such as search phase calls, have certain distinct and distinguishing characteristics which can be used to aid in identifying a species. These echolocation characteristics include the call frequency and duration, the slopes of the upper and lower portions of the call, and the inflection point or knee of the call where slopes change. Calls have distinguishing lowest and highest observed frequency ranges, frequencies with most power, and characteristic call frequencies or frequencies of the lowest slope of the call. MYSE has distinct high frequency search phase calls. MYSE, MYSO, and MYLU are all high frequency bats (characteristic frequency of 40 to 50 kHz) while PESU and EPFU are mid-frequency bats (40 kHz and 30 kHz respectively). See Appendix F for more detail. (Szewczak et al. 2015)

It is important to note that bat calls vary both between and within species. While certain characteristics are common to a particular species, there is variation among individuals, and bats are also known to alter their call characteristics depending on environmental influences (e.g., foraging in open versus cluttered habitats) and the presence of other bats. Ranges of some call characteristics overlap between species as well. (Neuweiler 1990, Schnitzler and Kalko 2001, Jung et. al. 2007)

In order to properly manually vet bat calls, many other characteristics are considered. These can include number of calls per second, bandwidth and characteristics of calls immediately before and after the call being identified. The expert would also identify characteristic features in the signal that would be attributed to echoes, multiple bats and effects of microphone placement as well as differentiate between search phase or other types of calls (such as a feeding buzz). While basic features such as those shown in Appendix F can be used as a general measure, many other features need to be considered. Therefore, manual vetting requires extensive expertise and results will vary depending on whether the expert is evaluating for likely or definitive species identification.

2.2.3 Range and Roosting Preferences

Precise locations of the range of each species of interest in this project are detailed below (NatureServe 2015). These maps are created with range information pre-WNS. Information is currently being collected by New England state agencies to aid in understanding the effects of WNS on species' ranges, and will be used to update species range maps. It is unclear at this time whether changes are occurring to species' range or only to population density within these ranges.

MYSE ranges across eastern and north central United States (Figure 2-1), as well as in Canadian providences (USFWS 2015). This species prefers tight holes and crevices that are sheltered from airflow and tree locations with more canopy cover (FHWA FRA 2015). MYSE is opportunistic, picking trees as day-roosts that have sufficient cavities, loose bark, and snags (SDBWG 2004, USFWS 2015, NatureServe 2015), and are associated with old-growth forests with ages 100+ years (FHWA FRA 2015, NatureServe 2015). Trees are preferred, with both dead and live trees utilized, but MYSE is known to occasionally use structures (FHWA FRA 2015) such as barns and sheds (USFWS 2015), open buildings, under house shutters (SDBWG 2004), bat houses, and bridges (NatureServe 2015). Recent studies have observed MYSE using live trees, snags, and anthropogenic structures as day-roosts (Dermody et al. 2017). Typically MYSE are found near dense forests and waterbodies (SDBWG 2004) and prefer foraging locations in forested areas (FHWA FRA 2015, Bailey et al. 2017). A recent study in Long Island, New York documented MYSE presence, noting that there was a strong negative correlation between occupancy probabilities of MYSE and the amount surrounding development, and that MYSE preferred habitats with forest patches (Bailey et al. 2017). Maternity roosts are found in tree crevices and beneath loose bark (NatureServe 2015), but males and non-reproductive females can be found roosting in cooler places (USFWS 2015). MYSE roost singly or in clusters (SDBWG 2004, USFWS 2015), with clusters not exceeding 100 individuals (SDBWG 2004). Recent studies have confirmed MYSE roosting in Nantucket, Massachusetts, observing a maternity colony of at least eleven individuals, fall season roosting, and potential hibernacula (Dowling et al. 2017). Recent studies have also confirmed MYSE roosting in Martha's Vineyard, Massachusetts, observing three maternity colonies and fall season roosting, and tracking female MYSE to both tree roosts and structures during maternity season (Baldwin et al. 2017). It is thought that relatively higher MYSE presence noted in coastal areas is due to these bats over-wintering in coastal locations (Baldwin et al. 2017, Dowling et al. 2017), where the fungus causing WNS is either not present or not as destructive (Baldwin et al. 2017). This species switches roosts often, with distances ranging 20 ft to 1.2 mi (6 m to 2 km) and an average distance of 0.42 mi (0.7 km) between roosts, and travels 40 to 50 mi (64 to 84 km) from hibernation to summer roosts (FHWA FRA 2015). Different roosts are used for day-roosts and night-roosts (NatureServe 2015). Night-roost and hibernacula preferences are in areas with high humidity around 90 percent in areas near standing water (SDBWG 2004). Ideal hibernation temperatures are 32 to 48°F (0 to 9°C) (FHWA FRA 2015). MYSE has been observed hibernating with MYLU, PESU, and EPFU, and may roost with these species in the summer as well (NatureServe 2015). Recent findings in Vermont noted a reproductive female MYSE summer roosting with a large maternity colony of MYLU and have tracked MYSE, MYLE and MYLU from hibernaculasono to summer roost sites where MYSE and MYLE as well as MYSE and MYLU were found roosting together in man-made structures (Bennett, 2017). Therefore it may be useful to track bridge use of these bats as well when describing favorable characteristics and document when MYSE individuals are also included in the roost.

MYSO ranges through the eastern U.S. (Figure 2-2), with populations suffering great declines within its range, particularly in the northeast U.S. Typically summer roosts are found in wooded areas, with dead trees in sunny open stands with lower canopy cover preferred (FHWA FRA 2015) as roosts as crevices beneath the bark are sufficiently warm. Live trees and tree hollows are also used, but bat houses and manmade structures are rarely utilized (FHWA FRS 2015, NatureServe 2015). Maternity colonies are typically found behind loose bark of both dead and live trees, and in tree cavities (NatureServe 2015). This species switches roosts often, with distances ranging 20 ft to 1.2 mi (6 m to 2 km) and an average distance of 0.42 mi (0.7 km) between roosts, and travel large distances from hibernation to summer roosts (FHWA FRA 2015). Some northern populations are thought to migrate to the south (Alabama, West Virginia, Kentucky, Indiana, Tennessee, and Missouri) for the winter, and predominately hibernate in caves, also utilizing mines, dams, and tunnels (NatureServe 2015). Ideal hibernation temperatures are less than 50°F (10°C) (FHWA FRA 2015). Proximity to water is known to be important (Bennett 2015, Hamilton 1943).

MYLU is found throughout much of the U.S. (Figure 2-3), with the exception of the south-central region, and throughout much of Canada. It is a common species and can exploit many habitats. Its preferred habitat is forested areas, riparian zones, and mountainous forested areas, but it is also common near urban areas, and is associated with human and manmade structures. Proximity to water is also known to be important (Bennett 2015). MYLU appears to be opportunistic in its roost selection and is known to use dimly lit buildings, mines, and caves as well as hollow trees (Hamilton 1943, SDBWG 2004, NatureServe 2015). Maternity roosts are often located in manmade structures such as attics and barns (SDBWG 2004, NatureServe 2015), and infrequently hollow trees (NatureServe 2015) so are more susceptible to disturbance by humans than bats that select natural roosts (SDBWG 2004). MYLU is thought to hibernate near summer roosts in the west, but travel hundreds of miles (hundreds of kilometers) between summer roosts and hibernacula in the northeast U.S. (Hamilton 1943, NatureServe 2015).

PESU is found in Canada and along the eastern portion of North America (Figure 2-4), and is considered rare within its range. This species exploits trees as roosts, changing roosts often and traveling from 60 to 450 ft (20 to 140 m) between roost locations. Tree cavities and manmade structures are utilized as maternity roosts, with some located in open sites that would typically not be used by other species (NatureServe 2015).

EPFU is common throughout the U.S. (Figure 2-5), with the exceptions of the extreme south-central region and the Florida peninsula (SDBWG 2004), and its range extending from southern Canada to Mexico into South America (NatureServe 2015). This species prefers forested locations, but has a wide range of habitats, and will roost in human structures including bridges (NatureServe 2015) and forage in in open urban areas (SDBWG 2004). EPFU also roosts in tree cavities, under bark, or in rock crevices (SDBWG 2004, NatureServe 2015), and is often found near floodplains (SDBWG 2004). Maternity roosts are also typically found in manmade structures, in large snags, under tree bark, or in tree cavities (SDBWG 2004) and are typically comprised of 25 to 75 adults (NatureServe 2015). Hibernation roosts are typically located in caves, mines, and buildings (SDBWG 2004, NatureServe 2015), with higher levels of males than females present in hibernating colonies (SDBWG 2004). Individuals typically travel less than 50 mi (80 km) between summer and winter roosts (SDBWG 2004, NatureServe 2015). EPFU also is sedentary, staying within 31 mi (50 km) of its birthplace (NatureServe 2015) and is observed to roost with other species (Gore and Studenrogh 2005).

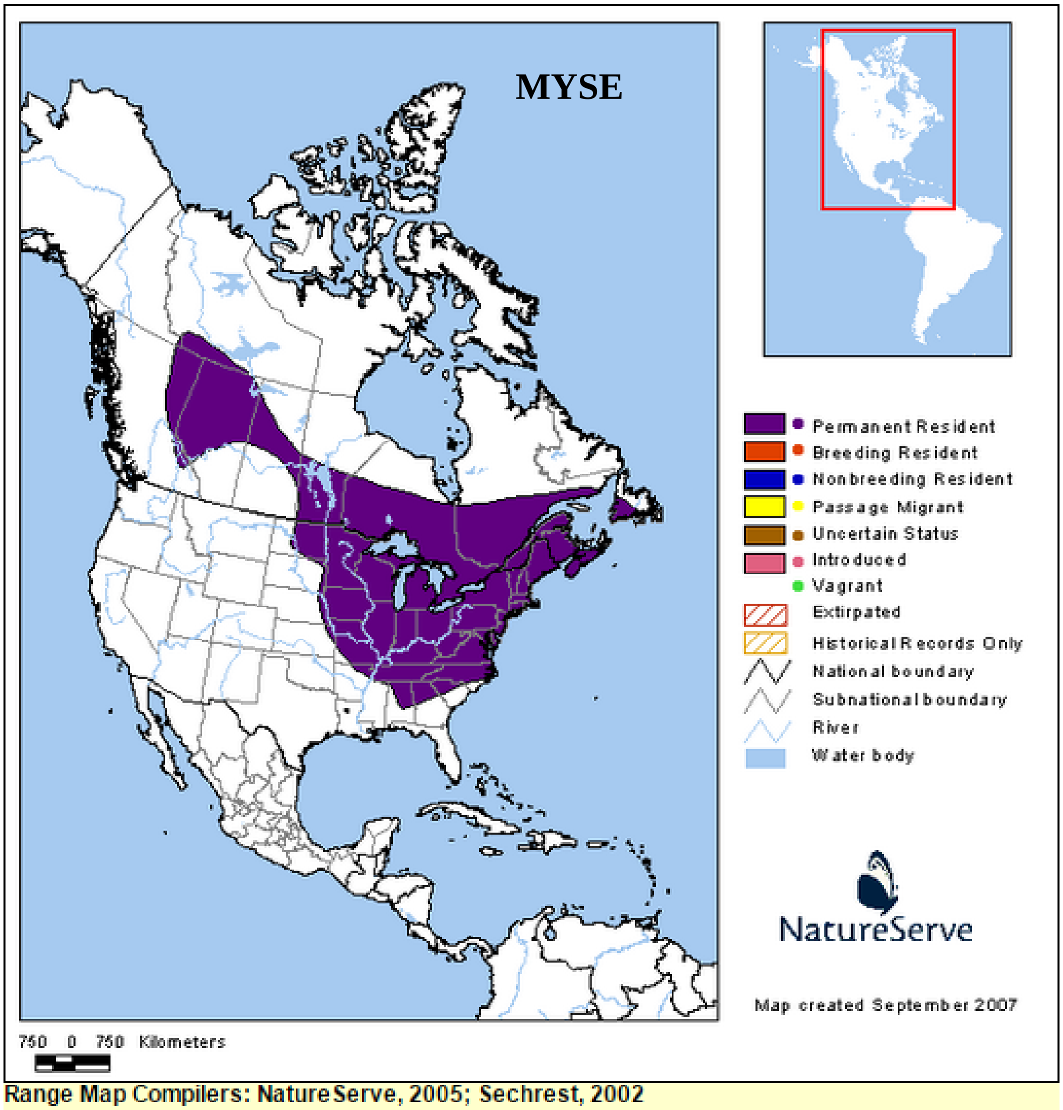


Figure 2-1: Range Map for MYSE–reproduced from NatureServe (Patterson et al. 2003)

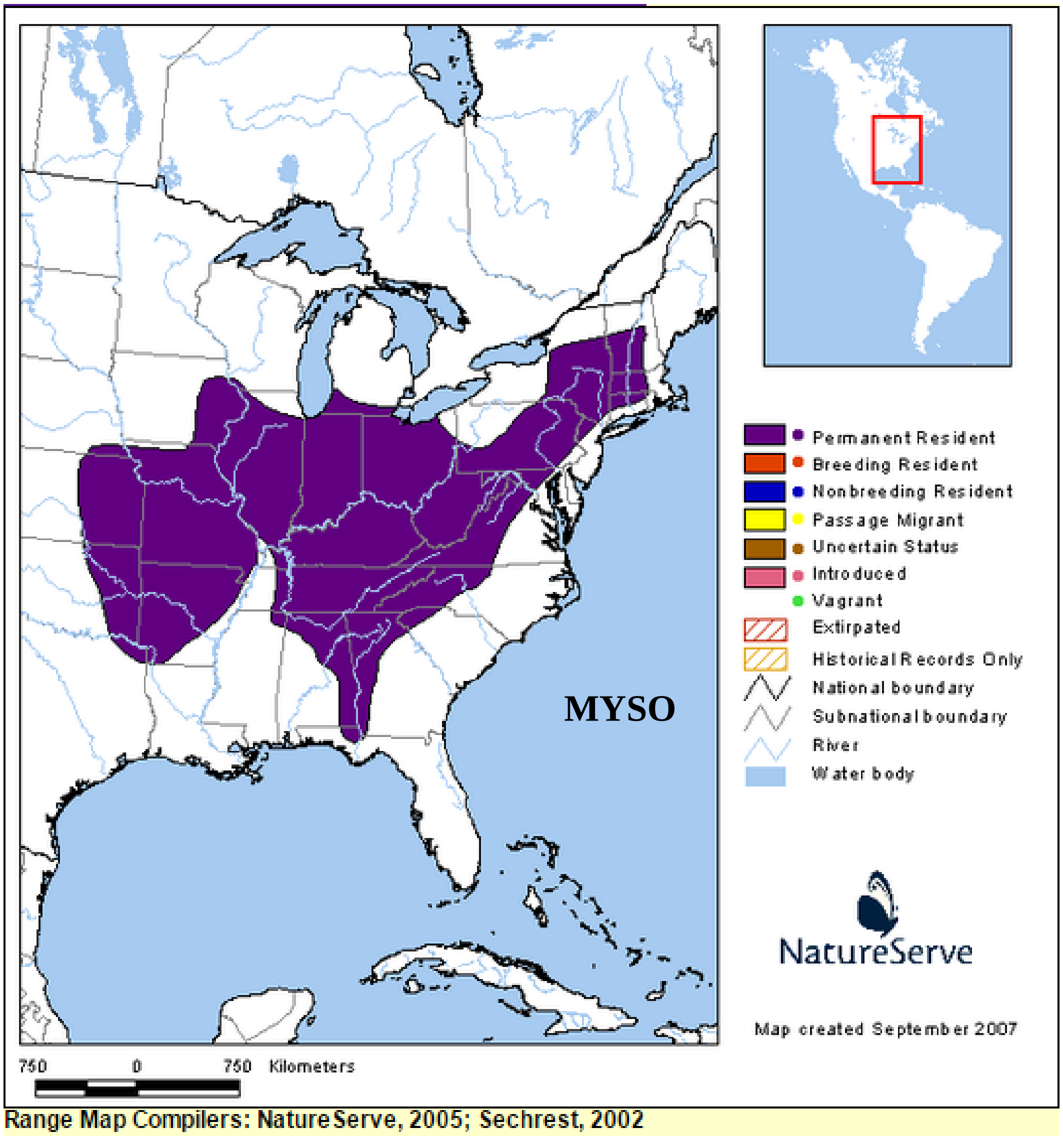


Figure 2-2: Range Map for MYSO–reproduced from NatureServe (Patterson et al. 2003)

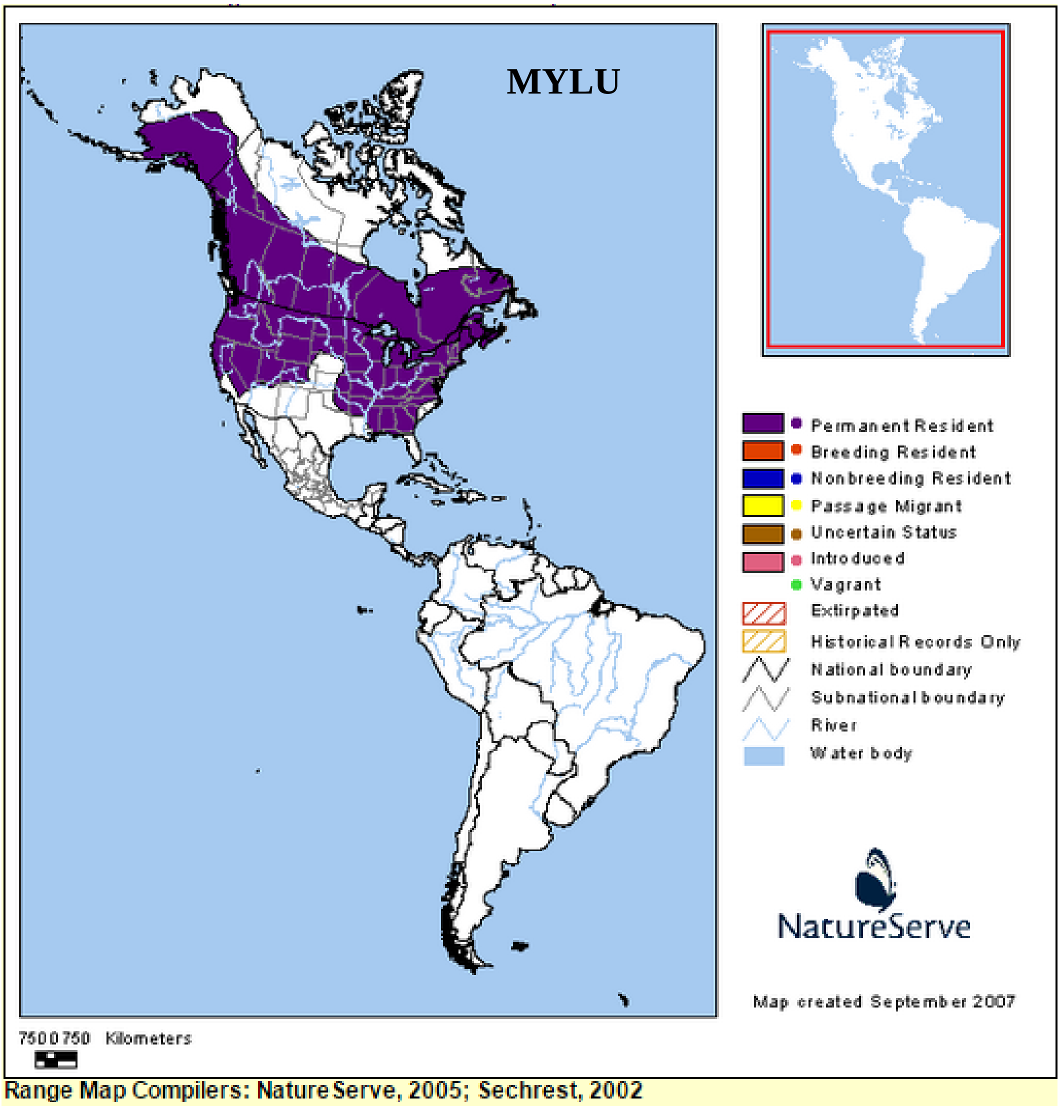


Figure 2-3: Range Map for MYLU–reproduced from NatureServe (Patterson et al. 2003)

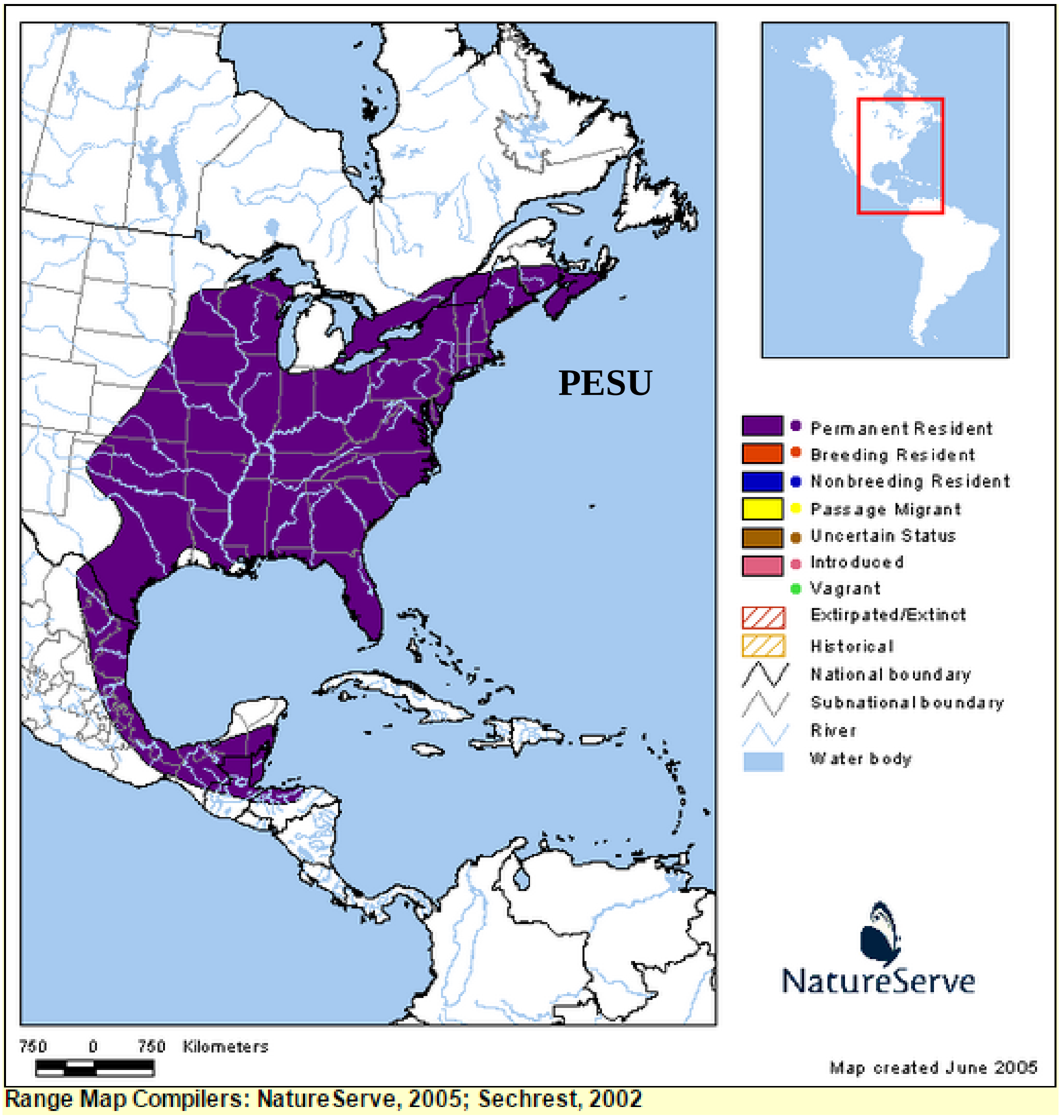


Figure 2-4: Range Map for PESU–reproduced from NatureServe (Patterson et al. 2003)

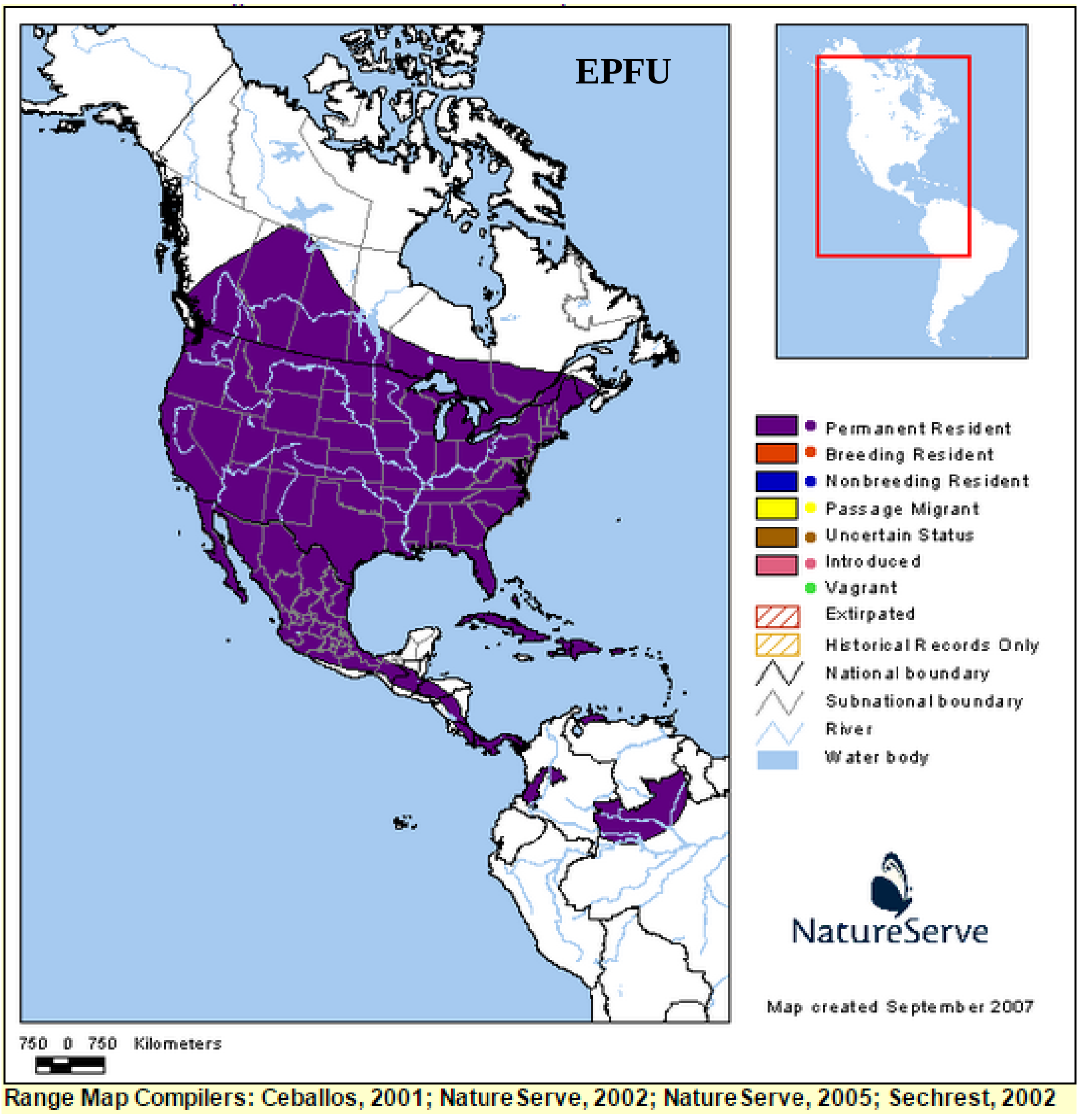


Figure 2-5: Range Map for EPFU–reproduced from NatureServe (Patterson et al. 2003)

2.2.4 Diet and Foraging Habits

All species of interest first emerge from their roosts to forage between sunset and dusk and again after night-roosting. All bats of interest forage by echolocation and are insectivorous, preying mainly on aquatic and terrestrial flying insects. MYSEs both hawk insects from the air and glean insects off of trees, vegetation, and water surfaces (Bennett 2015, NatureServe 2015). EPFU is largest of the bats of interest with more powerful jaw muscles and so can also feed on larger insects with harder exoskeletons (NatureServe 2015). All species of interest mainly forage in riparian areas, with MYSE also preferring forested areas and clearings (FHWA FRA 2015, NatureServe 2015, SDBWG 2004), and EPFU also preferring meadows and rural area lights that attract insects (NatureServe 2015, SDBWG 2004).

2.3 Bridge Component Terminology

Before detailing bat bridge roosting, a brief overview of bridge construction will provide clarification as there are different construction styles and different terminology can be used throughout the literature. As the focus of the current project is for DOT projects, typical highway beam bridge designs will be discussed. Bridges are comprised of a substructure and superstructure. The substructure of a bridge consists of the abutments, wingwalls, and piers, if applicable. The superstructure of a bridge consists of the bearings, girders, deck, overlay, and any expansion joints, if applicable. Generally, typical highway beam bridges are either jointed bridges or are jointless bridges. A common type of jointless bridges is integral abutment bridges. Figure 2-6 shows the location of these bridge components, denoting the terminology, and portrays the difference between jointed and integral abutment bridges.

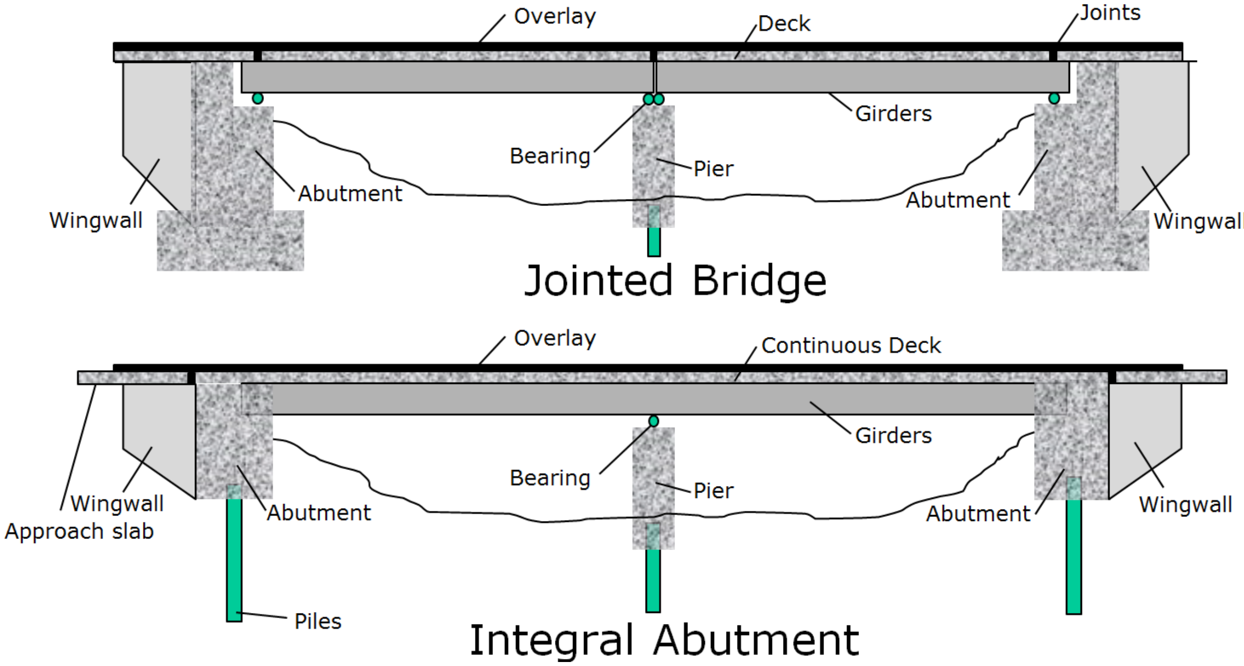


Figure 2-6: Location of bridge components and terminology

The main difference to notice between jointed and integral abutment bridges is that jointed bridges have expansion joints and integral abutment bridges do not. Importance of bridge construction style and construction details for bat bridge roosting will be discussed further, but are important to note and recognize. Certain construction styles or construction details can either provide or not provide potential roosting locations for bats in bridges meaning that categorically, certain bridge types are more or less likely to be utilized as day- or maternity roosts. While this distinction is important to be aware of, it is also important to note that any bridge construction style can deteriorate and potentially create appropriate roost locations.

There are many other types of bridges, such as arch, truss, cable stayed and suspension types, each of which may have specific features that could be used as roosting sites. Various construction details that provide appropriate crevices are more likely to be used as roost bridges. Bridge and bridge component materials used can also be very important to consider, as materials with more stable thermal properties are more likely to serve as roost sites.

2.4 Bridge Roosting

Bats use bridges for both day- and night-roosting as well as for maternity roosts and migration purposes. In depth and frequent inspection of bats roosting in bridges is a relatively newer research endeavor, especially with respect to the species of interest and region in the current project. This chapter aims to provide basic information on general preferences for bats' roosting in bridges, and is based on the studies summarized in Table 2-1 so is therefore subject to any limitations of the previous studies. Study results are often generalized, independent of the species being observed in the study. Previous research methodology can potentially skew perceived roosting results, such as lack of inspection of bridges of lower heights (FHWA FRA 2015) or limited inspection to bridges of certain types. One such example is studies that only focused on bridges over waterways, including Bennett et al. (2008), Adams and Hayes (2000), Arnett and Hayes (2000), Perlmeter (1996), Aughney (2008), Keeley (2007), and Shiel (1999). Cleveland and Jackson (2013) conducted a study in which all bridges spanned or were within 0.62 mi (1 km) of water. While some studies did inspect bridges over various crossings, such as Feldhamer et al. (2003), Geluso and Mink (2009), and Hendricks et al. (2005), some studies did not specify if selected inspected bridges were limited to water crossings. Characteristics of bridges that have been studied over a longer period of time may be reported multiple times, and therefore be over-represented in the literature.

2.4.1 General Preferences

There are 45 species of bats in the United States. 24 U.S. bat species are known to use highway structures (bridges and culverts; with culverts typically defined as bridges of 20 ft (6.1 m) or less in length) for roosting, including all species of interest in this project, and 15 have been determined to be likely to use highway structures (Keeley and Tuttle 1999). According to a study completed by Keeley and Tuttle (1999), there are approximately 33 million bats in the southern United States utilizing 3,600 highway structures (Keeley and Tuttle 1999). Bats' use of bridges can be beneficial by providing roost locations that are isolated and generally free of human disturbance and predators (Hendricks et al. 2005), and are used for maternity colonies, bachelor colonies, temporary roosts during migration (Keeley and Tuttle 1999, Keeley 2007, Smith and Stevenson 2013a, Adam and Hayes 2000, Bennett et al. 2008, Geluso and Mink 2009) and mating (Shiel 1999, Keeley and Tuttle 1999). In southern regions, some bridges may be used for hibernation, but it is highly unlikely to be the case in New England, where winter air temperatures reach well below freezing (Keeley and Tuttle 1999) and bridges do not offer adequate buffers from low temperatures as do caves (Geluso and Mink 2009). Even in southern U.S. locations with much warmer climates, such as Mississippi and New Mexico, few if any bats were observed roosting in bridges that were previously used in warmer months (Geluso and Mink 2009, Trousdale and Beckett 2004). However in a study conducted by Adams and Hayes (2000), a small number of bats were observed to use bridges in coastal Oregon during the winter months based on guano deposits collected in guano traps (Adams and Hayes 2000). While it is highly unlikely that bridges will be used by bat colonies during the colder months in New England, Trousdale and Beckett (2004) found individual bats persisting in locations utilized earlier in the year after the colony had dispersed for the roosting season (Trousdale and Beckett 2004). Peak usage of bridges for roosting occurs in late spring or early summer (Trousdale and Beckett 2004). Different species can also be found roosting together (Geluso and Mink 2009, Gore and Studenrogh 2005), especially in roost locations such as bridges in which space is not limiting (Gore and Studenrogh 2005). In general, preference is towards bridges with sufficient sun exposure to allow for higher temperatures in the evening hours, and in locations with appropriate surrounding habitat. In locations that lack available preferred roosting spaces, bats can still be found in crevices that are open and exposed to predation and weather, and in locations where bats are susceptible to disturbances and injuries from vehicles and humans (Keeley and Tuttle 1999).

2.4.1.1 Geographic Locations

A study conducted by Keeley and Tuttle (1999) focused on bats roosting in bridges throughout the southern 25 states of the United States noted that the number of day-roosts dropped above the 42º north latitude, and that bridges in the 23 northern states would likely not be warm enough for bat roosting. This was contradicted by a study conducted by Perlmeter (1996) in the Willamette National Forest, Oregon, north of the 44º north latitude, and another study conducted by Hendricks et al. (2005) in south-central Montana, with the general study area within the latitudes of 45°00' to 46°30' N. Bridges at these locations were utilized by bats for day- and night-roosting, but locations did not sustain suitable conditions for hibernation. All of the New England states lie between roughly 40°57.5' to 47°27.5' N. Findings of this project contradict the results of Keeley and Tuttle (1999) as bat roosting in bridges has been observed north of the 45º north latitude.

2.4.1.2 Material and Structure Details

Preferable roosts are in locations that are protected and have large thermal masses, allowing the structure to maintain its warmth at night (Arnett and Hayes 2000, Keeley and Tuttle 1999, Perlmeter 1996). Concrete has been reported as an ideal bridge material for roosting due to its thermal properties and detailing that provides crevices and enclosed spaces (Cleveland and Jackson 2013, Keeley and Tuttle 1999, Gore and Studenrogh 2005, Trousdale and Beckett 2004). Use of steel and wood bridges has also been reported (Arnett and Hayes 2000, Smith and

Stevenson 2013a). While bats are not observed roosting on metal surfaces as bats cannot grasp the surface and the material properties allow for rapid heat transmittal as compared to concrete (Gore and Studenrogh 2005), some studies have reported bats observed in steel bridges (Arnett and Hayes 2000, Smith and Stevenson 2013a, Cleveland and Jackson 2013, Gore and Studenrogh 2005) as well as findings of the current project (see Figure 4-4). Gore and Studenrogh (2005) specifically notes that bats observed in steel construction were roosting in concrete components within the bridge, thereby including steel construction in possible roosting bridges. Wood bridges are noted to contain crevices similar to those in artificial bat boxes, which aim to replicate crevices found in trees and buildings (Hendricks et al. 2005), and abandoned wooden bridges have specifically received protection for bat roosting on federal lands in certain areas (Adams and Hayes 2000). Compared to concrete, timber or wood bridges are sensitive to greater thermal and humidity variation, exhibiting larger shrinkage and swelling effects than concrete bridges, allowing for a variety of microclimates, which might be more preferable depending on the species. Wood bridges will not be used if they have recently been treated with creosote, a pungent oily wood preservative (Smith and Stevenson 2013a). Bats have been observed in bridges treated with creosote, but the coating was not fresh (Geluso and Mink 2009). Wooden bridges have been known to provide adequate roosting crevices and conditions, however the use of creosote can deter bats, perhaps leading to bats' observed preference to concrete bridges (Adams and Hayes 2000, Gore and Studenrogh 2005). Wood bridges may also allow for easier access by predators, including snakes (Gore and Studenrogh 2005). Although preferences may vary between regions, it is noted in Ireland that masonry bridges are the preferred material used as they provide more adequate crevices, assuming they are maintained correctly (Shiel 1999, Aughney 2008, Keeley 2007).

Bats often utilize cast-in-place beams as well as pre-stressed concrete girder spans (Arnett and Hayes 2000, Smith and Stevenson 2013a, Gore and Studenrogh 2005), and I-beam construction bridges are also known to be used as roost locations (Arnett and Hayes 2000, Cleveland and Jackson 2013, Gore and Studenrogh 2005). Slab bridges are used much less frequently than T-beam and box-beam bridges, with culverts rarely used for roosting (Hendricks et al. 2005) as well as flat-bottom bridges (Arnett and Hayes 2000, Bennett et al. 2008, Gore and Studenrogh 2005). Prestressed concrete bridges with multiple I-design beams were the most common roosting sites in a Florida study (Gore and Studenrogh 2005). However, recent work has documented use of a variety of culvert structures for roosting (Smith and Stevenson 2017).

The most favorable locations for bat roosting in bridges are expansion joints (Gore and Studenrogh 2005, VDOT Environmental Division 2014, Keeley 2007, Smith and Stevenson 2013b) usually that are sealed at the top (Gore and Studenrogh 2005), cracks in concrete, and cave-like environments (VDOT Environmental Division 2014, Keeley 2007, Smith and Stevenson 2013b). In areas where bats roost in expansion joints above support piers, clearance from the pier to the roost site was typically less than 20 in (50 cm) (Gore and Studenrogh 2005). Common places used as roosts include narrow spaces that are above high bridge beams, areas within concrete spalls, areas within pipe collars, areas behind or above insulation boards or expansion joints (VDOT

Environmental Division 2014, Smith and Stevenson 2013a and 2015), and in concrete downspouts (Cleveland and Jackson 2013, Gore and Studenrogh 2005) or steel drainage pipes (Smith and Stevenson 2013b and 2015). Narrow deep crevices are preferred, with bats found in crevices that are less than 2 in (5 cm) wide and at least 3 in (8 cm) deep (Gore and Studenrogh 2005), although specific preferences are dependent on the species (Shiel 1999). Bats often select bridges that are protected by hillsides or embankments (VDOT Environmental Division 2014). However, bat usage of bridges can be erratic (Shiel 1999). Other locations that are not used often but are considered possible roosting sites, even if for single bats, include, road signage, inside insulated pipes, housings for recessed lighting, areas between concrete piers, areas between guardrail beams and posts, areas with corrugated metal, and swallows' and Mud-daubers' (wasps') nests (Smith and Stevenson 2014 and 2015). Abandoned or unoccupied bird's nests may be utilized as bat roosts since microclimates appropriate for avian species is very similar to necessary locations for bats (Smith and Stevenson 2013a). Mud-daubers and bats also have similar preferences for spaces, so presence of this wasp species can be an indication of bats using the area (Bennett 2015).

Some research has indicated that structures located at least 10 ft (3 m) off the ground are preferable (Smith and Stevenson 2014 and 2015). Locations less than 4 ft (1.2 m) off the ground are less likely to be utilized by bats as this offers easy access to predators (Cleveland and Jackson 2013, VDOT Environmental Division 2014). Low structure height above ground or water should not necessarily be dismissed as possible roosting locations as bats have been observed in bridges with heights as low as 6.5 ft (2 m) (Smith and Stevenson 2013a), 3.6 ft (1.1 m) (Geluso and Mink 2009), 2.3 ft (0.7 m) (Keeley 2007) and 1.3 ft (0.4 m) (Ferrara and Leberg 2005). Bridge age can also be of consideration, with older bridges being preferable (Gore and Studenrogh 2005) as they typically provide more cracks and crevices that can be used as roost locations, and the deterioration of expansion materials provide new roost locations (Cleveland and Jackson 2013). Average age of bridges utilized by bats was found to be 33.5 years by Cleveland and Jackson (2013), while the average age of non-used bridges inspected in this study was 29.7 years (Cleveland and Jackson 2013). Gore and Studenrogh (2005) found similar results, observing age of bridges occupied by bats be on average 36 years old, and bridges unoccupied by bats to be 28 years old. This study also found average daily vehicular traffic was significantly lower in bridges occupied by bats than bridges without bat usage (Gore and Studenrogh 2005).

Photos of confirmed bridge roosting sites for various species can be found in Aughney (2008), Cleveland and Jackson (2013), Gore and Studenrogh (2005), Hendricks et al. (2005), Keeley (2007), Keeley and Tuttle (1999), Shiel (1999), Smith and Stevenson (2013a, 2013b, 2014, 2015), and VDOT Environmental Division (2014).

These previous studies discussed have provided excellent guidance on documented locations of bat roosts in bridges and related preferences and characteristics observed. However, it must be emphasized that bridges are rarely made of a single material, bridges may have characteristics in either the superstructure or substructure that are amenable for roosting, and any deterioration can have important consequences for roosting potential within a bridge. In addition, these studies are not specific to the New England region and cover many species, not just those of interest in this project.

2.4.1.3 Surrounding Landscape

Several factors in the surrounding habitat can be indications of bats' use of bridges for roosting. Evidence suggests that if bridges are located in preferable habitats and have the necessary crevices and characteristics, bats may use them as roost sites (Cleveland and Jackson 2013, Keeley 2007), and there is significant association between bridges used for roosting and the surrounding physiographic region (Bennett et al. 2008). Roadways can link wildlife corridors as bats' routes parallel landscape features (Smith and Stevenson 2013a). Specific landscape features to look for include large trees and mature forests, small fields, water, and the presence of watercourses for bats that forage on aquatic insects (Smith and Stevenson 2014 and 2015). Trees, hedgerows, and other vegetation are crucial landscape features (Cleveland and Jackson 2013) and integral components to insectivorous bat habitats, as treelines and hedgerows provide flyways utilized by bats for commuting between roosts and foraging grounds as well as migration (Smith and Stevenson 2013a). Typically, roosts are within 0.3 to 3 mi (0.5 to 5 km) from foraging grounds, due to the fact that reproductive success, growth success, pup mortality, and pup weight are correlated to travel distance to foraging grounds (Smith and Stevenson 2013a). Foraging areas will typically be in locations that concentrate insects, such as waterbodies, along forest edges and rocky ravines, near artificial light sources, near riparian corridors, and above tree canopy (SDBWG 2004). Certain plant species attract insects and thereby indirectly attract bats (Smith and Stevenson 2013a and 2014, Shiel 1999). While different bat species prefer different levels of vegetative cover (Keeley 2007), ivy or vegetation growing on or immediately next to bridges, can be utilized for roosts (Aughney 2008, Keeley 2007).

Bridges situated near or on large rivers with wide floodplains are particularly favorable as they provide abundant roosting areas with large food supply. These areas also are likely to serve as historic flyways during migration season and provide mating areas in the late fall (VDOT Environmental Division 2014). Proximity to water can be important, with all roost bridges studied by Cleveland and Jackson (2013) typically being within 0.6 mi (1 km) of water (Cleveland and Jackson 2013), however water noise and fast rushing water can reduce feeding activity in certain species of bats (Perlmeter 1996). In the studies conducted in Ireland, the majority of roosting locations were situated under the arch of masonry bridges, and that wet arches (arches over open waterways) were utilized more often than dry arches (arches over land/not water) suggesting a desire for bats to roost over waterways (Shiel 1999, Keeley 2007), though both were utilized. While riparian habitat and woodlands are preferred, bats have also been found in bridges surrounded by open farms and ranchlands, and by commercial residential areas (Cleveland and Jackson 2013). Bridges that do not span across waterways, including bridges that traverse busy roadways, should not be ruled out as potential roosts (Smith and Stevenson 2015). Lighting also plays a crucial role in determining bat usage of bridges, as illumination of roosts discourages nightly emergences and roost utilization (Keeley 2007).

Hendricks et al. (2005) found that bat use of bridges was related only to percent forest cover near bridges, and was unrelated to the immediate surrounding landscape, as few relationships were noticed between immediate landscape and occupied bridges. This was observed at scales of 0.3 mi (0.5 km) and 2 mi (3 km) relative to surrounding landscapes categorized as agriculture, aquatic/wetland, commercial/urban, forest, and rangeland. There was a significant difference between the mean forest cover around bridges used for day-roosts and bridges used for night-roosts or unused bridges. Bridges used for day-roosts were associated with higher forest cover. Bridges in open plains were used infrequently by bats. All but one day-roost was located within 3.0 mi (4.5 km) of the Yellowstone River riparian corridor. (Hendricks et al. 2005)

In another study, no statistically significant associations were determined relating bridge usage by bats and immediate surrounding habitat (Shiel 1999). It has been noted that different bat species prefer certain surrounding habitat characteristics, but no direct associations were concluded between bridge use and presence or absence of certain habitat types (Shiel 1999). While there is a trend towards roosting sites being utilized in areas with higher surrounding forest cover, other contributing factors may include distance between roosts, microclimates, and prey availability (Hendricks et al. 2005).

Bennett (2015) notes that these preferences vary for species in New England. The smaller cave bats can forage in dense clutter and narrow flyways under the canopy while migratory tree bats forage above the canopy, so they may choose different roost sites. Most species in New England prefer to roost with cover nearby the roost, such as trees or some type of hedgerow to travel safely along, but some, like the small-footed bat (*Myotis leibii*), will roost in open talus slopes and cliffs with little vegetation (Bennett 2015).

2.4.1.4 Microclimate Conditions

Roost microclimate selection is critical for reducing energy expenditures and increasing efficiency of thermoregulation (Ferrara and Leberg 2005). The temperature of roosts is a crucial component. While it is not necessary that the roost be warmed by direct sun exposure in all cases, sun-warmed roosts are preferable in New England, especially in the cooler months of March and April (Bennett 2015). Reproductive females prefer roosts that maintain thermal stability, having minimal temperature variations in roost temperatures to changes in ambient temperature, as compared to roost sites that achieve high temperatures only at certain times (Smith and Stevenson 2013b and 2014 and 2015, Gore and Studenrogh 2005, Ferrara and Leberg 2005), especially from May through July, which are the critical months when warmth is important for pregnancy and pup rearing (Bennett 2015, Smith and Stevenson 2013b, Ferrara and Leberg 2005). Males and non-reproductive females can be found roosting in cooler locations in bridges, where bats may enter torpor to reduce energy expenditures (Ferrara and Leberg 2005). However, it has been noted that the bats can congregate and use their body warmth to develop desirable microclimates within a bridge. Bridges that have suitable crevices and microclimates may not be used if they are not situated near feeding areas, or if the distance between roosts and feeding areas is too large, as having to travel farther distances increases the amount of energy spent and amount of food needed to be eaten (Keeley 2007).

Smith and Stevenson (2013b) conducted a study determining the microclimate of concrete bridges utilized as roosts by bats. Humidity as well as temperature is a key factor in determining roost and microclimate suitability as both factors influenced bats' utilization of bridges as roosts. Appropriate roost microclimates minimize thermoregulation energetic costs as well as reduced energy expenditure on activities pre- and during pup rearing. Nighttime temperatures are warmer than ambient conditions in concrete bridges while the daytime roost temperatures are typically 3.6 to 5.4^{o}F (2 to 3^{o}C) cooler than ambient conditions. Observed bridge roost temperatures ranged from 41.2^{o}F (5.1^{o}C) during non-reproductive times to more than 104^{o}F (40^{o}C) during pregnancy and pup-rearing. Temperatures above 104^{o}F (40^{o}C) induce a heat stress response from bats, including salivating, panting, and restlessness, with several species [including Yuma bat (*Myotis yumanensis)*, fringed Myotis (*Myotis thysanodes*), Occult little brown bat (*Myotis lucifugus occultus)*, and Pallid bat (*Antrozous pallidus*)] abandoning roosts with temperatures above 100^{o}F (38^{o}C) except in cases were movement within the roost allows for relief from temperature extremes. Ambient relative humidity ranged from 0 to 100% relative humidity, with roost conditions ranging between 30 to 55% relative humidity. The mean daytime temperatures were 81.4^{o}F (27.4^{o}C) for occupied roosts and 79.4^{o}F (26.3^{o}C) for unoccupied roosts with average ambient temperatures of 82.3^{o}F (27.9^{o}C). Mean daytime relative humidity levels were 38.8% for occupied roosts compared to ambient relative humidity levels of 40.1%. Mean nighttime temperatures of occupied roosts were 82.8^{o}F (28.2^{o}C) compared to the ambient temperatures of 73.8^{o}F (23.2^{o}C). Mean nighttime relative humidity levels of occupied roosts were 38.5% and ambient relative humidity levels were 51.8%. (Smith and Stevenson 2013b).

2.4.2 Bridges as Day-Roosts

Day-roost preferences in bridges are similar to general day-roosting criteria detailed in Section 2.1.2.2. Bridge day-roost use changes seasonally, with peak activity from April to October (Geluso and Mink 2009), and highest occupancy in July for maternity colonies. (Bennett et al. 2008, Geluso and Mink 2009). Parallel box bridges are most frequently used for day-roosts, as they provide adequate crevice sizes (Keeley and Tuttle 1999), and concrete box culverts have been more frequently reported as day-roosts by slow, low flying bat species that are adapted to dense environments (Smith and Stevenson 2013a). Bats tend to roost near the ends of the bridges longitudinally, near the abutments (Ferrara and Leberg 2005, Geluso and Mink 2009), closer to the mid-line of the bridge transversely, in narrow, dark spaces that are located in the warmer locations on the bridge, with roost selection based on predator avoidance and appropriate temperature (Ferrara and Leberg 2005). Some of the reported details of bridges used for roosts are described here, along with discrepancies between studies which highlight the variations in findings.

Keeley and Tuttle (1999) summarize the general minimum requirements of bridge and culvert day-roosts. For bridges, the most important factor is desirable thermal characteristics. Also important in descending order of importance is the construction material, crevice sizes [vertical crevices of 0.5 to 1.25 in (1.3 to 3.2 cm) wide and over 12 in (30.5 cm) deep], height of roost [over 10 ft (3 m) above ground, although this is disputed in Smith and Stevenson (2014 and 2015) which encourages all bridges to be considered, even the "less desirable" bridges under this height], and protection from weather and full sun exposure. Similar details were specified for culverts suggesting criteria for higher potential of bat usage. (Keeley and Tuttle 1999)

Feldhamer et al. (2003) conducted a study of bats using bridges as day roosts in southern Illinois. They found that bats used expansion joints and alcoves, with the smallest crevice size used of 0.75 in (19 mm), with most bats utilizing crevices of 1 in (2.5 cm) or greater. Mud-daubers were observed in many crevices, with few bats found in locations near areas with active wasp nests (Feldhamer et al. 2003). The average height above the ground level under the bridge was 16.7 ft (5.1 m), with a range of 3.2 to 32 ft (1 to 10 m) observed. Concrete was preferred, with only one bat observed using a steel girder, and no bats using wood bridges. Parallel box beam bridges were the most favored bridge, while no slab bridges with flat bottoms were used as they did not provide suitable microclimates. (Feldhamer et al. 2003)

Hendricks et al. (2005) conducted a study determining bat usage of bridges in south-central Montana, and preferred characteristics of day-roosts. Wood and concrete bridges were used as day-roosts, with wood bridges being more favorable than concrete. In wood bridges, bats typically used the undersides of the deck or locations in between the supports where the railing posts are anchored, and wooden bridges that were utilized as day-roosts showed no signs of night-roosting. In concrete bridges, bats typically utilized narrow slots in the underside of the bridge, in expansion joints where filler or seal material had eroded, and in the space in between two T-beam bridges (Hendricks et al. 2005). Typical spaces were 1.25 to 2 in (3 to 5 cm) wide and at least 4.5 to 12 in (11 to 30 cm) deep (Hendricks et al. 2005, Smith and Stevenson 2013a). The average minimum roost height was determined to be 15.7 ± 7.9 ft (4.8 ± 2.4 m), with roost heights as tall as 32.2 ft (9.8 m) above ground, which in general were found to be at higher heights than night-roosts. Day-roosts were located in more protected and confined areas than night-roosts, and frequently occurred in the vicinity of riparian river corridors. (Hendricks et al. 2005)

Geluso and Mink (2009) determined timber bridges in New Mexico to be significantly preferable in day-roost selection (over 99% of observations) with concrete and steel I-beam bridges also used. It should be noted that timber bridges represented approximately two thirds of the bridges surveyed in this study, so the results may be biased. Timber bridges were determined to be crucial roosting sites for maternity roosts, bachelor roosts, and transitory roosts for several species. The majority of the bats observed (99.9%) were found in narrow crevices and cracks, with the most preferable location being spaces up to 1 in (25 mm) wide and approximately 15 in (38 cm) deep. Average crevice widths observed for roosting was 0.7 in (17 mm). Crevices chosen were dark and protected from predators, but not always protected from the weather, and several wet bats were observed. Bats were observed roosting on top of one another, typically stacked two to four individuals deep, utilizing deep cracks in the bridges, while individual bats were occasionally observed in more shallow locations. Bats were also found utilizing open areas infrequently, were observed in expansion joints, and one was observed using a cliff swallow (*Petrochelidon pyrrhonota*) nest. Proximity to water resources was determined to be a likely factor in bridge use. (Geluso and Mink 2009)

Bennett et al. (2008) studied bridge day-roosting by Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) in South Carolina and found that larger concrete girder bridges were the favored construction and material type, with flat-bottom slab bridges and timber bridges not used. Larger bridges may be beneficial as they provide a variety of microclimates, ensuring preferred conditions will be met. It was observed that bats tend to roost near the abutments of bridges traversing waterways, and were typically found in open areas between support beams, rarely being found in expansion joints. Surrounding conditions, bridge characteristics, bridge construction type, and amount of disturbance at the site were found to be important to roost selection. Additionally, no staining was observed by the bats, with only guano pellets being occasionally observed on structural elements or the ground. (Bennett et al. 2008)

While other species were also encountered in the study by Bennett et al. (2008), it should be noted that the species observed day roosting in bridges are known to roost in more open locations than other species (Gore and Studenrogh 2005, Trousdale and Beckett 2004), and this species and study area climate differ from the conditions of the current project and observations may differ for the species of interest in New England.

2.4.3 Bridges as Night-Roosts

Studies show that bats frequently utilize bridges for night-roosts, with several factors influencing roost selection for night-roosting such as temperature, size, gender, timing, and location (Perlmeter 1996, Adam and Hayes 2000). Temperatures of night-roosts are influenced by the roost size, minutes after sunset/time of day, and daily solar radiation levels, with bridges maintaining higher temperatures throughout the night utilized more frequently (Perlmeter 1996). Benefits of using a warm night-roost can be outweighed if the bridge location is far from day-roosts (Perlmeter 1996). Size of the roost also affects use and the number of bats observed. Male bats are observed to almost always roost alone while females both roost alone and in clusters, with almost all clusters consisting of females (Perlmeter 1996). Roost activity and populations are highest when the species are in later stages of pregnancy. Surrounding areas can dictate which bridges are used by specific species of bats depending on diet as certain habitats provide better foraging areas and prey selection than others (Perlmeter 1996). Foraging habits also differ between species, with variations in timing of peak roost activity during the night and differences in amount of time spent foraging for food versus roosting (Perlmeter 1996).

Since night-roosts tend to be locations used as stopovers during the night, they can be in more exposed locations and tend to be less sheltered than day-roost locations. Night-roosts are found in a larger variety of bridges compared to day-roosts. While several bridge types have been reported to be utilized, including pre-stressed concrete girder spans, cast-in-place concrete spans, and steel I-beams (Keeley and Tuttle 1999, Adam and Hayes 2000), bats favored vertical concrete surfaces between beams to provide wind protection and radiant heat (Keeley and Tuttle 1999). Cast-in-place concrete bridges are reported as the preferred material and construction type, likely due to the thermal properties, with bats typically roosting in upper corners were girders and slab meet, assumed to further reduce heat loss while roosting (Adam and Hayes 2000). Long concrete box culverts were utilized if they are more than 5 ft (1.5 m) tall (Keeley and Tuttle 1999). Small culverts and bridges with flat bottom surfaces, or bridges that do not have inter-beam spacing, were not likely to be used (Keeley and Tuttle 1999) with no observations of bats roosting in concrete flat bottom bridges (Adam and Hayes 2000). Night-roosts are typically located under bridges near the abutments where air flow is reduced, and at the high points, in the warmest locations (Keeley and Tuttle 1999, Smith and Stevenson 2014, Adam and Hayes 2000). If bridges traverse waterways, mid-span locations away from the abutments tend to be cooler due to the water and increased wind/air flow (Adams and Hayes 2000). Typical roost characteristics include exposed, open locations (Hendricks et al. 2005, Smith and Stevenson 2013a), such as the vertical surface of a steel or concrete girder near an abutment, locations that are close to the bridge intersection with the embankment or ground surface, have a minimum height of 6.9 ± 3.0 ft (2.1 ± 0.9 m), and that are in darker locations in between the girders (Hendricks et al. 2005). Additionally, Adam and Hayes (2000) found that bridge characteristics, such as length, width, and height, are statistically significant to bridges selected as night-roosts, with selection trending towards larger bridges (longer, wider, and taller bridges). This may be due to increased roosting area, solar radiation retention, greater roost accessibility, and increased predator protection in larger bridges (Adam and Hayes 2000).

While patterns varied in each bridge, Adam and Hayes (2000) observed temporal patterns of bats using bridges as night-roosts. Bats use bridges as night-roosts most frequently in July and August, based on visual observation of bats and guano deposits. Bridges were used as night-roosts throughout the night, but were most frequently used with peak roosting observed 3:00AM to 4:30AM and most infrequently used an hour to an hour and a half after sunset. Bats were only observed after 6:00AM in September in small numbers, indicating that the bridges studied were only used as night-roosts and rarely as day-roosts. (Adam and Hayes 2000)

It is important to note that these studies represent select findings, with species and conditions not necessarily corresponding with New England conditions. Other studies, including the current project, have noted different night-roosting behavior regarding timing and bridge location.

2.4.4 Bridges as Maternity Roosts

Bridge maternity roost conditions are similar to day-roost conditions, assuming the location is large enough to house the maternity colony. Maternity roosts may tend to be selected at higher height above ground or water to avoid detection and predation (Ferrara and Leberg 2005) and have been found in bridges that contain large, deep crevices (Shiel 1999). In Montana, maternity roosts tend to be found in wooden bridges (Hendricks et al. 2005). Other locations included concrete box-beam bridges and expansion joints of T-beam bridges (Hendricks et al. 2005). Locally in New England, there is a known maternity colony of little brown bats utilizing a covered wooden bridge in Vermont.

2.4.5 Methods to Encourage Bridge Roosting

With dwindling bat populations, the provision of adequate roost locations for species is important in both preserving existing roost locations as well as implementing safe alternatives where necessary. However, many factors must be balanced when deciding whether to encourage bat roosting in a bridge. Before encouraging bats to roost in bridges it should be evaluated whether the site is a potentially harmful location. Only bridges and sites that are safe and appropriate to encourage bat roosting should be considered. Since routine maintenance and repair procedures are expected for bridges, the presence of bats can be problematic and lead to construction delays and additional costs, or harm to bats if precautions are not taken. Feldhamer et al. (2003) reported resistance from the state and county engineers in charge of bridge maintenance and construction, as they believed adding bat houses would provide a means of documenting structural use by endangered and threatened bat species that could impact the future maintenance and construction activities on the bridges, making projects unaffordable (Feldhamer et al. 2003). However, other locations have been found to provide benefits to both bats and the community, such as the Congress Street Bridge in Austin, Texas which supports a colony of up to 1.5 million Mexican free-tailed bats (*Tadarida brasiliensis*) that can consume anywhere from 10,000 to 20,000 lbs (4,436 to 9702 kg) of insects per night, including various agricultural pests (BCI 2017).

Where bridges are scheduled for maintenance or replacement, the deteriorated bridge would likely have favorable characteristics for bat roosting, containing appropriate crevices sizes (Hendricks et al. 2005, Keeley 2007). If the site is appropriate for bats to continue roosting, and if structurally sound, methods can be employed to encourage bats to return to the bridge after work is complete. Crevices can be maintained by filling holes with removable material, such as spray foams, prior to construction, though this can lead to difficulties in removing the fill material or leave crevices that are too shallow to be of use to bats (Shiel 1999, Keeley 2007).

The use of artificial roost boxes can be an effective measure to provide night and day roosts for several bat species (Arnett and Hayes 2000, Keeley and Tuttle 1999, Christensen et al. 2015, Gore and Studenrogh 2005), and is an inexpensive option causing no structural damage or loss of structural integrity of the bridge. These are structures that can be assembled and either attached to existing highway structures, or implemented as free-standing structures in the vicinity of the bridge to provide additional day-roosting capacity and assist in mitigation and bat management (Keeley and Tuttle 1999). Utilizing bat houses can also allow for roosts to be moved out of harm's way if bridge maintenance or replacement is required (Hubbuch 2015), although the success of this method has varied. If it is determined that artificial roosts are recommended in construction areas, they should be implemented up to two years before the start of the project for increased success in roost use (Smith and Stevenson 2014). A variety of bat houses are available that are designed to be compatible with specific roosting preferences and structure types. It is recommended that specialists be consulted when deciding on structures to ensure that the selection is appropriate and can house the entire expected bat colony.

Since roost loss and disturbance are important causes of bat decline, including bat roosts in highway structures can be an ideal mitigation strategy. Bats do not cause structural damage to bridges, although bat roosts should not be encouraged above metal highway structure components since organic matter that retains moisture causes oxidation of unprotected metal parts (Keeley and Tuttle 1999, Gore and Studenrogh 2005). When desired, bats should only be encouraged to roost in bridges that have appropriate conditions and are safe. Proper implementation of bridge features that promote roosting can be very beneficial by providing permanent safe roosts, actively encouraging the retention of threatened and endangered species, and providing symbiosis between the natural and built environment.

2.4.6 Methods to Exclude Bridge Roosting

Exclusion can be generally defined as implementing practices to remove bats from a location and preventing re-entry, either temporarily or permanently. This can be done by several measures, such as installing netting (Gore and Studenrogh 2005, Smith and Stevenson 2013a, 2014, 2015), one-way valves (Gore and Studenrogh 2005, Smith and Stevenson 2013a, 2014, 2015, Keeley and Tuttle 1999, Szewczak 2011), or by the use of foam sealants (Smith and Stevenson 2013a, 2014, 2015, Keeley and Tuttle 1999, Szewczak 2011). If done improperly, this can have negative effects on bats, including trapping bats inside the roost, (Smith and Stevenson 2013a, 2014, 2015, Keeley and Tuttle 1999, Szewczak 2011), causing pup abandonment, or accidentally allowing re-entry or occupancy of the assumed excluded structure (Smith and Stevenson 2013a, 2014, 2015, Szewczak 2011). Negative impacts are particularly salient for improperly or incompletely sealed crevices (Smith and Stevenson 2013a, 2014, 2015). Bats can also be excluded from bridges, intentionally or unintentionally, by the use of bright light illumination, high levels of activity or disturbance, high levels of noise, or strong odors in the vicinity of roosts.

Szewczak (2011) investigates the new innovative exclusion practice of ultrasonic acoustic deterrence/exclusion of bats. This exclusion practice uses speakers to emit ultrasonic acoustic pulses into the airspace surrounding the bridge or area intended to exclude bats. The generated ultrasonic noise is designed to interfere with the bats' echolocation abilities, which they rely on for spatial perception and navigation as well as feeding, therefore dissuading bats from using the local area. This ultrasonic white noise exclusion method can be useful when traditional exclusions measures are not logistically or economically feasible, such as in bridges with irregular or complex design, ubiquitous roosting potential, or inadequate access. This exclusion practice has been tested in small control studies, in small scale field experiments, and at wind farms. The equipment is not yet commercially available and has displayed varying levels of success thus far in trials. This exclusion practice has restrictions on effective exclusion area that is highly variable depending on local conditions. For example, broadcast coverage ranges can vary from 160 to 270 ft^2 (15 to 25 m^2) depending on the relative humidity in the area. A general guideline of expected coverage of 215 ft^2 (20 m^2), or placing speakers 66 ft (20 m) on center, has been recommended. These restrictions, as well as the potential for shadowing of emitted signals, may make this method ineffective for larger bridges. Further experimentation is necessary to determine any secondary effects to bats, which has not been extensively studied, and any human safety effects due to ultrasound exposure. It is important to not use ultrasonic acoustic deterrence methods indiscriminately as dissuading bat usage in large scale areas such as along feeding corridors can have unintended detrimental effects on local bat populations. (Szewczak 2011)

Day-roosts typically are more crucial to bat roosting than night-roosts as day-roosts are more vulnerable to threats and accommodate maternity colonies which include nonvolant pups that would be trapped in the excluded roosts. Bats tend to exhibit higher fidelity to maternity roosts, and so consequently day-roosts, as well as permanent structures which can also raise concerns about day-roost exclusions. Active maternity roosts should never be disturbed as they are more sensitive and susceptible to disturbance. Therefore, exclusions should be completed outside the general maternity roost timeframe of April/May through August/September (including ambient temperature restrictions) to ensure the colonies are not harmed or disturbed and no pups are trapped inside the roost (Gore and Studenrogh 2005, SDBWG 2004, Szewczak 2011), otherwise the confirmation of the absence of pregnant females and pups is needed (Gore and Studenrogh 2005). Excluding bats from maternity roosts can also create issues of mother bats' increased persistency to re-enter the roost if a nonvolant pup has been trapped inside (Gore and Studenrogh 2005) or a mother dropping her pup while transitioning to a new roost (SDBWG 2004).

Given the unique weather conditions in New England as compared to previous study locations, including harsh winters with low temperatures, bridge use by bats over the winter is considered extremely unlikely to non-existent. This provides a window for exclusion measures to be implemented with very high confidence of no harm to bats, so long as the exclusion practice is completed appropriately. Confirmation of the absence of bats is necessary before any exclusion measure is taken (Smith and Stevenson 2013a, Szewczak 2011), even when the probability of bridge roosting is minimal. In New England, however, restrictions on ambient temperature and time of year could ensure this without the need for full bridge inspections. Ensuring there are alternate roosts within the vicinity is also imperative for all exclusion operations (Szewczak 2011).

Christensen et al. (2015) includes a summary of the various measures taken in Europe to mitigate and reduce negative impacts of roadways on bats. These measures include various "wildlife crossings" of sorts, variations in lighting techniques, exclusion measures by physical barriers and noise, and surrounding habitat restoration, though there is little conclusive evidence on the success of these measures (Christensen et al. 2015).

In any case where exclusion methods are to be used in bridges, consultation with a wildlife expert is essential to ensure that means and methods are properly interpreted and implemented. Misunderstanding or misuse of exclusion methods and procedures could result in increased risk of harm to the bat population the exclusion intends to protect.

2.4.7 Observed Bridge Roosting for Species of Interest

All species of interest are known to utilize bridges for roosting, with lesser known information about certain species. The species of interest in this project are rarely specified in the literature pertaining to bridge roosting due to the lack of studies focused on the New England region and these species. Though recent study in Addison County, Vermont indicated that it is highly likely that MYSE, along with MYSO and MYLU, are currently roosting in two bridges scheduled for replacement (Lout and Ketterling 2017). Four MYSE have since been captured at the site and fitted with transmitters (Bennett 2017).

MYSE and MYSO are found in northeastern U.S. and have been reported to utilize bridges, preferring crevice roost sizes between 0.5 and 1 in (1.3 and 2.5 cm). MYLU and EPFU are found throughout the U.S. and are known to utilize bridges, but MYLU prefers crevice roost sizes between 0.5 to 1 in (1.3 to 2.5 cm), and EPFU prefers crevice roost sizes from 0.75 to 1.5 in (1.9 to 3.8 cm). PESU are found in eastern U.S. and utilize bridges, preferring open roosts that are more exposed and less sheltered compared to roosts selected by the other species of interest. Culverts have also been noted to be roost sites for these species. (Keeley and Tuttle 1999)

Timpone et al. (2010) conducted a study comparing roosting preferences of MYSO to MYSE in Missouri, and while the study examined roosting in trees, results indicated preferred roosting characteristics that can be applicable to determine roosting usage in bridges as well. Both bat species heavily rely on trees for roosting sites as they are primarily forest species. As these two species are sympatric, meaning they exist in and occupy overlapping geographical areas, they have similar preferences in roosting sites, but have been found to use statistically different trees. Compared to MYSO, MYSE chooses roost trees with higher canopy cover, meaning less sun exposure, and roost within or below the forest canopy. MYSE use shorter trees and trees with more cavities than MYSO. In general, MYSE was found to be more flexible and more opportunistic than MYSO in roost selection. MYSE roosted in both dead and live trees and manmade structures, preferring snags and certain species of tree (in descending preference: black oaks and Northern red oaks, Silver maple, Pin oak, American elm, Cottonwood, Honey locust, Shagbark hickory, and Shellbark hickory). As in hibernacula, it is expected that MYSE would roost much higher in crevices and cavities than other species. MYSE roosted in crevices and cavities as well as under exfoliating bark, moving roosts approximately every two days, spending no more than three consecutive nights roosting in a specific tree and no more than eleven days roosting in a specific manmade structure, travelling between 0.03 and 2.4 mi (0.05 and 3.9 km) between roosts and trees (Timpone et al. 2010).

2.5 Bridge Inspections

Bridges subject to construction or maintenance activities or demolition should be inspected for bat usage (FWHA FRA 2015, Cleveland and Jackson 2013). While it is relatively easy to determine the presence of bat usage of bridges, it can be difficult to prove the absence of use (Smith and Stevenson 2013, 2014). Observation of bat indicators can be highly dependent on the time of year and time of day of inspection, as well as the experience and interpretation of data by the inspector.

Inspections and surveys of bridges to identify potential bat roosts mainly focus on visual inspection. This inspection technique observes all signs of bat utilization, such as guano, urine stains, direct visual observation of bat roosting, direct observation of emergence, and detailed inspections of appropriate crevices and cavities. Specialized equipment such as borescopes can be invaluable tools in visual inspections to aid in inspecting small or deep crevices, and to confirm sources of staining. Infrared or thermal cameras can also be utilized, though their effectiveness in day-time inspections may be limited. Specialized equipment used during visual bridge inspections is discussed in more detail in Section 3.1.

At the time of their reporting, Smith and Stevenson (2014, 2013) addressed the lack of definitive guidelines for assessing bat occupation in bridges or appropriate remediation guidelines that should be taken (Smith and Stevenson 2013, 2014). In 2015 a joint report from the Federal Highway Administration and Federal Rail Administration (FHWA FRA 2015) provided a national guideline for bridge inspection, as will be discussed in Section 2.6. Keeley and Tuttle (1999) provide a detailed summary of bat use of highway structures, providing some guidelines and frameworks for inspection, and useful information about general bat usage of highway structures and appropriate measures to be taken.

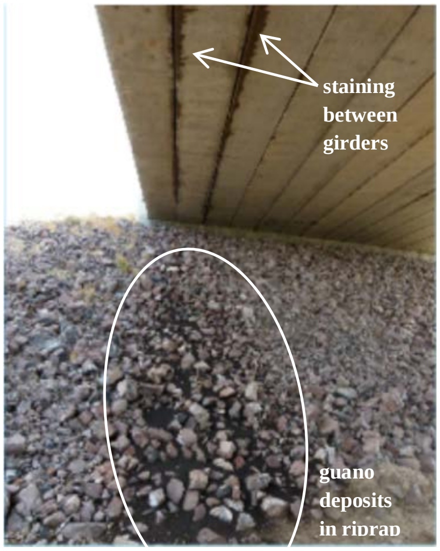
2.5.1 Evidence of Bats

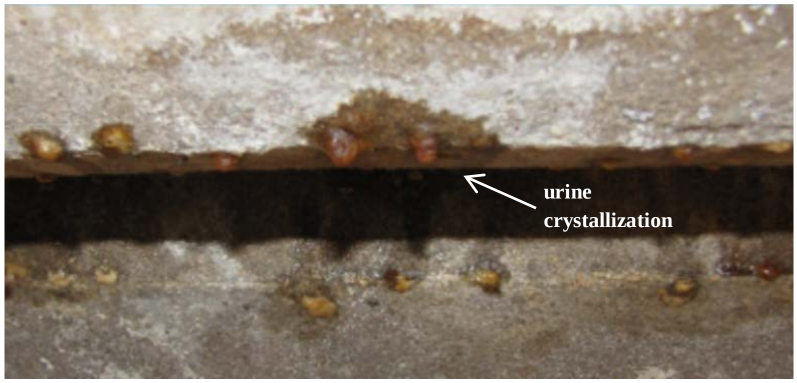
Signs of bats using bridges for roosting include direct visual observation of bats, audible chirping, guano deposits at or below the roost site, staining from urine and body oils, and sometimes odors (Keeley and Tuttle 1999, Hendricks et al. 2005, Shiel 1999, Keeley 2007, VDOT Environmental Division 2014). Bats can be visually observed, either live or dead, at bridge sites. Bats can be seen in specific locations detailed in Section 2.4, either seen in open areas or in crevices. Dead bats may be found under bridges or in the surrounding vicinity. The high pitched sounds that bats make are particularly useful if roosts are located within deep cracks or open joints (Keeley 2007, Bennett 2015). Guano tends to accumulate beneath the roost site either on the ground or on underlying structural elements, though this would be difficult to observe in a bridge over a water body and would be less obvious when small numbers of bats are roosting at a site. Guano accumulation can vary based on colony size as accumulations will be significantly different for large colonies versus roosting by several individual bats or smaller colonies. Stains from guano are dark and prominent when large colonies are present, and are located on concrete faces and beams under roosts (VDOT Environmental Division 2014). Staining from urine or birthing fluids can be lighter in color and similar to moisture staining in appearance. Figure 2-7 and Figure 2-8 show signs of staining and guano from large populations of migratory species and is as such not representative of some of the smaller populations and species found in New England. Bat staining usually has a gap of unstained material near the top of the surface where the bat body rests with a straight line of staining below, though staining can be difficult to distinguish from other staining causes. Bridge staining occurs for numerous reasons, including weathering and structural damage/causation such as leakage of water and debris through deteriorated bridge joints, corrosion, leaching, and efflorescence. Staining from structural causation is directly related to bridge deterioration and therefore common on bridges that are slated for repair, replacement and other construction projects. Several visits to a bridge site are typically not warranted for time and budget constraints, however visiting bridge sites multiple times in different weather conditions can sometimes aid in determining the staining causation. Bat odor can also be used by experienced personnel to determine bat usage at bridge sites, but these odors can be difficult to distinguish from other odors (such as rodent) and are not sufficient to conclusively determine use (Gore and Studenrogh 2005).

Smith and Stevenson (2014) note that there may not be obvious signs of bat occupancy in bridge roosts. There may not be visible accumulations of guano and/or urine staining depending on the location of the roost, and roosting bats may display minimal movements and vocalizations (Smith and Stevenson, 2014). This would be especially true for smaller roost populations, such as those in New England.

More extensive discussions on bridge inspections are covered in Section 2.6 and 2.7.

Figure 2-7: Bridge staining from known bat usage (photos courtesy of Jeff Gore, Florida Fish and Wildlife Conservation Commission)





a) b)

Figure 2-8: a) Bridge staining and guano accumulation below from known bat usage; **b)** Bridge staining from bat urine crystallization (photos courtesy of Smith and Stevenson (2014, 2015))

2.5.2 Visual Inspection Techniques

When inspecting bridges, it is important to examine both the underside of the bridge spans as well as the complete substructure. In areas that are not easily accessible or that cannot be examined physically closely, binoculars, spotting scopes, or zoom or telephoto lenses should be used. Indications of bat usage should be noted, and all observations, both use and nonuse of structural elements by bats, should be documented (VDOT Environmental Division 2014). An ideal, inspection would include access to all locations on the bridge, but expenses of traffic control, snooper trucks, and more involved access techniques are generally outside the scope of these inspections. However, coordination with structural inspection crews who may be scheduled to perform work on the bridge using these tools could be invaluable.

Cracks in concrete and expansion joints should be thoroughly investigated. Some bats may be roosting deep in a crack, hidden from sight, so it is important to check behind areas of deteriorating concrete and any cracks of the underside of the deck, the abutments, piers, and girders of the bridge. Expansion joints should be inspected using a flashlight and/or borescope to see if any bats are roosting (VDOT Environmental Division 2014). Borescopes can be useful in inspecting areas deep in the bridge that are otherwise not visible. Use of flashlights and borescopes or any invasive procedures may require a permit when observing endangered or threatened species or species of concern as these measures can cause unnecessary stress levels and harassment. The state and Fish and Wildlife Service region should be consulted to determine local requirements. Bats are very sensitive to stress, an even minimal stresses incurred during research activities can be harmful or detrimental to bats (SDBWG 2004).

2.5.3 Inspection Reporting

All information should be documented to justify bat presence, likely absence or inconclusive results from the inspection. Observations should include approximate numbers seen, any indications of dead or injured bats, and sketches indicating locations (VDOT Environmental Division 2014). Locations and amounts of guano should also be noted (VDOT Environmental Division 2014). In cases where species identification is crucial, guano can be sampled and sent for species identification by genetic testing, though this may not identify all species that may be co-habiting in the roost depending on the testing method utilized.

Thorough documentation is crucial in bridge inspections. Typical aspects to consider are signs of bat usage, structure characteristics (material type, construction type, maintenance, age, dimensions, structural components such as expansion joints or crevices, cracks), geographic location, surrounding environment and habitat type, and distance to nearest waterbody. Levels of human disturbance in close vicinity to bridges should be noted (Bennett et al. 2008) as this can be a crucial factor in determining likelihood of bat use in a bridge (FHWA FRA 2015). It is also important to note the date and time of inspection as time of year can be important in determining use and use type. It may be useful to incorporate inspection for bat usage on all official bridge inspection forms to begin collecting a database of information (Gore and Studenrogh 2005).

During inspections for evidence of bat usage of bridges, other factors can be important to collect, such as evidence and presence of other animal species (Shiel 1999, Aughney 2008, Keeley 2007). This information can be included in maintenance and repair plans for the future to ensure minimal damage to wildlife.

Specific methods and forms that have been developed for inspection reporting are discussed further in Section 2.6.

2.5.4 Timing

To determine if a particular bridge is used as a roost of any type, multiple inspections are necessary (Bennett et al. 2008), which is often not possible due to time and budget constraints. It has been recommended that bridges be inspected at least two to three times annually to accurately determine bridge use, as large time delays between surveys can yield unreliable results and not accurately represent bat utilization of the bridge. The more frequent the visits to the sites, the more accurate the data since bats frequently switch roosts. Bat use of bridges can be seasonal depending on location, so initial surveys in one season may not be representative of the actual bat usage of the bridge (Keeley 2007). Due to the transitory behavior of bats, inspection of locations showing non-use by bats one year does not guarantee that location will not be used in the future (FHWA FRA 2015, VDOT Environmental Division 2014, Gore and Studenrogh 2005). Bennett et al. (2008) suggests that the number of inspections should vary depending on if the bridge is a known roost site or not, with four to five summer inspections on a bridge to determine if it is used as a roost, and only two to see if it is currently being used that season (Bennett et al. 2008). However, multiple surveys are likely impractical in most DOT situations, in which case inspections and surveys should be completed during optimal use times and within a specified timeframe before the construction project initiation. Seven business days was originally outlined in FHWA/FRA (2015), although this was revised to a minimum of one year in U.S. DOT (2017). A one year minimum requirement may be difficult to accomplish for some accelerated construction projects, and may not be indicative of current use. Summer is the optimal time that bats use bridges in New England. If construction is scheduled for the months of May to July, it is necessary to determine if the bridge is a maternity roost (Keeley 2007). For any bridges containing maternity colonies, construction should be scheduled prior to the re-occupancy of the roost in late spring/early summer or postponed until after the dispersal of the roost in late summer/early fall (Hendricks et al. 2005, Geluso and Mink 2009) and be completed in the winter season (FHWA FRA 2015). Cleveland and Jackson (2013) recommend postponing all construction activities at a site during the months of March to August if bats are present, regardless of if it is used as a maternity colony or for general roosting. However, in New England this covers most of the available construction season for bridge work, making this an impractical recommendation and might make exclusion during off-season months the only alternative. Further, most bridges are inspected for structural aspects every two years. Training of these inspectors to incorporate reporting of possible bat roosting would be a valuable resource to complement specific inspections for bat roosts.

2.5.5 Human Safety

The main way to ensure human safety with bat usage of structures is to teach inspectors and maintenance crews to not touch or handle bats (Keeley and Tuttle 1999, Smith and Stevenson 2014, VDOT Environmental Division 2014, Hendricks et al. 2005, Keeley 2007, Gore and Studenrogh 2005). Bats can be vectors for rabies and histoplasmosis (Keeley and Tuttle 1999, Smith and Stevenson 2014, SDBWG 2004), and West Nile virus (SDBWG 2004). Rabies can be avoided if there is no contact between humans and bats. Histoplasmosis is a systemic infection of the respiratory tract caused by a fungus found in dust from bat guano and bird feces. As this can be located in areas with droppings, it is advised to wear personal protective equipment masks, especially if working in the area, and to practice dust-suppression techniques (Keeley and Tuttle 1999, Smith and Stevenson 2014). Other equipment suggested for safe inspections are flashlights and/or headlamps, hard hats, safety vests, binoculars or spotting scopes, digital cameras, cellular phone, heavy duty boots, and cover-alls (VDOT Environmental Division 2014). It is important to reiterate the necessity to obtain proper permitting and avoid harassment or disturbance of bats if flashlights and/or headlamps are used, especially when the species of interest are threatened and endangered. Red lighting may be less of a disturbance than white light and is recommended for flashlights and general lighting during inspections. Caution and safety of inspection personnel should follow all other requirements of general bridge inspection.

2.6 Additional Bridge Monitoring Techniques

While visual inspection is a main bridge monitoring technique used to determine bat usage of bridges, other methods can be utilized. These other methods include infrared monitoring and emergence studies, acoustic monitoring, guano testing, and capture techniques.

Infrared monitoring is a non-invasive technique that can be used to identify bats' roost locations within bridges and monitor bats' emergence from bridges. Thermal cameras and night vision goggles can be used in this technique. Further discussion of infrared monitoring, emergence studies, and equipment is in Section 3.1.2. Acoustic monitoring aids in identifying species in the local area by providing a basis for species encountered at bridge locations. This monitoring technique does not alone confirm bat roosting in bridges. Acoustic monitoring involves using specialized equipment and software, such as microphones, acoustic detectors, and various automated acoustic bat identification software programs. Further discussion of acoustic monitoring is in Section 3.1.3. When guano deposits are available, bat species can be identified through DNA sequencing of the guano. Methods for guano testing include pooled testing, which can test larger guano samples and provide results on an array of species present, and individual pellet testing which provides species results for the single sample. Further discussion of guano testing is in Section 3.1.4. Capture techniques, such as mist-netting and harp-trapping, are more commonly used for positive identification of species, but are a more invasive technique that can harass or stress these individuals and requires specific permitting.

2.7 Bat Bridge Surveys

There are several existing surveys that were developed to inspect bridges for bat occupancy (Aughney 2008, Cervone 2015, FHWA FRA 2015, U.S. DOT 2016, Keeley and Tuttle 1999, Keeley 2007, Shiel 1999, Smith and Stevenson 2014). Currently, if working under the programmatic agreement, one national bridge survey is required prior to any bridge work that can impact bats (any bridge work conducted below the deck surface, including work completed from the underside of a bridge or from boring down to the underside of a bridge, any bridge work affecting expansion joints, including deck removal, and/or bridge demolition) (U.S. DOT 2016). These survey forms are discussed in the following sections to recommended best practices for determining the bat roosting potential of New England bridges.

2.7.1 Legal Requirements

Currently, MYSO is a federally endangered species and MYSE is federally threatened. Section 7(a)(1) of the Endangered Species Act (ESA) requires the conservation of listed species by federal agencies. Section 7(a)(2) of the ESA requires federal agencies to seek consultation for any actions that may affect listed species. With the spreading of WNS and associated changes to required conservation and mitigation measures, the USFWS along with the FHWA and state DOTs have experienced increased workloads, uncertainties regarding required actions, and possible delays in projects. As such, the USFWS and FHWA have worked together to develop a consultation and conservation strategy for both the MYSO and MYSE species to aid in project planning, transparency and predictability of procedures, and providing consistency in conservation approaches. (USFWS 2017)

Since MYSE is a federally threatened species, it is subject to Section 4(d) of the ESA which details exemptions and "take" prohibitions. Much of what is outlined in the final 4(d) ruling is related to prohibitions on purposeful and incidental "take" of MYSE within the WNS zone during tree removal activities or activities within close proximity to hibernacula. These currently apply to 150 feet (46 m) around a known, occupied roost tree. Time of year restrictions are also implemented for these conditions, restricting work within the MYSE maternity season of June 1st through July 31st. Comment 18 in the final 4(d) ruling states that there are no prohibitions to "take" of MYSE occupying bridges as bridges are uncommon roost locations for MYSE and are as such inconsequential: "While bridge and culvert use for the species has been documented, it is relatively uncommon compared to tree or other types of roost sites…and, therefore, did not warrant specific provisions in this final rule." (Federal Register 2015)

Since MYSO is a federally endangered species, it is not subject to any 4(d) exemptions. Activities impacting MYSO and any activities that are prohibited under the 4(d) ruling for MYSE that may impact MYSE require consultation with the USFWS. If MYSE populations continue to decline and the species is listed as federally endangered in the future, the species will no longer be subject to such 4(d) exemptions. (USFWS 2017)

2.7.2 Bridge Survey Protocol

The FHWA and Federal Railroad Administration (FRA) issued a Programmatic Consultation Biological Assessment report "Range-Wide Biological Assessment for Transportation Projects for Indiana Bat and Northern Long-Eared Bat" in April of 2015 that included a 'Bridge/Structure Assessment Form,' reproduced in Appendix A-2 (FHWA FRA 2015). This report was finalized, and the U.S. Department of Transportation (U.S. DOT) (including the Federal Highway Administration, Federal Railroad Administration, and Federal Transit Administration) issued the "Programmatic Biological Assessment for Transportation Projects in the Range of the Indiana Bat and Northern Long-Eared Bat" in November of 2016 (U.S. DOT 2016). This report includes an updated 'Bridge/Structure Assessment Form,' which has been reproduced in Appendix A-1.

When Programmatic Consultation is required for a project this current federal form is used across the United States for MYSO and MYSE habitat protection during bridge maintenance or removal as it aids in determining the likelihood of bat roosting in bridges subject to maintenance work. The form may also be required by some states when species are state endangered, and may also be used informally for documentation of non-mandatory bridge evaluations. It is highly useful to document signs of bats observed at a bridge as it is focused on noting any visual or auditory cues of bats, guano deposits, or staining to determine bat presence. Photos are provided as well to guide inspectors. This federal form also requires acknowledgement of areas inspected in the bridge, making note of potential roost locations (vertical crevices 0.5 to 1.25 in (1.3 to 3.2 cm) wide and more than 4 in (10.2 cm) deep that are sealed at the top, all unsealed crevices greater than 12 in (30 cm) deep, all guardrails, all expansion joints, spaces between concrete end walls the bridge deck, and the vertical surfaces on concrete I-beams), and level of human disturbance at the bridge. Bridges with the presence of any bat indicators on site will be removed from work schedules, and further consultation with the USFWS is required to proceed. If completed inspections have documented bats are not present, the maintenance or construction project may proceed. Negative surveys that indicate bat absence at a bridge are valid for one year. Initially, this federal form was required to be completed within seven days of construction initiation. Recent changes now require that the federal form be completed a minimum of one year prior to construction. While a note is made cautioning the potential absence of some presence indicators during hibernation periods, the federal form is allowed to be completed any time at least a year prior to construction. (FHWA FRA 2015, U.S. DOT 2016)

2.7.3 Additional Surveys

Keeley and Tuttle (1999) provided survey forms in the appendices of their report, which they suggest should be utilized in inspections. These forms are reproduced in Appendix A-3. Different equipment is discussed that can be used for inspections, such as high-powered rechargeable lights, binoculars for visual inspections in dark crevices or cavities, or in culverts, acoustic monitors or electronic devices that detect high frequency vibrations, and mirrors mounted on telescoping poles. To maintain records of bat usage of bridges, bridge inspectors should be educated to determine signs of bat use, and documentation should be added to existing reports. (Keeley and Tuttle 1999)

Standard Surveys, as reported in Smith and Stevenson (2014), were presented as the minimum necessary requirements for bridge surveys. Advanced Surveys, as reported in Smith and Stevenson (2014), are recommended to be followed in areas where there is particularly high potential for negative impacts to bats. These survey recommendations are reproduced in Appendix A-4 and are used to determine specific site characteristics, including characterizing the local environment of the bridge, determining all potential and existing roost sites, and identifying crucial foraging areas and commuting routes. A comprehensive survey will therefore include surrounding areas, and will identify all important breeding and roosting sites within 0.6 mi (1 km) of the site of interest. Observations and results are used to determine the predicted impacts to bats. (Smith and Stevenson 2014)

Additionally, Cervone (2015) developed a draft paper with a simplified bridge survey method based on the inspection form from FHWA FRA (2015) which was also developed by the authors (Cervone 2015). This form is reproduced in Appendix A-5. Shiel (1999), Aughney (2008), and

Keeley (2007) discuss following standard surveys devised in previous studies, however do not explicitly state details of the survey that was followed.

2.7.4 Project Surveys

The current required protocol is the federal survey form 'Bridge/Structure Assessment Form' (U.S. DOT 2016). In addition, the three additional surveys from Keeley and Tuttle (1999), Smith and Stevenson (2014), and Cervone (2015) each have useful components, but are not necessarily suitable survey methods for New England bridge roost identification. The U.S. DOT (2016) survey identifies bat indicators to determine presence at a bridge site and demonstrates some of the potential roost areas within a bridge that should be inspected to determine presence or absence of bats roosting in the bridge. However, this should be considered a minimum requirement, and there are some difficulties in completing the survey as are explained further in Section 4.2. Keeley and Tuttle (1999) focus on the collection of necessary information to gather on known roost bridges, but do not address inspection methods to determine presence. Smith and Stevenson (2014) also focus more on roost documentation, and also include valuable information on locations to inspect to determine bat presence. However this survey is not easily applicable for bridge inspections in the field as it is solely an outlined guide or summary. Cervone (2015) includes a survey checklist, however it may be biased toward roost sites that were observed in certain regions and the meaning or significance of final results of the survey are not clearly defined.

In Section 4.2, the development of a new survey form, intended to supplement the current protocol 'Bridge/Structure Assessment Form' (U.S. DOT 2016) is developed and presented. The intention of this form is to obtain additional information about bridges that have likely presence or likely absence. This information can be used to clarify summaries in the current survey that are not clearly defined, and can be used to fully document the characteristics of bridge environments and structural characteristics that can be used to benefit long term studies on bats' use of bridges.

3.0 Project Scope

Upon project initiation in 2014, the research team conducted an extensive process of interviewing regional and national representatives from Fish and Wildlife offices and Departments of Transportation (DOTs) along with several consulting companies and researchers. From this effort, it was found that there was only one bridge documented to be used as a bat roost in New England, with possible bat sightings at one other bridge. However, it was clearly conveyed by most contacts that little to no effort had been focused on determining whether bats utilized bridges in New England. Therefore, the primary objective of developing a screening tool and demonstrating its accuracy in determining the presence of MYSE roosting in New England bridges was altered to include a concerted effort at evaluating the methods that would be used to identify bridges with potential bat roosting in New England. Additional information was collected and disseminated related to preferred structural types for bat roosting, New England bat population distributions, and evaluation of existing public data already collected by State Fish and Wildlife Departments and Transportation Agencies throughout New England. Other species of focus include MYSO, MYLU, PESU, and EPFU. This project is a proactive means to develop a survey tool to assess the likelihood of bat presence in bridges, develop a regional knowledge base of bats for New England Transportation Agencies, and provide demonstrations of field observations of bridges to verify the usefulness of the survey tool along with the evaluation of other field observation methods (visual inspection, infrared monitoring and emergence studies, acoustic monitoring, and species identification through guano sampling).

This current project funded by the New England Transportation Consortium was given the Notice to Proceed on May 07, 2015. Field work was completed during summers of 2015 and 2016.

3.1 Types of Monitoring and Equipment

In determining bat usage of bridges, different monitoring techniques were utilized, including visual inspection (both rapid visual screenings and more detailed visual inspections), acoustic monitoring, infrared monitoring and emergence studies, and species identification through guano samples.

3.1.1 Visual Inspection Monitoring

Visual inspection was completed at all bridges inspected during this project. Rapid visual screenings were conducted on all bridges, and involved documenting signs of deterioration, making note of construction type and surrounding locations, and, depending on location access, using flashlights and ladders to inspect some obvious crevices, cracks, and expansion joints. These rapid visual screenings determined a bridge’s preliminary potential for bat roosting based on various bridge and surrounding area characteristics noted to be preferable for roosting from the literature review. These rapid visual screenings were imperative to begin field work in summer

2015 as at that time only one bridge in New England was known to be utilized by bats (the covered bridge in Addison County, VT). Rapid visual screenings provided a starting database for potential bridges in New England to be chosen for further monitoring. From the rapid visual screenings, and from input from state DOTs, the final fifteen bridges were chosen for full monitoring in summer 2015. In summer 2016, three of these bridges were replaced with different bridges, resulting in a total of eighteen bridges considered for the project. Bridges in summer 2016 were fully monitored and visually inspected in more detail, including: investigating all readily accessible crevices using ladders, flashlights, waders and a borescope; noting and documenting the presence of staining, deterioration, and potential guano deposit accumulations; potential suitable habitats in the bridge; and completion of survey forms and documentation. When bridge decks or piers were inaccessible using a ladder due to height or waterway, binoculars were used to assess conditions. Two bridge survey inspection forms were completed for each bridge that was fully inspected; the federal form (FHWA FRA 2015), and a supplemental form developed through the project (Section 4.2 and Appendix B).

The main pieces of equipment used in visual inspection were flashlights, waders, a ladder for investigating crevices, and a monocular and a borescope for investigating inaccessible crevices, as well as a camera for documentation. Flashlights fitted with red bulbs were utilized when inspecting inside crevices to avoid potential disturbance to bats, though white light was often used once likely absence was determined for the crevice. A Milwaukee 12-volt lithium-ion 9.5 mm M-Spector AV inspection camera kit borescope was also utilized. This borescope has a small 0.4 in (9.5 mm) camera head on a 3 ft (0.9 m) rigid cable allowing for inspection of crevices in the bridge and in small spaces otherwise inaccessible. The zoom feature allows for better inspections, and the LED brightness control can be useful in not disturbing any bats found roosting in crevices. Compared to other units, the Milwaukee borescope was chosen as it was equipped with the necessary features for inspection, including the appropriately small camera head and long cable, and was a recommended, durable brand. The borescope was utilized to investigate deep crevices and hard to reach cracks and expansion joints. In some cases, the borescope was also useful in identifying the source of staining at bridge locations. Figure 3-1 demonstrates visual inspection of bridges using a ladder and flashlight. Figure 3-2 shows the use of the borescope to investigate crevices in the bridge.

Figure 3-1: Demonstrating visual inspection of bridges utilizing a ladder and flashlight

Figure 3-2: Demonstrating use of borescope to inspect crevice in bridge abutment

3.1.2 Infrared Monitoring and Emergence Studies

Infrared monitoring used a thermal camera to attempt to locate bats roosting in bridges as well as emerging or foraging during emergence studies. Limited use of the thermal camera and infrared monitoring was completed in summer 2015. Each bridge inspected in summer 2016 had extensive investigation including use of infrared monitoring. A FLUKE Ti400 IR Fusion Technology thermal camera was utilized for infrared monitoring. This piece of equipment can measure -4 to 2192°F (-20 to 1200°C) with an accuracy of ± 1.1°F (± 2°C). The removable 2x Telephoto Infrared Smart Lens was also purchased for the project which allowed for target magnification, permitting total bridge monitoring including high heights or hard to reach bridge components. This unit and accessories were chosen based on the versatility of the unit, allowing for full bridge thermal inspections, the capabilities to record images and videos and usefulness of the integrated software.

Infrared monitoring was used to analyze various potential roost locations, as mentioned in the literature review, in bridges chosen for further investigation in summer 2016 to determine how useful this monitoring technique is at identifying roost locations within bridges. The thermal camera was evaluated for its ability to identify "hot spots" and temperature variations in bridges that can aid in determining possible localized roosting locations.

Emergence studies were completed at bridges chosen for further monitoring in summer 2016. Different from a traditional emergence study, this monitoring technique was applied to all fifteen bridges regardless of roost activity, and involved observing the bridge sites from sunset through nightfall or longer. The purposes were to determine if any bats emerged from the bridge and to document bat activity in the local area in the evening to evaluate likely roosting in areas within the vicinity of the bridge. Evening emergence studies only identify bats emerging from their day roosts in the evening, though observation throughout the night can also observe night roosting. Infrared monitoring was used during each emergence study to aid in locating bats emerging from the bridge or flying and foraging in the local area. Hand held acoustic monitoring was also utilized during emergence studies later in the summer 2016 monitoring to assist in finding bats with the thermal camera. The acoustic data was used to determine the likely species of bats present foraging in the local area (Section 3.1.3 details information about acoustic monitoring).

Night-vision goggles owned by a state agency were used twice in the field by the research team when meeting with personnel at bridge sites during bridge monitoring. These goggles were useful in observing bat activity in the evening, though they did not have the capability to record any observations.

3.1.3 Acoustic Monitoring

Acoustic monitoring was completed at the bridges selected for further monitoring during each summer. The acoustic monitoring technique was implemented three times during each summer to determine temporal bat activity. Bridges were monitored in the "early" season between May and mid-June (post-emergence from hibernation pre-maternity roosting), "mid" season between early and mid-July (during maternity roosting), and "late" season between early and mid-August (post-maternity season pre-hibernation). In the summer 2015, bridges were only monitored in the mid-and late seasons due to the project Notice to Proceed date. In the summer 2016, bridges were monitored for all three seasons.

Acoustic monitoring can be a valuable method in bat-bridge surveys both for detecting patterns of bat activity (timing when bats are coming to or going from a roost in relation to dawn and dusk) and for preliminary identification of particular species that are present in the area, and was so chosen as a monitoring tool in this project. The field of acoustic bat surveys is rapidly advancing through hardware improvements (including acoustic detectors, microphones, and data storage abilities), software for viewing spectrograms of call sequences and/or automated species identification, and manual vetting of call data. There is a wide array of opinions among biologists as to “the best” hardware to use. Researchers have demonstrated that many variables, including detector and microphone type, deployment, and weatherproofing (Adams et al. 2012, Waters and Walsh 1994, Britzke et al. 2010), contribute to discrepancies among these options, and that there is a low level of agreement among automated identification software programs (Lemen et al. 2015). Because no single acoustic detector or automated species identification software can be agreed upon as “the best” by experts in the field and because no two detector models record all the same call data and because no two software programs agree on the species identification of every call (Adams et al. 2012, Britzke et al. 2010, Lemen et al. 2015, Waters and Walsh 1994), there is no “right” choice. However, many biologists agree on choosing hardware that is best suited to the survey purpose and goals (level of experience with the equipment and software, active versus passive, stationary versus mobile transect, zero-cross versus full-spectrum, presence/probable absence for a particular species versus all species activity) and using either more than one automated software program and/or manually vetting all call data of interest to the project goals can help narrow down the choices.

While there are several possible detector models that could have been used for this type of study, only one detector model was chosen for data consistency among sites. Each monitored site was instrumented with two Pettersson D500x ultrasonic bat detectors to collect nightly bat activity. Acoustic monitors were programmed to collect calls from dusk through dawn daily, and were left in the field for a minimum of three days. The acoustic monitors were equipped with 8GB memory cards, which sometimes filled up and limited the number of nights of data collected in many locations. This is indicated by data presented of less than the full three nights of programming. The Pettersson units were chosen based on suitability for passive surveys, long-standing microphone reliability compared to some of the other detectors considered, microphone sensitivity and frequency range, and ability to record full-spectrum call data, which would allow for more visual observation of call features during manual vetting. The Pettersson D500X Special Edition FD Ultrasound Detector/Recorder units utilized record full-spectrum ultrasound in real time. These units have a frequency range of 15 to 190 kHz with a 500 kHz sampling rate with the high-pass filter enabled. The various power modes and recording settings allow for the units to be deployed in the field for extended periods of time. A headphone jack allows for active monitoring on equipped units. This unit is fully compatible with SonoBat software.

Two types of microphone placements were used during acoustic monitoring. For identifying the species of bats passing by the bridge area, microphones were directed at the general bridge flyway to record search phase calls, rather than the social and emergence-type calls produced by bats coming and going directly from the roost. This placement was used for initial monitoring to obtain general bridge data. The advantage of this placement is that signals from any bat flying under the bridge should be captured, while the negative is that it will likely pick up calls from any bats foraging along the waterway under the bridge, so positive identification of roosting at the bridge sites warrants further investigation. In a few locations where a likely roost was identified, a more localized placement of the microphone was used for one of the microphones. However, there are potential problems with this placement and subsequent acoustical analysis: the wide angle and sensitivity of the microphone which is not purely directional; the potential for calls emitted as bats exit roosts to not be identified by automated acoustic bat identification software; and the potential for reflection of acoustic signals off of bridge components degrading call recordings. The selected locations for localized microphone placement were selected to evaluate the effectiveness of this method. Figure 3-3 (a) shows generalized microphone placement intended to identify species in the local bridge area. Figure 3-3 (b) shows localized microphone placement intended to detect specific roost activity.

Two general types of programs for bat call classification are zero-cross and full-spectrum. Each software developer, whether zero-cross or full spectrum, has developed their own algorithms for determining the species identification from recorded calls, utilizing expert evaluation of call characteristics, described in Section 2.2.2. Both program types are capable of classifying recorded bat calls, but the two program types deliver differing approaches to using the acoustic input data.

SonoBat (2016), a provider of full-spectrum software, details differences between zero-cross and full-spectrum analyses. Acoustic signal data records contain bat calls as well as sources of white noise such as insects, wind, water flow, vehicles, and vegetation. Bat calls are converted to electrical signal data based on the call signal's strength, amplitude, and frequency content. Zero-cross programs condense acoustic signals, extracting the average frequency of the acoustic signal over eight oscillations, and deliver only time-frequency data without considering call amplitude, creating the same result for strong and weak signals. Zero-cross programs are therefore more limited and only able to interpret the most dominant, strongest frequency in the acoustic signal. This can inhibit zero-cross programs from discerning bat calls from other sources of white noise, and can lead to misinterpretations. Full-spectrum programs account for amplitude changes in the acoustic signals by analyzing overlapping windows of the signals to deliver a complete representation of the acoustic signal. Full-spectrum programs can also differentiate between multiple signal frequency sources. In theory this allows full-spectrum programs to differentiate and interpret bat calls from other white noise, and observe more detail in acoustic signals. As such, full-spectrum programs are thought to be better able to identify bat calls and differentiate between species, provide higher quality results and higher confidence. Full-spectrum programs also allow for ease in manual vetting as the calls are clearly displayed with call shape and frequency and amplitude levels shown in the processed data. Zero-cross and full-spectrum programs can deliver similar results, however the two programs can vary in their interpretation of acoustic signals. Additionally, zero-cross programs are not well equipped to identify low frequency calls as they have fewer oscillations and so less data is extracted per acoustic signal. (SonoBat 2016)

Currently, only zero-cross programs are approved by the USFWS with no full-spectrum programs approved for automated acoustic bat identification. Available zero-cross programs include EchoClass (v. 3.1), BCID (Bat Call Identification Software) (v. 2.7d), and Kaleidoscope Pro (v. 3.1.1, 3.1.4, 3.1.4, or 4.0.0 zero-crossing). Candidate full-spectrum programs include SonoBat (v. 3.x.x), BCID (v. 2.x), and Kaleidoscope Pro (v. 3.x.x). Zero-cross programs have a full call library, meaning there is a database of zero-cross calls that have been recorded directly from known bat species that make up a documented call reference. Approved zero-cross programs compare the recorded unknown calls from data collected to the call reference to identify the unknown species. Zero-cross programs have been independently tested through the United States Geologic Survey (USGS) to verify the results of the program and are as such approved for used by the USFWS for automated acoustic bat identification. Full-spectrum programs do not have a full call library since historic recordings for some programs were often recorded in zero-cross format, and the call library is the same as was used in developing the programs. Full-spectrum program classifications need to be verified by a third party and independent call library to ensure the programs can correctly identify unknown species' calls. For this project, a full-spectrum program was chosen to allow for more detailed analysis and manual vetting, and zero-cross programs were chosen to comply with approved automated acoustic bat identification software programs as set by the USFWS.

SonoBat (v. 3.2.2 NE) (SonoBat) software was used to initially identify and classify bat calls recorded at each bridge site. SonoBat is a full-spectrum program chosen for the ability to visibly display full-spectrum data for manual vetting and process full-spectrum data, including scrubbing noise. SonoBat v. 3.2.2 NE classifies the five species of interest in this project along with *Myotis leibii* (MYLE), *Lasiurus borealis* (LABO), *Lasionycteris noctivagans* (LANO), *Lasiurus cinereus* (LACI), *Nycticeius humeralis* (NYHU), and *Corynorhinus rafinesquii* (CORA). Files were first attributed using SonoBat D500x File Attributer 2.6.vi software to include the monitoring site location for each file. Files were then scrubbed using SonoBat Batch Scrubber 5.5.vi software, with 'tolerant' sensitivity setting to retain as many potential bat calls as possible. Files were then classified using the SonoBatch feature. All recommended, default settings were used in classifications (SonoBatch settings: 'max # of calls to consider per file' = 8; 'acceptable call quality' = 0.8; 'acceptable quality to tally passes' = 0.2; 'decision threshold' = 0.9; 'filter selection' = 5 kHz; and 'autofilter' settings).

SonoBat classifies acoustic data in three ways; By Vote (ByVote), Mean Classification (MeanClssn), and Consensus Count (Consensus). ByVote species classification decisions are made based on decisions of individual calls classified in the call sequence of the file. MeanClssn species classification decisions are made based on the call classification exceeding the acceptable call quality decision threshold (input setting). Consensus is the final results generated by SonoBat, or the final species call tallies. Consensus species classification decisions are only tabulated if the ByVote and MeanClssn species classification decisions match, or reach a consensus. (SonoBat 2016)

EchoClass (v. 3.1) (EchoClass) software was also utilized to identify and classify all calls recorded at each bridge site. EchoClass was chosen as it is a zero-cross program approved by the USFWS. Species set 2 was used in classifications, which classifies the five species of interest in this project along with MYLE, LABO, LANO, and LACI. EchoClass does not allow users to change additional classification settings. Since EchoClass is a zero-cross program, Kaleidoscope (v3.1.5) file converter was used to convert all the recorded full-spectrum (.WAV) acoustic files to zero-cross (.ZC) files for processing. Files were converted to zero-cross using a division ratio of 8 and were output into nightly subdirectories. Noise was not filtered by Kaleidoscope (v3.1.5) during file conversion.

EchoClass determines the species classification and displays results as the Prominent Species. If EchoClass determines that there is another bat present in the call file, it will generate a second species classification displayed as Prominent Species 2nd bat. Both the prominent and second bat classifications are tabulated and reflected in the final species call tallies in the final results generated by EchoClass. (Britzke 2017)

Both SonoBat and EchoClass classify acoustic data against reference calls, outputting final classification results and maximum likelihood estimators (MLEs). MLEs reflect the program's confidence that the classified species was actually present at that site based on call characteristics and call sequences. Both programs generate MLEs that range from 0 to 1, with and MLE of 0 representing high probability of the presence of that species and an MLE of 1 representing high probability of absence of that species. EchoClass will display an MLE of -1 if the species was not detected at the site, meaning no calls were classified as that species, indicating that no MLE was calculated. EchoClass generates nightly MLEs while SonoBat generates one MLE based on the acoustic files input into the program to classify.

Further evaluation of acoustic data was performed by consultants regularly contracted by New England DOTs to provide acoustic surveys. Consultant "A" was hired to classify all collected acoustic files, provided in the converted zero-cross format, using BCID (v. 2.7d) and Kaleidoscope Pro (v. 3.1.7) (K-Pro). For analyses using K-Pro, classifier version 3.1.0 and the -1 more sensitive [Liberal] setting were used as recommended for MYSO and MYSE presence/absence surveys by the USFWS. Consultant "B" was contracted to classify all collected acoustic files, provided in the original full-spectrum format as well as zero-cross format, using K-Pro (v. 4.1.0) automated liberal settings and similar classifier designations as Consultant "A". These results were used to evaluate differences between automated acoustic bat identification software program results and compared these to the EchoClass and SonoBat results. One of these consultants was further contracted to provide manual vetting of potential MYSE calls (as identified by the program auto-classifier), while the other provided manual vetting checks of sample files at overall bridge locations for "plausible" or "not plausible" verifications. Additionally, 569 calls that EchoClass or SonoBat identified as MYSE (EchoClass output included first and second prominence and SonoBat identification under By Vote or Mean Classification) were manually vetted by a consultant regularly contracted by New England DOTs (Consultant "C") as well as a regional DOT biologist with expertise in manual vetting (DOT "D"). Consultant "C" also evaluated this subset of calls using the zero-cross program BCID (v. 2.7d). DOT "D" evaluated this subset of calls using the zero-crossing K-Pro (v. 4.0.4), BCID (v. 2.7d), and EchoClass (v. 3.1) to classify calls and provide comparison across programs and expert classifications. The Connecticut Department of Energy and Environmental Conservation Wildlife Division also manually vetted the calls in the partial data set collected at the monitored Connecticut bridge (Consultant "E").

a) b)

Figure 3-3: Microphone/detector placement (a) generalized and (b) localized

3.1.4 Guano Testing—DNA Analysis

Species can be identified through DNA sequences of feces. Guano deposits, or potential guano deposits, were collected whenever found at any bridge sites. Also collected were a few samples suspected to be from mice and were included to confirm negative readings in the data. These samples were then sent to two laboratories hired for species identification through guano, each specializing in a different method for analyzing guano. One laboratory was hired to run DNA sequencing of pooled samples and the other was hired to run DNA sequencing of individual fecal pellets. Utilizing two laboratories for species identification through guano DNA sequencing allowed for comparison of species results and potential usefulness of pooled sampling compared to individual sampling.

DNA sequencing of pooled sampling may be more useful when bat species present at a bridge site in the local area is unknown and multiple species may be present. Pooled sampling allows for up to 200 fecal pellets to be included in a sample and can detect a bat species from just one fecal pellet in the sample, returning a list of all present species. The only bridge site with known species was the covered bridge in Addison County, VT, and while it was a known MYLU maternity roost, other species had been identified through past mist netting (including MYSE), so pooled sampling was thought to be a useful monitoring tool to identify species using the bridge. The laboratory is specifically equipped to sequence guano fecal samples with personnel including experts in DNA techniques as well as bat biologists, and is purported to detect ninety-two percent of the world's barcoded bats to a species level. More information about pooled sample DNA sequencing and this laboratory can be found in Walker et al. (2016).

Testing individual pellets allows for species classifications as well. For individual pellet testing, DNA extractions were performed from the guano samples using DNA extraction protocols (Qiagen Stool Mini Kit) adjusting the volume for size of the guano sample. The samples were then analyzed at the *cytochrome oxidase I* and the *cytochrome b* regions, as these have been previously used in bats, and are informative for identifying bat species of interest (Clare 2011, Larsen et al. 2012, Nadin-Davis et al. 2012, Patrick and Stevens 2014, and Miller-Butterworth et al. 2014). Species were then assigned to sampled species by comparing the unknown DNA sequences obtained to reference sequences deposited from known species in NIH's Genbank database.

3.2 Rapid Visual Screenings

In total, 191 bridges were evaluated throughout New England by rapid visual screenings in the summers of 2015 and 2016. The locations of these bridges are shown on the map in Figure 3-4 with yellow dots indicating the bridges that were visually screened (note: due to the large geographic scale of the surveys, some inspection dots appear overlapping). Since this method was used in order to select representative bridges for further study, the intent was to document types of bridges that had higher or lower likelihood of being used as a roost based on previous literature. Other parameters considered for bridges in the current project in addition to high roosting potential were proximity to other bridges to be studied, inclusion of a variety of bridge materials and configurations studied, and distribution of studied bridges throughout New England. Red stars in Figure 3-4 indicate the final bridge selection locations.

The rapid visual screenings noted bridge characteristics that would have high or low potential for roosting to aid in determining the preliminary potential of a bridge to be utilized as a bat roost. Many bridges inspected were of prestressed or precast construction. These bridges have beam and girders placed next to each other during construction which leaves a gap between the members. Several examples of this type of bridge encountered can be seen in Figure 3-5, viewed from under the bridge. Sometimes the gaps between girders were filled, or partially filled with caulking, foam, or neoprene sealants, as shown in Figure 3-6. When these fill materials deteriorate, openings between the beams are formed that can extend the full height of the girder and could be utilized by bats for roosting, as shown in Figure 3-7. Expansion joints are another location that can potentially be utilized by bats for roosting, with examples shown in Figure 3-8. Note that these expansion joints are within concrete deck elements, regardless of whether the bridge girders are steel or concrete. Many expansion joints encountered had substances accumulated below them that are typical of debris leaking through deteriorated joints, but in some cases could possibly be mixed with guano deposits. Upon inspection of the expansion joints, there were typically no conclusive signs of bat roosting, though it could not be ruled out in many cases. Figure 3-9 shows pictures of the materials encountered next to the view up inside the expansion joint. While some bridge types can be ruled out as not having features suitable for roosting, localized deterioration can create suitable roosting locations in any area in any bridge. Examples of bridges with localized deterioration can be seen in Figure 3-10, which show how the deterioration caused concrete spalling and corrosion created suitable roosting crevices. Not all deterioration leads to the creation of appropriate or suitable roosting crevices. Figure 3-11 shows deterioration that does not lead to suitable roosting crevices as these examples of deterioration show corrosion, concrete spalling, and deterioration that have removed concrete volume without creating crevices. This sort of localized deterioration does create potential footholds on bridges and these locations can potentially be used as night-roost locations. Features including pipes shown in Figure 3-12 can create appropriate crevices and provide additional locations that can be utilized as roost locations. Some of these were found included deteriorating insulation which could be a stable thermal environment. Others included roadway drain pipes that had become fully clogged or even paved over, creating potential roost locations. Other features can create cave-like environments, either built-in or due to deterioration, as shown in Figure 3-13, that can be utilized as roost locations. Crevices or gaps in the abutments or piers, shown in Figure 3-14, can be potential roost sites. There is also high potential for suitable roosting crevices when there are masonry abutments or piers made of stone or there are structural features with a stone façade, especially when the stonework is not grouted or includes deteriorating grout. The abutment shown in Figure 3-15 has both grouted and non-grouted stonework, showing the difference in available crevices depending on construction type. Figure 3-16 shows various bridges with non-grouted stonework and deteriorated grout providing potential roosting locations, and Figure 3-17 shows various bridges with grouted stonework that does not allow for roosting.

Other construction types and methods do not allow for suitable day- or maternity roosting crevices. Certain deck constructions do not allow for gaps or crevices that can be used for day- or maternity roosting, but do leave a potential for night-roosting or utilization of exposed roosts. Various inspected bridge decks lacking suitable crevices are shown in Figure 3-18. Integral abutments are a newer and preferred construction type that does not provide expansion joints, which limits available spaces for bats to roost. Various inspected bridges with integral abutments are shown in Figure 3-19. Bridges constructed with only smooth surfaces, such as those shown in Figure 3-20, do not provide suitable roosting locations. Once these bridges begin to deteriorate, there is potential for roosting sites. Some bridge abutments do not have much vertical clearance and have easy access by predators, making them less desirable roost locations. Various inspected bridges with easily accessible abutments are shown in Figure 3-21.

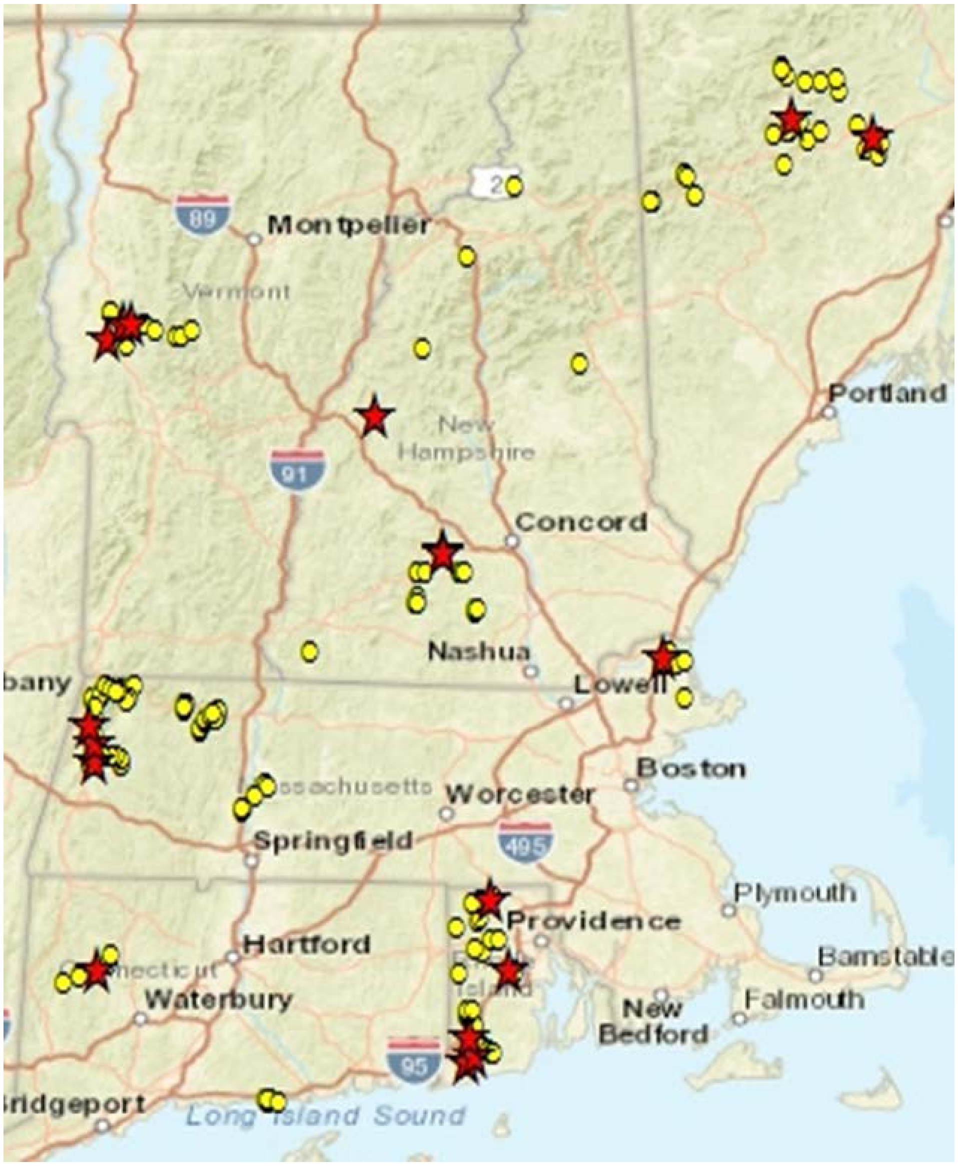


Figure 3-4: Bridges inspected (yellow dot) and fully monitored (red star) in summers 2015 and 2016

Figure 3-5: Precast concrete bridge construction leaving gaps between beams

Figure 3-6: Sealed gaps between beams

Figure 3-7: Deterioration of the sealed gaps between beams

Figure 3-8: Expansion joints

Figure 3-9: View into the expansion joint (left), and the material found below (right)

Figure 3-10: Localized deterioration creating suitable roosting crevices

Figure 3-11: Not all deterioration will create crevices

Figure 3-12: Pipes can create suitable roosting locations

Figure 3-13: Features that create cave-like environments can be suitable roosting locations

Figure 3-14: Crevices on abutments that can create suitable roosting crevices

Figure 3-15: Construction with grouted stonework and non-grouted stonework (left and right sections of photo)

(a)

(b)

Figure 3-16: Non-grouted stonework (a) or deteriorated grout (b) creates suitable roosting crevices and locations

Figure 3-17: Grouted stonework does not create suitable roosting crevices and locations

Figure 3-18: Bridge deck construction that does not create suitable roosting crevices and locations

Figure 3-19: Bridges with integral abutments

Figure 3-20: Bridges with only smooth surfaces lacking roosting locations

Figure 3-21: Bridge abutments with easy access by predators

3.3 Selection of Bridges

Since there was only one documented bridge utilized as a bat roost in New England at the start of the project, selection of bridges for further study was mainly based on the rapid visual screenings. The red stars in Figure 3-4 indicate the locations of bridges chosen for further study. The final bridges selected for further study were not necessarily those identified as having highest likelihood for bat roosting, but also considered other parameters such as proximity to other bridges to be studied, inclusion of a variety of bridge materials and configurations studied, and distribution of studied bridges throughout New England. Selection of the fifteen bridges to further monitor in summer 2015 was initiated through compiling of the National Bridge Inventory and the Geographic Information System software ArcGIS to create a map of all bridges in New England, differentiated by material type. Any bridges provided by state DOTs as having roosting potential or that were of interest were included in the developed driving routes for bridge rapid visual inspections. Care was taken to select bridges that were of basic desirable characteristics based on the initial literature review, such as bridges situated over or near waterways and in areas with minimal human disturbance, as well as the presence of expansion joints, bird's nests, wasp's nests, and deterioration creating sufficient cracks and crevices to be used as roosts, though it is noted that this would bias the bridges towards those similar to ones studied in the literature. Bridges chosen to be monitored also varied in material and construction type, with preference towards typical highway bridges maintained by the state DOTs. While it was desirable to monitor the same set of bridges in summer 2016 as summer 2015, some changes were warranted. Three of the fifteen bridges monitored in summer 2015 were replaced in summer 2016, providing a total of eighteen bridges monitored over the two summer project. Bat activity was discovered by DOT personnel at a bridge site in close proximity to other bridges being monitored, so to incorporate this bridge in summer 2016 monitoring, one bridge monitored in summer 2015 showing lower roosting potential was removed. Two other bridges that showed lower roosting potential and lower bat activity from summer 2015 monitoring were also removed to allow for the addition of a bridge in close proximity to known hibernacula and a bridge within the known range of MYSE.

In the initial selection of bridges, certain bridges were disregarded and ruled out for specific reasons. Figure 3-20 shows examples of bridges with smooth surfaces that lack crevices and footholds for bats which would be less suited to bat roosting. Bridges such as this, or bridges with other features lacking suitable roosts as described in Section 3.2, including bridges with fully grouted stonework, deck construction not allowing for roosting locations, integral abutments, or abutments with easy predator access, were in general not selected. Figure 3-22 shows an example of bridges with limited access due to steep embankments, fences, or other dangerous conditions that prohibited closer investigations of the bridge on at least one side, which were also not selected. Some bridges that would have otherwise been probable choices were not selected due to their location at or near high use public places which could infer higher risk of equipment damage or theft. Figure 3-23 shows bridges with very low clearances which were also not selected. While all heights should be considered, bridges with low clearances are less likely to be used for roosting, often had limited access, and led to concern of acoustic data noise from call reflection on the water surface. Figure 3-24 shows an example of bridges that had recent maintenance work completed. The bridge shown is a timber bridge that was recently treated with creosote and the local area smelled of tar, which would dissuade bats from roosting, though features of the bridge could have been ideal for roosting otherwise. Other bridges inspected had recent regrouting, concrete patches, or steel work, which could have recently caused disturbance to bats if they had been using the bridge. Some bridges inspected were located over a channelized river, as shown in Figure 3-25, or other non-ideal surrounding habitats, which were assumed to be less likely roosting locations than bridges with natural cover and so were not selected.

Figure 3-22: Example bridge with limited access

Figure 3-23: Example bridges with exceptionally low clearance

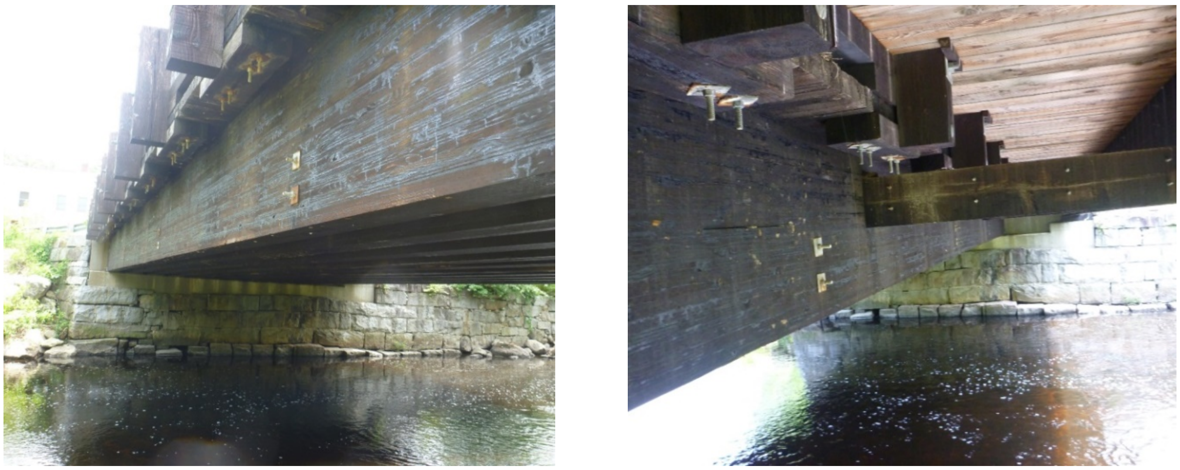


Figure 3-24: Example bridge with recent maintenance work (timber bridge recently treated, local area smelled of tar)

Figure 3-25: Example bridges over channelized river

4.0 Results

One of the most significant findings of this project is additional documented bridge roosts in New England. Another important result of the project is the creation of a supplemental bridge inspection survey form. Other relevant findings and project outcomes result from analysis of the data collected from field work during summers 2015 and 2016, namely call analysis of acoustic monitoring and thermal camera analysis of infrared monitoring. General results are presented here, with more detailed results relevant to specific bridges outlined in chapter 5.0

4.1 Newly Documented Bridge Roosting in New England

Through direct work by the research team as well as documentation sent to the research team by New England state DOTs, there are fifteen bridges in New England that are either confirmed or suspected bat roosts. The research team is aware of thirteen bridges documented as being used as bat roosts in New England: six in Vermont in Addison County, Windsor County, and Caledonia County, north of the 43º north latitude; five in Maine in Cumberland County, Oxford County, Waldo County, and Piscataquis County, north of the 43º, 44º, 45º, and 46º north latitudes; one in Essex County, Massachusetts, north of the 42º north latitude; and one in Washington County, Rhode Island, south of the 42º north latitude. These confirmed roost bridge types include covered wooden bridges, steel beam bridges, concrete beam bridges, and railroad bridges. Only the first of these was documented prior to the beginning of this project, with the others being identified over the two summer course of the project. The research team identified two of the thirteen confirmed roost bridges. These bridges are confirmed bat roosts either by documentation of bats or guano and/or staining observed at the bridge site. Figure 4-1 through Figure 4-8 and Figure 4-10 through Figure 4-13 show evidence of confirmed bat roosting at these documented bridge bat roost locations. Figure 4-9 shows the location in which bats emerged when they were disturbed as the masonry pier was being repaired. As can be seen by these figures, many bats were observed roosting in open, sheltered areas, as well as in confined locations as noted by the guano deposits, though reported documentation of expansion joints has also been provided. Of these thirteen confirmed bridge bat roosts in New England, only one is definitively confirmed as a maternity roost (a bridge in Addison County, Vermont), although it is highly likely that at least one more is as well (a bridge in Piscataquis County, Maine). Of these thirteen confirmed bridge bat roosts in New England, three are utilized as night-roosts (one bridge in Addison County, Vermont, one bridge in Essex County, Massachusetts, and one bridge in Washington County, Rhode Island), as either bats were only observed in the evenings, or guano deposits were found under night roost locations not suitable for day-roosting (Figure 4-3 and Figure 4-10). The research team is aware of two additional bridges that are highly suspected as being bat roosts; one in Providence County, Rhode Island; and one in Franklin County, Maine. A dead bat was found under the abutment of the bridge in Providence County, Rhode Island, shown in Figure 4-14, though no other conclusive signs of bats were observed at the bridge site. While not conclusive, a bat was suspected to be observed roosting and emerging from an expansion joint at the bridge in Franklin County, Maine with likely bat staining on an abutment.

One bridge roost in Addison County, VT is a covered bridge that has been a known documented maternity roost for approximately 100 to 200 MYLU, with a MYSE positively identified co-roosting in the colony through mist-netting in 2013. This site also has two bat houses in close proximity to the bridge that were installed when the bridge underwent renovations in previous years. The bat houses served as alternate roosts and are still used along with the bridge by the maternity colony. Unfortunately, this bridge burned down in September 2016. It will be interesting to observe the colony behavior in summer 2017 to determine if roost fidelity will lead to the colony using the bat houses or new bridge, or if the bridge characteristics will be replicated in another structure. In an effort to provide additional roosts for displaced bats, two more bat houses were erected nearby within a few weeks of the fire. EPFU were observed roosting in the bridge in Windsor County, VT as shown in Figure 4-4 and Figure 4-5. EPFU was also observed roosting at the bridge in Oxford County, ME however it tucked away into the structural elements away from sight before it could be photographed and documented. The railroad bridge pier in Piscataquis County, ME shown in Figure 4-9 needed mason repairs. As described by Sarah Boyden in the MaineDOT Environmental Office: "One of our staff talked to a man who repaired the grout on a stacked granite abutment…Apparently the man disturbed a large group of roosting bats – so many emerged from the crack that he took a break from his repair work to give them a chance to clear out of the roost." Another bridge in Piscataquis County, ME has been reported by several MaineDOT maintenance staff to have bats roosting although there is no formal documentation.

Of these fifteen confirmed or suspected bridge roosts, six have been monitored over the course of this project (of the eighteen total bridges), and four were discovered directly by the research team. Of the thirteen confirmed bridge roosts in New England, two were found by the research team and eleven were found by DOTs or state Fish and Wildlife Departments over the two summers of the project, as agencies have initiated new inspections prompted by the MYSE listing and related mandates. Four of the thirteen confirmed bridge roosts in New England were monitored on this project. The research team found two additional bridges that are highly suspected of being bat roosts. The rapid visual screenings also documented a large number of bridges with features similar to these documented roost locations. The variety of documented structures and roost types does not allow for any conclusions on preferred roosting features.

Figure 4-1: Guano evidence of roosting at bridge in Addison County, VT (confirmed as MYLU through DNA sequencing)

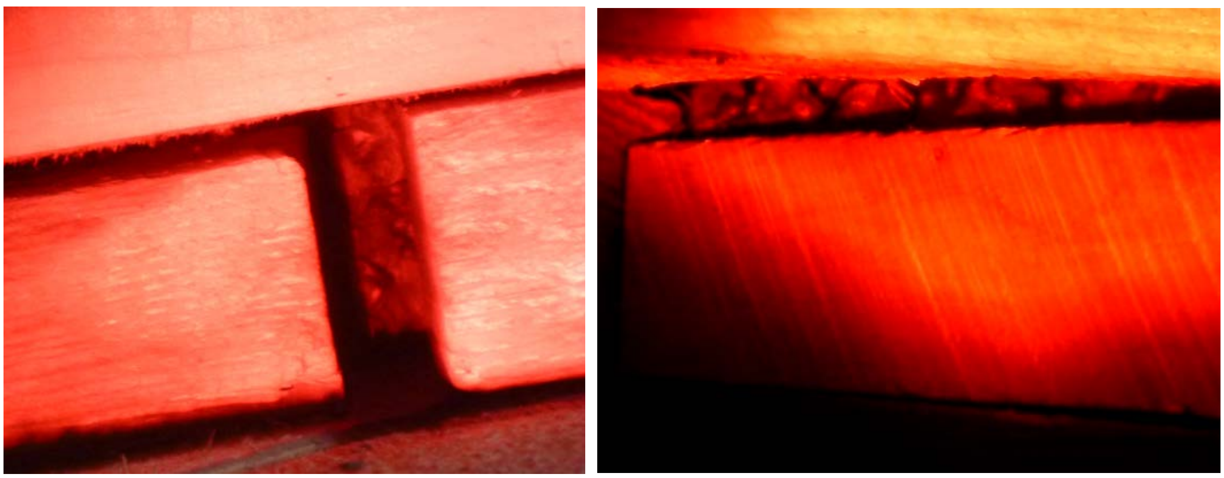


Figure 4-2: Maternity colony observed between truss components of bridge in Addison County, VT

(a)

(b)

Figure 4-3: Spalled and cracking concrete deck creating potential roost location (a) above observed guano deposits (b) in bridge in Addison County, VT (confirmed as MYLU through DNA sequencing)

Figure 4-4: Bats (EPFU) seen roosting at bridge in Windsor County, VT (photos courtesy of Alyssa Bennett, Vermont Fish & Wildlife Dept.)

Figure 4-5: Dead bat (EPFU) found at bridge in Windsor County, VT (photos courtesy of Alyssa Bennett, Vermont Fish & Wildlife Dept.)

Figure 4-6: Guano evidence of roosting at bridge in Cumberland County, ME (photos courtesy of Sarah Boyden, MaineDOT Environmental Office)

Figure 4-7: Guano evidence of roosting at bridge in Oxford County, ME (photos courtesy of Sarah Boyden, MaineDOT Environmental Office)

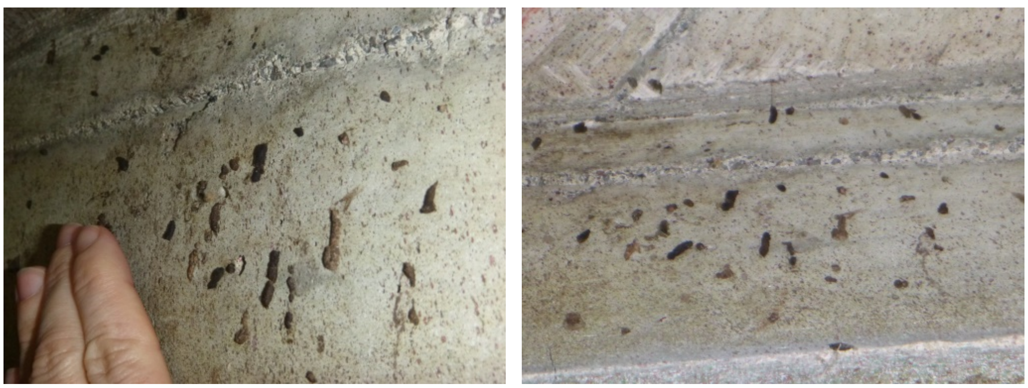
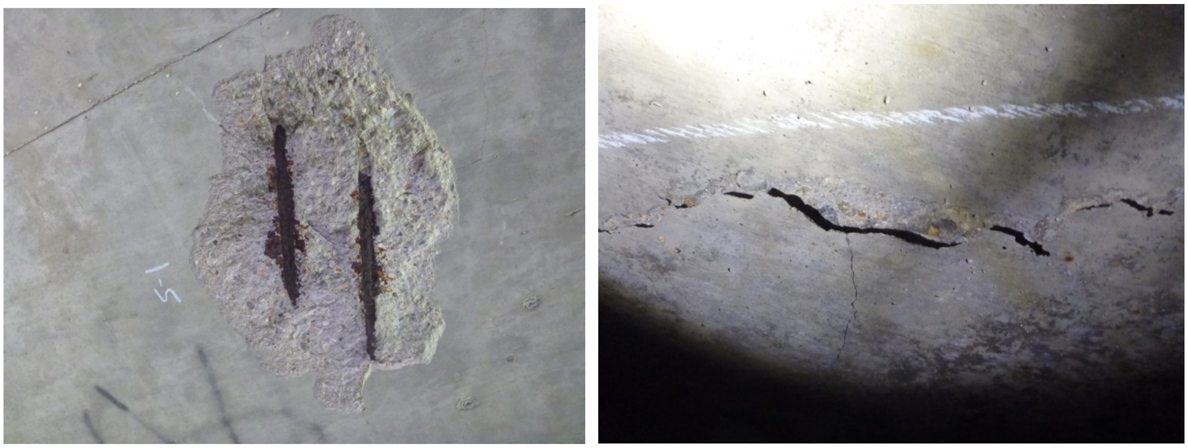


Figure 4-8: Guano evidence of roosting at bridge in Waldo County, ME (photos courtesy of Sarah Boyden, MaineDOT Environmental Office)

Figure 4-9: Arrow indicating the location where bats were roosting at bridge in Piscataquis County, ME (photo courtesy of Sarah Boyden, MaineDOT Environmental Office)



(a)

(b)

Figure 4-10: Spalled and cracking concrete deck creating potential roost location (a) above observed guano deposits (b) in bridge in Essex County, MA (confirmed as EPFU and MYLE through DNA sequencing)

Figure 4-11: Guano evidence of roosting at bridge in Washington County, RI (confirmed as EPFU through DNA sequencing)

Figure 4-12: Staining evidence of roosting on bridge girders at bridge in Washington County, RI

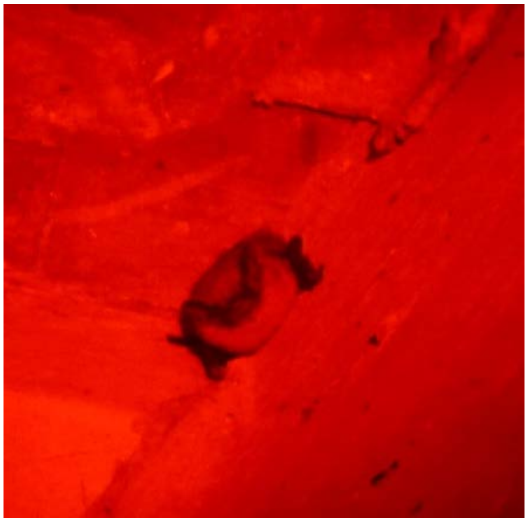


Figure 4-13: Bat observed roosting on bridge girders at bridge in Washington County, RI

Figure 4-14: Dead bat found below abutment at bridge in Providence County, RI

4.2 Bridge Surveys

One of the main objectives of this current project was to develop a survey tool to assess the likelihood of bat presence or roosting in a bridge to aid in the conservation efforts of state DOTs involved in bridge maintenance and construction projects. In April of 2015, the FHWA and FRA came out with the Programmatic Consultation Biological Assessment report "Range-Wide Biological Assessment for Transportation Projects for Indiana Bat and Northern Long-Eared Bat" including a 'Bridge/Structure Assessment Form' in the appendix, designed to determine the presence or absence of bats at a bridge (FHWA FRA 2015). Upon the release of this document, instead of devising a new survey tool for the project, the research team analyzed the federal 'Bridge/Structure Assessment Form' and its applicability for New England bridges.

The federal form is a useful tool for documenting definitive signs of bats present at bridge sites. The four main indicators of bats noted in the federal form are ‘visual,’ ‘sound,’ ‘droppings,’ and ‘staining’ with a photo appendix demonstrating what to expect to find for each of these indicators. The federal form provides a certain level of guidance on where to inspect bridges for signs of bat use by providing general areas within a bridge that have potential for roosting. This federal form is intentionally fairly generalized as to gather necessary data to confirm likely bat presence at a bridge without being overly cumbersome on state DOT agencies. However the federal form is highly subjective to the background of the individual filling out the form and their level of training in identifying signs of bat presence, and does not specifically provide guidance on what qualifications an inspector must have. Other confusions on filling out the federal form became evident through communications with personnel in New England agencies throughout the project.

Several key aspects of the federal form have been identified as problematic, especially for the New England region and for observation of bats in a post-WNS environment. These include presence indicators, the corresponding photos in the federal report intended to demonstrate what these presence indicators look like, the polarity in documentation of observing presence indicators, the oversimplification of data collected from the form, and timing.

The presence indicators were analyzed. The indicators of ‘visual’ and ‘sound’ were fairly straightforward while the indicators of ‘droppings’ and ‘staining’ proved more difficult. The presence indicator ‘visual’ of visually observing bats at bridge sites is straightforward, and is clearly an excellent means of documenting bat use of a bridge. The federal form also gives some guidance on certain specific locations to look for bats as well. The presence indicator ‘sound’ is also fairly straightforward.

The presence indicator ‘droppings’ or observing guano deposits at bridge sites is an excellent means of documenting bat activity in a bridge and aiding in determining bridge use. Observing guano at bridge sites served as a main indicator of bat use for the current project. However the accompanying photos in the federal report intended to demonstrate what to look for in identifying guano deposits are quite misleading for a number of reasons, especially for New England bridges in a post-WNS environment and for identifying MYSE or MYSO roosts. The photos shown in the federal report are of species other than MYSE and MYSO (Gore 2015) and are of larger colonies than would appear in New England, especially in New England bridges. Larger colonies leave larger guano deposits and leave more obvious signs of use. As such, the federal form is biased towards identifying large roost sites and does not fully capture the difficulty and level of effort required in observing guano deposits at New England bridges. Figure 4-15 shows these discrepancies between the photos included in the report to demonstrate the ‘dropping’ indicator and guano deposits observed in New England bridges. The lack of specified training required to fill out the federal form is also problematic for the ‘droppings’ indicator since guano can be easily mis-identified, especially if not properly trained. New England structural inspectors without wildlife training identified photos of guano as mouse droppings.

The presence indicator ‘staining’ is the most problematic, especially for New England bridges. Determining the source of staining in a bridge is biased towards the inspector’s background training. Road salts are extensively used in New England due to the harsh cold winters, leading to corrosion and rusting of steal components and bridge deterioration, so staining is very typical for any bridge slated for maintenance or construction work in New England. A New England structural inspector without wildlife training would likely determine that the cause of staining in bridges is due to structural causation, especially since rust staining can be very similar in appearance to bat staining. In some cases, definitive sources of staining cannot be identified. Even if there are definitive signs of structural staining, it can be unknown if structural staining is covering preexisting bat staining. In communications on the project, there were discrepancies between personnel from state agencies on whether or not to check off the staining indicator on the federal form if staining is of unknown causation, which yields different results from different inspectors. To alleviate this confusion, the research team devised and utilized a system to document all staining observed in bridges that were inspected on the project: “Y” indicates that definitive, confirmed bat staining was observed in the bridge; “Y*” indicates that staining of unspecified causation was observed in the bridge and further investigation is warranted; “N” indicates that definitive structural staining was observed in the bridge; and “N*” indicates that staining was observed in the bridge and appears to be structural or from other wildlife and not from bat, though it is not definitive or confirmed. Figure 4-16 demonstrates the need for further clarification on the ‘staining’ indicator of the federal form.

Currently, the presence of any of these four indicators will remove the bridge from work schedules and constitutes further consultation to the USFWS. Any bat roosting, maternity, day-, or night-roosting, may create bat indicators and can create signs of bat presence. Different roost types hold different levels of significance to bat colonies and different species, yet the federal form does not address differences in maternity versus day- versus night-roost use of bridges, which may be an important distinction in determining the importance of a bridge roost to a bat or colony. More guidance is needed from the USFWS.

Aside from these four indicators and indication of potential roost locations inspected in the bridge, the federal form gathers little additional data. The federal form asks about the level of human disturbance under the bridge, possibilities for netting corridors, and evidence of bats using birds’ nests. All of this additional information is important to gather, but more information would be useful, especially for longer-term data collection on trends of wildlife use of bridges.

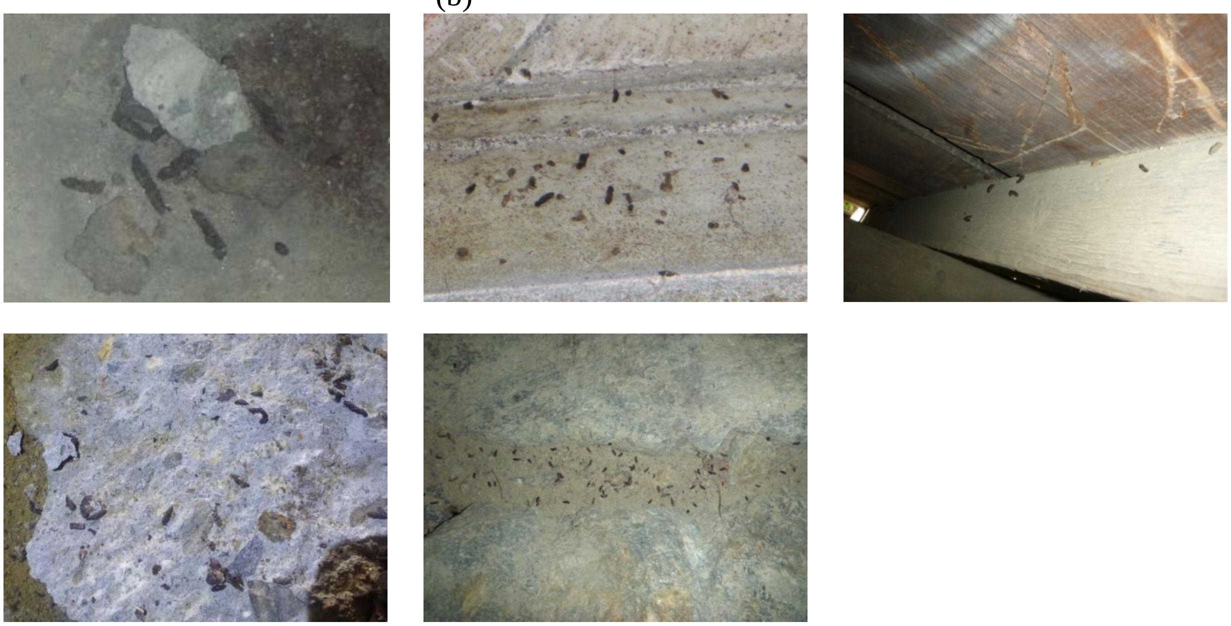
Additionally, currently this federal form is required to be completed a minimum of one year prior to construction, including winter months. The information provided in the federal report does include a note cautioning the potential absence of certain bat presence indicators during hibernation periods, though this information is not included on the actual federal form. Allowing the federal form to be completed during winter months when bats will be absent from bridges may not give an accurate or appropriate assessment of the bridge’s roosting potential and likely bat presence as bat indicators will be minimized. Requiring surveys to be completed in the spring through fall when bats are not hibernating and may be present or roosting in bridges would allow for a more accurate assessment of roosting potential.

Throughout the project, the research team developed a supplemental form, shown in Appendix B, to be used in conjunction with the federal form that aims to clarify any confusions with the federal form for New England bridges. This developed supplemental form is designed to determine presence or likely absence at bridges based on a wider variety of structural and surrounding area characteristics. Documentation is required on the following characteristics: the surrounding area of the bridge; the level of development or human population surrounding the bridge; features the bridge intersects; the level of disturbance at the bridge including human presence, traffic carried and intersected, and predator access; any evidence of bats including visual observation, guano, staining, sound, and odor, noting if the inspector is specifically training to identify signs of bats; the construction materials of bridge components and their condition; the presence of any cracks or crevices either due to construction details or due to deterioration; and any staining observed in the bridge and the determined causation. Photo documentation is also required, which allows for more convenient collaboration of potentially significant findings at a bridge, or verification of observations by experts. This supplemental form gathers more detailed information about bridges to serve as historical documentation of conditions and wildlife observations at bridge sites, specifically focused on bats. Gathering this additional relevant data provides useful information that can be used in gauging the roosting potential of a bridge. By using this supplemental form, inspectors are guided to the locations in bridges that may have bats by forcing inspectors to spend more time looking for signs of bats in potential roost locations that warrant further investigation. This supplemental form is a first attempt at expanding data collected on bridges. It is meant to be used as a sort of a weighted average evaluation of bridges, with each section carrying different weights based on its significance to roosting potential in bridges. This initial first attempt of the developed supplemental form does not include weighted values as the limited number of known and discovered bridge bat roosts in New England did not allow for significant determinations of the importance of each characteristic. Expected weighted values, as determine by the literature review, was not included in this supplemental form to avoid bias in filling out the forms.

Full inspections were completed at each of the fifteen bridges monitored in more detail in summer 2016, within the means of the project scope and equipment, with rapid monitoring inspections completed on subsequent visits to account for any changes observed during the summer. Both the federal form and the developed supplemental form were completed at each bridge during these inspections. The developed supplemental form provided much more in depth detail on each bridge. Neither of these forms was time consuming to complete. Average inspection times were one to two hours for the smaller bridges surveyed, with further inspections on follow up visits typically much shorter. Completing the forms was a small portion of the inspection time, typically 10 to 15 minutes. More details can be found in chapter 5.0 and Appendix C.

(a)

(b)



(c)

Figure 4-15: Guano deposits shown in the federal report intended to demonstrate the 'droppings' indicator on the federal form (photo on the left courtesy of Jeff Gore, Florida Fish and Wildlife Conservation Commission, photo on the right courtesy of Rick Reynolds, VDGIF) (a), guano deposits observed in the largest bat bridge roost known in New England to date (b), and guano deposits observed at New England bridges more representative of what to expect (c)


(a)


(b)

Figure 4-16: Photo of staining observed on a bridge pier shown in the federal report intended to demonstrate the ‘staining’ indicator on the federal form (photos courtesy of Jeff Gore, Florida Fish and Wildlife Conservation Commission) (a) and typical deterioration staining on a New England bridge pier slated for construction (b)

4.3 Call Analysis

Data collected from acoustic monitoring during summers 2015 and 2016 was analyzed. Initial analysis was completed by the research team. Further analysis was completed by consultants and DOT personnel. Additional explanation and breakdown of data collected for each bridge site is presented in the case studies of Section 5.0.

4.3.1 Acoustic Data Collection and Initial Analysis

The Pettersson D500x ultrasonic bat detector acoustic monitors were deployed for a minimum of three days, programmed to collect data from dusk through dawn, though the 8GB memory cards limited the number of nights of data collected in many locations. Microphones were placed near each bridge, facing the bridge flyway, in order to obtain data on the species abundance in the local area as well as to determine if any information could be determined on bats roosting in the bridges. The acoustic monitoring completed on this project is not intended to confirm bats roosting in bridges; further analysis and investigation must be completed to determine bridge roosting. Instead, this monitoring technique allows the research team to identify the species likely present in the local area to determine if the potential roost bridges selected for monitoring could be utilized by any of the species of interest, indicated by their likely presence at the site in the local area. This data is limited to the time of season and specific dates that data was collected. Acoustic monitoring of bridges on the current project also aids state DOTs, Fish and Wildlife Departments, and other agencies in better understanding local species distribution, particularly for MYSE calls potentially identified on this project. The purpose of the acoustic monitoring tasks on this project were not to conclusively identify acoustic calls as MYSE, but rather to evaluate methods for species identification from acoustic calls through automated software programs and manual vetting and identify any limitations of acoustic monitoring at bridge sites. Acoustic data was processed by the research team through the automated acoustic bat identification software programs SonoBat (v. 3.2.2 NE) and EchoClass (v3.1). Additional analysis of call data is presented in Section 4.3.2.

Microphones were placed at bridge sites in locations that gave a direct line to the bridge. Precautions were taken to ensure the monitors would not be subject to vandalism, such as hiding the acoustic monitors and placing microphones in the most inconspicuous locations possible given the site conditions, though two monitors were stolen over the course of the two summer project (one recovered), both in summer 2016 monitoring. Care was taken to ensure there was minimal vegetation surrounding the microphone or impeding the line to the bridge site to minimize white noise recordings and reflection of call signals to the extent possible. All monitored bridges traversed waterways, and care was taken to choose microphone placement that would limit the interference of any white noise recorded from water. Even with these provisions, fifty four percent of the 276,480 acoustic files recorded during field work over summers 2015 and 2016 were scrubbed as white noise by SonoBat processing. SonoBat classified eleven percent of the recorded calls through the Consensus classifications, sixteen percent through the ByVote classifications, and seventeen percent through the MeanClssn classifications while EchoClass classified thirty six percent. This increase in number of calls classified through EchoClass is likely due in part to the fact that prominent and secondary species classification decisions were included in EchoClass's final generated results. More details on call classifications can be found in Appendix E.

A number of factors can inhibit automated call classification. Program classification is based on typical search phase calls emitted by a species. Bats emit other calls such as feeding buzzes and emergence chatter which alters call characteristics from the search phase calls, making these calls unclassifiable, identifiable but with lower confidence, or potentially misclassified as another species. Some calls are not classified as they do not meet a set of minimum acceptable quality standards or other minimum requirements as outlined by the program software and/or input settings. This can be due to white noise recorded, such as vegetation, wind, insects, traffic, etc., that overpowers the call signal or call reflection from water or other surfaces. Calls that are not of sufficient length or recordings that do not have sufficient number of clear calls are unclassifiable, though the criteria for these can vary.

Microphone placement and weather data for nights the acoustic monitors were deployed was investigated to see if microphone placement or weather influenced program classifications. Microphones were placed in the same locations throughout the two summer project, except in select instances which necessitated a change, such as theft. Data on the weather conditions of precipitation amounts and wind speeds during the days acoustic monitors were deployed was collected (Weather Underground 2017). The number of call files scrubbed at each location as white noise and the number of acoustic files classified as bat calls was compared against the microphone locations and weather data. No consistent trends were observed when analyzing against microphone placement locations that were expected to collect more white noise, such as microphones that faced moving water or heavy vegetation, or nights with weather indicating a higher potential for white noise, such as precipitation or higher wind speeds.

Throughout analyses by the research team, program non-agreement was observed. For example, Table 4-1 shows a sample table of one early season monitoring night call data that was recorded at a VT bridge (VT_covered) with a known MYLU maternity colony with a known history of MYSE presence as a MYSE was positively identified co-roosting in the colony through mist-netting in 2013. Since there is a MYLU colony at this site, it is expected that the majority of calls classified would be MYLU. SonoBat classified the majority of calls as MYLU at this site while EchoClass classified the majority calls as LABO. EchoClass identified five MYSE calls, of which one was identified through manual vetting completed by a regional DOT biologist with expertise in manual vetting (DOT "D"). DOT "D" also evaluated these calls using the zero-crossing K-Pro (v. 4.0.4), BCID (v. 2.7d). According to the final generated outputs in SonoBat Consensus classifications, there were no MYSE calls recorded at this site. Seven calls were classified as MYSE through MeanClssn, though none of these were confirmed through manual vetting by DOT "D"; four were classified as MYLU, two were classified as an unidentified *Myotis* species, and one was classified as an unknown high frequency species. Both programs identified similar numbers of MYSO calls, but SonoBat's ByVote and MeanClssn classification totals are approximately double the Consensus count and the number of calls classified as MYSO by EchoClass. SonoBat and EchoClass did have some agreement however, such as the approximate number of EPFU and MYLE calls and the absence of PESU at the site.

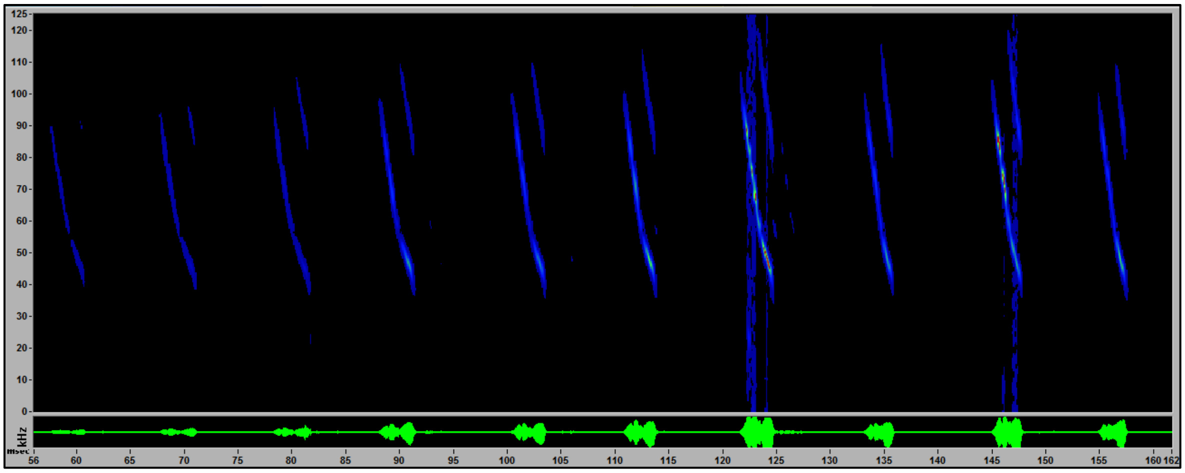
In total, 569 MYSE calls were classified by SonoBat and/or EchoClass during the research team's acoustical analyses over the course of summers 2015 and 2016. Of these, 79 were identified as likely MYSE calls through manual vetting completed by DOT "D". SonoBat and EchoClass agreed on a MYSE classification for twenty six calls. Of these, six were also identified by DOT "D". Two sample MYSE calls displayed on SonoBat identified through manual vetting are shown in Figure 4-17. The top figure (a) was classified as MYSE through SonoBat, EchoClass, K-Pro, and identified through manual vetting. BCID did not classify this call. The bottom figure (b) was classified as MYSE through SonoBat, K-Pro, BCID, and identified through manual vetting by DOT "D". EchoClass classified this call as LABO.

While the limitations of this method of data collection prevents confirmation bridge roosting solely from call identification, analysis of the timing of calls can give a better understanding of bat roosting behavior in the local area. Calls recorded immediately after dusk/sunset indicates that bats are emerging from roosts in the immediate vicinity of the bridge site. For example, Figure 4-18, shows a sample graph of nightly call data that was recorded at a RI bridge instrumented in the mid-season of 2015 monitoring, with the time of sunset in the local area noted. The number of calls is tabulated from preliminary SonoBat classifications completed following summer 2015 field work. Calls recorded immediately preceding sunset indicates that bats are emerging close to the monitoring location. This could suggest that bats may be roosting at the bridge or in adjacent habitat, and further investigation would be warranted if calls were identified as the species of interest. Calls that are recorded through the night and early morning hours indicate bats flying and foraging in the local area. This indicates that the bridge is likely in an area that supports bat habitat and foraging grounds, but does not necessarily provide further insight into bat roosting. Bats being consistently present throughout the evening into the early morning may suggest the bridge may be used as a potential night roost, but further investigation would be necessary for confirmation.

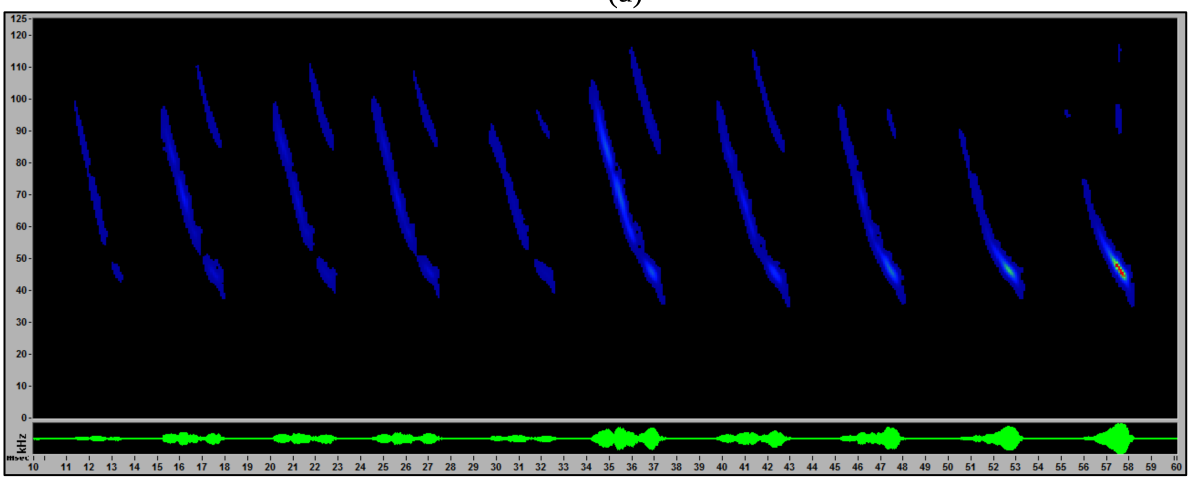
Acoustic monitoring was also used during emergence studies in the mid- and late season monitoring of summer 2016 to aid in detecting bat presence at the site and in identifying bats observed flying in the local area. There are several instances in which the research team noted that few or no bats were visually observed around the bridge or in the local area, yet acoustical analyses reveal several species were present as the programs classified multiple species. The research team noted when one specific bat was followed with the microphone from the acoustic monitor, and while acoustical analyses again show multiple species present, the timing of calls suggests a fair amount of consistency in classifications, showing one species predominantly present, indicating the species of the bat being followed. It is unclear if the discrepancies between the visual observations recorded by the research team and the acoustical analyses results are due to bats present but unseen by the research team or issues with the automated acoustic bat identification software programs incorrectly identifying calls.

Table 4-1: Sample night call data from a VT bridge with known MYLU maternity colony instrumented in early season 2016

		EchoClass	SonoBat *Consensus*	SonoBat *ByVote*	SonoBat *MeanClssn*
Nightly Call Classifications	***MYSE***	5	0	0	7
	MYSO	69	60	126	149
	MYLU	57	212	371	358
	PESU	0	0	0	0
	EPFU	12	11	11	12
	LANO	4	1	1	1
	LABO	871	1	6	13
	LACI	12	7	7	8
	MYLE	2	1	3	3



(a)



(b)

Figure 4-17: Two sample MYSE calls identified by DOT "D" through manual vetting

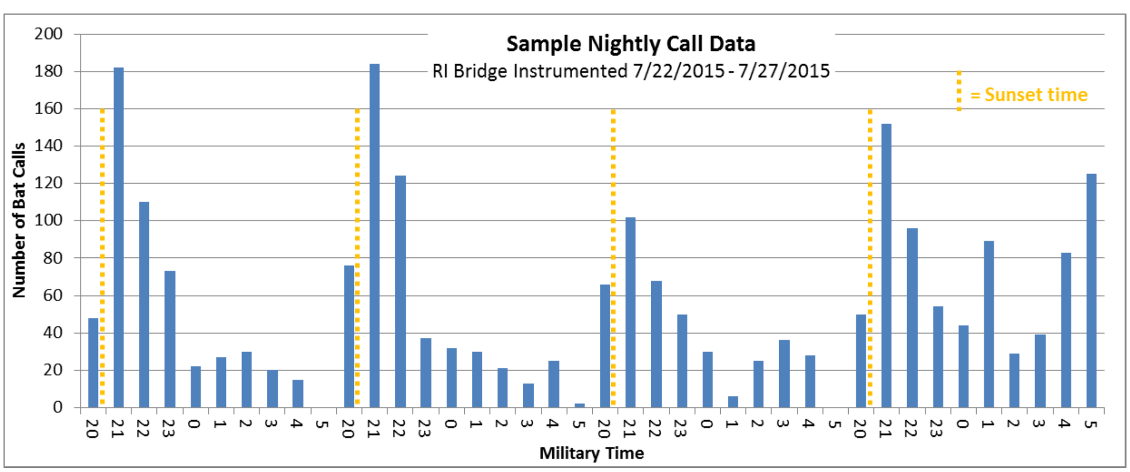


Figure 4-18: Sample nightly call data from a RI bridge instrumented in mid-season 2015

4.3.2 Further Call Analysis

In order to better understand inconsistencies in automated call identification, collected data was further analyzed as a full data set and as a partial data set. The full data set analysis consisted of having outside consultants re-analyze all collected nightly acoustic data from all bridge sites (one consultant did not include data from the Vermont bridges). These consultants then provided manual vetting of calls identified in their analysis as MYSE, with some additional manual vetting of MYLU calls. With additional time, all consultants would have manually vetted calls that can be similar and misidentified by the programs, such as other *Myotis* species (especially MYLU) and LABO for some programs. These decisions are guided by the consultant's personal experience and expertise, but were curtailed due to the high number of total calls in order to meet the timeline of this project.

For the full data set two consultants regularly contracted by New England DOTs to provide acoustic surveys were contracted to provide results from additional automated acoustic bat identification software programs. Consultant "A" was hired to classify all collected acoustic files, provided in the converted zero-cross format, using BCID (v. 2.7d) and Kaleidoscope Pro (v. 3.1.7) (K-Pro). For analyses using K-Pro, classifier version 3.1.0 and the -1 more sensitive [Liberal] setting were used as recommended for MYSO and MYSE presence/absence surveys by the USFWS. Consultant "B" was contracted to classify all collected acoustic files, provided in the original full-spectrum format as well as zero-cross format, using K-Pro (v. 4.1.0) automated liberal settings and similar classifier designations as Consultant "A". These results were used to evaluate differences between automated acoustic bat identification software program results and compared these to the EchoClass and SonoBat results. One of these consultants was further contracted to provide manual vetting of potential MYSE calls (as identified by the program auto-classifier), while the other provided manual vetting checks of sample files at overall bridge locations for "plausible" or "not plausible" verifications. Manual vetting of calls involves investigating specific characteristics of individual calls as detailed in Section 2.2.2. As noted above, a typical consultation would include additional manual vetting of other identified species to ensure potential MYSE calls were not overlooked.

A second set of analysis was performed using a partial data set. The partial data included all calls that EchoClass or SonoBat identified as MYSE (EchoClass output included first and second prominence and SonoBat identification under By Vote or Mean Classification), resulting in a total of 569 individual call files. This partial data set was manually vetted by a consultant regularly contracted by New England DOTs (Consultant "C") as well as a regional DOT biologist with expertise in manual vetting (DOT "D"). Additionally, Consultant "C" evaluated this subset of calls using the zero-cross program BCID (v. 2.7d) and DOT "D" evaluated this subset of calls using the zero-crossing K-Pro (v. 4.0.4), BCID (v. 2.7d), and EchoClass (v. 3.1) to classify calls and provide comparison across programs and expert classifications. BCID (v. 2.7d) results from Consultant "C" and DOT "D" were identical. The Connecticut Department of

Energy and Environmental Conservation Wildlife Division also manually vetted the calls in the partial data set collected at the monitored Connecticut bridge (Consultant “E”).

The results of multiple programs evaluating the full project data set is shown in **Table 4-2** for zero-cross and full spectrum software analysis. It can be seen that the number of files identified varies widely among programs, and it was notable that programs were not consistent in selecting identical call files, meaning that a smaller number of files identified by one program were not a subset of those selected by another program.

Table 4-3 presents analysis of only the subset of the partial data set consisting of pre-screened MYSE calls. This partial data set was analyzed with EchoClass (v. 3.1), BCID (v. 2.7d) and K-Pro (v. 4.0.4). This subset was then manually vetted by Consultant “C” who identified 117 possible MYSE calls, while Consultant “D” identified 79 as possible MYSE calls. The seven calls from CT-precast_concrete was further evaluated by the Connecticut Department of Energy and Environmental Conservation Wildlife Division who determined that these calls were MYLU or unknown *Myotis*, but could not be identified as MYSE. Further manual vetting of the full data set in both zero cross and full spectrum viewers by Consultant “B” is also shown in **Table 4-3**. Consultant “B” identified very few of the calls as MYSE, however the majority that the program identified as MYSE were manually identified as “high frequency” call or “unspecified *Myotis*” with the consultant noting that most bridge locations would warrant further study through mist netting or additional acoustic surveys to determine whether MYSE were present.

An overview of the data is presented in **Table 4-4**. In this table it is only noted whether a program or manual vetting process identified any MYSE presence at a bridge location. Based on these results it is shown that possible MYSE presence was identified at the majority of the 18 bridge sites by programs and less restrictive manual vetting. The results also highlight differences in manual vetting which warrant further discussion. Manual vetting differences are attributable predominantly to the perception of the intention of the study. Consultant “B” as well as the Connecticut Department of Energy and Environmental Conservation Wildlife Division (Consultant “E”) evaluated calls to determine whether they had very high confidence that the call could be identified as MYSE. Consultant “B” noted that the majority of bridges had calls that warranted further study, though calls were identified as unspecified *Myotis* due to uncertainty stemming from noise or echoes in the calls. Another consultant we discussed the project had a similar interpretation and referred vetting to a “legal standard”, or whether the identification was conclusive to the point that it would hold up in a court of law. However, others, such as Consultant “C” and DOT “D”, identified likely calls meriting further study at the bridge as MYSE, while sometimes making notes of any uncertainties in the call. The latter consultants view the manual vetting as a process to identify the potential sites to further investigate, but are comfortable listing these as MYSE pending further investigation. Consultant “A” fell between these two groups. This points out the importance of discussing results with any hired consultant to ensure that all parties involved are communicating the results of manual vetting and uncertainties consistently. These different approaches should also be considered when comparing results from different consultants, or data presented from different states or agencies. Overall, more calls were identified as MYSE when manual vetting was performed in zero cross viewers. The notes provided by consultants clarified that the full spectrum viewers allowed for better determination of echoes, multiple bat calls, and other effects which led to exclusion of additional call files. Another difference between results is that those vetting the full data set (Consultant "A" and Consultant "B") often noted calls before and after the file in question as adding additional insight into the classification, whereas those vetting the partial data set were only provided with individual files, with no context of calls that came immediately before or after.

The Consultant results and comments on manual vetting brought up several important points that should be considered in further study of bats roosting in bridges. The first is that those viewing data in full spectrum viewers tended to have more detailed comments and additional insight into specific characteristics of the calls. Consultants viewing the full data set noted the lower quality of the call files due to noise, echoes, reflections and other factors. One consultant recommended having microphones face away from the structure to avoid these problems, thereby getting the calls as the bats return or circle at the bridge to avoid noise from cars and trucks and reflections from the structure. This provides additional insight into the potential limitations of acoustic monitoring at a bridge, where identifying species in the vicinity is much more likely to be possible than identifying species roosting in the structure, though acoustics collected through hand-held operation while observing any bats exiting a structure may be the best to identify species roosting at the site.

Results in **Table 4-4** do not indicate confirmation of bats roosting at a bridge, but likely presence of a species in the vicinity of the bridge that warrants further study. Confirmation of species presence at a site could be provided through mist netting, guano testing or additional acoustic collection and analysis. Confirmation of roosting would require visual observation (detailed visual inspection of potential roost locations and/or visual observation of bats entering and exiting a roost), or mist netting at expected exit points.

Table 4-2: Auto identification of full data set by zero cross and full spectrum programs

	Zero Cross Analysis								Full Spectrum Analysis				
Program ➔	EchoClass		BCID		KPro				SonoBat			KPro	
Version➔	3.1		2.7d		3.1.7		4.1.0		3.2.2 NE			4.1.0	
Consultant➔	UMass		"A"		"A"		"B"		UMass			"B"	
	1st or 2nd Prominence	1st Prominence	Raw Output	With MLE[a]	Raw Output	With MLE[a]	Raw Output	With MLE[a]	Consensus	ByVote	Mean Clssn	Output	With MLE[a]
Bridge													
CT-precast_concrete	4	4	12	12	11	3	15	13	1	2	2	13	12
ME-concrete	1	0	10	10	0	0	0	0	0	0	1	0	0
ME-steel/wood	28	4	11	11	18	8	19	8	0	0	4	13	6
MA-concrete	109	40	192	192	106	9	163	160	10	11	26	158	158
MA-precast_concrete	0	0	1	1	3	3	6	4	0	0	0	5	5
MA-precast_concrete_2	8	5	11	11	9	4	10	4	0	0	4	14	12
MA-steel	29	12	99	99	45	40	52	47	9	13	26	43	41
NH-concrete_arch	5	2	8	8	4	0	5	1	0	0	0	4	0
NH-steel	0	0	0	0	0	0	0	0	0	0	0	0	0
NH-steel_truss	8	6	11	10	6	0	29	17	0	0	2	35	18
RI-concrete	2	1	6	6	8	6	10	6	0	0	0	9	7
RI-precast_concrete	84	32	65	65	38	12	74	26	0	0	3	82	40
RI-precast_concrete_2	15	4	7	7	14	9	20	9	0	0	1	16	8
RI-steel	1	1	0	0	0	0	2	0	0	0	0	1	0
RI-steel_2	7	2	3	3	5	2	8	2	0	0	1	4	0
VT-concrete_arch	7	0					26	0	0	1	2	27	0
VT-covered	67	17					83	0	12	32	35	85	0
VT-steel	69	21					103	0	7	12	42	103	0
TOTAL	***444***	***151***	***435***	***434***	***267***	***96***	***625***	***297***	***39***	***71***	***149***	***612***	***307***

[a]: Includes only data with nightly MLE less than or equal to 0.05

Table 4-3: Auto identification and manual vetting of partial data set. Shading indicates analysis on partial data set of 569 calls.

Program ➔	EchoClass and SonoBat	EchoClass		SonoBat			BCID	KPro				
Version➔	3.1 and 3.2.2 NE	3.1	3.1	3.2.2 NE			2.7d	4.0.4				
Consultant➔	UMass	"D"	UMass	UMass	UMass	UMass	"C" "D"	"D"	"C"	"D"	"B" [a]	"B"[a]
	Calls in Data Set	1^{st} Prominence	1^{st} or 2^{nd} Prominence	Consensus	ByVote	Mean Clssn	Individual Call	Individual Call	**Manual Vetting**			
Bridge									Full Spectrum	Zero Cross	Full Spectrum	Zero Cross
CT-precast_concrete	7	4	4	1	2	2	3	4	2[b]	1[b]	0	1[b]
ME-concrete	1	0	1	0	0	1	0	0	1	0	0	0
ME-steel/wood	31	4	28	0	0	4	2	4	2	7	0	0
MA-concrete	126	40	109	10	11	26	36	32	50	19	3	4
MA-precast_concrete	0		0	0	0	0					0	0
MA-precast_concrete_2	10	5	8	0	0	4	4	4	4	2	0	0
MA-steel	51	12	29	9	13	26	22	11	25	11	0	1
NH-concrete_arch	5	2	5	0	0	0	2	1	2	2	0	0
NH-steel	0		0	0	0	0					0	
NH-steel_truss	10	6	8	0	0	2	5	1	1	2	0	0
RI-concrete	2	1	2	0	0	0	0	0	1	0	0	0
RI-precast_concrete	84	32	84	0	0	3	24	15	7	8	0	1
RI-precast_concrete_2	16	4	15	0	0	1	3	4	0	1	0	0
RI-steel	1	1	1	0	0	0	1	0	0	1	0	0
RI-steel_2	7	2	7	0	0	1	0	0	0	0	0	0
VT-concrete_arch	9	0	7	0	1	2	1	0	1	1	0	0
VT-covered	101	17	67	12	32	35	13	5	4	10	1	0
VT-steel	108	21	69	7	12	42	20	15	17	14	0	1
TOTAL	***569***	***151***	***444***	***39***	***71***	***149***	***136***	***102***	***117***	***79***	***4***	***8***

[a]: Consultant "B" manually vetted against partial data set determined by their analysis, not the 569 calls used in other analysis. Stated that there were many calls that warranted further study but could only be identified as unspecified *Myotis* due to call quality.

[b]: CT Department of Energy and Environmental Conservation Wildlife Division identified these as MYLU though full spectrum evaluation.

Table 4-4: MYSE identification by automated program and manual vetting. Analysis on full and partial data sets included

Program→	EchoClass	SonoBat			BCID	KPro		Manual Vetting					
Version→	3.1	3.2.2 NE			2.7d	4.1.0	3.1.7	Consultant					
Consultant→	UMass and "D"	UMass			"A"	"B"	"A" "D"	"D"	"C"	"B"[d]	"A"	"B"[d]	"E"
	1^{st} Prominence	Consensus	ByVote	Mean Clssn		Full Spectrum	Zero cross	Zero Cross	Full Spectrum	Full Spectrum	Zero Cross	Zero Cross	Full Spectrum
Bridge													
CT-precast_concrete	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	Plausible	YES	NO
ME-concrete	NO[a]	NO	NO	YES	YES	NO	NO	NO	YES	NO	NO	NO	
ME-steel/wood	YES	NO	NO	YES	YES	YES	YES	YES	YES	NO	NO	NO	
MA-concrete	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	Plausible	YES	
MA-precast_concrete	NO	NO	NO	NO	YES	YES	YES	-	-	NO	-	NO	
MA-precast_concrete_2	YES	NO	NO	YES	YES	YES	YES	YES	YES	NO	Possible	NO	
MA-steel	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	Possible	YES	
NH-concrete_arch	YES	NO	NO	NO	YES	YES	NO[b]	YES	YES	NO	Possible	NO	
NH-steel	NO	NO	NO	NO	NO	NO	NO	-	-	NO	-	NO	
NH-steel_truss	YES	NO	NO	YES	YES	YES	NO[b]	YES	YES	NO	-	NO	
RI-concrete	YES	NO	NO	NO	YES	YES	YES	NO	YES	NO	NO	NO	
RI-precast_concrete	YES	NO	NO	YES	YES	YES	YES	YES	YES	NO	Plausible	YES	
RI-precast_concrete_2	YES	NO	NO	YES	YES	YES	YES	YES	NO	NO	NO	NO	
RI-steel	YES	NO	NO	NO	NO	NO[b]	NO	YES	NO	NO	-	NO	
RI-steel_2	YES	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO	NO	
VT-concrete_arch	NO[a]	NO	YES	YES	YES[c]	NO[b]		YES	YES	NO		NO	
VT-covered	YES	YES	YES	YES	YES[c]	NO[b]		YES	YES	YES		NO	
VT-steel	YES	YES	YES	YES	YES[c]	NO[b]		YES	YES	NO		YES	

[a]: YES if 2^{nd} Prominence included

[b]: YES if MLE not considered

[c]: MLE was not considered for these calls

[d]: Consultant "B" noted that many were unspecified *Myotis* and worth further study to determine if MYSE were present

4.4 Thermal Camera Analysis

The thermal camera was used to observe bat activity in and around monitored bridge locations. The thermal camera was used to attempt to locate bats roosting during daytime bridge inspections. It was also used during emergence studies to aid in observing nighttime bat activity. It was determined that the thermal camera was not particularly useful for observing bat roosting in bridges during daytime inspections as bats tend to congregate in a suitable microclimate, moving within roosts to maintain a similar body temperature as the surrounding material, and as bridge components are typically of materials with high insulating properties with consistent surface temperatures. Bats roosting in open locations or on the bridge exterior during the daytime would be captured by the thermal camera, but would be visible to the naked eye. Figure 4-19 shows an image of a bat roosting in a bridge that was first observed using a flashlight. Investigations of interior bridge locations did not exhibit conclusive thermal variations even in locations where it was known a bat was roosting. The thermal camera was tested by the research team, placing arms and hands behind various bridge components, and the thermal camera was unable to discern temperature variations due to the properties of the bridge materials. The thermal camera was able to scan through thinner, less insulating materials, such as a bat house made of plywood. Figure 4-20 shows a cluster of bats in the upper left-hand corner of the bat house, as identified using the thermal camera and verified with visual inspection.

The thermal camera was found to be most useful in observing bats at night. Figure 4-21 shows still images from the video feature of the thermal camera, demonstrating how the thermal camera can be used to identify bats in flight at dusk, and how it can be potentially useful on emergence studies. Figure 4-22 shows still images from a video taken with the thermal camera of a bat emerging and flying out of a wooden covered bridge. The research team was able to capture video of two bats emerging from a different bridge roost, though still images do not adequately convey this event. Figure 4-23 shows a comparison between what can be observed with the naked eye versus the thermal camera of bats emerging from a bat house. The thermal camera allows for a much more detailed observation of bat activity in the evening, and can aid in pinpointing the exact location that bats emerge from. This is essential after dusk and/or under a bridge structure.

The combined technique using a hand-held acoustic monitor in conjunction with the thermal camera was found to be much more effective than either alone. Since there were many potential roost locations within typical monitored bridge spans, a problem encountered during emergence studies was the inability of the research team to actively monitor all potential locations at once or positively identify the initial emergence of individual bats. Even with three individuals focusing on likely roost locations, the research team typically saw bats foraging next to bridges immediately after dusk, but in many cases could not identify their emergence location or conclusively see bats exiting any roosts. This likely means that the bats were roosting near the bridge site in close proximity rather than in the potential roost sites identified, however exiting from a roost elsewhere on the bridge could not be ruled out. The research team could visually confirm bats utilizing bridges as night-roosts, observed between 10:00PM to midnight at one bridge location, and as bats re-entered a known maternity colony in another.

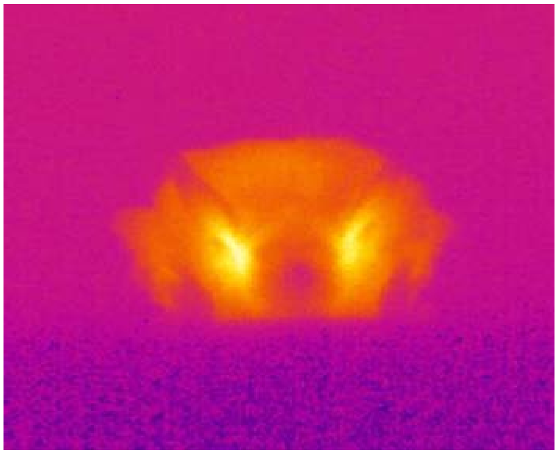


Figure 4-19: Thermal camera image of bat roosting in bridge, first observed using a flashlight

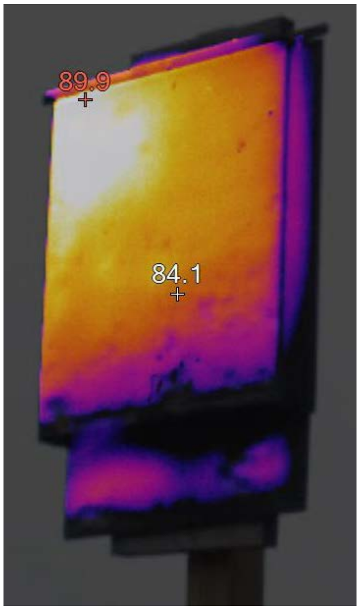


Figure 4-20: Thermal camera used to identify location of bats in bat house near VT-covered bridge

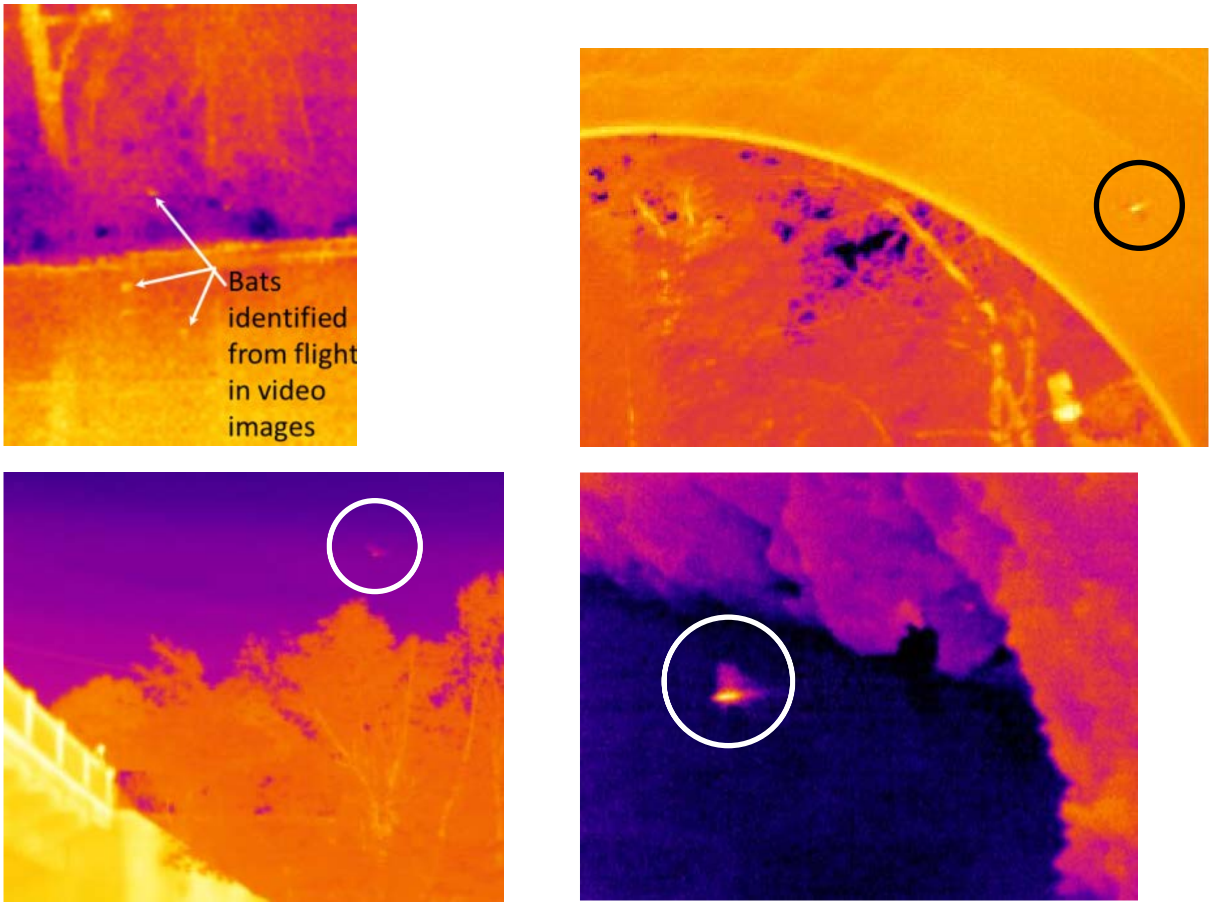


Figure 4-21: Thermal camera video used to identify bats in flight at dusk and night

Figure 4-22: Still images from a thermal camera video used to identify bats emerging from a wooden covered bridge at dusk

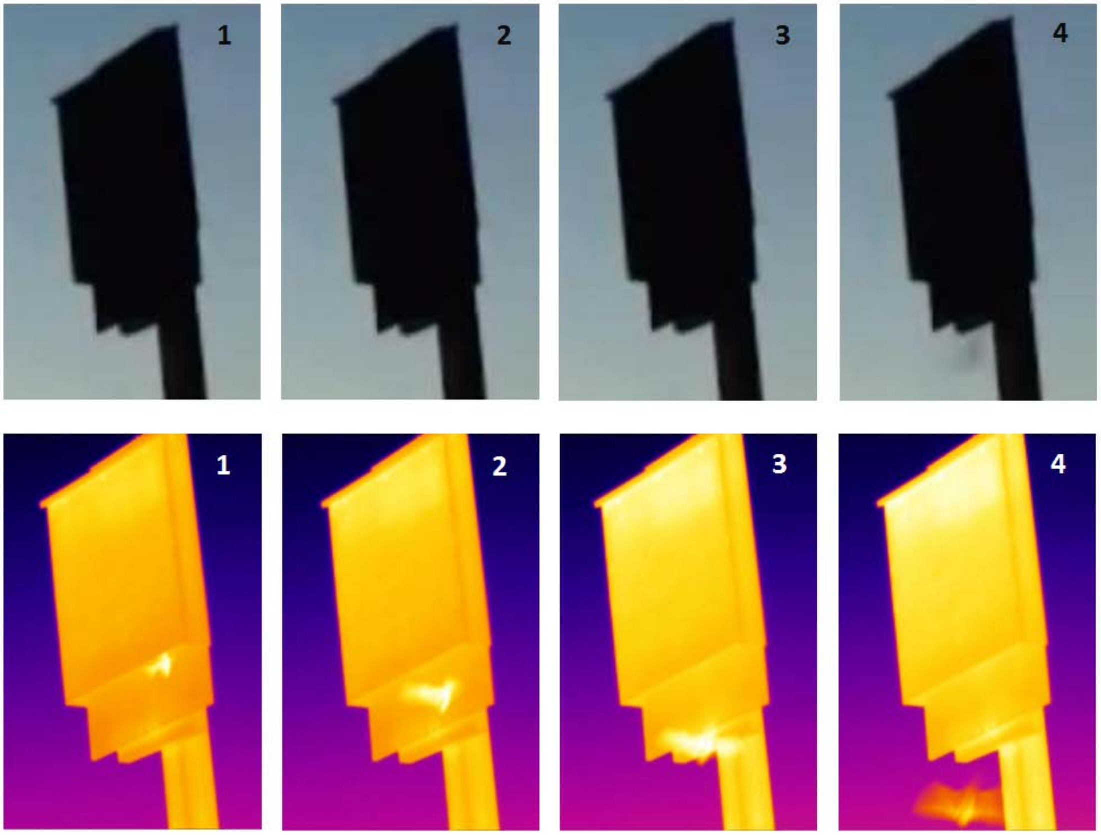


Figure 4-23: Comparison of bat house emergence observed with the thermal camera versus visual observation

5.0 Bridge Monitoring—Case Studies

A total of eighteen bridges were monitored throughout this project. All monitored bridges were situated over waterways as the literature review suggested this as being a desirable characteristic for bat roosting, though any bridge in reasonable proximity to foraging sites may have roosting potential. A total of fifteen bridges were selected for full monitoring in summer 2015; three in Massachusetts (two concrete and one steel construction), two in Maine (one concrete and one steel and wood construction), three in New Hampshire (two steel and one stone and concrete construction), four in Rhode Island (two steel and two concrete construction), three in Vermont (one wood, one steel, and one concrete construction), and none in Connecticut. Of these, three bridges were replaced for monitoring in summer 2016. One Massachusetts bridge was replaced by a coastal bridge within known range of MYSE; one of the Rhode Island bridges was replaced by a bridge with potential signs of bat roosting; one New Hampshire bridge was removed as it was determined to have low probability of bat use based on data from summer 2015; and one Connecticut bridge was added in a location known to be close proximity to hibernacula. Care was taken to ensure bridges were of various construction materials and styles, and were monitored throughout the three regions in New England: southern New England (CT and RI); central New England (MA, southern VT, and southern NH); and northern New England (northern VT, northern NH, and ME).

More detail on each bridge is described below in separate sections along with specific project findings. During the summer of 2015, acoustic monitors were placed at each bridge to determine the species likely present and their abundance in the surrounding areas. These initial results were based on automated call identification software only. This information, along with information gathered during the rapid visual screenings and visits to each site throughout the summer, was utilized in guiding bridge selection for summer 2016 in which the fifteen selected bridges were fully monitored. Each bridge monitored in the summer of 2016 was fully inspected within the means of the project. The research team utilized flashlights, waders, a ladder, a monocular, borescope, and thermal camera to conduct these inspections. No specialized equipment (such as snooper truck) was utilized, and some bridges had limited access in certain areas, particularly at the mid-span of the larger bridges. Both bridge inspection forms (the federal form and the developed supplemental form) were completed at these bridges.

Each of the bridges monitored in summer 2016 had two acoustic monitors placed at each site, with microphones placed at locations “A” and “B” described below. All monitors were placed in the same locations throughout the two summer project with the exception of a few bridges at which it was necessary to alter the monitor location. Vegetation, branches, and/or brush immediately surrounding the microphone was removed to create an unobstructed area between the microphone and the bridge site. Collected acoustic data classified by EchoClass and SonoBat (Consensus Counts, MeanClssn, and ByVote classifications) are shown for each bridge monitored. It is important to note that EchoClass species call classification counts presented in these tables include program classifications as first and second prominence, which may contribute to the increased number of classified calls as compared to SonoBat. Additional analysis of all presented data through additional automated software and manual vetting were presented in Section 4.3.2.

Data analysis was inconclusive regarding the influence of monitor location (facing moving water or heavy vegetation) and/or weather (nights with precipitation or higher wind speeds) on acoustic data collected and classified by the automated programs. Emergence studies were also completed at the bridges monitored in summer 2016. Acoustic monitors were used in mid- and late monitoring season emergence studies using a hand-held microphone to aid in locating bats in the local area. These results were analyzed using the automated acoustic bat identification software programs SonoBat and EchoClass. EchoClass typically classified a higher number of calls and included counts for acoustic files determined to be bat calls but of unknown species classification. No further analysis or manual vetting of emergence study hand-held acoustic monitoring was completed to confirm classifications. Any guano or deposits suspected to potentially be guano was collected if found from each site in summer 2016. These samples were sent to two laboratories for species identification, each performing a different type of analysis, detailed in Section 3.1.4. Results are compared to species identified through acoustic monitoring.

For all tables in this chapter the following comments apply. An “X” in a cell indicates that no field implementation took place in this monitoring period. A “/” in a cell indicates that no data was collected on this date. Most commonly this is due to the memory card filling up on one monitor, while still being collected on the other (any days with both cards full are omitted from the tables, resulting in less than three days presented). A “/” from the beginning of monitoring is either due to stolen equipment at the structure (2 bridges), distribution of available monitors not allowing for two monitor placements at the bridge, or error in programming the datalogger. It is important to note that EchoClass species call classification counts include program classifications as first and second prominence, which may contribute to the increased number of classified calls as compared to SonoBat. Any calls classified as NYHU or CORA were ignored as these are not included in EchoClass classifications and are not typical to the New England region.

5.1 Connecticut Bridges

One bridge was monitored in Connecticut in the summer of 2016. This bridge was chosen as it had promising characteristics based on the previous rapid visual screenings and is located in a region known to be in close proximity to hibernacula.

5.1.1 CT-precast_concrete

The bridge monitored over summer 2016 in Connecticut is of precast concrete construction, shown in Figure 5-1, given the identification name "CT-precast_concrete." Gaps between the precast concrete girders create appropriately sized roosting locations, shown in Figure 5-2. Pipes run along the upstream side of the bridge, which can be seen in Figure 5-3. Staining of unknown causation was observed between the girders, shown in Figure 5-4. All intermediate spaces between girders were inspected using the boroscope, shown in Figure 5-5, and no unusual internal staining was observed, indicating no bats roosting when the daytime inspection occurred. Some of the gaps were clean, shown in Figure 5-5 (a), while some had debris, shown in Figure 5-5 (b). Figure 5-5 (c) shows deterioration of the seal on the expansion joint between girders and the abutment, as the research team was able to see through to the deck surface. A mouse nest was also discovered in the abutment of CT-concrete, shown in Figure 5-5 (d). Bird's nests and Mud-Dauber's nests were observed, shown in Figure 5-6, indicating that the habitat of this bridge is conducive to that for bats. The surrounding vegetation and location appeared conducive to supporting bat habitat and foraging as the bridge is situated in a rural area with ample vegetation surrounding the bridge and has a ponded area upstream, shown in Figure 5-1 and Figure 5-7. Both the federal form and the developed supplemental form were completed and are included in Appendix C-1.

Microphone placement for acoustic monitoring at CT-precast_concrete is shown in Figure 5-8. Location A is upstream and further away from the bridge with the microphone attached to the branch of a bush. Location B is downstream and closer to the bridge. The microphone is attached to a sturdy branch the research team placed in the stream bank. Table 5-1, Table 5-2 and, Table 5-3 show acoustic results from monitoring CT-precast_concrete throughout early, mid- and late seasons.

Emergence studies were completed at CT-precast_concrete in the early and late monitoring seasons. No bats were seen exiting the bridge, and few bats were seen flying in the local area. While no bats were observed during the late monitoring season emergence study, automated analysis of emergence period acoustic data collected classified one bat species present in the local area (SonoBat and EchoClass: EPFU).

Figure 5-1: Precast concrete bridge selected in CT (CT-concrete)

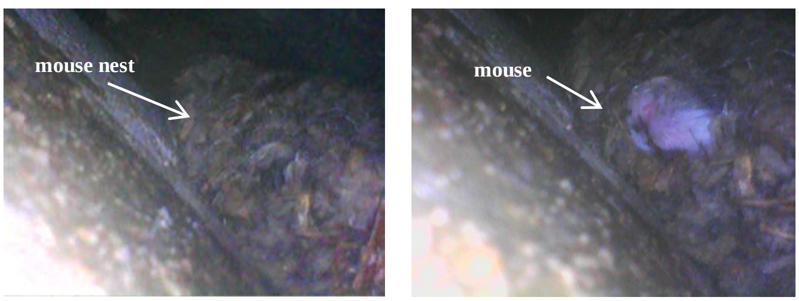
Figure 5-2: Gaps between girders in CT-concrete

Figure 5-3: Pipes running along CT-concrete

Figure 5-4: Staining of unknown causation between girders of CT-concrete

(a) (b)

(c)



(d)

Figure 5-5: Boroscope view showing clean spaces (a) and debris (b) between girders, deterioration in the seal of the expansion joint (c), and a mouse nest in the abutment (d) at CT-concrete

Figure 5-6: Mud-Dauber's nests observed on CT-concrete

Figure 5-7: Ponded area upstream of CT-concrete

Location A

Location B

Figure 5-8: CT-concrete microphone placement

Table 5-1: Early season automated acoustic monitoring results for CT-precast_concrete.

Night 1	2015								31 May 2016 no precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X	1							
MYLU	X	X	X	X	X	X	X	X				1	1	1	1	1
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	2	18	2	12	2	16	2	20
LANO	X	X	X	X	X	X	X	X	5	20	4	14	4	25	5	25
LABO	X	X	X	X	X	X	X	X		4						
LACI	X	X	X	X	X	X	X	X	6	27	13	26	13	26	13	26
MYLE	X	X	X	X	X	X	X	X	1							

Night 2	2015								01 June 2016 no precipitation, 5 MPH wind *Location B monitor recorded until 23:22PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X			1		1		1	
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X				1	1	1		1
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	3	12	7	7	7	7	8	9
LANO	X	X	X	X	X	X	X	X	1	7		6	1	15	1	13
LABO	X	X	X	X	X	X	X	X	3	2						
LACI	X	X	X	X	X	X	X	X	5	10	5	2	5	2	5	3
MYLE	X	X	X	X	X	X	X	X							1	

Night 3	2015								02 June 2016 no precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		/		/		/		/
MYSO	X	X	X	X	X	X	X	X		/		/		/		/
MYLU	X	X	X	X	X	X	X	X		/		/		/		/
PESU	X	X	X	X	X	X	X	X		/		/		/		/
EPFU	X	X	X	X	X	X	X	X	5	/	5	/	6	/	5	/
LANO	X	X	X	X	X	X	X	X	2	/	3	/	4	/	4	/
LABO	X	X	X	X	X	X	X	X		/		/		/		/
LACI	X	X	X	X	X	X	X	X	1	/	4	/	4	/	4	/
MYLE	X	X	X	X	X	X	X	X		/		/		/		/

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-2: Mid-season automated acoustic monitoring results for CT-precast_concrete.

Night 1	2015								05 July 2016 0.55in precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		2						
MYSO	X	X	X	X	X	X	X	X	2							
MYLU	X	X	X	X	X	X	X	X	1		1	1	1	2	2	1
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	21	34	24	51	29	56	30	61
LANO	X	X	X	X	X	X	X	X	21	55	13	40	28	57	25	59
LABO	X	X	X	X	X	X	X	X	2	8						
LACI	X	X	X	X	X	X	X	X	28	56	17	48	18	49	18	49
MYLE	X	X	X	X	X	X	X	X								1

Night 2	2015								06 July 2016 no precipitation, 1 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		1						1
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X	2		2		3	1	3	
PESU	X	X	X	X	X	X	X	X		1						
EPFU	X	X	X	X	X	X	X	X	55	111	107	187	120	217	139	202
LANO	X	X	X	X	X	X	X	X	30	69	21	41	40	71	41	74
LABO	X	X	X	X	X	X	X	X	12	16						2
LACI	X	X	X	X	X	X	X	X	45	116	26	64	27	66	27	65
MYLE	X	X	X	X	X	X	X	X								

Night 3	2015								07 July 2016 no precipitation, 2 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	/	1	/		/		/	
MYSO	X	X	X	X	X	X	X	X	/	1	/		/		/	
MYLU	X	X	X	X	X	X	X	X	/	1	/		/	2	/	1
PESU	X	X	X	X	X	X	X	X	/	1	/		/		/	
EPFU	X	X	X	X	X	X	X	X	/	78	/	155	/	167	/	163
LANO	X	X	X	X	X	X	X	X	/	49	/	28	/	44	/	44
LABO	X	X	X	X	X	X	X	X	/	39	/		/		/	
LACI	X	X	X	X	X	X	X	X	/	51	/	32	/	33	/	32
MYLE	X	X	X	X	X	X	X	X	/		/		/		/	

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-3: Late season automated acoustic monitoring results for CT-precast_concrete.

Night 1	2015								08 August 2016 no precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	8	20	11	7	11	7	15	12
LANO	X	X	X	X	X	X	X	X	2	9	4	11	4	14	4	16
LABO	X	X	X	X	X	X	X	X	1	4						1
LACI	X	X	X	X	X	X	X	X	5	5		4		5	1	4
MYLE	X	X	X	X	X	X	X	X								

Night 2	2015								09 August 2016 no precipitation, 2 MPH wind *Location B monitor recorded until 23:23PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X	1				1			1
PESU	X	X	X	X	X	X	X	X		1						
EPFU	X	X	X	X	X	X	X	X	39	52	50	43	56	45	54	50
LANO	X	X	X	X	X	X	X	X	8	13	5	8	9	10	9	10
LABO	X	X	X	X	X	X	X	X	6	8						1
LACI	X	X	X	X	X	X	X	X	6	6	5		5		5	
MYLE	X	X	X	X	X	X	X	X	1							

Night 3	2015								10 August 2016 0.01in precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X					1			
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X						1		
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	64		87		95	99		
LANO	X	X	X	X	X	X	X	X	9		6		13	15		
LABO	X	X	X	X	X	X	X	X	10							
LACI	X	X	X	X	X	X	X	X	5							
MYLE	X	X	X	X	X	X	X	X								

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.2 Maine Bridges

Two bridges were fully monitored in Maine during both summers 2015 and 2016. These bridges were chosen based on observing promising characteristics during rapid visual screenings.

5.2.1 ME-concrete

One bridge monitored summers 2015 and 2016 in Maine is of concrete construction, shown in Figure 5-9, given the identification name "ME-concrete." This bridge has various levels of deterioration and interesting aspects that may provide roost locations for bats, such as downspouts, seen in Figure 5-10, some of which have been paved over and were therefore fully sealed at the bridge deck, and a partial rock retaining wall adjacent to the abutment as seen in Figure 5-11. The boroscope was used to investigate the nongrouted and deteriorated retaining walls around ME-concrete. Images captured with the borescope can be seen in Figure 5-12, showing no signs of bat use. There are various cracks, crevices, and expansion joints in the bridge that can provide appropriate spaces for roosting, seen in Figure 5-13. Staining of unknown causation was widespread at specific potential roost sites, shown in Figure 5-14. Birds were observed and bird's nests were seen at this location as well as Mud-Dauber's nests shown in Figure 5-15, indicating that the habitat of this bridge is conducive to that for bats. The surrounding habitat around the bridge seemed conducive to bat habitat and foraging as it is located along a forested river. Both the federal form and the developed supplemental form were completed and are included in Appendix C-2.

During the summer 2016 monitoring, two potential guano deposits were found near an abutment of this bridge; several pellets were observed below a downspout shown in Figure 5-16 (a), and a single much larger pellet of unknown feces was collected nearby, shown in Figure 5-16(b). Unfortunately the several pellet sample was lost during field work. The larger, single pellet sample was collected for species identification, and was identified as toad feces through the pooled sampling laboratory. An expansion joint was identified as a potential roost location through bridge monitoring that is in close proximity to the downspout and potential guano deposits. The gasket above this expansion joint was replaced during the fall of 2016. A representative of the MaineDOT Environmental Office did not find specific guano pieces in the joint location they accessed, but collected general debris accumulated in the expansion joint which was also sent for guano species identification testing. Results from the analysis of the general debris were negative for bat species.

Microphone placement for acoustic monitoring at ME-concrete is shown in Figure 5-17. Location A is upstream and further from the bridge. The microphone is attached to a branch of a dead tree. Location B is also upstream but is much closer to the bridge. It is attached to a branch of a tree near a popular fishing and wading area. Table 5-4, Table 5-5, and Table 5-6 show acoustic results from monitoring ME-concrete throughout early, mid- and late seasons.

Emergence studies were completed at ME-concrete in the mid-season monitoring and twice in late season monitoring. During these emergence studies, several bats were observed in the local area. Automated analysis of emergence period acoustic data collected classified several species being present in the local area (mid-season SonoBat: MYLU, EPFU, LANO, LACI; mid-season EchoClass: MYLU, EPFU, LANO, LACI, LABO, MYSO, PESU; late season SonoBat: EPFU, LANO, LACI; late season EchoClass: EPFU, LANO, LACI, LABO). During the mid-season emergence study, a suspected bat was potentially seen roosting and emerging from an expansion joint, shown in Figure 5-18. The research team is unable to verify this as it was not captured on video or camera. The research team inspected this expansion joint as thoroughly as possible in subsequent visits, using the monocular as this location was inaccessible by other means. Further investigation could not confirm roosting in the joint.

Figure 5-9: Concrete bridge selected in ME (ME-concrete)

Figure 5-10: Downspouts at ME-concrete

Figure 5-11: Rock partial retaining wall adjacent to the abutment at ME-concrete

Figure 5-12: Boroscope view of gaps in non-grouted and deteriorated retaining walls by ME-concrete

Figure 5-13: Possible roost locations at ME-concrete

Figure 5-14: Staining of unknown causation at ME-concrete

Figure 5-15: Mud-Dauber’s nests observed at ME-concrete

(a) (b)

Figure 5-16: Potential guano deposits (unconfirmed species), potential evidence of roosting at ME-concrete (a) and observed larger fecal pellet of unknown species (confirmed to be a toad species) (b)

Location A

Location B

Figure 5-17: ME-concrete microphone placement

Figure 5-18: Potential roost location in the expansion joint of ME-concrete, not verified

Table 5-4: Early season automated acoustic monitoring results for ME-concrete.

Night 1	2015								06 June 2016 0.08in precipitation, 3 MPH wind *Location A & B monitor recorded until 02:17AM							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X							1	
MYSO	X	X	X	X	X	X	X	X	4	4						
MYLU	X	X	X	X	X	X	X	X	6	1	3		5	1	8	
PESU	X	X	X	X	X	X	X	X	10		19		19		24	
EPFU	X	X	X	X	X	X	X	X	71	8	59	5	62	5	64	7
LANO	X	X	X	X	X	X	X	X	12	3	24	11	43	25	43	26
LABO	X	X	X	X	X	X	X	X	27						1	
LACI	X	X	X	X	X	X	X	X	11	3	4	3	5	3	4	3
MYLE	X	X	X	X	X	X	X	X	1							

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-5: Mid-season automated acoustic monitoring results for ME-concrete.

Night 1	20 July 2015 0.05in precipitation, 3 MPH wind *Location B monitor recorded until 00:25AM								11 July 2016 no precipitation, 5 MPH wind *Location B monitor recorded until 02:17AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		1														
MYSO		6							1	2						
MYLU	13	1	22	2	27	4	32	3	20		54	1	58	1	71	1
PESU	6		25	1	29	1	43	1	1			0				
EPFU	101	47	106	46	111	51	121	55	1068	369	1014	322	1036	334	1072	355
LANO	38	5	37	14	64	33	63	35	34	34	70	93	155	186	139	189
LABO	115	30	9		18		18		159	37		0	1		5	
LACI	43	22	28	10	28	11	32	11	68	60	16	27	17	27	19	29
MYLE																
Night 2	21 July 2015 0.12in precipitation, 1 MPH wind *Location A monitor recorded until 21:39PM								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/	X	X	X	X	X	X	X	X
MYSO	3	/		/		/		/	X	X	X	X	X	X	X	X
MYLU	8	/	5	/	12	/	8	/	X	X	X	X	X	X	X	X
PESU	2	/		/		/	1	/	X	X	X	X	X	X	X	X
EPFU	92	/	100	/	101	/	110	/	X	X	X	X	X	X	X	X
LANO	12	/	20	/	32	/	32	/	X	X	X	X	X	X	X	X
LABO	13	/		/		/		/	X	X	X	X	X	X	X	X
LACI	15	/	5	/	5	/	5	/	X	X	X	X	X	X	X	X
MYLE		/		/		/		/	X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-6: Late season automated acoustic monitoring results for ME-concrete.

Night 1	17 August 2015 no precipitation, 1 MPH wind *Location A monitor recorded until 03:02AM								15 August 2016 no precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/								
MYSO	6	/		/		/		/	2	1						
MYLU		/	1	/	1	/	3	/	67	2	64	3	71	3	108	4
PESU	1	/		/		/		/	8							
EPFU	1579	/	1662	/	1758	/	1755	/	1637	604	780	390	1017	425	864	422
LANO	98	/	75	/	181	/	185	/	22	21	310	169	405	248	421	245
LABO	158	/		/		/		/	521	107	2	2	2	2	16	2
LACI	145	/	34	/	38	/	36	/	29	38	8	13	8	13	8	15
MYLE		/		/		/		/								

Night 2	2015								16 August 2016 0.3in precipitation, 3 MPH wind *Location B monitor recorded until 22:41PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	2	454		178		209	2	225
LANO	X	X	X	X	X	X	X	X		7		130		201		233
LABO	X	X	X	X	X	X	X	X		80						
LACI	X	X	X	X	X	X	X	X		6		14		14		15
MYLE	X	X	X	X	X	X	X	X								

Night 3	2015								17August 2016 0.32in precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		/		/		/		/
MYSO	X	X	X	X	X	X	X	X	20	/	17	/	17	/	27	/
MYLU	X	X	X	X	X	X	X	X	19	/	3	/	3	/	7	/
PESU	X	X	X	X	X	X	X	X	195	/	81	/	97	/	96	/
EPFU	X	X	X	X	X	X	X	X	3	/	37	/	50	/	49	/
LANO	X	X	X	X	X	X	X	X	88	/		/		/		/
LABO	X	X	X	X	X	X	X	X	1	/		/		/		/
LACI	X	X	X	X	X	X	X	X		/		/		/		/
MYLE	X	X	X	X	X	X	X	X		/		/		/		/

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.2.2 ME-steel/wood

One bridge monitored summers 2015 and 2016 in Maine is a steel girder bridge with a wooden deck, shown in Figure 5-19, given the identification name "ME-steel/wood." This bridge has experienced significant levels of deterioration in the steel girders and has staining at the abutments as can be seen in Figure 5-20. The deterioration near the abutments shown in Figure 5-21 produced deep crevices and cave-like spaces for potential bat roosts. These spaces were investigated with the boroscope, as shown in Figure 5-22. The wooden decking has crevices between the boards, shown in Figure 5-23 but it is unclear if these spaces would be appropriate to be utilized by bats. All bridge crevices were fully inspected using the boroscope, and no obvious signs of bats were observed, indicating no bats roosting when the daytime inspection occurred. This one lane bridge is located in a secluded part of Maine off a dirt road in a rural forested area. The surrounding vegetation seemed conducive to supporting bat habitat and foraging, and there were ample mosquitos and other insects present at all field visits. Both the federal form and the developed supplemental form were completed and are included in Appendix C-3.

Microphone placement for acoustic monitoring at ME-steel/wood is shown in Figure 5-24. Location A is upstream of the bridge with the microphone attached to a tree trunk on the streambank. Location B is downstream of the bridge on a tree branch over the waterway. Table 5-7, Table 5-8, and Table 5-9 show acoustic results from monitoring ME-steel/wood throughout early, mid- and late seasons.

Emergence studies were completed at ME-steel/wood in the early and mid- monitoring seasons. No bats were seen exiting the bridge, and very few bats were observed during emergence studies. During the mid-season emergence study, the research team observed a bat fly to a potential roost tree within about 200 ft (60 m) of the bridge. While only one bat was visually observed downstream, Automated analysis of emergence period acoustic data collected classified three bat species present in the local area (SonoBat: MYLU, LANO; EchoClass: MYLU, MYSO).

Figure 5-19: Wooden deck on steel beam construction bridge selected in ME (ME-steel/wood)

Figure 5-20: Significant deterioration and staining in ME-steel/wood

Figure 5-21: Potential roosts by the abutments in ME-steel/wood

Figure 5-22: Boroscope views of spaces by the abutments at ME-steel/wood

Figure 5-23: Spacing between layers of wooden decking in ME-steel/wood

Location A

Location B

Figure 5-24: ME-steel/wood microphone placement

Table 5-7: Early season automated acoustic monitoring results for ME-steel/wood.

Night 1	2015								06 June 2016 0.08in precipitation, 3 MPH wind *Location A monitor recorded until 03:04AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	1							
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X							1	
PESU	X	X	X	X	X	X	X	X		1						
EPFU	X	X	X	X	X	X	X	X			1	3	1	3	2	3
LANO	X	X	X	X	X	X	X	X								1
LABO	X	X	X	X	X	X	X	X	1	2						1
LACI	X	X	X	X	X	X	X	X	1	8	1	7	1	7	1	7
MYLE	X	X	X	X	X	X	X	X								

Night 2	2015								07 June 2016 0.13in precipitation, 1 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X								
LANO	X	X	X	X	X	X	X	X				1		3		4
LABO	X	X	X	X	X	X	X	X								
LACI	X	X	X	X	X	X	X	X		8		4		4		5
MYLE	X	X	X	X	X	X	X	X								

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-8: Mid-season automated acoustic monitoring results for ME-steel/wood.

Night 1	20 July 2015, 0.05in precipitation, 3 MPH wind								11 July 2016, no precipitation, 5 MPH wind, *Location A monitor recorded until 01:22AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/		2	1						1
MYSO	/		/		/		/									
MYLU	/		/		/		/									2
PESU	/		/		/		/									
EPFU	/	2	/	2	/	2	/	4			1	5	1	6	1	5
LANO	/		/	2	/	4	/	3					1		1	
LABO	/	3	/		/		/		9	9						
LACI	/	2	/	1	/	1	/	1			1		1		1	
MYLE	/		/		/		/			4	2		2		4	6

Night 2	21 July 2015, 0.12in precipitation, 1 MPH wind								12 July 2016, no precipitation, 2 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/		/	2	/		/		/	
MYSO	/		/		/		/		/		/		/		/	
MYLU	/		/		/		/		/		/		/		/	
PESU	/		/		/		/		/		/		/		/	
EPFU	/	2	/		/		/	3	/	3	/	6	/	6	/	9
LANO	/		/	1	/	4	/	5	/		/		/	1	/	1
LABO	/		/		/		/		/	9	/		/		/	
LACI	/		/		/		/		/	1	/	1	/	1	/	1
MYLE	/		/		/		/		/		/		/	2	/	

Night 3	22 July 2015, 0.07in precipitation, 6 MPH wind								13 July 2016, no precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/	1	/		/		/		/	1	/		/		/	1
MYSO	/	1	/		/		/		/		/		/		/	
MYLU	/	1	/		/	1	/	1	/		/		/		/	
PESU	/		/		/		/		/		/		/		/	
EPFU	/	1	/	1	/	1	/	1	/		/	2	/	2	/	5
LANO	/		/	1	/	1	/	1	/	1	/	2	/	4	/	4
LABO	/	2	/		/		/	1	/	1	/		/		/	
LACI	/		/	2	/	2	/	2	/	1	/		/		/	
MYLE	/		/		/		/		/		/		/		/	

Notes: “X”=No data collected, “/”= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-9: Late season automated acoustic monitoring results for ME-steel/wood.

Night 1	17 August 2015 no precipitation, 1 MPH wind								15 August 2016 no precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	1	1							4	1						2
MYSO																
MYLU																
PESU																
EPFU	2		4	2		2	1	3								
LANO		1		1	7	4	7	5			1		1		1	
LABO	9	5						1	11	8	1		1		1	1
LACI	3	3		1	1	1	2	1	1		1		1		1	
MYLE								5			1	1	1	1	4	5

Night 2	18 August 2015 no precipitation, 1 MPH wind								16 August 2016 0.3in precipitation, 2 MPH wind *Location A monitor recorded until 00:07AM *Location B monitor recorded until 00:23AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	3															
MYSO																
MYLU																
PESU																
EPFU			3	2	4	2	5	2							2	
LANO			1	3	5	6	6	6						2		2
LABO	7	9	3				1									
LACI	4	8		1	1	1	1	1	1							
MYLE	1						1									

Night 3	19 August 2015 no precipitation, no wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	5	5							X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU	7	4	8	1	7	2	10	4	X	X	X	X	X	X	X	X
LANO	2	1	1	4	10	6	13	8	X	X	X	X	X	X	X	X
LABO	16	14	6				1		X	X	X	X	X	X	X	X
LACI	4	3		1	1	1	1	1	X	X	X	X	X	X	X	X
MYLE	2	1		1		1	3	4	X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.3 Massachusetts Bridges

Three bridges were fully monitored in Massachusetts in both summers 2015 and 2016. The bridges were chosen based on bridges with promising characteristics based on rapid visual screenings. One bridge monitored in summer 2015 that had limited bat activity and potential for bat roosting was replaced in summer 2016 for a coastal bridge in an area that is known to have MYSE species.

5.3.1 MA-concrete

One bridge monitored summer 2016 in Massachusetts is of concrete construction, shown in Figure 5-25, given the identification name "MA-concrete." This bridge was added in summer 2016 as it is situated close to the coast in a town known to have MYSE. Staining of unspecified causation was observed at the top of all the wooden supports where the piers meet the deck, seen in Figure 5-26. All of these crevices were fully inspected using the boroscope, shown in Figure 5-27, and no obvious signs of bats were observed, indicating no bats roosting when the daytime inspection occurred. The boroscope was used to investigate other crevices at MA-concrete, seen in Figure 5-28, showing no signs of bat use. This bridge has several pipe details, seen in Figure 5-29 and Figure 5-30, and birds' nests, seen in Figure 5-30, and Mud-Dauber's nests, seen in Figure 5-31, were observed throughout the bridge. This bridge is situated in a semi-forested rural area with a ponded area upstream and ample roosting and foraging habitat for bats in the surrounding areas, shown in Figure 5-32. Both the federal form and the developed supplemental form were completed and are included in Appendix C-4.

Guano deposits were observed, shown in Figure 5-33, underneath an area where a piece of concrete on the underside of the deck had spalled off, creating potential footholds for bats and a potential night roost location. Guano was collected from this location during mid- and late season monitoring, and was sent in for species identification. This guano was identified as MYLE in the mid-season monitoring and both MYLE and EPFU in the late season monitoring by the pooled sampling laboratory. The individual pellet testing laboratory was unable to identify any bat species. Both EPFU and MYLE species were identified through acoustic monitoring during all three monitoring seasons, with higher numbers of EPFU calls identified and lower numbers of MYLE calls identified.

Microphone placement for acoustic monitoring at MA-concrete is shown in Figure 5-34. Location A is upstream and farther from the bridge with the microphone attached to a tree on the bank of the stream. Location B is downstream of the bridge, set slightly behind the abutment, on a tree branch. Table 5-10, Table 5-11, and Table 5-12 show acoustic results from monitoring MA-concrete throughout early, mid- and late seasons.

Emergence studies were completed at MA-concrete in the early and late monitoring season. No bats were seen exiting the bridge, and very few bats were observed. While only one bat was observed during the late monitoring season emergence study, automated analysis of acoustic data collected classified four different bat species present in the local area (SonoBat: EPFU, LANO, LACI; EchoClass: EPFU, LANO, LACI, LABO). The potential night roost location was also monitored, though no bats were actively seen roosting.

Figure 5-25: Concrete bridge selected in MA (MA-concrete)

Figure 5-26: Staining on piers and gaps where piers meet deck at MA-concrete

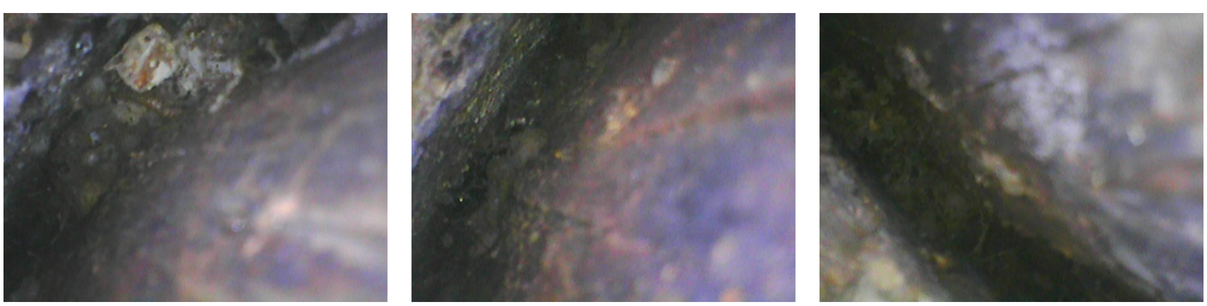


Figure 5-27: Boroscope views between deck and wooden piers at MA-concrete

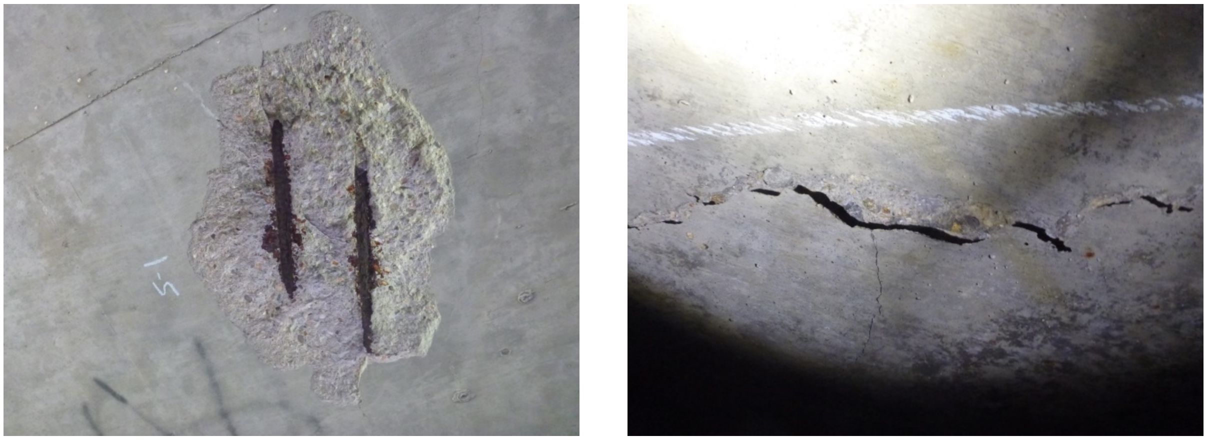
Figure 5-28: Boroscope views of crevices in MA-concrete

Figure 5-29: Pipes observed at MA-concrete

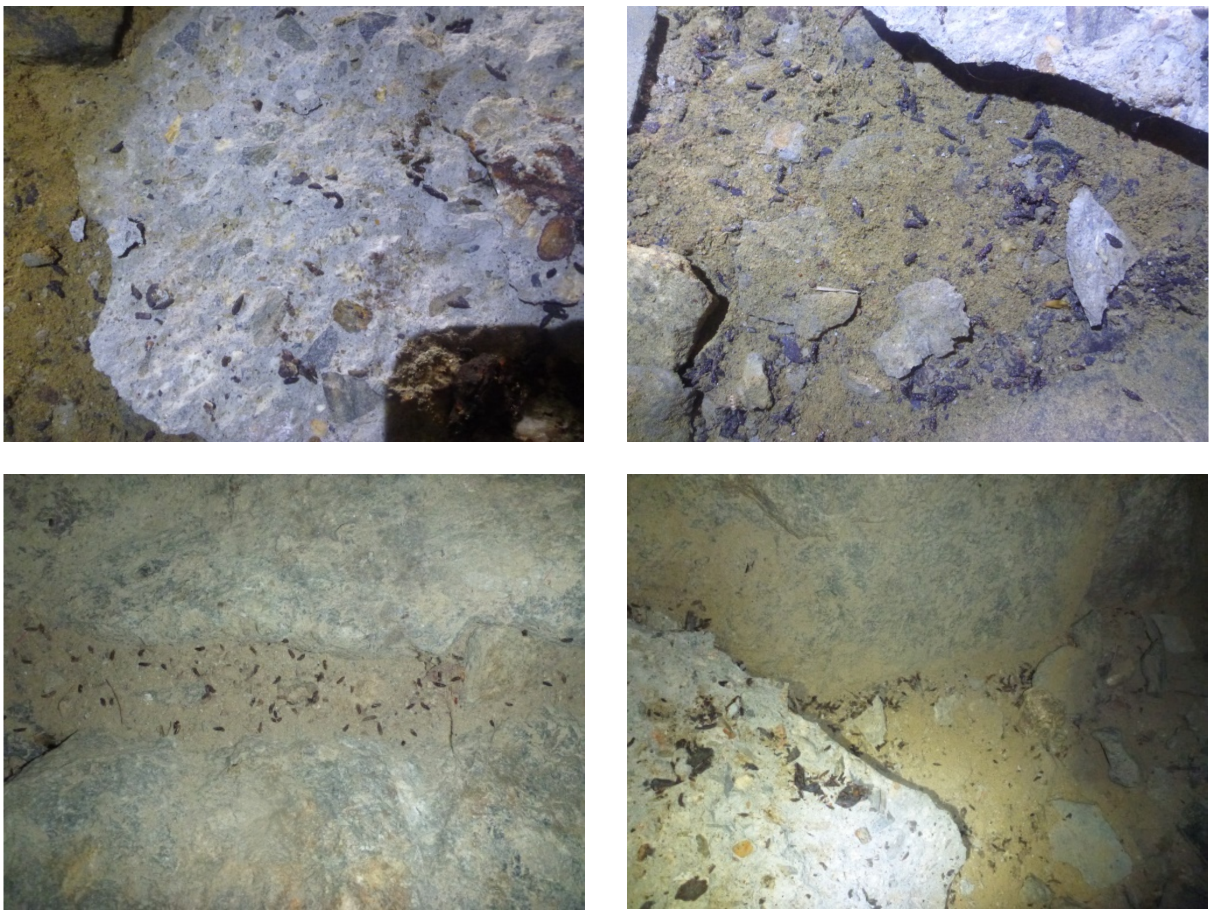
Figure 5-30: Birds' nests and pipes observed at MA-concrete

Figure 5-31: Mud-Dauber’s nests observed at MA-concrete

Figure 5-32: Surrounding habitat at MA-concrete



(a)



(b)

Figure 5-33: Spalled and cracking concrete deck creating potential roost location (a) above observed guano deposits (confirmed to be MYLE and EPFU) (b) in bridge in Essex County, MA

Location A

Location B

Figure 5-34: MA-concrete microphone placement

Table 5-10: Early season automated acoustic monitoring results for MA-concrete.

Night 1	2015								06 June 2016, no precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	2	4		1		1		2
MYSO	X	X	X	X	X	X	X	X	3	1						
MYLU	X	X	X	X	X	X	X	X							1	
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	20	51	24	37	31	41	29	69
LANO	X	X	X	X	X	X	X	X	13	11	11	12	26	33	27	38
LABO	X	X	X	X	X	X	X	X	12	51						3
LACI	X	X	X	X	X	X	X	X	24	43	7	12	7	12	7	12
MYLE	X	X	X	X	X	X	X	X		3		1		1	1	2

Night 2	2015								07 June 2016, 0.08in precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		3		2		2		4
MYSO	X	X	X	X	X	X	X	X	1	2						
MYLU	X	X	X	X	X	X	X	X								1
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	43	35	40	25	46	30	44	43
LANO	X	X	X	X	X	X	X	X	6	11	17	13	32	31	34	35
LABO	X	X	X	X	X	X	X	X	18	39		2		3		2
LACI	X	X	X	X	X	X	X	X	21	25	12	8	13	8	12	8
MYLE	X	X	X	X	X	X	X	X		6	1	4	1	4	1	6

Night 3	2015								08 June 2016, no precipitation, 10 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		3						1
MYSO	X	X	X	X	X	X	X	X		1						
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	1	6	4	10	5	12	6	16
LANO	X	X	X	X	X	X	X	X	1		4	4	4	9	5	9
LABO	X	X	X	X	X	X	X	X	1	16						
LACI	X	X	X	X	X	X	X	X	4	3	3	2	3	2	3	2
MYLE	X	X	X	X	X	X	X	X		13		5		7		11

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-11: Mid-season automated acoustic monitoring results for MA-concrete.

Night 1	2015								11 July 2016 no precipitation, 4 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	1	2	1	1	1	1	1	2
MYSO	X	X	X	X	X	X	X	X	6	1						
MYLU	X	X	X	X	X	X	X	X								1
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	23	59	23	40	30	48	34	66
LANO	X	X	X	X	X	X	X	X	19	11	21	22	29	41	35	50
LABO	X	X	X	X	X	X	X	X	33	85	1		2	1	3	4
LACI	X	X	X	X	X	X	X	X	22	21	11	9	11	9	12	9
MYLE	X	X	X	X	X	X	X	X		1	1	2	1	2	3	3

Night 2	2015								12 July 2016 no precipitation, 5 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	19	30	1		1		2	2
MYSO	X	X	X	X	X	X	X	X	29				1		1	
MYLU	X	X	X	X	X	X	X	X			10	1	16	2	24	2
PESU	X	X	X	X	X	X	X	X							1	
EPFU	X	X	X	X	X	X	X	X	101	38	103	52	115	53	125	83
LANO	X	X	X	X	X	X	X	X	17	12	32	15	60	42	71	44
LABO	X	X	X	X	X	X	X	X	120	104		1		1	4	2
LACI	X	X	X	X	X	X	X	X	51	42	25	39	25	39	27	45
MYLE	X	X	X	X	X	X	X	X	5	3	3	2	4	3	5	4

Night 3	2015								13 July 2016 no precipitation, 7 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	8	20		1	1	1	1	3
MYSO	X	X	X	X	X	X	X	X	10	5						
MYLU	X	X	X	X	X	X	X	X			6	3	7	6	10	24
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	120	43	121	51	141	58	146	80
LANO	X	X	X	X	X	X	X	X	12	8	35	15	55	40	68	48
LABO	X	X	X	X	X	X	X	X	84	193					3	1
LACI	X	X	X	X	X	X	X	X	30	41	23	77	24	79	24	83
MYLE	X	X	X	X	X	X	X	X	8	6	2	3	2	5	3	11

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-12: Late season automated acoustic monitoring results for MA-concrete.

Night 1	2015								15 August 2016, no precipitation, 7 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	2	4	1	1	1	1	2	2
MYSO	X	X	X	X	X	X	X	X	8							
MYLU	X	X	X	X	X	X	X	X	1		1		2		2	
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	23	14	20	27	21	31	30	33
LANO	X	X	X	X	X	X	X	X	5	15	20	15	34	29	32	30
LABO	X	X	X	X	X	X	X	X	18	16			2		1	1
LACI	X	X	X	X	X	X	X	X	20	18	12	12	12	13	12	12
MYLE	X	X	X	X	X	X	X	X	2	2		2		2		3

Night 2	2015								16 August 2016, 0.05in precipitation, 3 MPH wind, *Location A monitor recorded until 00:52AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		8		1		1		2
MYSO	X	X	X	X	X	X	X	X	3							
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	8	21	8	22	10	27	12	30
LANO	X	X	X	X	X	X	X	X	2	5	2	5	8	15	6	17
LABO	X	X	X	X	X	X	X	X	4	13	1		1		1	1
LACI	X	X	X	X	X	X	X	X	1	17	1	29	1	29	1	29
MYLE	X	X	X	X	X	X	X	X	1	2		4		4		7

Night 3	2015								17August 2016, no precipitation, 7 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	/	2	/		/		/	2
MYSO	X	X	X	X	X	X	X	X	/		/		/		/	
MYLU	X	X	X	X	X	X	X	X	/		/		/		/	
PESU	X	X	X	X	X	X	X	X	/		/		/		/	
EPFU	X	X	X	X	X	X	X	X	/	15	/	21	/	24	/	23
LANO	X	X	X	X	X	X	X	X	/	5	/	5	/	9	/	10
LABO	X	X	X	X	X	X	X	X	/	12	/		/		/	
LACI	X	X	X	X	X	X	X	X	/	25	/	9	/	9	/	9
MYLE	X	X	X	X	X	X	X	X	/	2	/	2	/	2	/	3
	X	X	X	X	X	X	X	X	/		/		/		/	

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-12: ***continued*** Late season automated acoustic monitoring results for MA-concrete.

Night 4	2015								18 August 2016 no precipitation, 7 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	/	1	/		/		/	
MYSO	X	X	X	X	X	X	X	X	/		/		/		/	
MYLU	X	X	X	X	X	X	X	X	/		/		/		/	
PESU	X	X	X	X	X	X	X	X	/		/		/		/	2
EPFU	X	X	X	X	X	X	X	X	/	21	/	25	/	29	/	36
LANO	X	X	X	X	X	X	X	X	/	19	/	19	/	38	/	39
LABO	X	X	X	X	X	X	X	X	/	16	/		/		/	1
LACI	X	X	X	X	X	X	X	X	/	38	/	12	/	12	/	12
MYLE	X	X	X	X	X	X	X	X	/		/	1	/	1	/	2

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.3.2 MA-precast_concrete

One bridge monitored summer 2015 in Massachusetts is a precast concrete bridge, shown in Figure 5-35, given the identification name "MA-precast_concrete." Gaps between the precast concrete girders create appropriately sized roosting locations. There is an interesting drainage feature in this bridge, shown in Figure 5-35 and close up in Figure 5-36, which may be a possible roost location as it is relatively sheltered from predators and was dry inside with several crevices. There is noted staining of unidentifiable and unknown causation, show in Figure 5-37, that may be localized urine staining from roosting. While this bridge is situated over a waterway which has been noted to be a preferable characteristic, it is situated over the Housatonic River and is contaminated with polychlorinated biphenyls (PCBs) (signage shown in Figure 5-38), and it is unclear if this has any impact on bat usage. This bridge is protected by vegetation, and has a surrounding habitat plausible to support bat roosting in the bridge and foraging habitat.

MA-precast_concrete was only monitored in summer 2015 and was removed for summer 2016 monitoring. In preparing for the summer 2016 monitoring season, preliminary results from summer 2015 monitoring were considered. Table 5-13 and Table 5-14 show acoustic results from monitoring MA-precast_concrete throughout mid- and late seasons. When looking at the acoustic data (preliminary SonoBat results), this location recorded the second fewest number of calls over the entire summer 2015 monitoring, indicating lower bat activity in the local area as compared to other bridge sites monitored. This bridge had limited access with the upstream side fenced off and a resident's yard on one downstream side, which would not allow for thorough inspection in summer 2016. Additionally, setting up and retrieving equipment in summer 2015 proved to be difficult. As such, this bridge was not included in summer 2016 field work.

Figure 5-35: Precast concrete bridge selected in MA (MA-precast_concrete)

Figure 5-36: Drainage feature in MA-precast_concrete

Figure 5-37: Staining in between beams in MA-precast_concrete

Figure 5-38: Sign warning of water contamination of river under MA-precast_concrete

Table 5-13: Mid-season automated acoustic monitoring results for MA-precast_concrete.

Night 1	29 July 2015, no precipitation, 3 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/	X	X	X	X	X	X	X	X
MYSO	3	/		/		/		/	X	X	X	X	X	X	X	X
MYLU		/		/	1	/		/	X	X	X	X	X	X	X	X
PESU		/		/		/		/	X	X	X	X	X	X	X	X
EPFU	6	/	5	/	5	/	14	/	X	X	X	X	X	X	X	X
LANO	3	/	2	/	11	/	12	/	X	X	X	X	X	X	X	X
LABO	1	/		/		/	1	/	X	X	X	X	X	X	X	X
LACI	16	/	2	/	2	/	2	/	X	X	X	X	X	X	X	X
MYLE		/		/		/		/	X	X	X	X	X	X	X	X

Night 2	30 July 2015, 0.01in precipitation, 5 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/	X	X	X	X	X	X	X	X
MYSO		/		/		/		/	X	X	X	X	X	X	X	X
MYLU		/		/		/		/	X	X	X	X	X	X	X	X
PESU		/		/		/		/	X	X	X	X	X	X	X	X
EPFU	2	/	6	/	6	/	10	/	X	X	X	X	X	X	X	X
LANO	4	/		/	2	/	2	/	X	X	X	X	X	X	X	X
LABO	3	/		/		/	1	/	X	X	X	X	X	X	X	X
LACI	11	/	5	/	5	/	5	/	X	X	X	X	X	X	X	X
MYLE		/		/		/		/	X	X	X	X	X	X	X	X

Night 3	31 July 2015, no precipitation, 7 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/	X	X	X	X	X	X	X	X
MYSO		/		/		/		/	X	X	X	X	X	X	X	X
MYLU		/		/		/		/	X	X	X	X	X	X	X	X
PESU		/		/		/		/	X	X	X	X	X	X	X	X
EPFU	3	/	3	/	5	/	7	/	X	X	X	X	X	X	X	X
LANO	3	/	1	/	4	/	4	/	X	X	X	X	X	X	X	X
LABO	2	/		/		/		/	X	X	X	X	X	X	X	X
LACI	6	/		/		/		/	X	X	X	X	X	X	X	X
MYLE		/		/		/		/	X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-13: *continued* Mid-season automated acoustic monitoring results for MA-precast_concrete.

Night 4	01 August 2015 0.25in precipitation, 5 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/	X	X	X	X	X	X	X	X
MYSO		/		/		/		/	X	X	X	X	X	X	X	X
MYLU		/		/		/		/	X	X	X	X	X	X	X	X
PESU		/		/		/		/	X	X	X	X	X	X	X	X
EPFU	1	/		/		/		/	X	X	X	X	X	X	X	X
LANO	1	/	1	/	2	/	2	/	X	X	X	X	X	X	X	X
LABO	1	/		/		/		/	X	X	X	X	X	X	X	X
LACI	8	/	4	/	4	/	4	/	X	X	X	X	X	X	X	X
MYLE		/		/		/		/	X	X	X	X	X	X	X	X

Night 5	02 August 2015 no precipitation, 4 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/	X	X	X	X	X	X	X	X
MYSO	1	/		/		/		/	X	X	X	X	X	X	X	X
MYLU		/		/		/	2	/	X	X	X	X	X	X	X	X
PESU		/		/		/		/	X	X	X	X	X	X	X	X
EPFU	3	/	3	/	3	/	12	/	X	X	X	X	X	X	X	X
LANO		/	5	/	8	/	8	/	X	X	X	X	X	X	X	X
LABO	6	/		/		/		/	X	X	X	X	X	X	X	X
LACI	11	/	2	/	2	/	2	/	X	X	X	X	X	X	X	X
MYLE		/		/		/		/	X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-14: Late season automated acoustic monitoring results for MA-precast_concrete.

Night 1	26 August 2015 no precipitation, 7 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU									X	X	X	X	X	X	X	X
LANO					2		2		X	X	X	X	X	X	X	X
LABO		2							X	X	X	X	X	X	X	X
LACI		2							X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X
Night 2	27 August 2015 no precipitation, 7 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO								1	X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU									X	X	X	X	X	X	X	X
LANO									X	X	X	X	X	X	X	X
LABO		4							X	X	X	X	X	X	X	X
LACI	1								X	X	X	X	X	X	X	X
MYLE						1			X	X	X	X	X	X	X	X
Night 3	28 August 2015 no precipitation, 2 MPH wind *Location A monitor recorded until 03:42AM								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU									X	X	X	X	X	X	X	X
LANO									X	X	X	X	X	X	X	X
LABO									X	X	X	X	X	X	X	X
LACI	1		2		2		2		X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-14: *continued* Late season automated acoustic monitoring results for MA-precast_concrete.

Night 4	29 August 2015, no precipitation, 2 MPH wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/		X	X	X	X	X	X	X	X
MYSO	/		/		/		/		X	X	X	X	X	X	X	X
MYLU	/		/		/		/		X	X	X	X	X	X	X	X
PESU	/		/		/		/		X	X	X	X	X	X	X	X
EPFU	/	1	/		/		/		X	X	X	X	X	X	X	X
LANO	/		/	1	/	1	/	1	X	X	X	X	X	X	X	X
LABO	/		/		/		/		X	X	X	X	X	X	X	X
LACI	/	3	/	4	/	4	/	4	X	X	X	X	X	X	X	X
MYLE	/		/		/		/		X	X	X	X	X	X	X	X

Night 5	30 August 2015, no precipitation, 2 MPH wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/		X	X	X	X	X	X	X	X
MYSO	/		/		/		/		X	X	X	X	X	X	X	X
MYLU	/		/		/		/		X	X	X	X	X	X	X	X
PESU	/		/		/		/		X	X	X	X	X	X	X	X
EPFU	/		/		/		/	2	X	X	X	X	X	X	X	X
LANO	/	1	/		/	2	/	2	X	X	X	X	X	X	X	X
LABO	/	1	/		/		/		X	X	X	X	X	X	X	X
LACI	/	2	/		/		/		X	X	X	X	X	X	X	X
MYLE	/		/		/		/	1	X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.3.3 MA-precast_concrete_2

One bridge monitored summers 2015 and 2016 in Massachusetts is of concrete construction, shown in Figure 5-39, given the identification name "MA-precast_concrete_2." Gaps between the girders are appropriately sized for bat roosting. There are also gaps of appropriate roosting size where the beams meet the abutments, shown in Figure 5-40. There was significant staining observed from this gap location along the abutments from unspecified causation, shown in Figure 5-41. All intermediate spaces between girders and the abutments were fully inspected using the ladder and the boroscope, shown in Figure 5-42 (a), as well as all accessible areas between girders, shown in Figure 5-42 (b). No unusual internal staining was observed, indicating no bats roosting when the daytime inspection occurred. Two large cracks in one abutment of MA-precast_concrete_2 are shown in Figure 5-43, along with the boroscope view into these cracks, showing no signs of bat use. This bridge is situated near a seemingly abandoned barn, shown in Figure 5-44, which is another potential roost location, suggesting a likelihood of bats in the area as there are potential alternative roosts. This bridge is situated in a forested rural area with ample roosting and foraging habitat for bats in the surrounding areas. Both the federal form and the developed supplemental form were completed and are included in Appendix C-5.

The owner of a golf course adjacent to MA-precast_concrete_2 inquired about the project when the research team was at the bridge site. The owner mentioned that there have been several bats in the local area, and that bats roost in the barn the golf carts are stored. This barn in situated in close vicinity to MA-precast_concrete_2, and the owner allowed the research team access to the barn to observe the guano deposits and staining, shown in Figure 5-45. These barns also have several barn swallow birds' nests, supporting the association of birds' nests and locations with appropriate bat roosting habitat.

Microphone placement for acoustic monitoring at MA-precast_concrete_2 is shown in Figure 5-46. Location A is upstream of the bridge with the microphone attached to the trunk of a tree by the abutment. Location B is downstream of the bridge with the microphone attached to a metal stake from an old wire fence on the streambank. Table 5-15, Table 5-16, and Table 5-17 show acoustic results from monitoring MA-precast_concrete_2 throughout early, mid- and late seasons.

An emergence study was completed at MA-precast_concrete_2 in the mid- monitoring season. No bats were seen exiting the bridge or flying in the local area, though the evening was cloudy and slightly windy which could have influenced bat activity.


Figure 5-39: Concrete bridge selected in MA (MA-precast_concrete_2)

Figure 5-40: Gaps under beams at MA-precast_concrete_2


Figure 5-41: Staining of unspecified causation from gaps under beams at MA-precast_concrete_2

(a)

(b)

Figure 5-42: Boroscope view of gaps between girders and abutment (a) and gaps between girders (b) at MA-precast_concrete_2

(a)

(b)

Figure 5-43: Cracks in the abutment (a) and boroscope views of the crack at MA-precast_concrete_2

Figure 5-44: Abandoned barn near MA-precast_concrete_2

(a)

(b)

Figure 5-45: Inside of golf cart barn close to MA-precast_concrete_2 (a) and guano observed (b)

Location A

Location B

Figure 5-46: MA-precast_concrete_2 microphone placement

Table 5-15: Early season automated acoustic monitoring results for MA-precast_concrete_2.

Night 1	2015								31 May 2016 no precipitation, 8 MPH wind *Location B monitor recorded until 03:16AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	5						3	
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X								1
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	4	1		1	1	1	2	1
LANO	X	X	X	X	X	X	X	X		2	1	2	3	2	2	2
LABO	X	X	X	X	X	X	X	X		1						
LACI	X	X	X	X	X	X	X	X	2	5	6	4	6	4	6	4
MYLE	X	X	X	X	X	X	X	X								

Night 2	2015								01 June 2016 no precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	1	/		/		/		/
MYSO	X	X	X	X	X	X	X	X	1	/		/		/		/
MYLU	X	X	X	X	X	X	X	X		/		/		/	1	/
PESU	X	X	X	X	X	X	X	X		/		/		/		/
EPFU	X	X	X	X	X	X	X	X	3	/	3	/	4	/	4	/
LANO	X	X	X	X	X	X	X	X	1	/	2	/	2	/	3	/
LABO	X	X	X	X	X	X	X	X	1	/		/		/		/
LACI	X	X	X	X	X	X	X	X	4	/	3	/	4	/	3	/
MYLE	X	X	X	X	X	X	X	X		/		/		/		/

Night 3	2015								02 June 2016 no precipitation, 7 MPH wind *Location A monitor recorded until 00:07AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		/		/		/		/
MYSO	X	X	X	X	X	X	X	X		/		/		/		/
MYLU	X	X	X	X	X	X	X	X		/		/		/		/
PESU	X	X	X	X	X	X	X	X		/		/		/		/
EPFU	X	X	X	X	X	X	X	X	1	/	1	/	1	/	2	/
LANO	X	X	X	X	X	X	X	X	1	/	2	/	4	/	5	/
LABO	X	X	X	X	X	X	X	X		/		/		/		/
LACI	X	X	X	X	X	X	X	X	7	/	2	/	2	/	2	/
MYLE	X	X	X	X	X	X	X	X		/		/		/		/

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-16: Mid-season automated acoustic monitoring results for MA-precast_concrete_2.

Night 1	29 July 2015 no precipitation, 3 MPH wind								05 July 2016 0.49in precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		1														
MYSO																
MYLU								1								
PESU												4		4		4
EPFU	14	19	14	20	19	29	20	25	5	68	7	59	11	64	19	69
LANO	5	18	14	10	32	18	33	20		2	9	17	20	22	20	20
LABO	12	7						1	23	18		1		1		1
LACI	38	24	31	22	31	22	32	23	27	98	41	99	44	99	41	100
MYLE																

Night 2	30 July 2015 0.01in precipitation, 5MPH wind								06 July 2016 no precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/								
MYSO		/		/		/		/		1						
MYLU		/		/		/		/				2		2		2
PESU		/		/		/		/							6	
EPFU	8	/	16	/	22	/	20	/	6	30	4	14	5	17	17	16
LANO	5	/	8	/	17	/	20	/		8	8	13	14	24		22
LABO	17	/		/		/	1	/	9	7						
LACI	49	/	51	/	52	/	51	/		9		8		8		8
MYLE		/		/		/		/		1						

Night 3	31 July 2015 no precipitation, 7 MPH wind								07 July 2016 0.1in precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/								
MYSO		/		/		/		/								
MYLU		/		/		/		/								1
PESU		/		/		/		/								
EPFU		/	2	/	3	/	3	/	5	59	11	42	11	45	15	51
LANO	2	/	4	/	7	/	8	/		4	11	15	17	22	17	26
LABO	3	/		/		/		/	15	3		1		1		1
LACI	10	/	12	/	13	/	13	/	10	34	15	28	15	28	15	28
MYLE		/		/		/		/								

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-16: ***continued*** Mid-season automated acoustic monitoring results for MA-precast_concrete_2.

Night 4	01 August 2015 0.25in precipitation, 5 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass** (X)		**SonoBat** *Consensus* (X)		**SonoBat** *ByVote* (X)		**SonoBat** *MeanClssn* (X)	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/	X	X	X	X	X	X	X	X
MYSO		/		/		/		/	X	X	X	X	X	X	X	X
MYLU		/		/		/		/	X	X	X	X	X	X	X	X
PESU	1	/		/		/		/	X	X	X	X	X	X	X	X
EPFU	5	/	6	/	7	/	8	/	X	X	X	X	X	X	X	X
LANO		/	3	/	8	/	6	/	X	X	X	X	X	X	X	X
LABO	5	/		/		/		/	X	X	X	X	X	X	X	X
LACI	19	/	21	/	22	/	21	/	X	X	X	X	X	X	X	X
MYLE		/		/		/		/	X	X	X	X	X	X	X	X
Night 5	02 August 2015 no precipitation, 4 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass** (X)		**SonoBat** *Consensus* (X)		**SonoBat** *ByVote* (X)		**SonoBat** *MeanClssn* (X)	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/	X	X	X	X	X	X	X	X
MYSO		/		/		/		/	X	X	X	X	X	X	X	X
MYLU		/		/		/		/	X	X	X	X	X	X	X	X
PESU		/		/		/		/	X	X	X	X	X	X	X	X
EPFU	3	/	4	/	5	/	7	/	X	X	X	X	X	X	X	X
LANO	1	/	7	/	11	/	11	/	X	X	X	X	X	X	X	X
LABO	8	/		/		/		/	X	X	X	X	X	X	X	X
LACI	15	/	20	/	20	/	20	/	X	X	X	X	X	X	X	X
MYLE		/		/		/		/	X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-17: Late season automated acoustic monitoring results for MA-precast_concrete_2.

Night 1	26 August 2015 no precipitation, 7 MPH wind								08 August 2016 no precipitation, 3 MPH wind *Location A monitor recorded until 22:37PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE																1
MYSO										1						
MYLU			1		1		1					1	2			1
PESU																
EPFU				1		1	1	1		10	2	7	2	7	2	7
LANO					1	1	1	1				4	8		2	
LABO										5						
LACI	2	1	1	2	1	2	1	2	1	17	1	24	1	24	1	24
MYLE																
Night 2	27 August 2015 no precipitation, 7 MPH wind								09 August 2016 no precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/		/	1	/		/		/	
MYSO	/		/		/		/		/	1	/		/		/	
MYLU	/		/		/		/		/		/		/		/	
PESU	/		/		/		/		/		/		/		/	
EPFU	/	3	/	3	/	3	/	5	/	30	/	26	/	32	/	31
LANO	/		/	2	/	3	/	4	/	10	/	9	/	19	/	20
LABO	/	2	/		/		/		/	6	/		/		/	
LACI	/	2	/	1	/	1	/	1	/	25	/	25	/	26	/	26
MYLE	/		/		/		/		/		/		/		/	
Night 3	28 August 2015 no precipitation, 2 MPH wind								10 August 2016 0.33in precipitation, 5 MPH wind *Location B monitor recorded until 21:14PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/		/		/		/		/	
MYSO	/		/		/		/		/		/		/		/	
MYLU	/		/		/		/		/		/	1	/		/	
PESU	/		/		/		/		/		/		/		/	
EPFU	/		/		/		/		/	133	/	63	/	17	/	16
LANO	/	1	/	2	/	3	/	3	/	16	/	41	/	17	/	16
LABO	/		/		/		/		/	29	/		/		/	1
LACI	/	4	/	5	/	5	/	5	/	12	/	1	/		/	
MYLE	/		/		/		/		/		/		/		/	

Notes: “X”=No data collected, “/”= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-17: *continued* Late season automated acoustic monitoring results for MA-precast_concrete_2.

Night 4	29 August 2015 no precipitation, 2 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/		X	X	X	X	X	X	X	X
MYSO	/		/		/		/		X	X	X	X	X	X	X	X
MYLU	/		/		/		/		X	X	X	X	X	X	X	X
PESU	/		/		/		/		X	X	X	X	X	X	X	X
EPFU	/		/		/		/		X	X	X	X	X	X	X	X
LANO	/	1	/	7	/	13	/	13	X	X	X	X	X	X	X	X
LABO	/		/		/		/		X	X	X	X	X	X	X	X
LACI	/	13	/	15	/	15	/	15	X	X	X	X	X	X	X	X
MYLE	/		/		/		/		X	X	X	X	X	X	X	X

Night 5	30 August 2015 no precipitation, 2 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/		X	X	X	X	X	X	X	X
MYSO	/		/		/		/		X	X	X	X	X	X	X	X
MYLU	/		/		/		/		X	X	X	X	X	X	X	X
PESU	/		/		/		/		X	X	X	X	X	X	X	X
EPFU	/	2	/	1	/	1	/	3	X	X	X	X	X	X	X	X
LANO	/	7	/	24	/	32	/	32	X	X	X	X	X	X	X	X
LABO	/		/		/		/		X	X	X	X	X	X	X	X
LACI	/	13	/	10	/	10	/	10	X	X	X	X	X	X	X	X
MYLE	/		/		/		/		X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.3.4 MA-steel

One bridge monitored summers 2015 and 2016 in Massachusetts is of steel girder construction, shown in Figure 5-47, given the name “MA-steel.” This bridge has various levels of deterioration and corrosion noted throughout the bridge and has some staining of unknown causation, shown in Figure 5-48. Though it is likely to be of structural causation, this staining could also possibly be mixed with urine or guano staining. Figure 5-50 shows cave-like environments near the abutments, and Figure 5-49 shows potential roost crevices observed in the structure due to deterioration. Birds’ nests, seen in Figure 5-51, and Mud-Dauber’s nests, seen in Figure 5-52, were observed throughout the bridge, which may be possible signs of the bridge having appropriate habitat for bats. All crevices along the segment of the bridge from the abutments to the piers on either side was fully inspected using the boroscope, as can be seen in Figure 5-53, showing debris and/or no unusual staining was observed, indicating no bats roosting when the daytime inspection occurred. This bridge is located in a quiet area, with surrounding vegetation seemingly conducive to bat habitat and foraging. Both the federal form and the developed supplemental form were completed and are included in Appendix C-6.

Microphone placement for acoustic monitoring at MA-steel is shown in Figure 5-54. Location A is upstream of the bridge with the microphone attached to a branch overhanging the waterway. Location B is downstream of the bridge with the microphone attached to the trunk of a tree on the streambank. Table 5-18, Table 5-19, and Table 5-20 show acoustic results from monitoring MA-steel throughout early, mid- and late seasons.

Emergence studies were completed at MA-steel in the mid- and late monitoring seasons. No bats were observed exiting the bridge, and very few bats were observed in the local area with weather conditions being clear or partly cloudy, calm with no wind, and warm, which are ideal conditions for bat activity. While no bats were observed during the late monitoring season emergence study, automated analysis of emergence period acoustic data collected classified one bat species present in the local area (SonoBat: LACI).

Figure 5-47: Steel bridge selected in MA (MA-steel)

Figure 5-48: Staining of unconfirmed causation (likely structural) at MA-steel

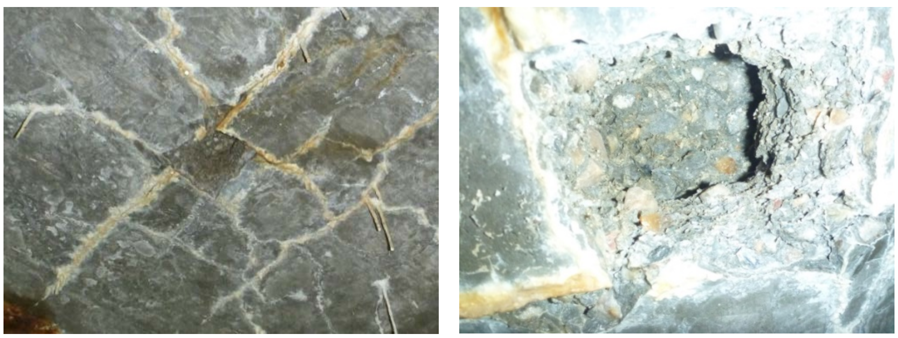


Figure 5-49: Potential roost crevices observed at MA-steel

Figure 5-50: Cave-like environments near the abutments at MA-steel

Figure 5-51: Bird's nests observed at MA-steel

Figure 5-52: Mud-Dauber's nests observed at MA-steel

Figure 5-53: Boroscope views into cracks showing debris in crevices at MA-steel

Location A   Location B

Figure 5-54: MA-steel microphone placement

Table 5-18: Early season automated acoustic monitoring results for MA-steel.

Night 1	2015								31 May 2016 no precipitation, 8 MPH wind *Location A monitor recorded until 03:58AM							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	1							1
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X					1			
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X								
LANO	X	X	X	X	X	X	X	X							1	
LABO	X	X	X	X	X	X	X	X	1							
LACI	X	X	X	X	X	X	X	X	1	1	2	4	2	4	2	4
MYLE	X	X	X	X	X	X	X	X	2	3						

Night 2	2015								01 June 2016 no precipitation, 5 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	/	13	/	1	/	3	/	6
MYSO	X	X	X	X	X	X	X	X	/		/		/		/	
MYLU	X	X	X	X	X	X	X	X	/		/	1	/	3	/	3
PESU	X	X	X	X	X	X	X	X	/		/		/		/	
EPFU	X	X	X	X	X	X	X	X	/	2	/		/		/	
LANO	X	X	X	X	X	X	X	X	/		/	2	/	3	/	3
LABO	X	X	X	X	X	X	X	X	/	17	/		/		/	
LACI	X	X	X	X	X	X	X	X	/	4	/	39	/	39	/	39
MYLE	X	X	X	X	X	X	X	X	/	4	/		/		/	1

Night 3	2015								02 June 2016 no precipitation, 7 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	/	1	/		/	1	/	1
MYSO	X	X	X	X	X	X	X	X	/		/		/		/	
MYLU	X	X	X	X	X	X	X	X	/		/		/		/	
PESU	X	X	X	X	X	X	X	X	/		/		/		/	
EPFU	X	X	X	X	X	X	X	X	/	1	/		/		/	2
LANO	X	X	X	X	X	X	X	X	/		/		/	1	/	1
LABO	X	X	X	X	X	X	X	X	/	5	/		/		/	
LACI	X	X	X	X	X	X	X	X	/	11	/	14	/	14	/	14
MYLE	X	X	X	X	X	X	X	X	/		/	1	/	1	/	2

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-19: Mid-season automated acoustic monitoring results for MA-steel.

Night 1	29 July 2015 no precipitation, 3 MPH wind								05 July 2016 0.49in precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/	2	/		/	1	/	2		2	4		4		4	
MYSO	/	1	/		/		/		1							
MYLU	/		/		/		/	1								1
PESU	/		/		/		/									
EPFU	/	27	/	7	/	9	/	18		9	5	10	6	12	8	17
LANO	/	3	/	3	/	10	/	12		3	3	6	3	10	3	13
LABO	/	12	/		/		/		5	8						
LACI	/	10	/	23	/	23	/	23	4	14	1	10	1	10	1	10
MYLE	/	9	/	6	/	6	/	7				2		2	1	2

Night 2	30 July 2015 0.01in precipitation, 5 MPH wind								06 July 2016 no precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/		2	4					3	1
MYSO	/		/		/		/									
MYLU	/		/		/		/							1		
PESU	/		/		/		/									
EPFU	/	27	/	8	/	12	/	20	4	8	2	8	3	10	4	12
LANO	/	2	/	6	/	16	/	17		8	2	10	7	24	8	22
LABO	/	14	/		/		/		6	11						
LACI	/	4	/	7	/	7	/	7	11	30	3	9	3	9	3	9
MYLE	/		/		/		/	1	1	1		5		5	1	7

Night 3	31 July 2015 no precipitation, 7 MPH wind *Location B monitor recorded until 23:19PM								07 July 2016 0.1in precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/		3	1	2	2	2	2	4	4
MYSO	/		/		/		/									
MYLU	/		/		/		/									
PESU	/		/		/		/									
EPFU	/	2	/	1	/	2	/	1	4	11	4	19	7	23	13	37
LANO	/		/		/	3	/	3	1	10	4	9	12	39	13	42
LABO	/	3	/		/		/		4	16				1		
LACI	/	3	/	5	/	5	/	5	21	74	10	24	10	26	11	28
MYLE	/		/	1	/	1	/	2				3		4		3

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-20: Late season automated acoustic monitoring results for MA-steel.

Night 1	26 August 2015 no precipitation, 7 MPH wind								08 August 2016 no precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/								
MYSO	1	/		/		/		/								
MYLU		/	1	/	1	/	1	/								
PESU		/		/		/		/								
EPFU		/		/		/	1	/			1	1	1	2	3	3
LANO		/	2	/	3	/	3	/								
LABO	2	/		/		/		/	1	4						
LACI	1	/	1	/	1	/	1	/		2	4	10	4	10	4	10
MYLE		/		/		/		/	1							

Night 2	27 August 2015 no precipitation, 7 MPH wind								09 August 2016 no precipitation, 2 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/								
MYSO		/		/		/		/								
MYLU		/		/		/		/								
PESU		/		/		/		/								
EPFU	1	/		/		/	1	/		2	1	2	2	3	1	3
LANO	1	/	1	/	2	/	2	/		1		1		1		2
LABO		/		/		/		/	2	4						
LACI		/		/		/		/	3	3	9	11	9	11	9	11
MYLE		/		/		/		/								

Night 3	28 August 2015 no precipitation, 2 MPH wind *Location B monitor recorded until 23:05PM								10 August 2016 0.33in precipitation, 5 MPH wind *Location A monitor recorded until 01:23AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/								
MYSO		/		/		/		/		1						
MYLU		/		/		/		/								1
PESU		/		/		/		/								
EPFU		/		/		/		/	3	12	12	12	12	13	21	22
LANO		/		/	1	/	1	/		1		3	2	11	2	11
LABO		/		/		/		/	4	5						1
LACI	2	/	4	/	4	/	4	/	5	17	3	5	3	5	3	5
MYLE		/		/		/		/		1						

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.4 New Hampshire Bridges

Three bridges were fully monitored in New Hampshire in summer 2015, and two bridges were fully monitored in summer 2016. The bridges were initially chosen based on bridges with promising characteristics based on rapid visual screenings. One bridge was removed from the summer 2016 monitoring schedule due to lack of activity and less potential for bat roosting.

5.4.1 NH-concrete_arch

One of the bridges monitored summers 2015 and 2016 in New Hampshire is of concrete construction with a stone façade, shown in Figure 5-55, given the identification name "NH-concrete_arch." While this bridge is not very accessible for in depth inspection, as seen in Figure 5-56, and the inside concrete arch appears too smooth to support roosting underneath the bridge, as seen in Figure 5-57, the stone façade of the bridge provides ample cracks and crevices and is covered in staining, as seen in Figure 5-58. The causation of these stains is unspecified, and could be due to bats roosting in between the stones on the façade. The monocular was used to investigate inaccessible bridge locations as much as possible in attempts to determine the sources of staining, though no conclusive sources were identified. The retaining walls approaching the bridge were more accessible for inspection. The boroscope was used to investigate crevices, shown in Figure 5-59, showing clean spaces, ants, and a possible mouse nest, but no indication of bat use. This bridge was encountered on route and in close proximity to another bridge with a possible bat sighting, so it is assumed that bats are in the local area and could be utilizing this bridge as a roost. Conversations with local residents also indicated that bats roost in buildings in the vicinity of the bridge, and are regularly observed foraging near the bridge site. This bridge is located close to a local town center (population under 5,000 (City-Data.com 2010)), but has vegetation cover and green space in the local area. Both the federal form and the developed supplemental form were completed and are included in Appendix C-7.

Several fecal deposits were observed in between the crevices in the façade, shown in Figure 5-60. While it was assumed that these were mouse droppings, some of these samples were collected and sent in for species identification. Neither the pooled sampling nor the individual pellet testing laboratory could determine a species identification.

Microphone placement for acoustic monitoring at NH-concrete_arch is shown in Figure 5-61. Location A is upstream and far from the bridge with the microphone attached to a stick the research team drove into the streambank near a tree. Location B is downstream of the bridge on a tree branch on the streambank. Table 5-21, Table 5-22, and Table 5-23 show acoustic results from monitoring NH-concrete_arch throughout early, mid- and late seasons.

An emergence study was completed at NH-concrete_arch in the mid- monitoring season. While only two bats were seen at a time visually, the acoustic monitors consistently recorded bat calls after sunset and automated analysis of emergence period acoustic data collected classified several bat species present in the local area (SonoBat: EPFU, LANO, LACI; EchoClass: EPFU, LANO, LACI, LABO, MYLU, PESU). The research team was not able to confirm if bats emerged from or roosted in the bridge as the bridge spans a large distance and access is limited at one abutment.

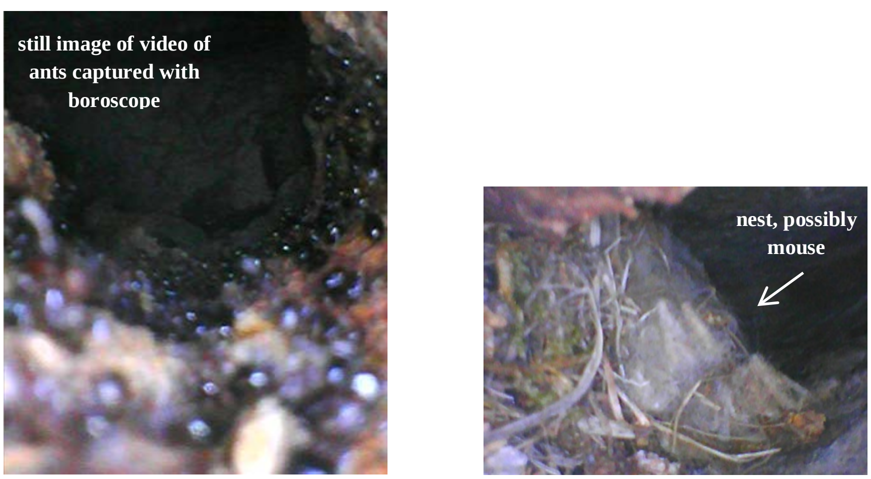
Figure 5-55: Concrete bridge selected in NH (NH-concrete_arch)

Figure 5-56: Inaccessibility of NH-concrete_arch

Figure 5-57: Smooth inside arch in NH-concrete_arch

Figure 5-58: Roosting crevices and staining on the stone façade in NH-concrete_arch

(a)



(b)

Figure 5-59: Boroscope views into cracks in the retaining wall approach to NH-concrete showing clean gaps (a) and other organisms (b) at NH-concrete_arch

Figure 5-60: Fecal samples collected from the crevices in the stone façade at a bridge in NH-concrete_arch (assumed mouse, though unconfirmed species)

Location A

Location B

Figure 5-61: NH-concrete_arch microphone placement

Table 5-21: Early season automated acoustic monitoring results for NH-concrete_arch.

Night 1	2015								07 May 2016 0.03in precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	1	1						
MYSO	X	X	X	X	X	X	X	X						1		2
MYLU	X	X	X	X	X	X	X	X		4		1		3	1	1
PESU	X	X	X	X	X	X	X	X	1			1		1	2	1
EPFU	X	X	X	X	X	X	X	X	2			3	1	4	5	3
LANO	X	X	X	X	X	X	X	X	16	2	10	2	23	4	23	4
LABO	X	X	X	X	X	X	X	X	1	8						
LACI	X	X	X	X	X	X	X	X	63	2	51	3	52	3	51	3
MYLE	X	X	X	X	X	X	X	X				1		1		1

Night 2	2015								08 May 2016 no precipitation, 11 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	1							
MYSO	X	X	X	X	X	X	X	X		9				1		
MYLU	X	X	X	X	X	X	X	X		2			1	1		1
PESU	X	X	X	X	X	X	X	X		1		1		1		1
EPFU	X	X	X	X	X	X	X	X	12		26	1	29	2	34	1
LANO	X	X	X	X	X	X	X	X	15		3		7		8	
LABO	X	X	X	X	X	X	X	X	6	8					1	
LACI	X	X	X	X	X	X	X	X	29	2	7	1	8	1	7	1
MYLE	X	X	X	X	X	X	X	X								

Night 3	2015								09 May 2016 no precipitation, 14 MPH wind *Location A monitor recorded until 02:31AM *Location B monitor recorded until 03:32AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X	1	4						1
MYLU	X	X	X	X	X	X	X	X		2		1		4		1
PESU	X	X	X	X	X	X	X	X		2		2		2		2
EPFU	X	X	X	X	X	X	X	X	5	1	8	3	9	3	17	3
LANO	X	X	X	X	X	X	X	X	10		4	1	10	1	11	1
LABO	X	X	X	X	X	X	X	X	4	4						1
LACI	X	X	X	X	X	X	X	X	6	2	1	1	1	1	1	1
MYLE	X	X	X	X	X	X	X	X								

Notes: “X”=No data collected, “/”= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-22: Mid-season automated acoustic monitoring results for NH-concrete_arch.

Night 1	31 July 2015 no precipitation, 6 MPH wind								12 July 2016 no precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE										1						
MYSO	2	1								4						
MYLU	2		1		2		1			23		13		24		20
PESU																
EPFU	3	8	2	63	3	74	7	112		28		78		96		116
LANO	1	95	3	26	7	72	7	76		26		10		35		37
LABO	2	4								11						1
LACI	13	273	11	169	11	173	11	180		93		58		64		62
MYLE																

Night 2	01 August 2015 no precipitation, 5 MPH wind								13 July 2016 no precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE																
MYSO	1									1						
MYLU	3		2		3		2			35		31		40		35
PESU												1		1		1
EPFU	7	3	12	18	14	19	15	31		4		13		15		20
LANO	2	24	4	7	9	18	8	17		8		2		8		9
LABO	7		2		2		3			10						
LACI	13	228	24	265	25	265	25	270		21		6		7		8
MYLE	1															

Night 3	02 August 2015 no precipitation, 5 MPH wind								14 July 2016 no precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE										1						
MYSO	2	1								4						
MYLU	7	1	8		9	1	10			23		17		24		19
PESU										1						
EPFU	32	22	44	100	53	120	59	160		21		66		81		91
LANO	14	96	16	26	36	68	40	68		31		12		44		43
LABO	23	10								18						2
LACI	19	280	6	190	7	193	6	197		89		28		32		28
MYLE																

Notes: “X”=No data collected, “/”= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-22: ***continued*** Mid-season automated acoustic monitoring results for NH-concrete_arch.

Night 4	03 August 2015 0.14in precipitation, 8 MPH wind *Location B monitor recorded until 22:10PM								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO	2								X	X	X	X	X	X	X	X
MYLU	12		12		20		15		X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU	39	30	51	123	63	139	77	157	X	X	X	X	X	X	X	X
LANO	24	143	19	38	65	92	64	96	X	X	X	X	X	X	X	X
LABO	42	5					1		X	X	X	X	X	X	X	X
LACI	40	174	19	54	19	54	20	60	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-23: Late season automated acoustic monitoring results for NH-concrete_arch.

Night 1	18 August 2015, 2.48in precipitation, 4 MPH wind								16 August 2016, 0.18in precipitation, 2 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/									
MYSO	/		/		/		/			7						
MYLU	/	3	/	1	/	3	/	2	1	10	2	10	3	26	2	19
PESU	/		/		/		/		16	2	16	4	16	4	20	7
EPFU	/	12	/	10	/	14	/	28	21	6	38	14	46	14	61	31
LANO	/	5	/	12	/	36	/	36	180	18	63	7	139	14	142	16
LABO	/	31	/		/		/	1	23	58		1		2	1	6
LACI	/	37	/	38	/	39	/	38	160	24	190	3	190	3	194	3
MYLE	/		/		/		/									

Night 2	19 August 2015, no precipitation, 55 MPH wind, *Location B monitor recorded until 22:36PM								17 August 2016, no precipitation, 10 MPH wind, *Location B monitor recorded until 01:01AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/									
MYSO	/	1	/		/		/			2						
MYLU	/		/	1	/	1	/	1	1	3		3		4		9
PESU	/		/		/		/		95	2	51	2	51	2	73	2
EPFU	/	8	/	18	/	18	/	40	75	14	323	20	351	24	440	26
LANO	/	1	/	2	/	8	/	9	227	7	50	6	128	17	127	17
LABO	/	3	/		/		/		77	27					1	
LACI	/	10	/	1	/	1	/	1	235	13	98	8	98	9	103	8
MYLE	/		/		/		/									

Night 3	2015 (X)								18 August 2016, no precipitation, 4 MPH wind, *Location A monitor recorded until 23:56PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		/		/		/		/
MYSO	X	X	X	X	X	X	X	X		/		/		/		/
MYLU	X	X	X	X	X	X	X	X		/		/		/		/
PESU	X	X	X	X	X	X	X	X	5	/	1	/	1	/	4	/
EPFU	X	X	X	X	X	X	X	X	15	/	71	/	87	/	109	/
LANO	X	X	X	X	X	X	X	X	126	/	32	/	68	/	68	/
LABO	X	X	X	X	X	X	X	X	8	/		/		/		/
LACI	X	X	X	X	X	X	X	X	111	/	64	/	64	/	77	/
MYLE	X	X	X	X	X	X	X	X		/		/		/		/

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.4.2 NH-steel

One bridge monitored summer 2015 in New Hampshire is of steel construction, shown in Figure 5-62, given the identification name "NH-steel." This bridge was initially suggested by the NH DOT, and has staining observed on the abutments along with cracks and crevices seen in Figure 5-63. This bridge is situated in a rural location with ample vegetation in the surrounding habitat making the location seem plausible to support bat habitat and foraging.

This bridge was only monitored in summer 2015 and was removed for summer 2016 monitoring. Table 5-24 and Table 5-25 show acoustic results from monitoring NH-steel throughout mid- and late seasons. The staining observed in the bridge was likely efflorescence or from other sources of structural causation, and was determined to be unlikely from bats. Having integral abutments and no expansion joints minimizes the available structural locations that can be used as potential bat roost sites. The abutments on this bridge are also low to the ground, allowing for easy access to predators. As such, this bridge was not included in summer 2016 field work.

Figure 5-62: Steel bridge selected in NH (NH-steel)

Figure 5-63: Staining observed at the abutments in NH-steel (likely structural)

Table 5-24: Mid-season automated acoustic monitoring results for NH-steel.

Night 1	31 July 2015 no precipitation, 2 MPH wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU	36	58	32	68	42	76	38	84	X	X	X	X	X	X	X	X
LANO	5	46	11	21	14	32	15	37	X	X	X	X	X	X	X	X
LABO	10	9			1		1		X	X	X	X	X	X	X	X
LACI	19	126	19	117	19	118	19	120	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Night 2	01 August 2015 no precipitation, 2 MPH wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU	60	67	107	77	120	92	123	88	X	X	X	X	X	X	X	X
LANO	7	39	2	12	4	23	7	22	X	X	X	X	X	X	X	X
LABO	15	8						1	X	X	X	X	X	X	X	X
LACI	15	58	5	55	5	55	5	56	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Night 3	02 August 2015 no precipitation, 3 MPH wind *Location A monitor recorded until 23:47PM								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU	1								X	X	X	X	X	X	X	X
EPFU	120	83	205	89	219	106	232	98	X	X	X	X	X	X	X	X
LANO	3	32	9	25	17	37	24	48	X	X	X	X	X	X	X	X
LABO	30	13							X	X	X	X	X	X	X	X
LACI	7	96	6	79	6	81	6	85	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-24: *continued* Mid-season automated acoustic monitoring results for NH-steel.

Night 4	03 August 2015 0.38in precipitation, 5 MPH wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU		1				1			X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU		146		196		213		223	X	X	X	X	X	X	X	X
LANO		65		39		64		62	X	X	X	X	X	X	X	X
LABO		30							X	X	X	X	X	X	X	X
LACI		74		33		33		33	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-25: Late season automated acoustic monitoring results for NH-steel.

Night 1	18 August 2015 no precipitation, 1 MPH wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU		1		1		1		1	X	X	X	X	X	X	X	X
PESU	1		1		2		1		X	X	X	X	X	X	X	X
EPFU	83	23	141	32	165	36	171	42	X	X	X	X	X	X	X	X
LANO	156	14	87	5	113	18	114	19	X	X	X	X	X	X	X	X
LABO	10	28	2	4	2	4	2	10	X	X	X	X	X	X	X	X
LACI	59	17	32	6	32	6	32	6	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Night 2	19 August 2015 no precipitation, 1 MPH wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU	3		1		1		1		X	X	X	X	X	X	X	X
EPFU	85	15	141	28	157	31	160	32	X	X	X	X	X	X	X	X
LANO	72	9	44	7	67	21	62	22	X	X	X	X	X	X	X	X
LABO	38	9					2		X	X	X	X	X	X	X	X
LACI	63	17	31	1	32	1	31	2	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-25: *continued* Late season automated acoustic monitoring results for NH-steel.

Night 3	20 August 2015 0.02in precipitation, 4 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU		1							X	X	X	X	X	X	X	X
PESU	1		2		2		2		X	X	X	X	X	X	X	X
EPFU	27	16	37	18	45	23	46	20	X	X	X	X	X	X	X	X
LANO	43	2	13	3	29	6	34	6	X	X	X	X	X	X	X	X
LABO	9	14	1	1	2	1	1	1	X	X	X	X	X	X	X	X
LACI	36	9	29	4	30	4	30	4	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X
Night 4	21 August 2015 0.26in precipitation, 3 MPH wind								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU				1		1		1	X	X	X	X	X	X	X	X
PESU	1	1						1	X	X	X	X	X	X	X	X
EPFU	53	16	81	24	85	27	84	25	X	X	X	X	X	X	X	X
LANO	16	3	8	1	13	3	15	2	X	X	X	X	X	X	X	X
LABO	9	6	1	1	1	1	1	1	X	X	X	X	X	X	X	X
LACI	14	3	6	3	7	3	6	3	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X
Night 5	22 August 2015 no precipitation, 1 MPH wind *Location A monitor recorded until 01:19AM								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU	35		57		60		62		X	X	X	X	X	X	X	X
LANO	38		15		27		29		X	X	X	X	X	X	X	X
LABO	4								X	X	X	X	X	X	X	X
LACI	11		2		2		3		X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.4.3 NH-steel_truss

One bridge monitored summers 2015 and 2016 in New Hampshire is a steel truss bridge, shown in Figure 5-64, given the identification name "NH-steel_truss." This bridge was provided by the NH DOT as a possible roosting site; an animal thought to be a bat (not confirmed) was reported to have flown out and startled a bridge inspector in a previous inspection. This bridge is made mostly of steel, however there are potential roost sites, shown in Figure 5-65, as the metal surfaces under the bridge are not smooth and could potentially be used as open roosts. While the height of the bridge prevented detailed inspection of the crevices between members along the span of the deck, the abutments and non-grouted stone wingwalls (shown in Figure 5-66) as well as concrete structures in the surrounding area (shown in Figure 5-67) were thoroughly inspected as much as possible. There is a collapsed concrete underground structure, shown in Figure 5-68, that has been fenced off to prevent anyone from falling into the hole and appears to provide cave-like environments for possible bat roosting. Bird's nests are present, shown in Figure 5-69, which is a suggestion that the bridge habitat is conducive to supporting bat roosting. The forested rural surrounding habitat for this bridge appears to be conducive to bat habitat and foraging areas. Both the federal form and the developed supplemental form were completed and are included in Appendix C-8.

Fecal deposits were observed at NH-steel_truss that were assumed to be mouse deposits. Samples were collected once during mid- and twice during late season monitoring in summer 2016, shown in Figure 5-70, and were sent in for species identification. The pooled sampling laboratory identified the sample collected in mid-season monitoring to be *Peromyscus leucopus* (mouse), and no other samples were identified by either laboratory.

Microphone placement for acoustic monitoring at NH-steel_truss is shown in Figure 5-71. Location A and B are downstream and far from the bridge. The microphone of location A is attached to a tree trunk in an open rocky area on the streambank. The microphone of location B is attached to a tree trunk on the opposite streambank. Table 5-26, Table 5-27, and Table 5-28 show acoustic results from monitoring NH-steel_truss throughout early, mid- and late seasons.

Emergence studies were completed at NH-steel_truss in the early, mid-, and late monitoring seasons. No bats were seen exiting the bridge, and few bats were seen flying in the local area. The Research team observed two bats during the mid- monitoring season emergence study, but automated analysis of emergence period acoustic data collected classified several bat species present in the local area (SonoBat: MYLU, EPFU, LANO, LACI; EchoClass: MYLU, EPFU, LANO, LACI, LABO). During the late monitoring season emergence study, only one bat species (SonoBat and EchoClass: EPFU) was classified to be present in the local area, through the research team noted that there was quite a bit of white noise from the river rapids that seemed to be potentially affecting the detection of acoustic calls by the monitor. This finding was not confirmed through additional analyses of microphone placement.

Figure 5-64: Steel truss bridge selected in NH (NH-steel_truss)

Figure 5-65: Potential open roost locations in NH-steel_truss on the uneven surfaces

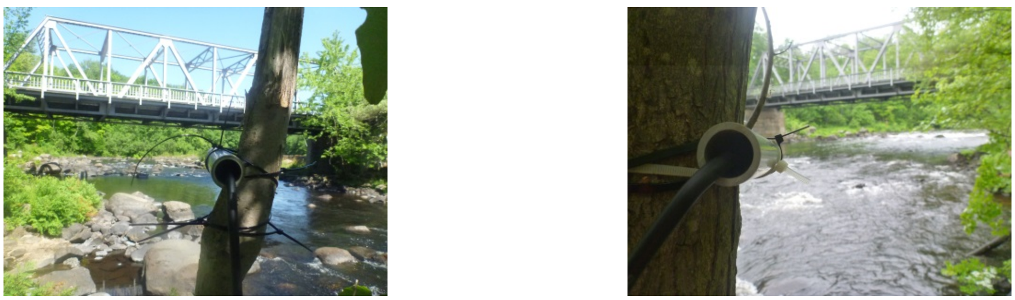
Figure 5-66: Non-grouted stone wingwalls at NH-steel_truss

Figure 5-67: Concrete structures near NH-steel_truss

Figure 5-68: Abandoned concrete underground structure near the abutment in NH-steel_truss providing a cave-like environment and potential roost locations

Figure 5-69: Bird's nest at NH-steel_truss

Figure 5-70: Mouse fecal samples collected from NH-steel_truss (confirmed mouse)



Location A Location B

Figure 5-71: NH-steel_truss microphone placement

Table 5-26: Early season automated acoustic monitoring results for NH-steel_truss.

Night 1	2015								07 June 2016 0.03in precipitation, 5 MPH wind *Location A monitor recorded until 23:51PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		/		/		/		/
MYSO	X	X	X	X	X	X	X	X		/		/		/		/
MYLU	X	X	X	X	X	X	X	X	1	/	4	/	4	/	4	/
PESU	X	X	X	X	X	X	X	X		/		/		/		/
EPFU	X	X	X	X	X	X	X	X	2	/	4	/	4	/	5	/
LANO	X	X	X	X	X	X	X	X		/		/		/		/
LABO	X	X	X	X	X	X	X	X	3	/		/		/		/
LACI	X	X	X	X	X	X	X	X		/	1	/	1	/	1	/
MYLE	X	X	X	X	X	X	X	X		/		/		/		/

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-27: Mid-season automated acoustic monitoring results for NH-steel_truss.

Night 1	31 July 2015 no precipitation, 6 MPH wind *Location A monitor recorded until 03:45AM								12 July 2016 no precipitation, 3 MPH wind *Location A monitor recorded until 23:52PM *Location B monitor recorded until 23:49PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	3	1					2			2						
MYSO	51	52							11	6				1		
MYLU	3	2	5	7	9	10	14	9	11		12	4	19	7	22	4
PESU	1		1		1		1		1		1		1		1	
EPFU	31	33	17	31	20	33	22	38	32	3	41	7	42	7	59	9
LANO	12	1	10	10	29	30	31	31	2			1	2	1	3	1
LABO	39	69	1	1	1	1	1	6	18	6					1	
LACI	8	1	8	2	8	2	8	2	5				1			
MYLE																
Night 2	01 August 2015 no precipitation, 5 MPH wind *Location B monitor recorded until 03:23AM								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass** (X)		**SonoBat** *Consensus* (X)		**SonoBat** *ByVote* (X)		**SonoBat** *MeanClssn* (X)	
Location	***A*** (/)	***B***	***A*** (/)	***B***	***A*** (/)	***B***	***A*** (/)	***B***	***A*** (X)	***B*** (X)	***A*** (X)	***B*** (X)	***A*** (X)	***B*** (X)	***A*** (X)	***B*** (X)
MYSE	/	2	/		/		/		X	X	X	X	X	X	X	X
MYSO	/	13	/		/		/		X	X	X	X	X	X	X	X
MYLU	/	3	/	3	/	5	/	6	X	X	X	X	X	X	X	X
PESU	/		/		/		/		X	X	X	X	X	X	X	X
EPFU	/	22	/	13	/	16	/	17	X	X	X	X	X	X	X	X
LANO	/	1	/	10	/	21	/	22	X	X	X	X	X	X	X	X
LABO	/	28	/		/		/		X	X	X	X	X	X	X	X
LACI	/	3	/	5	/	5	/	5	X	X	X	X	X	X	X	X
MYLE	/		/		/		/		X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-28: Late season automated acoustic monitoring results for NH-steel_truss.

Night 1	18 August 2015 2.48in precipitation, 4 MPH wind								16 August 2016 0.18in precipitation, 2 MPH wind *Location B monitor recorded until 23:00PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									/		/		/		/	
MYSO	5	2						2	/	1	/		/		/	
MYLU		1	2	1	3	3	3	1	/	1	/		/		/	1
PESU							1	3	/		/		/		/	
EPFU	11	8	4	1	4	2	8	11	/		/		/		/	
LANO			4	7	10	9	9		/		/		/		/	
LABO	11	9					3	3	/	3	/		/		/	
LACI	4		1	2	1	2	1		/		/		/		/	
MYLE					1				/		/		/		/	

Night 2	19 August 2015 no precipitation, 55 MPH wind *Location A monitor recorded until 02:31AM *Location B monitor recorded until 23:47PM								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO	2								X	X	X	X	X	X	X	X
MYLU					1				X	X	X	X	X	X	X	X
PESU	1		1		1		1		X	X	X	X	X	X	X	X
EPFU	2	3	1	2	1	2	4	3	X	X	X	X	X	X	X	X
LANO				1	3	2	3	2	X	X	X	X	X	X	X	X
LABO	4	1					1		X	X	X	X	X	X	X	X
LACI	1		1	1	1	1	1	1	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.5 Rhode Island Bridges

Four bridges were fully monitored in Rhode Island in the summers of 2015 and 2016. The bridges were chosen based on bridges with promising characteristics based on rapid visual screenings. One bridge monitored in 2015 was replaced for the summer of 2016. The removed bridge was had lower potential for bat roosting, and the added bridge had signs of bat activity.

5.5.1 RI-concrete

One bridge monitored summer 2016 in Rhode Island is of precast concrete I-girder construction, shown in Figure 5-72, given the identification name "RI-concrete." This bridge was suggested by the RI DOT Office of Environmental Programs after finding signs of bat use. Staining on the girders was observed, shown in Figure 5-73, as well as guano deposits, show in Figure 5-74. The bridge has drainage features, seen in Figure 5-75, one of which had a bird's nest inside. Birds were present and Mud-Dauber's nests were observed, shown in Figure 5-76, were observed, supporting the notion that birds and bats choose similar habitats. The bridge is situated in a rural, forested area, and the surrounding habitat seems conducive to support bat habitat and foraging areas. Both the federal form and the developed supplemental form were completed and are included in Appendix C-9.

Figure 5-77 shows the construction style of RI-concrete eliminating construction crevices, and crevices due to deterioration were not observed, however bats did use this bridge, as can be seen in Figure 5-78 where bats were observed using the sides of girders as open night-roosts. Bats were only seen during the night, when the research team returned between 10:00PM and midnight, and were not observed roosting on bridge girders earlier that evening.

Guano samples were collected during mid- and late season monitoring and sent in for species identification. Late-season guano samples were identified as EPFU by the pooled sampling laboratory, and no other samples were identified by either laboratory. EPFU was identified through acoustic monitoring during all three monitoring seasons, and tended to have one of the highest numbers of identified calls per night monitored.

Microphone placement for acoustic monitoring at RI-concrete is shown in Figure 5-79. Both location A and B are downstream of the bridge. The microphone at location A was attached to a tree trunk by the streambank. The microphone at location B was attached to a tree trunk near the bridge abutment on the opposite streambank. This microphone is facing a corner of the bridge that had staining and guano. This microphone placement was used to evaluate calls from this type of placement, though the likelihood of reflection off of the concrete surfaces and differences in potential bat emergence calls was expected to potentially interfere with acoustic data. Nevertheless, observation of a high number of non-identifiable call files may indicate bat activity. Acoustical analyses did not indicate differences between localized and generalized microphone placements at RI-concrete. Table 5-29, Table 5-30, and Table 5-31 show acoustic results from monitoring RI-concrete throughout early, mid- and late seasons.

Emergence studies were completed at RI-concrete in the early and late monitoring seasons. During the early monitoring season emergence study, no bats were definitively seen. The research team observed something dropping straight down from a swallow's nest at dusk, but was unable to confirm if it was a bat or a swallow. During the late monitoring season emergence study, bats were consistently observed in the local area and could be seen roosting and emerging from the bridge throughout the night, shown in Figure 5-78. Automated analysis of emergence period acoustic data collected classified several species being present in the local area (SonoBat: EPFU, LANO, LABO, LACI, MYLE; EchoClass: EPFU, LANO, LABO, LACI, MYLU, MYSE).

Figure 5-72: Concrete bridge selected in RI (RI-concrete)

Figure 5-73: Staining evidence of roosting on bridge girders at RI-concrete

Figure 5-74: Guano evidence of roosting at RI-concrete (confirmed EPFU)

Figure 5-75: Drainage features observed in RI-concrete

Figure 5-76: Mud-Dauber’s nests observed on girders of RI-concrete

Figure 5-77: Deck construction of RI-concrete eliminating gaps and construction crevices

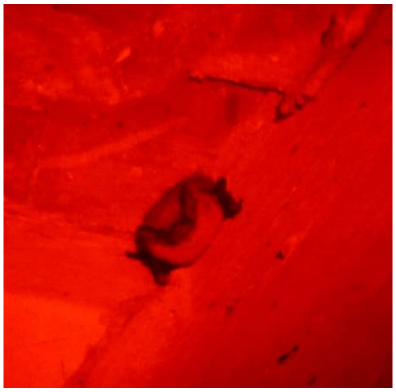


Figure 5-78: Bat observed night-roosting on open face of girder in RI-concrete

Location A

Location B

Figure 5-79: RI-concrete microphone placement

Table 5-29: Early season automated acoustic monitoring results for RI-concrete.

Night 1	2015								14 June 2016, no precipitation, 7 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X					1			
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	31	5	53	31	53	31	63	51
LANO	X	X	X	X	X	X	X	X	6		5	3	9	11	9	13
LABO	X	X	X	X	X	X	X	X	10	34						
LACI	X	X	X	X	X	X	X	X	7	4	3	6	3	6	3	8
MYLE	X	X	X	X	X	X	X	X	1							

Night 2	2015								15 June 2016, no precipitation, 4 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	34	5	50	21	51	25	51	33
LANO	X	X	X	X	X	X	X	X	8		7		15		16	4
LABO	X	X	X	X	X	X	X	X	9	28						
LACI	X	X	X	X	X	X	X	X	24	8	7	5	7	5	7	7
MYLE	X	X	X	X	X	X	X	X								

Night 3	2015								16 June 2016, no precipitation, 3 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X		1						
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	46	8	81	40	84	44	94	80
LANO	X	X	X	X	X	X	X	X	8		5	5	17	14	17	18
LABO	X	X	X	X	X	X	X	X	22	63						1
LACI	X	X	X	X	X	X	X	X	20	12	12	18	12	21	13	23
MYLE	X	X	X	X	X	X	X	X								

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-30: Mid-season automated acoustic monitoring results for RI-concrete.

Night 1	2015								20 July 2016 no precipitation, 3 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		/		/		/		/
MYSO	X	X	X	X	X	X	X	X		/		/		/		/
MYLU	X	X	X	X	X	X	X	X	1	/		/		/		/
PESU	X	X	X	X	X	X	X	X	1	/		/		/		/
EPFU	X	X	X	X	X	X	X	X	87	/	184	/	195	/	210	/
LANO	X	X	X	X	X	X	X	X	4	/	8	/	21	/	34	/
LABO	X	X	X	X	X	X	X	X	78	/	4	/	4	/	5	/
LACI	X	X	X	X	X	X	X	X	10	/	5	/	6	/	6	/
MYLE	X	X	X	X	X	X	X	X		/		/		/		/

Night 2	2015								21 July 2016 no precipitation, 4 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	1	/		/		/		/
MYSO	X	X	X	X	X	X	X	X		/		/		/		/
MYLU	X	X	X	X	X	X	X	X		/		/		/	1	/
PESU	X	X	X	X	X	X	X	X	3	/		/		/	1	/
EPFU	X	X	X	X	X	X	X	X	195	/	338	/	356	/	381	/
LANO	X	X	X	X	X	X	X	X	17	/	30	/	56	/	70	/
LABO	X	X	X	X	X	X	X	X	179	/	5	/	5	/	15	/
LACI	X	X	X	X	X	X	X	X	29	/	9	/	9	/	14	/
MYLE	X	X	X	X	X	X	X	X		/		/		/	1	/

Night 3	2015								22 July 2016 no precipitation, 10 MPH wind *Location A monitor recorded until 01:59AM							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		/		/		/		/
MYSO	X	X	X	X	X	X	X	X		/		/		/		/
MYLU	X	X	X	X	X	X	X	X		/		/		/		/
PESU	X	X	X	X	X	X	X	X	1	/		/		/		/
EPFU	X	X	X	X	X	X	X	X	118	/	166	/	179	/	203	/
LANO	X	X	X	X	X	X	X	X	20	/	27	/	55	/	61	/
LABO	X	X	X	X	X	X	X	X	98	/	3	/	3	/	12	/
LACI	X	X	X	X	X	X	X	X	32	/	9	/	9	/	12	/
MYLE	X	X	X	X	X	X	X	X		/		/		/		/

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-31: Late season automated acoustic monitoring results for RI-concrete.

Night 1	2015								23 August 2016, no precipitation, 4 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	8		24	12	24	12	27	16
LANO	X	X	X	X	X	X	X	X	3		4	1	4	2	4	3
LABO	X	X	X	X	X	X	X	X	7	4	1		1		1	
LACI	X	X	X	X	X	X	X	X	2		0	2		2		3
MYLE	X	X	X	X	X	X	X	X								

Night 2	2015								24 August 2016, no precipitation, 3 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X	1	3						
EPFU	X	X	X	X	X	X	X	X	41	6	74	63	77	68	95	97
LANO	X	X	X	X	X	X	X	X	2	2	4	4	6	9	6	13
LABO	X	X	X	X	X	X	X	X	13	42	2	4	2	4	2	7
LACI	X	X	X	X	X	X	X	X	2	8	1	21	1	21	1	22
MYLE	X	X	X	X	X	X	X	X								

Night 3	2015								25 August 2016, no precipitation, 8 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		1						
MYSO	X	X	X	X	X	X	X	X	1							
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	34	8	65	52	68	53	81	85
LANO	X	X	X	X	X	X	X	X	7	1	4	5	9	13	14	11
LABO	X	X	X	X	X	X	X	X	15	27	3	1	3	1	6	2
LACI	X	X	X	X	X	X	X	X	8	5	1	2	1	2	2	2
MYLE	X	X	X	X	X	X	X	X				1		1		1

Notes: “X”=No data collected, “/”= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.5.2 RI-precast_concrete

One bridge monitored summers 2015 and 2016 in Rhode Island is a precast concrete bridge, shown in Figure 5-80, given the identification name "RI-precast_concrete." Gaps between the concrete girders can potentially provide roosting locations for bats, shown in Figure 5-81. This particular bridge has several areas with staining of unidentified causation between these girders and where the girders meet the abutment, shown in Figure 5-82, which could potentially be staining from bats roosting. All accessible intermediate spaces between girders and where girders meet the abutment were inspected using the boroscope, shown in Figure 5-83, and no unusual internal staining was observed, indicating no bats roosting when the daytime inspection occurred. By visiting this bridge site multiple times in different weather conditions, the causation of one source of staining was determined to be water staining, as shown in Figure 5-84. When first visited, the observed stains were of unknown causation, but a subsequent visit during a rainstorm determined the staining was caused by water seepage through the bridge wearing surface and joints. In addition, the research team was able to fully inspect all intermediate spaces between girders using the borescope and observed no unusual internal staining, indicating no bats roosting when the daytime the inspection occurred. The surrounding habitat seems conducive to support bat habitat and foraging areas. Both the federal form and the developed supplemental form were completed and are included in Appendix C-10.

Microphone placement for acoustic monitoring at RI-precast_concrete is shown in Figure 5-85. Location A is upstream of the bridge further away. The microphone is attached to a trimmed tree trunk on the streambank. Location B is downstream and close to the bridge with the microphone attached to a tree trunk near the abutment. Table 5-32, Table 5-33, and Table 5-34 show acoustic results from monitoring RI-precast_concrete throughout early, mid- and late seasons.

An emergence study was completed at RI-precast_concrete in the mid- monitoring season. No bats were seen exiting the bridge, through bats were observed in the local area. Bats were seen foraging throughout the evening, with only few bats seen at a time.

Figure 5-80: Precast concrete bridge selected in RI (RI-precast_concrete)

Figure 5-81: Spaces between the girders in RI-precast_concrete appropriately sized for bat roosts

Figure 5-82: Staining of unidentified causation between the girders and where the girders and abutment meet in RI-precast_concrete

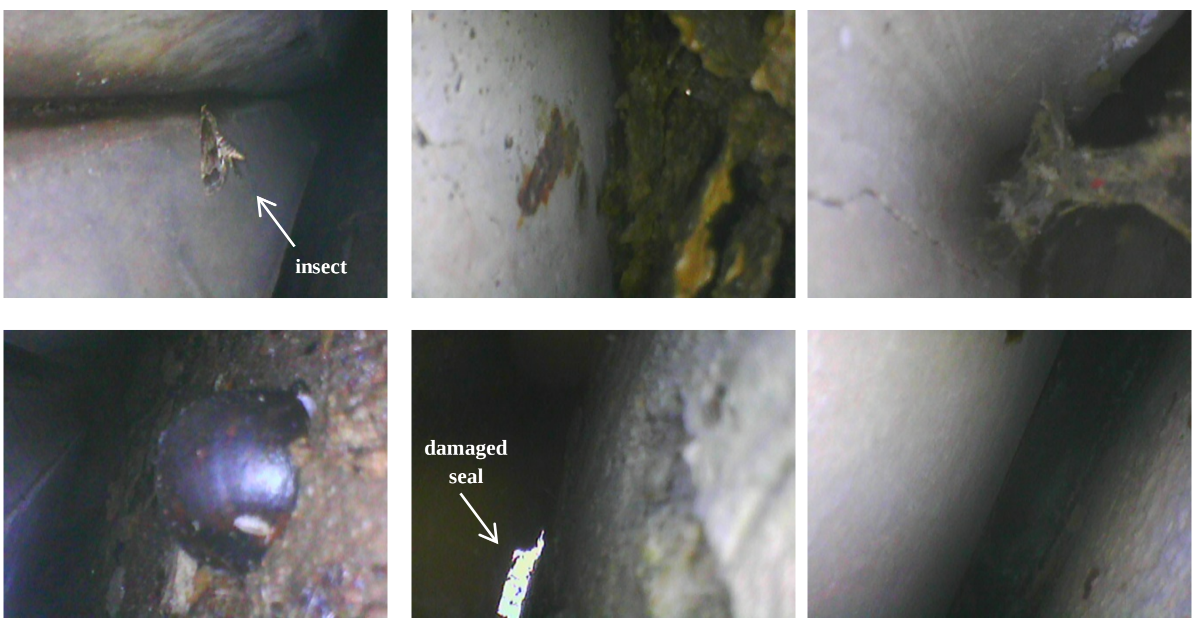


Figure 5-83: Boroscope view between girders and between girders and the abutment at RI-precast_concrete showing insects, debris, structural components, sealant damage, and clean gaps

Figure 5-84: Source of staining determined through multiple visits and various weather conditions at RI-precast_concrete

Location A

Location B

Figure 5-85: RI-precast_concrete microphone placement

Table 5-32: Early season automated acoustic monitoring results for RI-precast_concrete.

Night 1	2015								14 June 2016 no precipitation, 7 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		1						1
MYSO	X	X	X	X	X	X	X	X	1							
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	15	14	7	29	10	31	10	36
LANO	X	X	X	X	X	X	X	X	2	13	17	15	25	28	29	33
LABO	X	X	X	X	X	X	X	X	5	34	1	2	1	2	3	10
LACI	X	X	X	X	X	X	X	X	18	41	6	17	6	18	6	18
MYLE	X	X	X	X	X	X	X	X								

Night 2	2015								15 June 2016 no precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X	1	1					1	
MYLU	X	X	X	X	X	X	X	X						1		1
PESU	X	X	X	X	X	X	X	X		2						
EPFU	X	X	X	X	X	X	X	X	8	19	2	39	3	52	7	67
LANO	X	X	X	X	X	X	X	X	15	46	9	35	26	76	26	79
LABO	X	X	X	X	X	X	X	X	15	86		3		3	1	24
LACI	X	X	X	X	X	X	X	X	168	239	124	172	125	174	128	174
MYLE	X	X	X	X	X	X	X	X	1							

Night 3	2015								16 June 2016 no precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X								
PESU	X	X	X	X	X	X	X	X	4	1	5		5	1	5	
EPFU	X	X	X	X	X	X	X	X	4	10	1	31	5	37	6	44
LANO	X	X	X	X	X	X	X	X	5	15	19	14	29	30	28	34
LABO	X	X	X	X	X	X	X	X	10	41	3	3	4	3	4	7
LACI	X	X	X	X	X	X	X	X	72	108	32	61	32	61	34	65
MYLE	X	X	X	X	X	X	X	X	1							

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-33: Mid-season automated acoustic monitoring results for RI-precast_concrete.

Night 1	22 July 2015 no precipitation, 8 MPH wind								20 July2016 no precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		1					1			6						1
MYSO	21	2			1	1			1	4				1		
MYLU	7	1	19	2	32	3	29	4			2	7	3	10	2	8
PESU																1
EPFU	31	52	32	63	34	82	37	78	20	39	15	66	18	73	23	97
LANO	15	13	14	24	20	43	24	45	13	38	20	24	34	41	38	44
LABO	42	97	6	7	6	8	7	14	9	79	1	5	1	5	3	16
LACI	41	131	70	165	70	167	73	174	25	56	9	11	10	11	10	13
MYLE	4	3	3	2	3	2	6	3		1		2		4		6
Night 2	23 July 2015 no precipitation, 4 MPH wind								21 July 2016 no precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	3	2							1	26						
MYSO	17	1							5	74						
MYLU	1		10	2	14	3	18	4	7	1	6	3	12	9	7	14
PESU	2	2						1		7						2
EPFU	32	45	30	72	32	81	42	85	62	104	60	173	73	208	101	249
LANO	7	9	6	24	16	51	16	57	16	96	46	43	85	100	93	109
LABO	43	78	9	6	9	7	17	11	50	402	2	40	2	45	5	112
LACI	53	137	85	174	85	177	86	178	54	177	16	49	17	50	20	51
MYLE	2						1		1	2		8		8		14
Night 3	24 July 2015 0.22in precipitation, 3 MPH wind								22 July 2016 no precipitation, 10 MPH wind *Location B monitor recorded until 01:02AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	6	8														
MYSO	120	8							1	1						
MYLU	15		82	11	121	17	109	17	2	1	4		8	1	5	1
PESU										2		1		1		2
EPFU	26	52	26	69	30	77	37	84	72	91	78	113	94	124	122	155
LANO	11	11	8	11	21	25	22	24	22	19	34	13	82	39	93	43
LABO	82	87	2	5	2	7	4	13	73	166		16		17	6	56
LACI	25	53	23	54	23	55	23	54	58	53	6	7	6	7	6	8
MYLE		1														

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-33: *continued* Mid-season automated acoustic monitoring results for RI-precast_concrete.

Night 4	25 July 2015 no precipitation, 4 MPH wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	1	6							X	X	X	X	X	X	X	X
MYSO	4	2	1		1		1	3	X	X	X	X	X	X	X	X
MYLU	3	2	5	7	7	13	7	10	X	X	X	X	X	X	X	X
PESU		3		2		2		2	X	X	X	X	X	X	X	X
EPFU	120	107	133	192	150	226	182	252	X	X	X	X	X	X	X	X
LANO	43	52	22	47	52	100	53	112	X	X	X	X	X	X	X	X
LABO	39	173	3	4	4	4	5	12	X	X	X	X	X	X	X	X
LACI	57	135	30	66	32	68	30	70	X	X	X	X	X	X	X	X
MYLE								2	X	X	X	X	X	X	X	X
Night 5	26 July 2015 0.03in precipitation, 7 MPH wind *Location A monitor recorded until 01:02AM *Location B monitor recorded until 23:23PM								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO	7	1							X	X	X	X	X	X	X	X
MYLU	2		4	1	4	1	4	2	X	X	X	X	X	X	X	X
PESU							1		X	X	X	X	X	X	X	X
EPFU	82	84	78	91	92	106	97	107	X	X	X	X	X	X	X	X
LANO	18	12	31	45	52	70	60	80	X	X	X	X	X	X	X	X
LABO	50	118	1	3	1	8	4	19	X	X	X	X	X	X	X	X
LACI	31	47	10	6	10	6	11	7	X	X	X	X	X	X	X	X
MYLE	1								X	X	X	X	X	X	X	X

Notes: “X”=No data collected, “/”= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-34: Late season automated acoustic monitoring results for RI-precast_concrete.

Night 1	25 August 2015, no precipitation, 2 MPH wind								23 August 2016, no precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	8	8							1	/		/		/		/
MYSO	8	1							6	/		/		/		/
MYLU	4	1	5		7	1	7	1		/	3	/	4	/	5	/
PESU				1		2	1	2	2	/		/		/		/
EPFU	64	19	64	34	69	43	81	40	596	/	225	/	287	/	280	/
LANO	6	2	6	7	21	15	21	15	6	/	192	/	250	/	260	/
LABO	42	73	1	8	2	9	14	46	116	/		/		/	1	/
LACI	2	3							4	/	1	/	1	/	2	/
MYLE							2			/	1	/	1	/	1	/

Night 2	26 August 2015, no precipitation, 4 MPH wind, *Location A monitor recorded until 23:45PM								24 August 2016, no precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									6	/		/		/		/
MYSO		3							8	/		/		/		/
MYLU				1		3		2	2	/	3	/	3	/	7	/
PESU							1	2	1	/		/	1	/		/
EPFU	12	13	18	15	23	16	21	20	273	/	126	/	175	/	172	/
LANO	1		2	4	5	8	5	7	19	/	97	/	143	/	161	/
LABO	10	21		1		1	1	4	69	/	3	/	3	/	8	/
LACI	12	8	5	9	5	9	6	9	40	/	5	/	5	/	5	/
MYLE										/		/		/	2	/

Night 3	2015 (X)								25 August 2016, no precipitation, 8 MPH wind, *Location A monitor recorded until 20:32PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		/		/		/		/
MYSO	X	X	X	X	X	X	X	X		/		/		/		/
MYLU	X	X	X	X	X	X	X	X		/		/		/		/
PESU	X	X	X	X	X	X	X	X		/		/		/		/
EPFU	X	X	X	X	X	X	X	X	1	/		/		/		/
LANO	X	X	X	X	X	X	X	X		/		/	1	/	1	/
LABO	X	X	X	X	X	X	X	X	1	/		/		/	1	/
LACI	X	X	X	X	X	X	X	X		/		/		/		/
MYLE	X	X	X	X	X	X	X	X		/		/		/		/

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.5.3 RI-precast_concrete_2

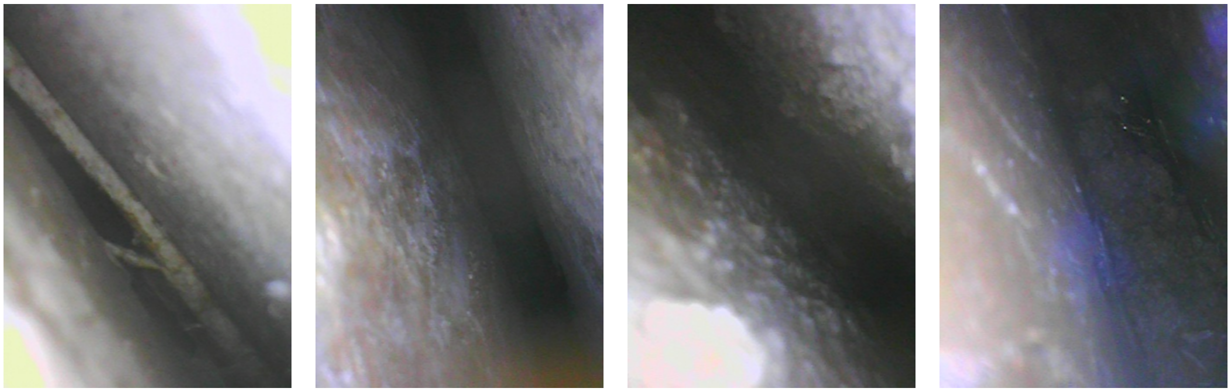
One bridge monitored summers 2015 and 2016 in Rhode Island is a deteriorated concrete bridge, shown in Figure 5-86, given the identification name "RI-precast_concrete_2." This bridge has several cracks and crevices, some shown in Figure 5-87, that can be potential roost sites, and have staining of unidentified causation. All accessible intermediate spaces between girders and where girders meet the abutment were inspected using the waders and the boroscope, shown in Figure 5-88, and no unusual internal staining was observed, indicating no bats roosting when the daytime inspection occurred. Bird's nests were observed, shown in Figure 5-89, indicating that the bridge would be suitable for bat roosting. This bridge has surrounding vegetation that can support bat habitat and foraging. During summer 2016 monitoring, a local resident inquired about the project and told the research team they used to see high bat activity in the local area. Both the federal form and the developed supplemental form were completed and are included in Appendix C-11.

Microphone placement for acoustic monitoring at RI-precast_concrete_2 is shown in Figure 5-90. Location A is upstream of the bridge on a tree branch on the streambank. Location B is downstream of the bridge on a tree branch on the streambank. Table 5-35, Table 5-36, and Table 5-37 show acoustic results from monitoring RI-precast_concrete_2 throughout early, mid- and late seasons.

An emergence study was completed at RI-precast_concrete_2 in the late monitoring season. No bats were seen exiting the bridge, and few bats were seen in close vicinity to the bridge. Many bats were consistently observed in the local area, however, and bats were observed emerging from a potential roost tree in the local area in close proximity to the bridge site. Automated analysis of emergence period acoustic data collected classified several species being present in the local area (SonoBat: EPFU, LANO, LABO, LACI; EchoClass: EPFU, LANO, LABO, LACI, MYLU).

Figure 5-86: Deteriorated concrete bridge selected in RI (RI-precast_concrete_2)

Figure 5-87: Cracks and crevices that can be potential roost sites in RI-precast_concrete_2



(a)

(b)

(c)

Figure 5-88: Boroscope view between girders and between girders and the abutment, showing clean gaps (a) debris (b) and spiders/insects (c), at RI-precast_concrete_2

Figure 5-89: Bird's nests observed at RI-precast_concrete_2

Location A

Location B

Figure 5-90: RI-precast_concrete_2 microphone placement

Table 5-35: Early season automated acoustic monitoring results for RI-precast_concrete_2.

Night 1	2015								14 June 2016 no precipitation, 7 MPH wind *Location A monitor recorded until 00:53AM *Location B monitor recorded until 00:07AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	1							
MYSO	X	X	X	X	X	X	X	X								
MYLU	X	X	X	X	X	X	X	X				1		1		1
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	21	6	11	3	14	3	16	3
LANO	X	X	X	X	X	X	X	X	16	2	19	2	32	4	32	4
LABO	X	X	X	X	X	X	X	X	21	7	1		3		5	1
LACI	X	X	X	X	X	X	X	X	6	1	2		2		3	
MYLE	X	X	X	X	X	X	X	X	1							

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-36: Mid-season automated acoustic monitoring results for RI-precast_concrete_2. Highlighted cells indicate call classification confirmation through manual vetting.

Night 1	22 July 2015 no precipitation, 8 MPH wind *Location A monitor recorded until 01:02AM *Location B monitor recorded until 00:18AM								20 July 2016 no precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	2	1														
MYSO	3	1								4						
MYLU	2	2	3	1	6	2	3	2	3	2	6	7	6	11	8	7
PESU								1	1					0		1
EPFU	37	69	15	53	18	61	31	68	92	64	90	54	93	60	99	69
LANO	1	5	11	28	27	33	32	41	12	7	9	22	20	35	21	41
LABO	38	51	1	5	1	5	8	14	43	65	4	6	4	8	24	8
LACI	14	19	16	5	16	5	16	5	24	27	14	21	14	21	16	25
MYLE																1

Night 2	2015 (X)								21 July 2016 no precipitation, 4 MPH wind *Location A monitor recorded until 00:36AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		/		/		/		/
MYSO	X	X	X	X	X	X	X	X	1	/		/		/		/
MYLU	X	X	X	X	X	X	X	X	1	/	3	/	3	/	3	/
PESU	X	X	X	X	X	X	X	X		/		/		/		/
EPFU	X	X	X	X	X	X	X	X	81	/	69	/	75	/	79	/
LANO	X	X	X	X	X	X	X	X	16	/	16	/	24	/	28	/
LABO	X	X	X	X	X	X	X	X	37	/	4	/	4	/	7	/
LACI	X	X	X	X	X	X	X	X	8	/	5	/	5	/	5	/
MYLE		/								/		/		/		/

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-37: Late season automated acoustic monitoring results for RI-precast_concrete_2.

Night 1	25 August 2015 no precipitation, 2 MPH wind								23 August 2016 no precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		4					1			2						
MYSO										1						
MYLU						1		1	1				1	2		1
PESU		1						3								
EPFU	47	12	72	45	86	51	100	78	29	16	25	25	28	28	29	31
LANO	30	2	6	9	21	28	21	27	1	3	6	7	9	10	10	10
LABO	30	127	5	28	6	32	11	95	14	6	1		2		4	3
LACI	34	18	1	2	2	2	1	2	7	6						
MYLE		1		1		1		5								

Night 2	26 August 2015 no precipitation, 4 MPH wind *Location A monitor recorded until 23:45PM								24 August 2016 no precipitation, 3 MPH wind *Location A monitor recorded until 22:31PM *Location B monitor recorded until 23:44PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		3							1							
MYSO		1								1						
MYLU								1								1
PESU								3								
EPFU	9	1	9	4	9	4	17	6	37	61	26	54	29	60	29	67
LANO	4	1	2	4	9	10	8	11	2	4	2	12	2	14	5	21
LABO	6	32		1	1	1		2	7	20		1		1	1	5
LACI	10	4	1	9	1	10	2	11	1	2						
MYLE																

Night 3	27 August 2015 no precipitation, 6 MPH wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/	1	/		/		/		X	X	X	X	X	X	X	X
MYSO	/	3	/		/		/		X	X	X	X	X	X	X	X
MYLU	/		/	1	/	1	/	2	X	X	X	X	X	X	X	X
PESU	/		/		/	1	/	1	X	X	X	X	X	X	X	X
EPFU	/	1	/	4	/	4	/	5	X	X	X	X	X	X	X	X
LANO	/		/	5	/	13	/	12	X	X	X	X	X	X	X	X
LABO	/	24	/	3	/	4	/	15	X	X	X	X	X	X	X	X
LACI	/	9	/		/		/		X	X	X	X	X	X	X	X
MYLE	/		/		/		/		X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.5.4 RI-steel

One bridge monitored summer 2015 in Rhode Island is steel girder bridge, shown in Figure 5-91, given the identification name "RI-steel." There are pipes on this bridge, one with insulation that is deteriorating and partially removed from the pipe and one with a pipe collar, seen in Figure 5-91 and Figure 5-92, respectively, which are bridge features that could provide roosting locations for bats. Residents of the area recalled seeing bats in the neighborhood and specifically noted birds of prey that congregated on an industrial chimney next to the bridge at dusk. Staining was observed along the abutments, and can be seen in Figure 5-91. This bridge is situated in a location with surrounding vegetation seemingly able to support bat habitat and foraging, however this bridge is also located close to an urban area (population approximately 10,400 (City-Data.com 2010)).

This bridge was only monitored in summer 2015 and was removed for summer 2016 monitoring. Table 5-38 and Table 5-39 show acoustic results from monitoring RI-steel throughout mid- and late seasons. In preparing form the summer 2016 monitoring season, preliminary results from summer 2015 monitoring were considered. Preliminary acoustical analyses results (preliminary SonoBat results) showed this location recorded the least number of calls over the entire summer 2015 monitoring, indicating lower bat activity in the local area as compared to other bridge sites monitored. The proximity of this bridge to more populated areas was determined to suggest limited available bat habitat in the area. As such, this bridge was not included in summer 2016 field work. Subsequent acoustical analyses using EchoClass identified only one MYSE, and the possibility of MYSE roosting in man-made structures does not preclude the use.

Figure 5-91: Steel construction bridge selected in RI (RI-steel) with pipe insulation deterioration (arrows)

Figure 5-92: Pipes around RI-steel bridge

Table 5-38: Mid-season automated acoustic monitoring results for RI-steel. Highlighted cells indicate call classification confirmation through manual vetting.

Night 1	22 July 2015 no precipitation, 9 MPH wind								2016							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	1								X	X	X	X	X	X	X	X
MYSO	1								X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU								1	X	X	X	X	X	X	X	X
EPFU	5	13	6	6	6	7	12	11	X	X	X	X	X	X	X	X
LANO	1	1	1	2	5	7	6	7	X	X	X	X	X	X	X	X
LABO	12	9						1	X	X	X	X	X	X	X	X
LACI	1	4	3	4	3	4	3	4	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Night 2	23 July 2015 no precipitation, 8 MPH wind								2016							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU	7		8		8		11		X	X	X	X	X	X	X	X
LANO			1		3		3		X	X	X	X	X	X	X	X
LABO	6								X	X	X	X	X	X	X	X
LACI	3		4		5		4		X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-38: ***continued*** Mid-season automated acoustic monitoring results for RI-steel.

Night 3	24 July 2015 0.03in precipitation, 6 MPH wind *Location A monitor recorded until 21:45PM								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU			1		1		2		X	X	X	X	X	X	X	X
LANO			1		1		1		X	X	X	X	X	X	X	X
LABO	1								X	X	X	X	X	X	X	X
LACI			1		1		1		X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-39: Late season automated acoustic monitoring results for RI-steel.

Night 1	25 August 2015 0.68in precipitation, 8 MPH wind *Location A monitor recorded until 23:59PM *Location B monitor recorded until 04:01AM								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE									X	X	X	X	X	X	X	X
MYSO									X	X	X	X	X	X	X	X
MYLU									X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU	3	2	7	6	9	7	13	11	X	X	X	X	X	X	X	X
LANO	1				2		2		X	X	X	X	X	X	X	X
LABO	5	2	1		1		1		X	X	X	X	X	X	X	X
LACI		1							X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.5.5 RI-steel_2

One bridge monitored summer 2015 and 2016 in Rhode Island, a steel girder bridge, shown in Figure 5-93 and given the identification name "RI-steel_2," was added after finding a dead bat below one abutment. The dead bat found is shown in Figure 5-94, and was identified as a *Myotis* of uncertain species by biologists at the Hadley Fish and Wildlife office. The abutment under which the bat was found has crevices and a clogged drainage pipe, shown in Figure 5-95, Figure 5-96, and Figure 5-97, that could provide roosting locations for bats. Figure 5-96 (b) shows the view into the drainpipe as observed with the boroscope, indicating that the pipe is clogged. These crevices also have various levels of staining that were from unidentified causation at the time of initial inspection. After subsequently inspecting the bridge during a rainstorm, it was identified that much of the staining is predominantly caused by water damage, as shown in Figure 5-98, though staining is too extensive to definitively identify all sources. Figure 5-99 shows where insulation has fallen out of the expansion joint, allowing for access far up into the abutment, where crevices due to deterioration were observed to extend approximately 3 ft (1 m) or more. Various images of the expansion joint were captured with the boroscope, shown in Figure 5-100 (a), including examples of intact, Figure 5-100 (b), and damaged, Figure 5-100 (c), sections. Figure 5-100 (d) shows crevices that extended to the roadway expansion joint, with extensive staining and mineral buildup from water seepage. The center piers of this bridge, which were inaccessible for in depth, close up inspection, have staining of unidentified causation, shown in Figure 5-101. Bird's nests, shown in Figure 5-102, and Mud-Dauber's nests, shown in Figure 5-103, were observed at the bridge, indicating that the bridge would be suitable for bat roosting. This bridge has surrounding vegetation seemingly able to support bat habitat. Both the federal form and the developed supplemental form were completed and are included in Appendix C-12.

Microphone placement for acoustic monitoring at RI-steel_2 is shown in Figure 5-104. Location A was downstream of the bridge facing the abutment under which the dead bat was found with the microphone attached to a tree. This monitor was stolen during early monitoring in 2016, so subsequent abutment acoustic monitoring was at location C. Location C also faces an abutment but is upstream of the bridge with the microphone attached to a tree trunk. These microphones face the location where the dead bat was assumed to roost. This microphone placement was used to evaluate calls from this type of placement, though the likelihood of reflection off of the concrete surfaces and differences in potential bat emergence calls was expected to potentially interfere with acoustic data. Nevertheless, observation of a high number of non-identifiable call files may indicate bat activity. Acoustical analyses did not indicate differences between localized and generalized microphone placements at RI-steel_2. Location B was also downstream of the bridge with the microphone attached to a log on the streambank. Table 5-40, Table 5-41, and Table 5-42 show acoustic results from monitoring RI-steel_2 throughout early, mid- and late seasons. The microphone location changed in the mid- and late season monitoring of this bridge in 2016.

An emergence study was completed at RI-steel_2 in the early monitoring season. No bats were directly seen exiting the bridge or in the local area, though it was difficult to observe the entire bridge span. Weather conditions were partly cloudy, calm with no wind, and warm in the evening, which are ideal conditions for bat activity.

Figure 5-93: Steel construction bridge selected in RI (RI-steel_2)

Figure 5-94: Dead bat found below abutment at RI-steel_2

Figure 5-95: Abutment under which the dead bat was found at RI-steel_2

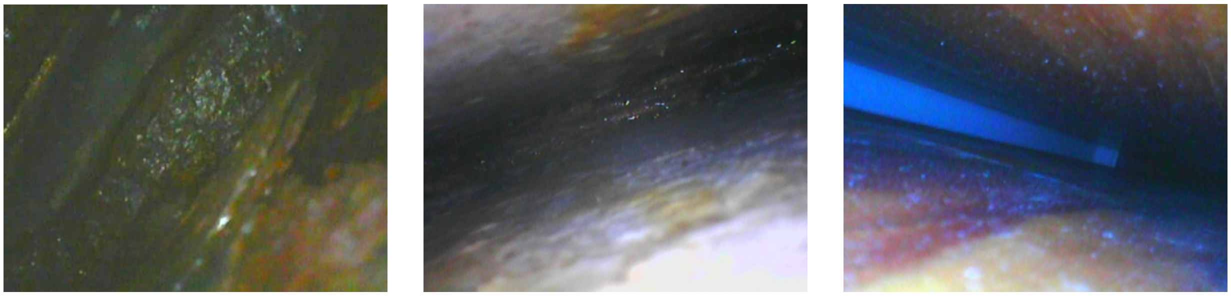
(a) (b)

Figure 5-96: Drainpipe above the location where the dead bat was found (a) and boroscope view inside, indicating it is clogged (b) at RI-steel_2

Figure 5-97: Crevices and staining in the abutment under which the dead bat was found at RI-steel_2

Figure 5-98: Staining caused by water damage at RI-steel_2

Figure 5-99: Insulation (left) that has fallen out of an expansion joint (right) at RI-steel_2



(a)

(b) (c) (d)

Figure 5-100: Boroscope views into the expansion joint (a), and examples of intact (b) and damaged (c) and (d) sections of the expansion joint at RI-steel_2

Figure 5-101: Staining of unidentified causation in the center pier of RI-steel_2

Figure 5-102: Birds and bird's nests seen at RI-steel_2

Figure 5-103: Mud-Dauber's nests seen at RI-steel_2

Location A Location B Location C

Figure 5-104: RI-steel_2 microphone placement

Table 5-40: Early season automated acoustic monitoring results for RI-steel_2.

Night 1	2015								14 June 2016 no precipitation, 10 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	/		/		/		/	
MYSO	X	X	X	X	X	X	X	X	/	1	/		/		/	
MYLU	X	X	X	X	X	X	X	X	/		/	1	/	2	/	3
PESU	X	X	X	X	X	X	X	X	/	1	/		/		/	
EPFU	X	X	X	X	X	X	X	X	/	112	/	58	/	66	/	78
LANO	X	X	X	X	X	X	X	X	/	14	/	58	/	82	/	87
LABO	X	X	X	X	X	X	X	X	/	22	/	1	/	1	/	1
LACI	X	X	X	X	X	X	X	X	/	39	/	9	/	9	/	11
MYLE	X	X	X	X	X	X	X	X	/		/		/		/	

Night 2	2015								15 June 2016 no precipitation, 7 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	/	2	/		/		/	
MYSO	X	X	X	X	X	X	X	X	/	2	/		/		/	
MYLU	X	X	X	X	X	X	X	X	/	2	/	1	/	2	/	3
PESU	X	X	X	X	X	X	X	X	/	2	/		/		/	
EPFU	X	X	X	X	X	X	X	X	/	391	/	232	/	260	/	288
LANO	X	X	X	X	X	X	X	X	/	66	/	136	/	212	/	236
LABO	X	X	X	X	X	X	X	X	/	65	/		/		/	2
LACI	X	X	X	X	X	X	X	X	/	52	/	11	/	13	/	11
MYLE	X	X	X	X	X	X	X	X	/		/		/		/	

Night 3	2015								16 June 2016 no precipitation, 2 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	/		/		/		/	
MYSO	X	X	X	X	X	X	X	X	/		/		/		/	
MYLU	X	X	X	X	X	X	X	X	/	2	/	1	/	4	/	1
PESU	X	X	X	X	X	X	X	X	/		/		/		/	1
EPFU	X	X	X	X	X	X	X	X	/	420	/	237	/	285	/	298
LANO	X	X	X	X	X	X	X	X	/	43	/	114	/	177	/	212
LABO	X	X	X	X	X	X	X	X	/	43	/		/		/	
LACI	X	X	X	X	X	X	X	X	/	71	/	18	/	20	/	20
MYLE	X	X	X	X	X	X	X	X	/		/		/		/	

Notes: “X”=No data collected, “/”= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-41: Mid-season automated acoustic monitoring results for RI-steel_2. Note microphone location change in 2016 monitoring.

Night 1	22 July 2015 no precipitation, 8 MPH wind								20 July2016 no precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***B***	***C***	***B***	***C***	***B***	***C***	***B***	***C***
MYSE		1							1							
MYSO		4		2		3		5								
MYLU		3		1		7		2	2		2		2		2	
PESU																
EPFU	6	50	5	57	7	64	9	66	39		35		39		44	
LANO	9	6	13	9	23	29	20	32	22		20		35		30	
LABO	3	41		1		1		3	19		1		1		1	
LACI	10	19	8	6	8	7	8	6	18		11		11		11	
MYLE									1		1		1		1	
Night 2	23 July 2015 no precipitation, 6 MPH wind								21 July 2016 no precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***B***	***C***	***B***	***C***	***B***	***C***	***B***	***C***
MYSE									1						1	
MYSO		1		1		1		1	1							
MYLU		2		2		3		3	5		6		6		6	
PESU		1									1		1		1	
EPFU	3	47	3	74	4	79	11	80	62		37		41		52	
LANO	6	8	2	16	9	23	8	29	16		19		37		38	
LABO	2	40		4		4		4	17						1	
LACI	19	19	17	15	17	15	17	15	19		8	1	8	1	10	1
MYLE		1							1							
Night 3	24 July 2015 no precipitation, 4 MPH wind								22 July 2016 0.06in precipitation, 6 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***B***	***C***	***B***	***C***	***B***	***C***	***B***	***C***
MYSE		1														
MYSO		1		1		1		3	3							
MYLU				1		1		3					1			
PESU																
EPFU	8	58	9	42	13	55	26	55	85		67		78		77	
LANO	6	5	3	12	6	29	7	35	30		39		64		69	1
LABO	6	37		1		1	1	1	24						1	
LACI	17	16	8	7	8	7	8	8	26	1	9		9		9	
MYLE		1		1		1		2								

Notes: “X”=No data collected, “/”= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-41: ***continued*** Mid-season automated acoustic monitoring results for RI-steel_2. Note microphone location change in 2016 monitoring.

Night 4	25 July 2015 no precipitation, 5 MPH wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***B***	***C***	***B***	***C***	***B***	***C***	***B***	***C***
MYSE									X	X	X	X	X	X	X	X
MYSO						2			X	X	X	X	X	X	X	X
MYLU		1		2		3		3	X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU	18	54	22	58	25	64	34	69	X	X	X	X	X	X	X	X
LANO	14	9	18	22	38	49	38	53	X	X	X	X	X	X	X	X
LABO	8	34						2	X	X	X	X	X	X	X	X
LACI	24	46	6	5	6	5	7	5	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Night 5	26 July 2015 no precipitation, 4 MPH wind								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***B***	***C***	***B***	***C***	***B***	***C***	***B***	***C***
MYSE		1							X	X	X	X	X	X	X	X
MYSO		2							X	X	X	X	X	X	X	X
MYLU		1		1		2		2	X	X	X	X	X	X	X	X
PESU									X	X	X	X	X	X	X	X
EPFU	22	57	28	65	33	77	42	78	X	X	X	X	X	X	X	X
LANO	18	21	14	27	23	55	29	60	X	X	X	X	X	X	X	X
LABO		37		3		3		6	X	X	X	X	X	X	X	X
LACI	33	33	27	12	27	13	27	12	X	X	X	X	X	X	X	X
MYLE									X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-42: Late season automated acoustic monitoring results for RI-steel_2. Note microphone location change in 2016 monitoring.

Night 1	25 August 2015 no precipitation, 2 MPH wind								23 August 2016 no precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***B***	***C***	***B***	***C***	***B***	***C***	***B***	***C***
MYSE																
MYSO		12														
MYLU		1		3		8		5								
PESU		1		1		1		1	1		1		1		1	
EPFU	6	22	11	31	13	33	17	35	14	22	27	10	31	11	32	19
LANO	8	3	1	4	6	5	4	5	6	3	2	7	5	23	5	21
LABO	8	45		3		3		12	8	11	1		1		1	
LACI	11	11	8	1	8	1	8	1	10	6	1	3	1	3	1	3
MYLE																

Night 2	26 August 2015 no precipitation, 3 MPH wind								24 August 2016 no precipitation, 4 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***B***	***C***	***B***	***C***	***B***	***C***	***B***	***C***
MYSE																
MYSO				1		1		1	1				1			
MYLU		1		1		1		1								
PESU		2		2		2		2	1		1		1		1	
EPFU	83	109	98	221	118	274	141	249	25	7	22	6	24	6	29	16
LANO	19	14	23	17	52	38	56	56	8	2	8	10	11	24	11	25
LABO	57	163		1		1		3	5	13	1		2		2	
LACI	25	34	0	7		7		7	4	9	1	2	1	2	1	2
MYLE																

Night 3	27 August 2015 no precipitation, 7 MPH wind								25 August 2016 no precipitation, 5 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***B***	***C***	***B***	***C***	***B***	***C***	***B***	***C***
MYSE																
MYSO		1		1		2		1	4		1		1		4	
MYLU									5		1		2		2	
PESU		2		3		3		3	1						2	
EPFU	34	54	29	78	33	83	41	85	24	2	25	8	25	9	31	14
LANO	5	6	5	13	18	18	12	23	9	6	12	13	15	22	18	22
LABO	16	38						3	36	7	6		6		10	1
LACI	4	15	2	6	2	6	2	6	9	15	3	1	3	1	4	1
MYLE																

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.6 Vermont Bridges

Three bridges were fully monitored in Vermont during summers 2015 and 2016. The bridges were chosen based on bridges with promising characteristics based on rapid visual screenings and proximity to a known bridge bat roost.

5.6.1 VT-concrete_arch

One bridge monitored summer 2015 and 2016 in Vermont is a precast concrete arch bridge, shown in Figure 5-105, given the identification name "VT-concrete_arch." While a newer construction with little deterioration, this bridge has several locations that could be used as roosts for bats, namely the gaps between the concrete segments of the bridge, shown in Figure 5-106. There was staining of unspecified causation by some of these gaps, shown in Figure 5-107. All gaps and joints were inspected. The boroscope was used for these inspections in accessible areas, shown in Figure 5-108, and the monocular and flashlight were used where inaccessible. Intact neoprene filler material was present in all locations, shown in Figure 5-108 (b), and there was no observed indication of bat use or presence. The vents in Figure 5-109 are currently fully screened but could provide access to the hollow sections if deteriorated which can potentially provide cave-like roost environments for bats to roost. The surrounding vegetation seems to be able to support bat habitat and foraging. This bridge is within close vicinity (less than 7.5 mi (12 km) driving) to VT-covered, so it is in a geographic location that is known to have bat populations. During 2016 monitoring, residents from the local area inquired about the project and told the research team that this general area used to have many bats, but bat activity has dwindled in recent years. Both the federal form and the developed supplemental form were completed and are included in Appendix C-13.

Microphone placement for acoustic monitoring at VT-concrete_arch is shown in Figure 5-110. Location A and B are downstream of the bridge. The microphone of location A is attached to a tree branch on the streambank and the microphone of location B is attached to a tree branch on the opposite streambank. This river is a popular swimming area for local residents, particularly around the bridge area. The monitor at location A was stolen during mid-season monitoring in 2016 (subsequently recovered) and as such, location A was not instrumented in subsequent monitoring. Table 5-43, Table 5-44, and Table 5-45 show acoustic results from monitoring VT-concrete_arch throughout early, mid- and late seasons.

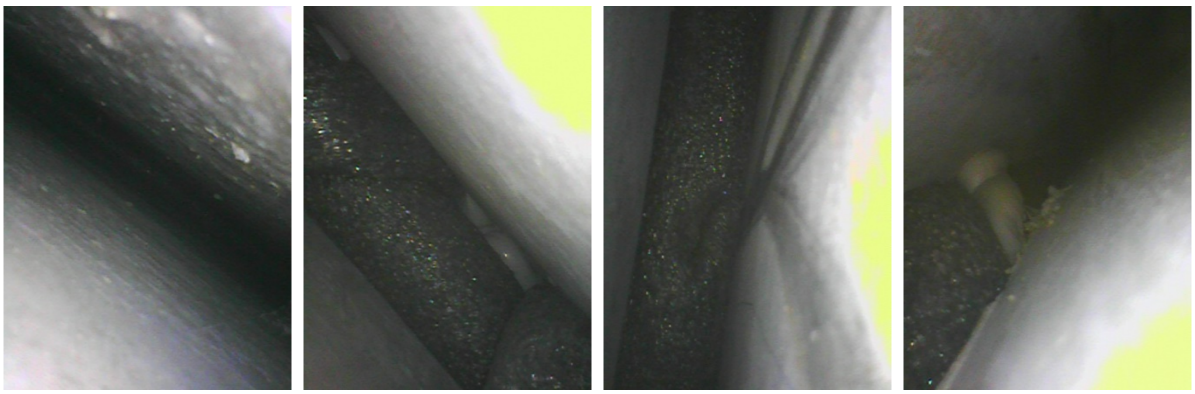
Emergence studies were completed at VT-concrete_arch in the mid- and late monitoring seasons. No bats were confirmed exiting the bridge, though there was consistent activity in the local area and under the bridge as bats foraged throughout the evening during both emergence studies. During the mid- monitoring season emergence study, a bat was thought to possibly enter into a gap at the edge arch segment and façade. However, the event was not captured on camera and inspection of the location with the monocular and flashlight approximately ten minutes later did not observe any bats. The research team noted consistent activity and followed one bat for a while during the mid-monitoring season emergence study, though automated analysis of emergence period acoustic data collected classified several bat species during this time (SonoBat and EchoClass: EPFU, LANO, LABO, MYLU, MYSO, LACI). Analysis of call timing suggests consistency in classifications, indicating the bat species that was being followed was MYLU. During the late monitoring season emergence study, the research team noted that there were about five very active bats foraging in the local area, with automated acoustic analyses classifying several species (SonoBat: MYLU, LABO, LACI; EchoClass: MYLU, LABO, MYSE, MYSO).

Figure 5-105: Concrete arch bridge selected in VT (VT-concrete_arch)

Figure 5-106: Gaps as possible roosts between segments of VT-concrete_arch

Figure 5-107: Staining of unspecified causation by gaps in VT-concrete_arch

(a)



(b)

(c)

Figure 5-108: Boroscope view into gaps between concrete segments (a) showing intact sealants (b) and a spider (c) at VT-concrete_arch

Figure 5-109: Vents on the opposite side of VT-concrete_arch

Location A

Location B

Figure 5-110: VT-concrete_arch microphone placement

Table 5-43: Early season automated acoustic monitoring results for VT-concrete_arch.

Night 1	2015								07 June 2016 no precipitation, 3 MPH wind							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		1						
MYSO	X	X	X	X	X	X	X	X	10	22			1	2		1
MYLU	X	X	X	X	X	X	X	X	10	13	12	18	33	43	18	22
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X	1	2	3	3	3	3	3	3
LANO	X	X	X	X	X	X	X	X	1		3	3	3	3	3	4
LABO	X	X	X	X	X	X	X	X	16	31						
LACI	X	X	X	X	X	X	X	X	5	5	7	4	7	4	7	4
MYLE	X	X	X	X	X	X	X	X						1		
Night 2	2015								08 June 2016 0.06in precipitation, 4 MPH wind *Location A monitor recorded until 00:19AM *Location B monitor recorded until 23:25PM							
	EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*		EchoClass		SonoBat *Consensus*		SonoBat *ByVote*		SonoBat *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X								
MYSO	X	X	X	X	X	X	X	X	53	44			1	1	1	
MYLU	X	X	X	X	X	X	X	X	17	19	16	14	52	32	22	21
PESU	X	X	X	X	X	X	X	X								
EPFU	X	X	X	X	X	X	X	X								
LANO	X	X	X	X	X	X	X	X								
LABO	X	X	X	X	X	X	X	X	17	16						2
LACI	X	X	X	X	X	X	X	X	3	1	2	2	3	2	2	2
MYLE	X	X	X	X	X	X	X	X								

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-44: Mid-season automated acoustic monitoring results for VT-concrete_arch.

Night 1	31 July 2015 no precipitation, 2 MPH wind *Location A monitor recorded until 03:09AM *Location B monitor recorded until 02:18AM								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		2				1	1		X	X	X	X	X	X	X	X
MYSO	148	188			2	12	1	7	X	X	X	X	X	X	X	X
MYLU	778	938	224	363	550	873	464	487	X	X	X	X	X	X	X	X
PESU	1	1	2		2		10	3	X	X	X	X	X	X	X	X
EPFU	8	10	6	3	6	4	9	9	X	X	X	X	X	X	X	X
LANO	4	4	3	1	4	1	5	3	X	X	X	X	X	X	X	X
LABO	257	290	1	4	4	10	26	23	X	X	X	X	X	X	X	X
LACI	10	17	5	4	5	5	6	8	X	X	X	X	X	X	X	X
MYLE								2	X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-45: Late season automated acoustic monitoring results for VT-concrete_arch.

Night 1	18 August 2015 no precipitation, 1 MPH wind *Location A monitor recorded until 03:54AM *Location B monitor recorded until 00:28AM								16 August 2016 0.56in precipitation, 2 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		3						1	/	1	/		/		/	
MYSO	204	256			21	5	2	1	/	338	/		/	3	/	
MYLU	656	519	312	261	860	665	392	358	/	365	/	35	/	227	/	69
PESU	4	8					6	2	/	7	/	44	/	44	/	56
EPFU	20	15	16	24	17	25	23	27	/	1	/		/		/	1
LANO	3	4	1	1	3	1	2	1	/		/		/	1	/	
LABO	523	347	8	1	26	7	25	16	/	179	/	2	/	7	/	22
LACI	7	6	1	1	3	1	1	1	/		/		/		/	
MYLE	1	1							/		/		/		/	

Night 2	2015								17 August 2016 0.43in precipitation, 7 MPH wind *Location B monitor recorded until 21:14PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	/		/		/		/	
MYSO	X	X	X	X	X	X	X	X	/	13	/		/	2	/	
MYLU	X	X	X	X	X	X	X	X	/	181	/	68	/	125	/	75
PESU	X	X	X	X	X	X	X	X	/		/	1	/	1	/	1
EPFU	X	X	X	X	X	X	X	X	/	3	/	1	/	1	/	2
LANO	X	X	X	X	X	X	X	X	/		/		/		/	
LABO	X	X	X	X	X	X	X	X	/	20	/		/	1	/	1
LACI	X	X	X	X	X	X	X	X	/	2	/		/		/	
MYLE	X	X	X	X	X	X	X	X	/		/		/		/	

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.6.2 VT-covered

One bridge monitored summers 2015 and 2016 in Vermont is a covered wooden timber construction bridge that is a known documented and monitored maternity roost, shown in Figure 5-111, given the identification name "VT-covered." Prior to this project there were repeated captures of reproductive females, including a MYSE, at the site. The construction details of this bridge can be seen in Figure 5-112, and support a plethora of roosting crevices for bats. Chirping was audible inside the bridge and bats were seen roosting between bridge members, shown in Figure 5-113. This bridge roost and two bat houses installed during construction that were left in place in close proximity to the bridge provide day-, night-, and maternity roosts for a colony of about 100 to 200 MYLU bats, with one MYSE confirmed using the bridge during mist netting in a previous study in 2013. There were birds and bird's nests observed on the structural members underneath the bridge, supporting the notion that birds and bats choose similar habitats. The bridge is situated over a waterway, supporting the notion that bridges traversing waterways is a preferable roost location. The surrounding habitat is conducive to bat roosting and foraging with many mosquitos and other insects present at all field visits. Both the federal form and the developed supplemental form were completed and are included in Appendix C-14. This bridge burned down in September 2016. While the bat houses remain, it is unclear how the colony will respond, though bats were observed roosting in a bat house near the bridge two days after the fire.

Guano deposits were present at the bridge, shown in Figure 5-114. Samples were collected during mid-season monitoring and sent in for species identification. The pooled sampling laboratory identified MYLU while the individual pellet testing laboratory was unable to identify any bat species. MYLU was identified through acoustic monitoring during all three monitoring seasons.

Microphone placement for acoustic monitoring at VT-covered is shown in Figure 5-115. Location A is upstream of the bridge with the microphone attached to a fallen tree on the stream bank. For the 2015 monitoring, no microphone was used at location A and location C was used instead. Location C was also upstream of the bridge with the microphone attached to a tree trunk on the opposite stream bank. Location C was not used in summer 2016 monitoring as the vegetation around the tree had grown, making the site unusable for microphone placement. Location B is downstream of the bridge with the microphone attached to a tree branch on the stream bank by the abutment. Table 5-46, Table 5-47, and Table 5-48 show acoustic results from monitoring VT-covered throughout early, mid- and late seasons.

An emergence study was completed at VT-covered in the mid- monitoring season. Though the research team did not specifically keep tally as this has been an actively monitored roost site, many bats were observed emerging from the bridge and there was consistent activity in the surrounding area with many bats foraging at the site. The thermal camera was used to capture video of bats entering and exiting the bridge, and still images are shown in Figure 5-116. Automated analysis of emergence period acoustic data collected classified several species being present in the local area (SonoBat: EPFU, MYLU, LANO; EchoClass: EPFU, MYLU, LABO, LACI, MYSE, MYSO).

Figure 5-111: Covered wooden bridge selected in VT (VT-covered)

Figure 5-112: Bridge detail providing bat roost locations in VT-covered

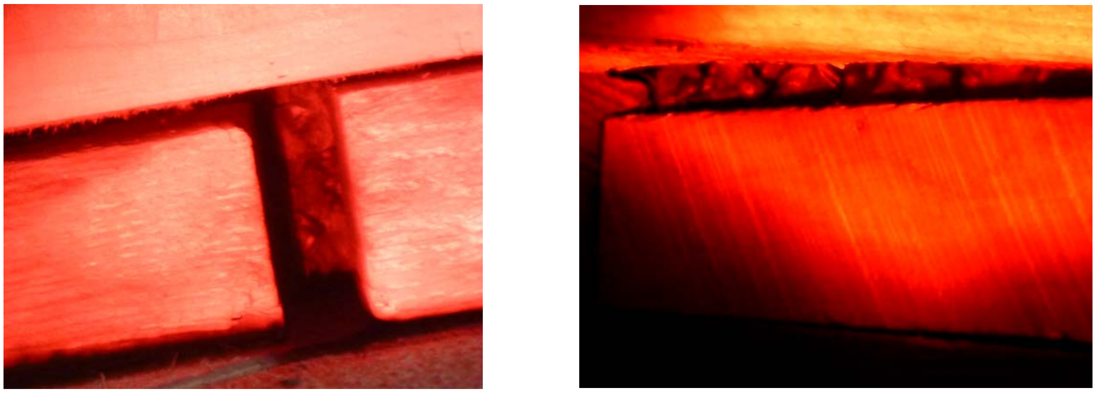


Figure 5-113: Maternity colony observed between truss components of VT-covered

Figure 5-114: Guano evidence of roosting VT-covered (confirmed MYLU)

Location A   Location B

Figure 5-115: VT-covered microphone placement

Figure 5-116: Infrared imaging of bat emergence from VT-covered

Table 5-46: Early season automated acoustic monitoring results for VT-covered.

Night 1	2015								7 June 2016 no precipitation, 3 MPH wind *Location B monitor recorded until 02:01AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	5	53		10		25	7	23
MYSO	X	X	X	X	X	X	X	X	69	122	60	180	126	410	149	370
MYLU	X	X	X	X	X	X	X	X	57	9	212	17	371	85	358	132
PESU	X	X	X	X	X	X	X	X		2				2		4
EPFU	X	X	X	X	X	X	X	X	12	1	11		11		12	
LANO	X	X	X	X	X	X	X	X	4		1		1	3	1	3
LABO	X	X	X	X	X	X	X	X	871	1234	1	1	6	13	13	17
LACI	X	X	X	X	X	X	X	X	12		7	1	7	1	8	1
MYLE	X	X	X	X	X	X	X	X	2	6	1	2	3	8	3	20
Night 2	2015								8 June 2016 0.06in precipitation, 4 MPH wind *Location A monitor recorded until 21:33PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X		/		/		/		/
MYSO	X	X	X	X	X	X	X	X	6	/		/		/	1	/
MYLU	X	X	X	X	X	X	X	X	10	/	10	/	18	/	14	/
PESU	X	X	X	X	X	X	X	X		/		/		/		/
EPFU	X	X	X	X	X	X	X	X	2	/	2	/	2	/	2	/
LANO	X	X	X	X	X	X	X	X	1	/		/		/		/
LABO	X	X	X	X	X	X	X	X	17	/		/		/		/
LACI	X	X	X	X	X	X	X	X		/		/		/		/
MYLE	X	X	X	X	X	X	X	X		/		/		/		/

Notes: “X”=No data collected, “/”= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-47: Mid-season automated acoustic monitoring results for VT-covered.

Night 1	2015								12 July 2016 no precipitation, 2 MPH wind *Location B monitor recorded until 01:36AM *Location B monitor recorded until 01:14AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	2	5	1		1	2	1	1
MYSO	X	X	X	X	X	X	X	X	13	23	107	360	234	670	263	582
MYLU	X	X	X	X	X	X	X	X	7		266	15	635	114	431	33
PESU	X	X	X	X	X	X	X	X	7	1	0	1	2	7	1	7
EPFU	X	X	X	X	X	X	X	X	104	15	75	7	82	9	89	15
LANO	X	X	X	X	X	X	X	X	8	4	9	2	18	4	18	5
LABO	X	X	X	X	X	X	X	X	2011	2090	3	1	22	29	23	15
LACI	X	X	X	X	X	X	X	X	21	3	9	3	9	3	13	3
MYLE	X	X	X	X	X	X	X	X	1		0	3	5	31	4	11

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-48: Late season automated acoustic monitoring results for VT-covered. Note microphone location change in 2016 monitoring.

Night 1	18 August 2015 no precipitation, 1 MPH wind *Location B monitor recorded until 04:09AM								16 August 2016 0.56in precipitation, 2 MPH wind *Location A monitor recorded until 00:27AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***B***	***C***	***B***	***C***	***B***	***C***	***B***	***C***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		2		1		4		3		/		/	0	/	0	/
MYSO	211	43	5	25	96	91	18	54	82	/	5	/	18	/	12	/
MYLU	16	112	251	377	758	659	377	577	130	/	286	/	490	/	422	/
PESU	17	5				1	2	3		/		/	0	/	2	/
EPFU	53	103	31	45	32	50	41	64	40	/	19	/	24	/	29	/
LANO	1	3	3	5	5	8	5	17		/	1	/	3	/	4	/
LABO	1560	1093	2	1	17	12	7	12	469	/	5	/	12	/	26	/
LACI	5	9				1	1	2	3	/	1	/	1	/	1	/
MYLE		6		1		4		6	1	/	1	/	1	/	1	/

Night 2	19 August 2015 no precipitation, 3 MPH wind *Location C monitor recorded until 21:39PM								2016							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***B***	***C***	***B***	***C***	***B***	***C***	***B***	***C***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	/		/		/		/		X	X	X	X	X	X	X	X
MYSO	/	6	/	4	/	10	/	10	X	X	X	X	X	X	X	X
MYLU	/	11	/	33	/	83	/	62	X	X	X	X	X	X	X	X
PESU	/	2	/		/		/		X	X	X	X	X	X	X	X
EPFU	/	28	/	5	/	5	/	7	X	X	X	X	X	X	X	X
LANO	/	3	/	2	/	2	/	4	X	X	X	X	X	X	X	X
LABO	/	153	/		/		/	6	X	X	X	X	X	X	X	X
LACI	/	1	/		/		/		X	X	X	X	X	X	X	X
MYLE	/		/		/		/		X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.6.3 VT-steel

One bridge monitored 2015 and 2016 in Vermont is a steel girder bridge, shown in Figure 5-117, given the identification name "VT-steel." Significant structural deterioration can be seen in the cracks and expansion joint in Figure 5-117. The expansion joint between the beams, shown in Figure 5-118, could be potential roost locations. Bird's nests were observed at this bridge, seen in Figure 5-119, indicating that the habitat was suitable for bat roosting. While carrying a large volume, high speed traffic load, the surrounding vegetation seems to be able to support bat habitat and foraging areas, and the bridge is also within close vicinity (less than 6 mi (9.6 km) driving) to VT-covered, so it is in a geographic location that is known to have bat populations. Guano deposits were found in summer 2016 situated under an area of deck deterioration, shown in Figure 5-120, which can provide footholds for a potential roost location. The guano deposits observed during mid-season monitoring were removed with additional deposits observed in the same location during subsequent visits to the bridge site both later in the mid-season monitoring and during late season monitoring, indicating this is an active roost location, though bats were never observed actively roosting at this location by the research team during daytime or early evening inspections. The steel girders were treated with a grease coating during the course of the project, seen in Figure 5-119, while not present at earlier visits, seen in Figure 5-117 and Figure 5-118. The treatment of girders did not deter night roosting on the concrete footholds. Both the federal form and the developed supplemental form were completed and are included in Appendix C-15.

Guano samples were collected twice during mid- and once late season monitoring and sent in for species identification. These samples were all identified as MYLU by the pooled sampling laboratory identified, while the individual pellet testing laboratory was unable to identify any bat species. MYLU was identified through acoustic monitoring during all three monitoring seasons, with higher numbers of calls identified. This bridge is also in close proximity to VT-covered, housing a known MYLU colony.

Microphone placement for acoustic monitoring at VT-steel is shown in Figure 5-121. Location A and B are downstream of the bridge. The microphone for location A was attached to a fallen tree branch crossing the waterway. The microphone for location B was attached to a tree branch on the opposite stream bank, positioned at an extreme angle to the bridge. Table 5-49, Table 5-50, and Table 5-51 show acoustic results from monitoring VT-steel throughout early, mid- and late seasons.

Emergence studies were completed at VT-steel in the early, mid-, and late monitoring seasons. No bats were confirmed exiting the bridge. During the early monitoring season emergence study, no bats were seen in the local area, though it was drizzling. Bats were observed in the local area for subsequent emergence studies. The potential night roost location in VT-steel was checked during the mid- and late monitoring season emergence studies as well, during dusk and early evening hours, though no bats were actively observed roosting or emerging from the bridge. Automated analysis of the mid- monitoring season emergence study acoustic data collected classified several bat species present in the local area (SonoBat: MYLU, EPFU, LANO; EchoClass: MYLU, EPFU, LANO, LABO, LACI, MYSO).

Figure 5-117: Steel construction bridge selected in VT (VT-steel)

Figure 5-118: Expansion joint as potential roost site in VT-steel

Figure 5-119: Bird's nest observed at VT-steel

(a)

(b)

Figure 5-120: Spalled and cracking concrete deck creating potential roost location (a) above observed guano deposits (b) in bridge in VT-steel

Location A

Location B

Figure 5-121: VT-steel microphone placement

Table 5-49: Early season automated acoustic monitoring results for VT-steel.

Night 1	2015								07 June 2016, no precipitation, 3 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	2	3				1	2	1
MYSO	X	X	X	X	X	X	X	X	23	30	19	16	38	32	40	39
MYLU	X	X	X	X	X	X	X	X	48	26	62	47	95	83	115	115
PESU	X	X	X	X	X	X	X	X	4	1			1			1
EPFU	X	X	X	X	X	X	X	X	2	2	4	2	4	3	7	4
LANO	X	X	X	X	X	X	X	X	2	1	2	4	2	5	2	5
LABO	X	X	X	X	X	X	X	X	194	218		2	1	4	6	8
LACI	X	X	X	X	X	X	X	X	108	25	167	71	167	71	170	72
MYLE	X	X	X	X	X	X	X	X		1	2		4	2	6	2

Night 2	2015								08 June 2016, 0.06in precipitation, 4 MPH wind, *Location A monitor recorded until 01:05AM, *Location B monitor recorded until 22:52PM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	X	X	X	X	X	X	X	X	6		1		1		2	1
MYSO	X	X	X	X	X	X	X	X	41	8	27		41	1	47	2
MYLU	X	X	X	X	X	X	X	X	2	1	6		9	2	15	1
PESU	X	X	X	X	X	X	X	X					1			
EPFU	X	X	X	X	X	X	X	X				1		1		2
LANO	X	X	X	X	X	X	X	X						1		1
LABO	X	X	X	X	X	X	X	X	129	21				1	3	
LACI	X	X	X	X	X	X	X	X		1	1		1		1	
MYLE	X	X	X	X	X	X	X	X	2	1	2		5	1	4	

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-50: Mid-season automated acoustic monitoring results for VT-steel.

Night 1	31 July 2015 no precipitation, 2 MPH wind								12 July 2016 no precipitation, 2 MPH wind							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	3	/		/		/	1	/	6	7	2	3	2	4	10	7
MYSO	51	/	5	/	8	/	9	/	171	66	50	42	115	83	128	85
MYLU	51	/	79	/	148	/	142	/	67	49	105	88	208	159	215	186
PESU		/		/		/	9	/	3	3	0				1	
EPFU	15	/	9	/	12	/	13	/	36	78	26	43	28	49	38	52
LANO	3	/	3	/	7	/	7	/	21	15	9	20	15	39	16	49
LABO	367	/	10	/	17	/	36	/	564	493	0	2	8	3	4	10
LACI	13	/	8	/	8	/	8	/	106	39	84	59	85	60	94	59
MYLE	3	/		/		/	1	/	1	2	2	3	4	4	5	9

Night 2	01 August 2015 no precipitation, 3 MPH wind *Location A monitor recorded until 01:18AM								13 July 2016 0.11in precipitation, 5 MPH wind *Location A monitor recorded until 03:56AM *Location B monitor recorded until 03:15AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE		/		/		/		/	10	8	1		3	1	2	6
MYSO	67	/	2	/	10	/	10	/	71	56	18	31	52	81	56	69
MYLU	43	/	94	/	211	/	199	/	83	55	100	114	141	203	198	236
PESU		/		/		/	1	/	1		0					
EPFU	19	/	10	/	17	/	13	/	46	42	43	21	46	24	50	33
LANO	1	/		/	6	/	6	/	12	4	11	9	17	11	26	21
LABO	410	/	6	/	12	/	23	/	294	461	2	8	5	14	16	27
LACI	3	/	3	/	3	/	4	/	32	27	31	21	31	23	32	23
MYLE	1	/		/	1	/	3	/		4	1		1	1	3	

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

Table 5-51: Late season automated acoustic monitoring results for VT-steel.

Night 1	18 August 2015 no precipitation, 1 MPH wind								16 August 2016 0.56in precipitation, 2 MPH wind *Location A monitor recorded until 01:05AM *Location B monitor recoded until 00:46AM							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	6	7					2	2	4	3					3	2
MYSO	80	301	8	12	23	42	26	25	60	75	5	13	14	30	12	25
MYLU	95	201	198	305	319	591	399	477	14	12	25	28	51	61	61	68
PESU	3	10	3		3		8	1								2
EPFU	20	43	10	74	13	83	21	113	32	16	24	8	24	10	31	14
LANO	8	105	4	17	23	46	20	56	1	1	1		5	4	4	5
LABO	576	703	40	11	47	23	103	42	161	199	1	1	1	1	14	7
LACI	100	172	18	26	18	27	20	27	18	10	16	21	16	21	17	22
MYLE	5	1	1	1	2	4	5	4	1	1				1		2

Night 2	19 August 2015 no precipitation, 3 MPH wind *Location A monitor recorded until 01:30AM								2016 (X)							
	EchoClass		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*		**EchoClass**		**SonoBat** *Consensus*		**SonoBat** *ByVote*		**SonoBat** *MeanClssn*	
Location	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
MYSE	4	/		/		/	1	/	X	X	X	X	X	X	X	X
MYSO	33	/	4	/	16	/	16	/	X	X	X	X	X	X	X	X
MYLU	46	/	106	/	185	/	207	/	X	X	X	X	X	X	X	X
PESU	1	/	2	/	2	/	5	/	X	X	X	X	X	X	X	X
EPFU	29	/	8	/	11	/	15	/	X	X	X	X	X	X	X	X
LANO	2	/	11	/	15	/	22	/	X	X	X	X	X	X	X	X
LABO	364	/	25	/	35	/	68	/	X	X	X	X	X	X	X	X
LACI	12	/	3	/	3	/	4	/	X	X	X	X	X	X	X	X
MYLE	3	/		/		/	1	/	X	X	X	X	X	X	X	X

Notes: "X"=No data collected, "/"= Data not collected, memory full, or lost due to programming error or stolen equipment, EchoClass output includes first and second prominence. See Section 4.3.2 for further data analysis.

5.7 Bridge Monitoring—Case Studies Summary and Conclusions

Over the summers of 2015 and 2016, eighteen bridges were monitored throughout New England. Fifteen bridges with promising characteristics and roosting potential were selected in summer 2015 from previous rapid visual screenings. In the summer of 2015, three bridges in Massachusetts, two bridges in Maine, three bridges in New Hampshire, four bridges in Rhode Island, three bridges in Vermont, and no bridges in Connecticut were inspected and instrumented with acoustic monitors. This collected data was analyzed and utilized, in addition to new information provided from New England state DOTs, to select bridges to monitor in summer 2016. One of the Massachusetts bridges monitored in 2015 was replaced by a different bridge in Massachusetts that is within the known range of MYSE and is situated by the coast. One of the Rhode Island bridges monitored in 2015 was replaced by a different bridge in Rhode Island that had definitive signs of bats roosting. Additionally, one of the New Hampshire bridges monitored in 2015 with determined low bat roosting potential was removed so a bridge could be added in Connecticut in a location close to known hibernacula. Bridge selection in both summers 2015 and 2016 was intended to provide a variety of bridge materials, construction types, and distribution throughout New England. A summary of monitoring techniques, uses, and consideration are described in Appendix D

The fifteen bridges selected for summer 2016 were monitored in more detail. Full inspections were completed at each bridge within the means of the project scope and equipment. The federal 'Bridge/Structure Assessment Form' (FHWA FRA 2015, U.S. DOT 2016) and the supplemental form developed through the project were completed at each bridge. While the federal form is useful at documenting definitive signs of bats at bridges and provides some general guidance on where to inspect each bridge, the supplemental form developed by the research team provides much more detail on specific characteristics of the bridge and surrounding area that provides useful information in gauging roosting potential at the site. Neither form was time consuming to complete (approximately 10 to 15 minutes added to inspection time), though the developed form does require additional reporting of information. It was found that the federal form was not clear in some of the terms and intent, which was also voiced from some DOT personnel, consultants and others attending the two workshops led by the research team. For instance, the staining indicator was found to be too subjective and results varied based on the background of the inspector. The supplemental form includes much more detail and requires additional photo documentation, which is useful for future investigations. The main purposes of the new supplemental form is to guide the inspector toward bridge components with higher likelihoods of roosting potential, and to document various bridge characteristics for future evaluation of characteristic differences and inventory of bridges used for roosting or not. This information could be used to evaluate possible use by other species determined to be of interest as well. It is expected that cross-training would be very useful to both train structural inspectors on indicators of bat use and educate wildlife experts on bridge components with higher roosting potential. It could also be useful if structural inspectors (ideally with some wildlife training) complete these forms, at least preliminarily, as part of routine structural inspections.

Various equipment was utilized during these detailed inspections. The boroscope was a very useful and inexpensive (less than $250) tool for investigation of crevices and some areas inaccessible for visual observation in bridges. The boroscope could also be used to confirm the sources of staining in some cases. The boroscope arm used did not articulate and was of limited length, so could not examine deep or winding crevices. The monocular was very useful for inspecting line of sight crevices, such as a clean joint between precast girders along the entire span of a bridge, or identifying locations worthy of further inspection. It was also useful for visual inspection of inaccessible areas, such as the exterior of expansion joints above piers. The thermal camera was found to be most useful at observing bats in the evening and during emergence studies. Since bats tend to congregate in the microclimate of a roost location and since bridge components tend to be thick with highly insulating thermal properties, the thermal camera was not useful at identifying roost locations within a bridge. The thermal camera may be able to capture images of bats identified in a known roost location, especially in locations observed through visual inspection, but the thermal camera was not able to identify these roost locations in an entire structure without previous knowledge.

Each bridge selected for monitoring in summer 2015 and 2016 was instrumented with acoustic monitors. Collected data was analyzed using the automated acoustic bat identification software programs EchoClass (v. 3.1) and SonoBat (v. 3.2.2 NE). Acoustic monitoring does not confirm bats were roosting in the bridges, but does give a sense of the species variety and abundance in the local area. Microphone placement and weather data for nights of deployment was investigated to see if placement or weather influenced program classification. Microphone locations expected to be more likely to record white noise (faced moving water or heavy vegetation) and weather records indicating precipitation or higher wind speeds was analyzed compared to the number of files recorded by the acoustic monitors, scrubbed as white noise from the programs, and classified as potential bat calls by the programs. No consistent trends could be identified. Any calls classified as MYSE during summer 2015 or 2016 monitoring by any classification type of either program were sent to DOT “D” for manual vetting. Of the 569 calls classified as MYSE by either program, 78 were identified as likely MYSE by DOT “D” through manual vetting. Further analysis was presented in Section 4.3.

Guano deposits, or potential guano deposits were collected at seven of the eighteen bridges monitored and sent in for species identification by two laboratories. One laboratory performed pooled testing, which can test larger guano samples and provide results on an array of species present, and the second laboratory performed individual pellet testing, which provides species results for the single sample. Bat presence was confirmed at four of these bridges through this monitoring technique, identifying MYLE, EPFU, and MYLU. Mouse and toad were also identified through samples the research team assumed were non-bat, but collected for verification. Bat species identified through guano testing were also classified through acoustic monitoring during all monitoring seasons. Overall, the pooled sampling laboratory provided more detailed results (species identification from ten of the thirteen collected samples), compared to the individual pellet testing laboratory (species identification from one of the twelve collected samples). A total of twenty samples were sent to the pooled testing laboratory; thirteen samples were sent from these seven project bridges, and seven samples were sent from additional bridge sites with guano samples provided by state DOT personnel. The pooled testing laboratory was able to identify species from fifteen samples (seventy five percent success rate in species identification). A total of thirty two samples were sent to the individual pellet testing; twelve samples were sent from these seven project bridges, and twenty were sent from additional New England sites with guano provided by state Fish and Wildlife personnel. The individual pellet testing laboratory was able to identify species from thirteen samples (forty one percent success rate in species identification), which the laboratory noted was a similar success rate compared to other bat guano projects.

Another monitoring technique used in further monitoring of these bridges in 2016 was emergence studies. This involved members of the research team watching the bridges from dusk through nightfall to observe any bats emerging or roosting in the bridge. Bats were actively observed emerging at two bridge locations. Two additional bridges had potential bat roosting activity, though it was not confirmed. During the mid- and late monitoring season emergence studies, hand-held acoustic monitors were used to aid in identifying bats observed flying in the local areas. While there were some noted discrepancies between the number of bats observed by the research team and classified through acoustical analyses, the timing of calls suggested a fair amount of consistency in species identified when following a specific bat with the acoustic monitor. The thermal camera was also used during emergence studies, which was incredibly useful in observing bat activity surrounding the bridges. Emergence studies were most useful when the thermal camera and hand-held acoustic monitor were used together.

6.0 Summary and Conclusions

Bat populations are declining globally due to several factors, though White-Nose Syndrome (WNS) is attributed to having the greatest impact on New England bat species' population declines. The northern long-eared bat (*Myotis septentrionalis*) (MYSE) has experienced severe population losses, causing the species to be listed as federally threatened under the Endangered Species Act in 38 states in 2015 (Federal Register 2015). This species is also currently listed as state endangered in Vermont and Massachusetts. While MYSE has been the primary focus in the current project, four additional species have been of interest: the Indiana bat (*Myotis sodalis*) (MYSO); the little brown bat (*Myotis lucifugus*) (MYLU); the tricolored bat (*Perimyotis subflavus*) (PESU), formerly known as the eastern pipistrelle (*Pipistrellus subflavus*); and the big brown bat (*Eptesicus fuscus*) (EPFU). MYSO has been a federally endangered species since 1967. MYLU and PESU are also experiencing significant population declines attributed to WNS. They are being evaluated by the U.S. Fish and Wildlife Service (USFWS) for listing under the Endangered Species Act. The Eastern Small Footed Bat (*Myotis leibii*) (MYLE) was initially excluded from this project, but is also of interest.

Bats are known and documented to use bridges for a variety of roosting activities throughout the United States and abroad, through little has been known about bats' use of New England bridges as it has not been researched, documented or generally understood. Burdens have been placed on State Transportation Agencies, as well as the U.S. Fish and Wildlife Service (USFWS) and State Fish and Wildlife Departments, to ensure bridge construction and maintenance activities do not interfere with conservation efforts for protected species. The objective of the current project was to provide guidance for determining the likely presence of MYSE roosting in New England bridges through developing a screening tool and evaluating regional bridge characteristics and inspection methods.

An extensive literature review related to the roosting behaviors and life cycles of bats was completed along with consultation with regional and national experts. A summary of general findings as well as those specific to the species of interest were reported. Bats can use bridges for diurnal/day-, nocturnal/night-, and maternity roosts, with the latter being the most vulnerable to disturbances. The literature review suggested that concrete was the most preferable material, followed by wood components, and suggested steel components were less likely to be used as roost locations. Bridges can potentially be categorically considered as having lower roosting potential based on construction style, materials, and details, though appropriately sized crevices may be created due to deterioration with age. Crevices introduced through construction details or deterioration that are 0.125 to 1.5 in (0.32 to 3.81 cm) wide and cave-like environments are ideal confined roost locations, while the sides of girders and underside of deck are often used for open roosts. Masonry work on bridges or stone façades when grout is deteriorated or stones are non-grouted has high potential to create suitable bat roosting locations. Pipes can also create appropriate crevices to provide roosting locations, especially when insulation has deteriorated. Bridges near waterways, with minimal human disturbance, and the presence of birds and/or Mud-dauber wasps' nests were noted as indicative of conditions also conducive to bat roosting. Bridge characteristics that are less likely to be used as roosts include short abutments allowing easier predator access, bridges with low clearances, bridges with only smooth surfaces, bridges without suitable surrounding vegetation, and bridges with signs of recent disturbance (such as major repairs or treatments). Lack of appropriately sized crevices, either due to construction or deterioration, will prohibit confined roosting, but may still allow for potential open and night-roost locations.

Based on the background information collected, field work was completed during summers (May through August) 2015 and 2016. Since there was only one known bridge bat roost in New England at project initiation, field work first consisted of rapid visual screenings of 191 bridges throughout New England to develop general background knowledge of New England bridges, then selection and further study of eighteen bridges. Bridges were selected from three regions in New England: southern New England (CT and RI); central New England (MA, southern VT, and southern NH); and northern New England (northern VT, northern NH, and ME). Fifteen bridges were selected for full monitoring in summer 2015: three in Massachusetts (two concrete and one steel construction), two in Maine (one concrete and one steel and wood construction), three in New Hampshire (two steel and one stone and concrete construction), four in Rhode Island (two steel and two concrete), three in Vermont (one wood, one steel, and one concrete), and none in Connecticut. Based on results from summer 2015 and additional input from DOTs, three bridges from summer 2015 monitoring were replaced for summer 2016: One Massachusetts bridge was replaced by a coastal bridge within known range of MYSE; one of the Rhode Island bridges was replaced by a bridge with potential signs of bat roosting noted by RI DOT; one New Hampshire bridge was removed as it was determined to have low probability of bat use based on data from summer 2015 and replaced by the addition of one Connecticut bridge in a location known to be close to hibernacula. Further study consisted of full visual inspections and documentation, completion of inspection forms (federal 'Bridge/Structure Assessment Form' (FHWA FRA 2015) and supplemental form developed through the project), acoustic monitoring, infrared monitoring and emergence studies, and collection and testing of guano samples. Equipment used during visual inspections included flashlights, waders, a ladder, a monocular, borescope, thermal camera, and camera. The boroscope allowed inspection of otherwise inaccessible crevices and could be used to confirm the sources of some staining. The thermal camera was most useful for capturing images of bats in open roost locations and observing bat activity in the evenings. Emergence studies were completed at all bridges monitored in summer of 2016, and involved observing bridges from dusk through nightfall to determine if any bats emerged from the bridge. The thermal camera was used to observe bat activity, and could pinpoint the exact location of emergence. A summary of monitoring techniques, uses, and consideration are described in Appendix D

Guano, potential guano, and feces from other species was collected at several sites, and samples were sent in for DNA sequencing to identify the species. Additional samples provided by state DOTs or Fish and Wildlife Departments were also tested. Two laboratories were hired; one performed pooled sampling which allows for up to 200 fecal pellets to be included in a sample, and the second performed individual pellet testing. Overall, the pooled sampling laboratory provided more detailed results compared to the individual pellet testing laboratory. The pooled sampling laboratory was able to provide a seventy five percent success rate in species identification for all submitted samples (species identification for ten of the thirteen project samples). The individual pellet testing laboratory was able to provide a forty one percent success rate in species identification for all submitted samples (species identification for one of the twelve project samples), and noted a similar success rate for this project compared to other bat guano projects. Species identified through guano testing were also classified through acoustic monitoring during all monitoring seasons. Guano testing confirmed bat presence at four of the eighteen monitored bridges.

Based on the eighteen bridges monitored and additional findings from New England DOTs during the course of this project, there are currently fifteen bridges in New England that are either confirmed or suspected bat roosts. Thirteen bridges are now documented as bat roosts in New England through either documentation of bat, guano deposits, and/or bat staining observed at the bridge site. These bridge types include covered wooden, steel beam, and concrete beam bridges for both roadways and railroads. Eleven were identified by the state DOTs or Fish and Wildlife Departments, with two of these being included in the bridges monitored on the project. The research team identified two bridges that were monitored on the project. One of the confirmed bridge roosts is a day- and maternity roost, with a second highly likely to be day- and maternity roost as well. Three of the confirmed roost bridges are utilized as night-roosts. Two additional bridges were identified through the project as highly suspected of being bat roosts and were included in the bridges monitored in the project. Therefore, roosting is confirmed or suspected at six of the eighteen monitored bridges.

Acoustic monitoring was completed at each bridge to determine bat presence in the local area around bridges during the following seasons: early season, anytime from late May to mid-June (post-emergence from hibernation pre-maternity roosting); mid-season, anytime from early to mid-July (during maternity roosting); and late season, anytime from early to mid-August (post-maternity season pre-hibernation). Bridges in summer 2015 were only monitored in mid- and late seasons due to delays in project initiation, but bridges in summer 2016 were monitored all three seasons. Acoustic monitoring was also used the mid- and late season emergence studies in summer 2016 to aid in locating bats in the local area.

Acoustic monitoring can be a valuable monitoring technique to detecting patterns of bat activity at a bridge site, and for identifying particular species likely present in the area, though it does not confirm bats are roosting in the bridge. There are two types of automated acoustic bat identification software programs for bat call species identification; zero-cross and full-spectrum. Zero-cross programs are currently the only automated acoustic bat identification software programs approved by the USFWS, while full-spectrum programs can allow for more detailed analysis of data. However, automated programs alone are not reliable to determine bat species. These must be further evaluated through expert manual vetting. Analysis of the timing of calls can provide insight into the roosting potential of bridges, with calls recorded close to sunset indicating that the species was roosting close to the monitoring location, and may warrant further investigation. In addition to the acoustical analysis completed by the research team, consultants were contracted to use additional automated acoustic bat identification software programs to evaluate differences between results of automated acoustic bat identification software programs. The current project confirmed previously reported non-agreement between automated acoustic bat identification software programs and the need for expertise in further evaluating call data and manual vetting. Final results must still be evaluated in terms of high or low likelihood of species presence. Given the current information gathered by the research team, it may be more productive to concentrate resources on more detailed visual inspection of bridges to confirm bat presence, roosting, and roosting potential at bridge sites rather than relying heavily on acoustical analyses.

Data collected for this research, as well as that collected by DOTs and consultants as part of other bridge inspection projects has other benefits. Historic data that infer a high level of confidence in species ID through automated programs could be valuable for mapping species distribution, relative abundance, and habitat associations over time. This could have significant management implications, particularly if the raw data is retained so that future advances and improvements in automated species identification become available to potentially reanalyze the data.

Expert manual vetting involves investigating specific characteristics of individual calls (such as the frequency, duration, upper slope, lower slope and bandwidth), other characteristics (such as calls per second and call type) and signs of call quality (such as echoes, multiple bats and microphone effects) to determine the species, as different species have distinguishing call features that allow for classification. Select manual vetting of any calls identified as MYSE through software was completed by multiple consultants and a regional DOT biologist with expertise in manual vetting and consultants. Manual vetting using full spectrum viewers tended to identify fewer calls as MYSE and differences were noted between manual vetting results depending on the certainty that the consultant felt was warranted to identify a call. Some consultants felt that identification of a species required certainty based on the call file alone, whereas others felt that the purpose of vetting was to identify sites that require further study.

The "Programmatic Biological Assessment for Transportation Projects in the Range of the Indiana Bat and Northern Long-Eared Bat" report (U.S. DOT 2016) includes a federal 'Bridge/Structure Assessment Form', designed to determine the presence or absence of bats at a bridge. This form is required when working under the Programmatic Agreement. Currently this applies to MYSO (federally endangered) habitat, but MYSE (federally threatened) is subject to Section 4(d) of the ESA which states that "While bridge and culvert use for the species has been documented, it is relatively uncommon compared to tree or other types of roost sites…and, therefore, did not warrant specific provisions in this final rule." (Federal Register 2015). However, if MYSE populations continue to decline and the species is listed as federally endangered in the future, the species will no longer be subject to such 4(d) exemptions. The federal form may also be required by some states when species are state endangered, and may also be used informally for documentation of non-mandatory bridge evaluations.

This form is a useful tool to document definitive signs of bat presence at a bridge site. Four main bat indicators are used in the federal form, 'visual,' 'sound,' 'droppings,' and 'staining.' According to the current regulations, presence of any indicator constitutes further consultation with the USFWS. Several key aspects of the federal form were identified as problematic for the observation of bats in a post-WNS, New England environment. The current regulations mandate each federal 'Bridge/Structure Assessment Form' to be completed a minimum of one year prior to construction which may be problematic for contracting of work and may not properly evaluate roosting potential at the time of year when the work will be completed. Maternity, day-, and night-roosting will all create signs of bat presence, though each type of roosting holds different significance to bat colonies and bat species, and therefore different significance for conservation measures. The federal form/report does not provide guidance on differences in observations of maternity versus day- versus night-roosting, and more guidance is needed from the USFWS. The federal form is subjective to the background of the inspector and their level of training in identifying bat indicators, and does not specifically provide guidance on what qualifications an inspector must have. This may be problematic as guano can be easily mis-identified without training. Photos provided as guidance in the federal report are of species other than MYSE and MYSO and are of larger colonies than would appear in New England, which leave more obvious signs of presence including larger guano deposits and higher levels of staining that would not be indicative of smaller colonies. The provided photos therefore may bias results to identifying larger colonies and roosts than would appear in New England, and do not fully represent the potential level of difficulty and effort required to observe smaller guano deposits in New England. The 'staining' indicator was found to be particularly problematic. Corrosion and rusting of steel elements, bridge deterioration, and related staining are common in New England bridges slated for maintenance or construction work. Debris and rust staining also can be very similar in appearance to bat staining, making it extremely difficult to assess whether bat staining could also be present at a site, but masked by structural staining. It is not clear whether marking 'staining' on the federal form is intended only when staining is confirmed to be caused by bats, or also when it is of unknown causation that could include bats, yielding different results from different inspectors. Staining known to be from non-bat sources is not specifically noted to be disregarded.

This research team developed a supplemental survey that serves two purposes: to guide the inspector toward characteristics of the bridge that are most likely to be used as roosts; and to provide historical documentation of bridge characteristics that can be used to compare wildlife use of bridges, specifically focused on bats. Several additional structural and surrounding area characteristics are included with documentation required. The supplemental survey is intended to be used in conjunction with the federal form, designed to determine presence or likely absence of bats at a bridge, and aims to clarify any confusion with the federal form for New England bridges. The form was found add minimally to inspection time. Highlighting bridge locations that are more likely to be used for roosting is intended to alert inspectors who may not be bat biologists to focus on areas where signs of bats are likely and prioritize their surveys. Recording historical documentation of bridge characteristics through the use of this standardized form would allow for a future analysis of data collected by various DOTs, consultants, state and federal biologists over an extended time period and could be useful for discovering correlations among habitat type, structure type, roost type, bat species use and other categories.

The merits and drawbacks of current methods of inspection and evaluation of bridges as potential roost sites were evaluated through this project. The research team has provided guidance on general features and characteristics of bridges, field inspection methods, documentation forms, and the use of technologies such as acoustic and infrared monitoring to evaluate bridges. The project has resulted in the documentation of additional bridges used for bat roosting, a supplemental inspection form for evaluation of bridges in New England, and documentation of results from technologies such as automated acoustic bat identification software programs and DNA analysis through guano testing. This information is intended to provide guidance to DOT personnel to determine best practices for evaluating their bridge inventory, to understand data and techniques used by consultants, and to prepare strategies for the possibility of further listing or upgrading of bat species by USFWS.

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Appendix A Existing Survey Protocol

Appendix A-1 U.S. DOT (2016)

Bridge/Structure Assessment Form

This form will be completed and submitted to the District Environmental Manager by the Contractor prior to conducting any work below the deck surface either from the underside, from activities above that bore down to the underside, or that could impact expansion joints, from deck removal on bridges, or from structure demolish. Each bridge/structure to be worked on must have a current bridge inspection. Any bridge/structure suspected of providing habitat for any species of bat will be removed from work schedules until such time that the DOT has obtained clearance from the US Fish and Wildlife Service, if required. Additional studies may be undertaken by the DOT to determine what species may be utilizing structures prior to allowing any work to proceed.

DOT Project #	**Water Body**	**Date/Time of Inspection**

Route:	**County:**	**Federal Structure ID:**	**Bat Indicators** Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	**Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)**

Areas Inspected (Check all that apply)

Bridges		**Culverts/Other Structures**		**Summary Info (circle all that apply)**			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep		**Crevices, rough surfaces or imperfections in concrete**		**Human disturbance or traffic under bridge/in culvert or at the structure**	High	Low	None

All crevices >12" deep & not sealed		**Spaces between walls, ceiling joists**		**Possible corridors for netting**	None/poor	Marginal	Excellent
All guardrails				**Evidence of bats using bird nests, if present?**	Yes	No	
All expansion joints							
Spaces between concrete end walls and the bridge deck							
Vertical surfaces on concrete I-beams							

Assessment Conducted By: ___________________________ **Signature(s):** ____
District Environmental Use Only: Date Received by District Environmental Manager: _____________

DOT Bat Assessment Form Instructions

1. Assessments must be completed a minimum of 1 year prior to conducting any work below the deck surface on all bridges that meet the physical characteristics described in the Programmatic Consultation, regardless of whether assessments have been conducted in the past. **Due to the transitory nature of bat use, a negative result in one year does not guarantee that bats will not use that structure in subsequent years.**
2. Any bridge/structure suspected of providing habitat for any species of bat will be removed from work schedules until such time that the DOT has obtained clearance from the USFWS, if required. Additional studies may be undertaken by the DOT to determine what species may be utilizing each structure identified as supporting bats prior to allowing any work to proceed.
3. Estimates of numbers of bats observed should be place in the Notes column.
4. Any questions should be directed to the District Environmental Manager.

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(U.S. DOT 2016)

APPENDIX C: Bridge/Structure Inspection Form

Bridge Inspection Form

This form will be completed and submitted to the District Environmental Manager by the Contractor prior to conducting any work below the deck surface either from the underside, from activities above that bore down to the underside, or that could impact expansion joints, from deck removal on bridges, or from structure demolish. Each bridge/structure to be worked on must have a current bridge inspection. Any bridge/structure suspected of providing habitat for any species of bat will be removed from work schedules until such time that the DOT has obtained clearance from the US Fish and Wildlife Service, if required. Additional studies may be undertaken by the DOT to determine what species may be utilizing structures prior to allowing any work to proceed.

DOT Project #	Water Body	Date/Time of Inspection

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	Notes: (e.g.,number & species of bats, if known)

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep		Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High	Low	None
All crevices >12" deep & not sealed		Spaces between walls, ceiling joists		Possible corridors for netting	None/poor	Marginal	excellent
All guardrails				Evidence of bats using bird nests, if present?	Yes	No	
All expansion joints							

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Spaces between concrete end walls and the bridge deck								
Vertical surfaces on concrete I-beams								

Inspection Conducted By: ______________________________ **Signature(s):**

____

District Environmental Use Only: Date Received by District Environmental Manager: _____________

DOT Bat Inspection Form Instructions

1. Inventories must be completed prior to conducting any work below the deck surface on all bridges that meet the physical characteristics described in the Programmatic Informal Consultation, regardless of whether inventories have been conducted in the past. **Due to the transitory nature of bat use, a negative result in one year does not guarantee that bats will not use that structure in subsequent years.**
2. Contractors must complete this form no more than seven (7) business days prior to initiating work at each bridge/structure location. Legible copies of this document must be provided to the District Environmental Manager within two (2) business days of completing the inspection. Failure to submit this information will result in that structure being removed from the planned work schedule.
3. Any bridge/structure suspected of providing habitat for any species of bat will be removed from work schedules until such time that the DOT has obtained clearance from the USFWS, if required. Additional studies may be undertaken by the DOT to determine what species may be utilizing each structure identified as supporting bats prior to allowing any work to proceed.
4. Estimates of numbers of bats observed should be place in the Notes column.
5. Any questions should be directed to the District Environmental Manager.

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(FHWA FRA 2015)

Revised Federal Form

APPENDIX C: Bridge/Structure Assessment Form

Bridge Assessment Form

This form will be completed and submitted to the District Environmental Manager by the Contractor prior to conducting any work below the deck surface either from the underside, from activities above that bore down to the underside, or that could impact expansion joints, from deck removal on bridges, or from structure demolish. Each bridge/structure to be worked on must have a current bridge inspection. Any bridge/structure suspected of providing habitat for any species of bat will be removed from work schedules until such time that the DOT has obtained clearance from the US Fish and Wildlife Service, if required. Additional studies may be undertaken by the DOT to determine what species may be utilizing structures prior to allowing any work to proceed.

DOT Project #	Water Body	Date/Time of Inspection

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep		Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High	Low	None
All crevices >12" deep & not sealed		Spaces between walls, ceiling joists		Possible corridors for netting	None/poor	Marginal	excellent
All guardrails				Evidence of bats using bird nests, if present?	Yes	No	
All expansion joints							

Spaces between concrete end walls and the bridge deck							
Vertical surfaces on concrete I-beams							

Assessment Conducted By: ______________________________ **Signature(s):**

____

District Environmental Use Only: Date Received by District Environmental Manager: _____________

DOT Bat Assessment Form Instructions

1. Assessments must be completed a minimum of 1 year prior to conducting any work below the deck surface on all bridges that meet the physical characteristics described in the Programmatic Informal Consultation, regardless of whether assessments have been conducted in the past. **Due to the transitory nature of bat use, a negative result in one year does not guarantee that bats will not use that structure in subsequent years.**
2. Legible copies of this document must be provided to the District Environmental Manager within two (2) business days of completing the assessment. Failure to submit this information will result in that structure being removed from the planned work schedule.
3. Any bridge/structure suspected of providing habitat for any species of bat will be removed from work schedules until such time that the DOT has obtained clearance from the USFWS, if required. Additional studies may be undertaken by the DOT to determine what species may be utilizing each structure identified as supporting bats prior to allowing any work to proceed.
4. Estimates of numbers of bats observed should be place in the Notes column.
5. Any questions should be directed to the District Environmental Manager.

Updated federal form simplified for project use

Bridge Assessment Form

DOT Project #	Water Body	Date/Time of Inspection

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	**Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)**

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25” wide & ≥4” deep		Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High	Low	None
All crevices >12” deep & not sealed		Spaces between walls, ceiling joists		Possible corridors for netting	None/poor	Marginal	excellent
All guardrails				Evidence of bats using bird nests, if present?	Yes	No	
All expansion joints							
Spaces between concrete end walls and the bridge deck							
Vertical surfaces on concrete I-beams							

Assessment Conducted By: ______________________________ **Signature(s):** ____

District Environmental Use Only: Date Received by District Environmental Manager: ____________

Appendix A-3 Keeley and Tuttle (1999)

Appendix II:
Survey Forms

THE FOLLOWING FORMS may prove useful in evaluating highway structures for actual or potential bat use. Some field experience may be necessary prior to initiating the surveys to develop familiarity with potential roost locations within structural designs. June is the best time of the year to conduct surveys, since nursery colonies are most detectable when rearing young.

Location

Sample #	Date	State	County	Highway type: Interstate	Highway type: U.S. Hwy.	Highway type: State	Highway type: County	Latitude	Longitude	Altitude	Ecological region
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
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27											
28											
29											
30											

Bats / Roost Types

Sample #	Bats present yes/no	Species	# of bats	# of species	Day roost yes/no	Nursery roost yes/no	Night roost intensity	# of roosts	Roost type: crevice	Roost type: plugged drain	Roost type: swallow nests	Roost type: imperfection or other
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
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21												
22												
23												
24												
25												
26												
27												
28												
29												
30												

Bridge Night Roost Index:

0 No sign of droppings or urine stains.

1 Small amount of such signs in only one location.

2 Small urine stains and scattered droppings in several locations.

3 Moderate dropping accumulations. Urine stains obvious within the bridge.

4 Large dropping accumulations. Fresh urine stains obvious and widespread.

5 Dropping accumulations several inches thick in several locations. Roosting evident throughout structure. Fresh urine stains in all optimal locations.

Structure Design

Sample #	Parallel box beam	Pre-stressed girder	Cast in place	Steel I-beam	Flat slab	Other: specify	Concrete box culvert: # of barrels and height	Concrete round culverts: diameter	Metal culvert: diameter	Ideal* crevices present yes/no
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
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22										
23										
24										
25										
26										
27										
28										
29										
30										

* Evidence of storm-water staining along the length of the crevice indicates that it is not sealed and should not be considered as an ideal roost.

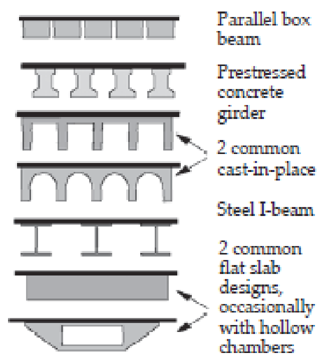

Figure 27. Cross-sections of Common Bridge Designs

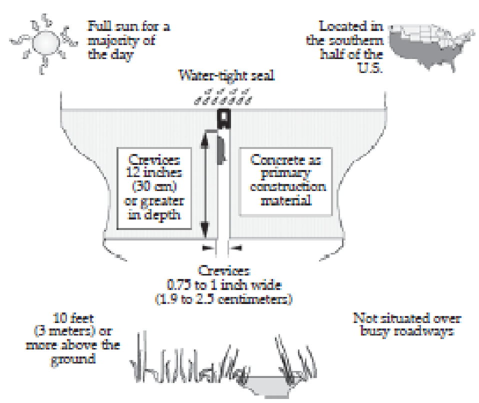

Figure 28. Ideal Highway Structure Roost Characteristics

Roost Substrate and Dimensions

Sample #	Roost Height Av.	Height Max.	Height Min.	Crevice Roost Width Av.	Crevice Width Max.	Crevice Width Min.	Crevice Depth Av.	Crevice Depth Max.	Crevice Depth Min.	Crevice Length	Roost Surface Concrete	Roost Surface Metal	Roost Surface Other
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
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26													
27													
28													
29													
30													

Surrounding Habitat

Sample #	Residential	Agriculture	Commercial	Woodland	Grassland	Ranching	Riparian	Mixed
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
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29								
30								

Conditions Beneath the Roost

Sample #	Bare ground	Open vegetation*	Closed vegetation†	Flowing water	Standing water	4-lane + highway	2-lane highway	Dirt road	Railroad	Concrete
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
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26										
27										
28										
29										
30										

* Vegetation not blocking flight path within 10' of bridge underside or more than one entrance of a culvert.

† Vegetation interfering with bat access to potential roosts, either blocking bridge underside or both ends of culverts.

(Keeley and Tuttle 1999)

Appendix A-4 Smith and Stevenson (2014)

1.1 *Standard survey* †

A standard survey to establish presence/absence, assess probability or severity of impact(s), and acquire information to recommend mitigation and/or compensation measures should include:

1.1.1 Date

1.1.2 Site description (includes both location and structure information)

1.1.3 Proposed activity (demolition, repair, maintenance)

1.1.4 If bats are presently, or have been, within the structure

1.1.4.1 Inspection of existing infrastructure

1.1.4.1.1 Structural fissures (cracked or spalled concrete, damaged or split beams, split or damaged timber railings, et cetera)

1.1.4.1.2 Crevices (expansion joints, space between parallel beams, spaces above supports piers, et cetera)

1.1.2.1.3 Alternative structures (drainage pipes, bolt cavities, open sections between support beams, swallow nests, et cetera). Nests, when abandoned or unoccupied, provide ancillary roost habitat for bats worldwide. Occupancy rates can approach 39 percent. Bats that exploit *Hirundo rustica* nests lay nearly prostrate within the nest cup and those within *Petrochelidon pyrrhonota* nests (gourd-shaped enclosed structures) are typically concealed and undetectable without a borescope or fiberscope.

1.1.4.2 Cursory inspection of natural structures and trees in proposed activity "footprint." The presence of bats in trees or rock crevices can be difficult without external signs (presence of guano, sounds of bats). Occupancy can be established by examination of suitable crevices, cavities, limb fractures, and loose bark. Specialist equipment (e.g., rope access, borescope) may be required in certain circumstances (advanced survey).

1.1.5 Species present

1.1.6 Roost information including type (e.g., diurnal, nocturnal), location, characteristics

1.1.7 Intensity (e.g., number of bats, time and duration of use)

1.1.8 Photographs to support written documentation

1.2 *Advanced survey*

Most sites will warrant standard surveys. However, where site-specific conditions or other findings suggest the potential for substantial adverse impacts to bats, advanced surveys designed to further evaluate specific concerns may be recommended. Thus, survey effort should be proportionate to survey purpose (i.e., to obtain adequate results for specific objectives) and may further identify:

1.2.1 Information from standard survey,

1.2.2 Species whose distribution includes site (identify potential for species of conservation concern),

1.2.3 Any features of particular ecological or conservation significance,

1.2.4 Specific roost sites (confirmed and potential) that occur in close proximity to site; detailed inspection of potential tree roosts identified by standard survey,

1.2.5 Any watercourses, flyways, crossing points, or foraging areas that may be impacted by construction and clearance activities,

1.2.6 Potential site-specific mitigation, compensation or enhancement measures,

1.2.7 Colony type and sex. Sexual segregation does occur within habitats of various species. Therefore, the occupation of habitats by males/females should be identified. This may become important (e.g., impact the selection of trees for felling) because a site that sustains females would be more significant than one that support males,

1.2.8 Identify time of survey with respect to biological season. Bat activity may differ between certain periods due to variations in availability of prey, recruitment of juveniles, or the availability of suitable roost sites. For example, summer roosts may not provide the appropriate microclimates necessary for hibernation. Therefore, a survey done outside the breeding season may impart a false impression of the site's importance,

1.2.9 Bat activity surveys. Appropriate during warmer months (April - September) and at dusk emergence and/or dawn re-entry, and may include documentation of active foraging and commuting habitats. emergence times and locations, intensity (estimate of population), species assessment via manual/automated bat detectors, and camera/video equipment (FLIR, infrared).

(Smith and Stevenson 2014)

Appendix A-5 Cervone (2015)

Bridge Inspection Checklist

If bridge inspections are completed in the future, the following check-off list is offered for consideration:

1.	Construction Material	Is bridge concrete or wooden?	Yes	No
2.	Age	Is bridge greater than 50 years old?	Yes	No
3.	Setting	Is bridge in a rural setting?	Yes	No
4.	River/Floodplain	Is bridge over a river in a floodplain?	Yes	No
5.	Darkness	Is it dark under the bridge?	Yes	No
6.	Dryness	Is it dry under the bridge?	Yes	No
7.	Structural Integrity	Is underside weathered with cracks?	Yes	No
8.	Confined Spaces	Cave-Like Environment?	Yes	No
9.	Visual	Any bats seen?	Yes	No
10.	Sound	Any bats heard?	Yes	No
11.	Droppings (Guano)	Any guano on ground or walls?	Yes	No
12.	Smell	Any smell of urine?	Yes	No
13.	Staining	Any staining on walls/beams?	Yes	No
14.	Expansion Joints	Any bats seen?	Yes	No
15.	Injured/dead bats	Any injured or dead bats?	Yes	No

For more details, please see specific descriptions for each as located at the end of this documentation.

(Cervone 2015)

Appendix B Developed Survey Form

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes* Bridge ID: ____

Date of Inspection: ____ Name of Inspector: ____

☐ Overview photos of bridge noting direction

1A) Surrounding Area

◯ Tree canopy at/near bridge *See Appendix photo 1.1*
◯ Dense trees in surrounding area *See Appendix photo 1.2*
◯ Minimal tree cover *See Appendix photo 1.3*

1B) Population

◯ Rural ◯ Suburban ◯ Urban

1C) Features Intersected

◯ Waterway
- ○ Stagnant
- ○ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

◯ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

◯ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

◯ High Disturbance *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
◯ Medium Disturbance *Minimal evidence of human disturbance below bridge*
◯ Low Disturbance *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

◯ High ◯ Medium ◯ Low ◯ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

◯ High ◯ Medium ◯ Low ◯ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

◯ High Access *Abutment <4 feet from ground* *See Appendix photo 1.4*
◯ Medium Access
◯ Low Access *Abutment >10 feet from ground* *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☐ Visual
- ○ Live ____ *number seen*
- ○ Dead ____ *number seen*
- ☐ *Photo documentation*

☐ Guano (*see Appendix photo 1.6*)
- ☐ *Photo documentation*

☐ Staining definitively from bats *More detailed in IV Staining*
- ☐ *Photo documentation*

☐ Audible ☐ Odor ☐ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

Page 1 of 7

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☐ ☐ Truss ☐ I-beam ☐ Box	☐ ☐ Slab ☐ Beam ☐ Box ☐ Cast in place ☐ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	○	○	○
Structure/Girder	○	○	○
Abutment	○	○	○
Expansion Joints ☐ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
	○	○	○
	○	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*
☐ Recessed Area *See Appendix photo 3.2*
☐ Spaces between beams *See Appendix photo 3.3*
☐ Other: *See Appendix photo 3.4*

Due to Deterioration

☐ < 3/8 inch *See Appendix photo 3.5*
☐ 3/8 inch to 2 inches *See Appendix photo 3.6*
☐ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☐ Staining observed in structure ☐ *Photo documentation*

Causation

☐ Staining definitively from structural causation *See Appendix photo 4.1*
☐ Staining from bats *See Appendix photo 4.2*
☐ Staining from birds *See Appendix photo 4.3*
☐ Staining unknown causation[a] *See Appendix photo 4.4*

[a]If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats

Page 2 of 7

V. APPENDIX—Photo Descriptions

I. BRIDGE SUMMARY

1.1

1.2

1.3

1.4

1.5

1.6

Above photo courtesy of Sarah Boyden, MaineDOT Environmental Office

II. CONSTRUCTION

Deck:

Above photo courtesy of Gill Engineering Associates

Structure Type:

Above photo courtesy of Gill Engineering Associates

Above photo courtesy of Gill Engineering Associates

Abutment:

Above photo courtesy of Sarah Boyden, MaineDOT Environmental Office

III. CONDITION

3.1

3.2

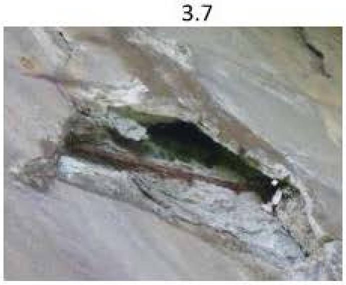
3.3

3.4

3.5

3.6

3.7



IV. STAINING

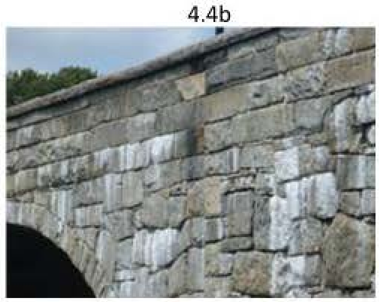
4.1

4.2

4.3

4.4a

4.4b



Appendix C Bridge Monitoring—Case Studies Forms Filled Out

Appendix C-1 CT-precast_concrete Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
CT-precast_concrete	Butternut River	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	**Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)**
						N*	Staining observed, appears to be structural and not from bats

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	**Crevices, rough surfaces or imperfections in concrete**		**Human disturbance or traffic under bridge/in culvert or at the structure**	High	Low X	None
All crevices >12" deep & not sealed	X	**Spaces between walls, ceiling joists**		**Possible corridors for netting**	None/poor X	Marginal	excellent
All guardrails	X			**Evidence of bats using bird nests, if present?**	Yes	No X	
All expansion joints	N/A			Birds' nests observed			
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: UMass Research Team **Signature(s):** ______________________

District Environmental Use Only: Date Received by District Environmental Manager: ______________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes*

Bridge ID: CT-precast_concrete

Date of Inspection: Summer 2016

Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

○ Tree canopy at/near bridge *See Appendix photo 1.1*
◉ Dense trees in surrounding area *See Appendix photo 1.2*
○ Minimal tree cover *See Appendix photo 1.3*

1B) Population

○ Rural
◉ Suburban
○ Urban

1C) Features Intersected

◉ Waterway
- ○ Stagnant
- ◉ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

○ High Disturbance *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
◉ Medium Disturbance *Minimal evidence of human disturbance below bridge*
○ Low Disturbance *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ◉ Medium ○ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

○ High ○ Medium ○ Low ◉ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

◉ High Access *Abutment <4 feet from ground* *See Appendix photo 1.4*
○ Medium Access
○ Low Access *Abutment >10 feet from ground* *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☐ Visual
- ○ Live ___ *number seen*
- ○ Dead ___ *number seen*
- ☐ *Photo documentation*

☐ Guano (*see Appendix photo 1.6)*
- ☐ *Photo documentation*

☐ Staining definitively from bats
- *More detailed in IV Staining*
- ☐ *Photo documentation*

☐ Audible
☐ Odor
☒ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☐ ☐ Truss ☐ I-beam ☐ Box	☒ ☐ Slab ☐ Cast in place ☐ Beam ☐ Box ■ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☒	☐	☐	☐
Other components of interest* (please specify below)							
drainage pipes	☒	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
carried pipes	☒	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes* (for potential roost evaluation only, NOT a structural assessment)

Component	Deterioration		
	Minor	Moderate	Severe
Deck	◉	○	○
Structure/Girder	◉	○	○
Abutment	◉	○	○
Expansion Joints ☒ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
drainage pipes	◉	○	○
carried pipes	◉	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*
☐ Recessed Area *See Appendix photo 3.2*
☒ Spaces between beams *See Appendix photo 3.3*
☒ Other: plastic components *See Appendix photo 3.4*

Due to Deterioration

☐ < 3/8 inch *See Appendix photo 3.5*
☒ 3/8 inch to 2 inches *See Appendix photo 3.6*
☐ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☑ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*
☐ Staining from bats *See Appendix photo 4.2*
☐ Staining from birds *See Appendix photo 4.3*
☒ Staining unknown causation* *See Appendix photo 4.4*

**If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Page 2 of 7

Bridge ID: CT-precast_concrete

Overview Photos

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Spaces between beams

Other: *plastic components*

Due to Deterioration

3/8 inch to 2 inches

IV. STAINING

Causation

Staining definitively from structural causation

Staining unknown causation

CT-precast_concrete Photo Appendix – page 3 of 3

Appendix C-2 ME-concrete Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
ME-concrete	Sandy River	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)
					X	N* / Y*	Potential guano samples collected Some observed staining appears to be structural and not from bats, but some observed staining is from unspecified causation

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High X	Low	None
All crevices >12" deep & not sealed	X	Spaces between walls, ceiling joists		Possible corridors for netting	None/poor X	Marginal	excellent
All guardrails	X			Evidence of bats using bird nests, if present?	Yes	No X	
All expansion joints	X (with binoculars)			Birds' nests observed			
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: _UMass Research Team___________ **Signature(s):** ____

District Environmental Use Only: Date Received by District Environmental Manager: ______________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes*

Bridge ID: ME-concrete

Date of Inspection: Summer 2016

Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

○ Tree canopy at/near bridge *See Appendix photo 1.1*
◉ Dense trees in surrounding area *See Appendix photo 1.2*
○ Minimal tree cover *See Appendix photo 1.3*

1B) Population

○ Rural
◉ Suburban
○ Urban

1C) Features Intersected

◉ Waterway
- ○ Stagnant
- ○ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

◉ High Disturbance *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
○ Medium Disturbance *Minimal evidence of human disturbance below bridge*
○ Low Disturbance *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ◉ Medium ○ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

○ High ○ Medium ○ Low ◉ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

○ High Access *Abutment <4 feet from ground* *See Appendix photo 1.4*
○ Medium Access
◉ Low Access *Abutment >10 feet from ground* *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☐ Visual
- ○ Live ___ *number seen*
- ○ Dead ___ *number seen*
- ☐ *Photo documentation*

☒ Guano *(see Appendix photo 1.6)*
- ☑ *Photo documentation*

☐ Staining definitively from bats *More detailed in IV Staining*
- ☐ *Photo documentation*

☐ Audible
☐ Odor
☐ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

Page 1 of 7

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone: *Grouted*	Stone: *Deteriorated Grout*	Stone: *Non-grouted*	Other
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☐ ☐ Truss ☐ I-beam ☐ Box	☒ ☐ Slab ■ Beam ☐ Box ■ Cast in place ☐ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
piers	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
guard rails	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
retaining wall	☐	☒	☐ ☐ Recently Treated	☐	☐	☒	☐
pipes	☒	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration: Minor	Deterioration: Moderate	Deterioration: Severe
Deck	○	◉	○
Structure/Girder	○	◉	○
Abutment	○	◉	○
Expansion Joints ☐ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	◉ ☒ Internal staining* ☒ External staining*
Other components of interest* (please specify below)			
piers	○	◉	○
guard rails	○	○	◉
retaining wall	○	○	◉
pipes	○	◉	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☒ Deck Joints *See Appendix photo 3.1*

☒ Recessed Area *See Appendix photo 3.2*

☐ Spaces between beams *See Appendix photo 3.3*

☒ Other: drains *See Appendix photo 3.4*

Due to Deterioration

☒ < 3/8 inch *See Appendix photo 3.5*

☒ 3/8 inch to 2 inches *See Appendix photo 3.6*

☒ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☑ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*

☐ Staining from bats *See Appendix photo 4.2*

☐ Staining from birds *See Appendix photo 4.3*

☒ Staining unknown causation* *See Appendix photo 4.4*

**If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Bridge ID: ME-concrete

Overview Photos

I. BRIDGE SUMMARY

1E) Evidence of Bats

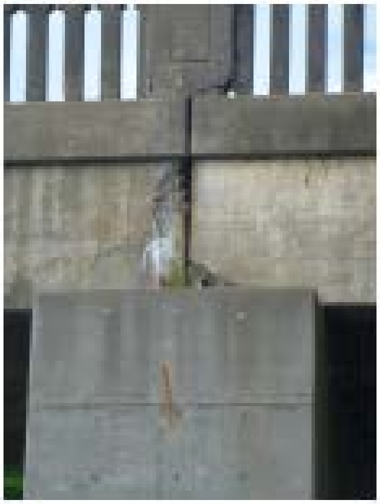
Guano

Staining

III. CONDITION
3A) Presence of Cracks/Crevices

Due to Construction

Deck Joints



Recessed Area

Other: *drains*

Left photo - opening behind pipe is typical non-functioning drain opening too high to inspect.

Due to Deterioration

< 3/8 inch

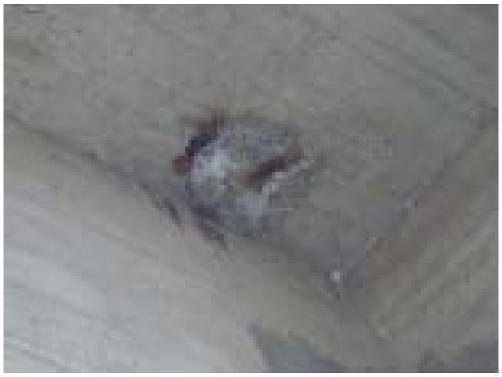
3/8 inch to 2 inches

> 2 inches

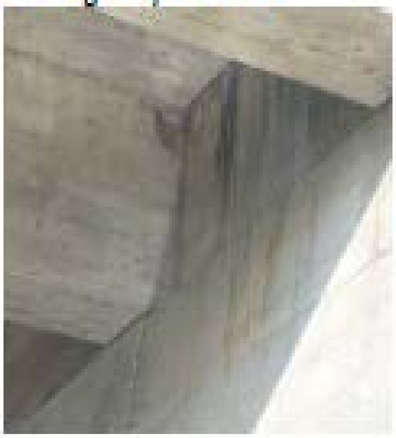
IV. STAINING

Causation

Staining definitively from structural causation



Staining likely from bats



Appendix C-3 ME-steel/wood Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
ME-steel/wood	Bowley Brook	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	**Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)**
						N*	Staining observed, appears to be structural and not from bats

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	**Crevices, rough surfaces or imperfections in concrete**		**Human disturbance or traffic under bridge/in culvert or at the structure**	High	Low	None X
All crevices >12" deep & not sealed	X	**Spaces between walls, ceiling joists**		**Possible corridors for netting**	None/poor	Marginal X	excellent
All guardrails	X			**Evidence of bats using bird nests, if present?**	Yes	No X	
All expansion joints	N/A						
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: UMass Research Team________ **Signature(s):** ______________________________

District Environmental Use Only: Date Received by District Environmental Manager: ____________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes*

Bridge ID: ME-steel/wood

Date of Inspection: Summer 2016

Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

- ◉ Tree canopy at/near bridge — *See Appendix photo 1.1*
- ○ Dense trees in surrounding area — *See Appendix photo 1.2*
- ○ Minimal tree cover — *See Appendix photo 1.3*

1B) Population

- ◉ Rural
- ○ Suburban
- ○ Urban

1C) Features Intersected

- ◉ Waterway
  - ○ Stagnant
  - ◉ Moving w/calm surface
  - ○ Riffle and pool
  - ○ Rapids
  - ○ Other
- ○ Land/Terrain
  - ○ < 0.5 miles from water
  - ○ 0.5 to 2 miles from water
  - ○ > 2 miles from water
- ○ Roadway/Railroad
  - Roadway Traffic Type
    - ○ Cars only
    - ○ Cars and Trucks
    - ○ Pedestrian/bike
    - ○ High volume rail (regular service)
    - ○ Low volume/speed or abandoned rail
  - Distance to waterway
    - ○ < 0.5 miles
    - ○ 0.5 to 2 miles
    - ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

- ○ High Disturbance — *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
- ○ Medium Disturbance — *Minimal evidence of human disturbance below bridge*
- ◉ Low Disturbance — *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

- ○ High
- ○ Medium
- ◉ Low
- ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

- ○ High
- ○ Medium
- ○ Low
- ◉ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

- ○ High Access — *Abutment <4 feet from ground* — *See Appendix photo 1.4*
- ◉ Medium Access
- ○ Low Access — *Abutment >10 feet from ground* — *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

- ☐ Visual
  - ○ Live ___ *number seen*
  - ○ Dead ___ *number seen*
  - ☐ *Photo documentation*
- ☐ Guano (*see Appendix photo 1.6)*
  - ☐ *Photo documentation*
- ☐ Staining definitively from bats
  - *More detailed in IV Staining*
  - ☐ *Photo documentation*
- ☐ Audible
- ☐ Odor
- ☒ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

Page 1 of 7

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone: *Grouted*	Stone: *Deteriorated Grout*	Stone: *Non-grouted*	Other
Deck	☐	☐	☒ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☒ ☐ Truss ■ I-beam ☐ Box	☐ ☐ Slab ☐ Beam ☐ Box ☐ Cast in place ☐ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
guard rails	☒	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	○	◉	○
Structure/Girder	○	○	◉
Abutment	○	◉	○
Expansion Joints ☒ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
guard rails	○	◉	○
	○	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*

☒ Recessed Area *See Appendix photo 3.2*

☐ Spaces between beams *See Appendix photo 3.3*

☐ Other: *See Appendix photo 3.4*

Due to Deterioration

☒ < 3/8 inch *See Appendix photo 3.5*

☒ 3/8 inch to 2 inches *See Appendix photo 3.6*

☒ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☒ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*

☐ Staining from bats *See Appendix photo 4.2*

☐ Staining from birds *See Appendix photo 4.3*

☐ Staining unknown causation[a] *See Appendix photo 4.4*

[a]If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats

Bridge ID: ME-steel/wood

Overview Photos

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Recessed Area

Due to Deterioration

< 3/8 inch

3/8 inch to 2 inches

> 2 inches

IV. STAINING

Causation

Staining definitively from structural causation

Appendix C-4 MA-concrete Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
MA-concrete	Artichoke River	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	**Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)**
					X	Y*	Potential guano samples collected Staining observed, from unspecified causation

Areas Inspected (Check all that apply)

Bridges		**Culverts/Other Structures**		**Summary Info (circle all that apply)**			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	**Crevices, rough surfaces or imperfections in concrete**		**Human disturbance or traffic under bridge/in culvert or at the structure**	High	Low X	None
All crevices >12" deep & not sealed	X	**Spaces between walls, ceiling joists**		**Possible corridors for netting**	None/poor X	Marginal	excellent
All guardrails	X			**Evidence of bats using bird nests, if present?**	Yes	No X	
All expansion joints	N/A			Birds' nests observed			
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: UMass Research Team ____________ **Signature(s):** ______________________________

District Environmental Use Only: Date Received by District Environmental Manager: ____________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes*

Bridge ID: MA-concrete

Date of Inspection: Summer 2016

Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

○ Tree canopy at/near bridge *See Appendix photo 1.1*
◉ Dense trees in surrounding area *See Appendix photo 1.2*
○ Minimal tree cover *See Appendix photo 1.3*

1B) Population

◉ Rural
○ Suburban
○ Urban

1C) Features Intersected

◉ Waterway
- ◉ Stagnant
- ○ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

○ High Disturbance *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
◉ Medium Disturbance *Minimal evidence of human disturbance below bridge*
○ Low Disturbance *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ◉ Medium ○ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

○ High ○ Medium ○ Low ◉ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

○ High Access *Abutment <4 feet from ground* *See Appendix photo 1.4*
◉ Medium Access
○ Low Access *Abutment >10 feet from ground* *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☐ Visual
- ○ Live ___ *number seen*
- ○ Dead ___ *number seen*
- ☐ *Photo documentation*

☒ Guano (*see Appendix photo 1.6*)
- ☑ *Photo documentation*

☐ Staining definitively from bats *More detailed in IV Staining*
- ☐ *Photo documentation*

☐ Audible ☐ Odor ☐ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☐ ☐ Truss ☐ I-beam ☐ Box	☒ ■ Slab ■ Cast in place ☐ Beam ☐ Box ☐ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
3 timber piers	☐	☐	☒ ☐ Recently Treated	☐	☐	☐	☐
PVC piping	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☒
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	◉	○	○
Structure/Girder	◉	○	○
Abutment	◉	○	○
Expansion Joints ☒ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
3 timber piers	◉	○	○
PVC piping	◉	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*

☒ Recessed Area *See Appendix photo 3.2*

☐ Spaces between beams *See Appendix photo 3.3*

☐ Other: *See Appendix photo 3.4*

Due to Deterioration

☒ < 3/8 inch *See Appendix photo 3.5*

☒ 3/8 inch to 2 inches *See Appendix photo 3.6*

☒ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☒ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*

☐ Staining from bats *See Appendix photo 4.2*

☒ Staining from birds *See Appendix photo 4.3*

☒ Staining unknown causation* *See Appendix photo 4.4*

**If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Bridge ID: MA-concrete

Overview Photos


I. BRIDGE SUMMARY

1E) Evidence of Bats

Guano




III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Recessed Area

Due to Deterioration

< 3/8 inch

3/8 inch to 2 inches

> 2 inches

IV. STAINING

Causation

Staining definitively from structural causation

Staining from birds

Staining unknown causation

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
MA-precast_concrete_2	Town Brook	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)
						N*	Staining observed, appears to be structural and not from bats

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High	Low X	None
All crevices >12" deep & not sealed	X	Spaces between walls, ceiling joists		Possible corridors for netting	None/poor	Marginal X	excellent
All guardrails	X			Evidence of bats using bird nests, if present?	Yes	No X	
All expansion joints	N/A						
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: UMass Research Team Signature(s): ____________________

District Environmental Use Only: Date Received by District Environmental Manager: ____________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes*

Bridge ID: MA-precast_concrete_2

Date of Inspection: Summer 2016

Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

- (●) Tree canopy at/near bridge — *See Appendix photo 1.1*
- ( ) Dense trees in surrounding area — *See Appendix photo 1.2*
- ( ) Minimal tree cover — *See Appendix photo 1.3*

1B) Population

(●) Rural ( ) Suburban ( ) Urban

1C) Features Intersected

- (●) Waterway
  - ( ) Stagnant
  - (●) Moving w/calm surface
  - ( ) Riffle and pool
  - ( ) Rapids
  - ( ) Other
- ( ) Land/Terrain
  - ( ) < 0.5 miles from water
  - ( ) 0.5 to 2 miles from water
  - ( ) > 2 miles from water
- ( ) Roadway/Railroad
  - Roadway Traffic Type
    - ( ) Cars only
    - ( ) Cars and Trucks
    - ( ) Pedestrian/bike
    - ( ) High volume rail (regular service)
    - ( ) Low volume/speed or abandoned rail
  - Distance to waterway
    - ( ) < 0.5 miles
    - ( ) 0.5 to 2 miles
    - ( ) > 2 miles

1D) Level of Disturbance

Human Disturbance

- ( ) High Disturbance — *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
- (●) Medium Disturbance — *Minimal evidence of human disturbance below bridge*
- ( ) Low Disturbance — *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

( ) High (●) Medium ( ) Low ( ) Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

( ) High ( ) Medium ( ) Low (●) Not Applicable

Predator Access *(i.e. raccoon, etc.)*

- ( ) High Access — *Abutment <4 feet from ground* — *See Appendix photo 1.4*
- ( ) Medium Access
- (●) Low Access — *Abutment >10 feet from ground* — *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

- ☐ Visual
  - ( ) Live ___ *number seen*
  - ( ) Dead ___ *number seen*
  - ☐ *Photo documentation*
- ☐ Guano (*see Appendix photo 1.6)*
  - ☐ *Photo documentation*
- ☐ Staining definitively from bats — *More detailed in IV Staining*
  - ☐ *Photo documentation*

☐ Audible ☐ Odor ☒ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☐ ☐ Truss ☐ I-beam ☐ Box	☒ ☐ Slab ☐ Beam ■ Box ☐ Cast in place ■ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
guard rails	☒	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
girder gap seal	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☒
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	◉	○	○
Structure/Girder	○	◉	○
Abutment	○	◉	○
Expansion Joints ☒ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
guard rails	◉	○	○
girder gap seal	○	◉	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*
☐ Recessed Area *See Appendix photo 3.2*
☒ Spaces between beams *See Appendix photo 3.3*
☐ Other: *See Appendix photo 3.4*

Due to Deterioration

☒ < 3/8 inch *See Appendix photo 3.5*
☒ 3/8 inch to 2 inches *See Appendix photo 3.6*
☒ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☑ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*
☐ Staining from bats *See Appendix photo 4.2*
☐ Staining from birds *See Appendix photo 4.3*
☒ Staining unknown causation[#] *See Appendix photo 4.4*

[#]*If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Bridge ID: MA-precast_concrete_2

Overview Photos

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Spaces between beams

Due to Deterioration

< 3/8 inch *and* 3/8 inch to 2 inches

3/8 inch to 2 inches

> 2 inches

IV. STAINING

Causation

Staining definitively from structural causation

Staining unknown causation

Appendix C-6 MA-steel Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
MA-steel	Town Brook	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	**Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)**
						N* / Y*	Some observed staining appears to be structural and not from bats, but some observed staining is from unspecified causation

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	**Crevices, rough surfaces or imperfections in concrete**		**Human disturbance or traffic under bridge/in culvert or at the structure**	High X	Low	None
All crevices >12" deep & not sealed	X	**Spaces between walls, ceiling joists**		**Possible corridors for netting**	None/poor	Marginal	excellent X
All guardrails	X			**Evidence of bats using bird nests, if present?**	Yes	No X	
All expansion joints	N/A			Birds' nests observed			
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: _UMass Research Team_____________ **Signature(s):** ____

District Environmental Use Only: Date Received by District Environmental Manager: ______________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes* Bridge ID: MA-steel

Date of Inspection: Summer 2016 Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

- (●) Tree canopy at/near bridge — *See Appendix photo 1.1*
- ( ) Dense trees in surrounding area — *See Appendix photo 1.2*
- ( ) Minimal tree cover — *See Appendix photo 1.3*

1B) Population

( ) Rural (●) Suburban ( ) Urban

1C) Features Intersected

- (●) Waterway
  - ( ) Stagnant
  - (●) Moving w/calm surface
  - ( ) Riffle and pool
  - ( ) Rapids
  - ( ) Other
- ( ) Land/Terrain
  - ( ) < 0.5 miles from water
  - ( ) 0.5 to 2 miles from water
  - ( ) > 2 miles from water
- ( ) Roadway/Railroad
  - Roadway Traffic Type
    - ( ) Cars only
    - ( ) Cars and Trucks
    - ( ) Pedestrian/bike
    - ( ) High volume rail (regular service)
    - ( ) Low volume/speed or abandoned rail
  - Distance to waterway
    - ( ) < 0.5 miles
    - ( ) 0.5 to 2 miles
    - ( ) > 2 miles

1D) Level of Disturbance

Human Disturbance

- (●) High Disturbance — *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
- ( ) Medium Disturbance — *Minimal evidence of human disturbance below bridge*
- ( ) Low Disturbance — *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

( ) High ( ) Medium (●) Low ( ) Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

( ) High ( ) Medium ( ) Low (●) Not Applicable

Predator Access *(i.e. raccoon, etc.)*

- ( ) High Access — *Abutment <4 feet from ground* — *See Appendix photo 1.4*
- (●) Medium Access
- ( ) Low Access — *Abutment >10 feet from ground* — *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

- ☐ Visual
  - ( ) Live ___ *number seen*
  - ( ) Dead ___ *number seen*
  - ☐ *Photo documentation*
- ☐ Guano (*see Appendix photo 1.6*)
  - ☐ *Photo documentation*
- ☐ Staining definitively from bats
  - *More detailed in IV Staining*
  - ☐ *Photo documentation*

☐ Audible ☐ Odor ☒ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone: *Grouted*	Stone: *Deteriorated Grout*	Stone: *Non-grouted*	Other
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☒ ☐ Truss ■ I-beam ☐ Box	☐ ☐ Slab ☐ Cast in place ☐ Beam ☐ Box ☐ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
piers	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
guard rails	☐	☐	☒ ■ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	○	○	◉
Structure/Girder	○	○	◉
Abutment	○	◉	○
Expansion Joints ☒ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
piers	○	◉	○
guard rails	◉	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*

☐ Recessed Area *See Appendix photo 3.2*

☐ Spaces between beams *See Appendix photo 3.3*

☐ Other: *See Appendix photo 3.4*

Due to Deterioration

☒ < 3/8 inch *See Appendix photo 3.5*

☒ 3/8 inch to 2 inches *See Appendix photo 3.6*

☒ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☑ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*

☐ Staining from bats *See Appendix photo 4.2*

☐ Staining from birds *See Appendix photo 4.3*

☐ Staining unknown causation* *See Appendix photo 4.4*

**If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Bridge ID: MA-steel

Overview Photos

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Recessed Area

Due to Deterioration

< 3/8 inch

3/8 inch to 2 inches

> 2 inches

IV. STAINING

Causation

Staining definitively from structural causation

Appendix C-7 NH-concrete_arch Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
NH-concrete_arch	Contoocook River	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)
					X	N* / Y*	Potential guano samples collected Some observed staining appears to be structural and not from bats, but some observed staining is from unspecified causation

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High	Low X	None
All crevices >12" deep & not sealed	X	Spaces between walls, ceiling joists		Possible corridors for netting	None/poor X	Marginal	excellent
All guardrails	N/A			Evidence of bats using bird nests, if present?	Yes	No X	
All expansion joints	N/A						
Spaces between concrete end walls and the bridge deck	N/A						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: _UMass Research Team___________	**Signature(s):** ____
District Environmental Use Only:	Date Received by District Environmental Manager: ______________

SUPPLEMENTAL BRIDGE ISURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes* Bridge ID: NH-concrete_arch

Date of Inspection: Summer 2016 Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

○ Tree canopy at/near bridge *See Appendix photo 1.1*
○ Dense trees in surrounding area *See Appendix photo 1.2*
◉ Minimal tree cover *See Appendix photo 1.3*

1B) Population

○ Rural ◉ Suburban ○ Urban

1C) Features Intersected

◉ Waterway
- ○ Stagnant
- ◉ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

○ High Disturbance *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
◉ Medium Disturbance *Minimal evidence of human disturbance below bridge*
○ Low Disturbance *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ◉ Medium ○ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

○ High ○ Medium ○ Low ◉ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

◉ High Access *Abutment <4 feet from ground* *See Appendix photo 1.4*
○ Medium Access
○ Low Access *Abutment >10 feet from ground* *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☐ Visual
- ○ Live ___ *number seen*
- ○ Dead ___ *number seen*
- ☐ *Photo documentation*

☒ Guano (*see Appendix photo 1.6*)
- ☑ *Photo documentation*

☐ Staining definitively from bats
- *More detailed in IV Staining*
- ☐ *Photo documentation*

☐ Audible ☐ Odor ☐ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☐ ☐ Truss ☐ I-beam ☐ Box	☒ ☐ Slab ■ Cast in place ☐ Beam ☐ Box ☐ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☐	☐ ☐ Recently Treated	☐	☐	☒	☐
Other components of interest* (please specify below)							
facade	☐	☐	☐ ☐ Recently Treated	☒	☒	☐	☐
approach walls	☐	☐	☐ ☐ Recently Treated	☐	☐	☒	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	◉	○	○
Structure/Girder	◉	○	○
Abutment	◉	○	○
Expansion Joints ☒ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
facade	◉	○	○
approach walls	◉	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*
☐ Recessed Area *See Appendix photo 3.2*
☐ Spaces between beams *See Appendix photo 3.3*
☒ Other: stonework *See Appendix photo 3.4*

Due to Deterioration

☐ < 3/8 inch *See Appendix photo 3.5*
☐ 3/8 inch to 2 inches *See Appendix photo 3.6*
☐ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☒ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*
☐ Staining from bats *See Appendix photo 4.2*
☐ Staining from birds *See Appendix photo 4.3*
☒ Staining unknown causation* *See Appendix photo 4.4*

**If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Bridge ID: NH-concrete_arch

Overview Photos

I. BRIDGE SUMMARY

1E) Evidence of Bats

Guano

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Other: *stonework*

IV. STAINING

Causation

Staining definitively from structural causation

Staining unknown causation

Appendix C-8 NH-steel_truss Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
NH-steel_truss	Contoocook River	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)
					X		Potential guano samples collected

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High	Low X	None
All crevices >12" deep & not sealed	X	Spaces between walls, ceiling joists		Possible corridors for netting	None/poor X	Marginal	excellent
All guardrails	X			Evidence of bats using bird nests, if present?	Yes	No X	
All expansion joints	N/A			Birds' nests observed			
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: UMass Research Team ____________ **Signature(s):** ______________________________

District Environmental Use Only: Date Received by District Environmental Manager: ______________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes*

Bridge ID: NH-steel_truss

Date of Inspection: Summer 2016

Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

- ○ Tree canopy at/near bridge — *See Appendix photo 1.1*
- ◉ Dense trees in surrounding area — *See Appendix photo 1.2*
- ○ Minimal tree cover — *See Appendix photo 1.3*

1B) Population

○ Rural ◉ Suburban ○ Urban

1C) Features Intersected

◉ Waterway
- ○ Stagnant
- ○ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

- ○ High Disturbance — *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
- ○ Medium Disturbance — *Minimal evidence of human disturbance below bridge*
- ○ Low Disturbance — *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ○ Medium ◉ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

○ High ○ Medium ○ Low ◉ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

- ○ High Access — *Abutment <4 feet from ground* — *See Appendix photo 1.4*
- ○ Medium Access
- ◉ Low Access — *Abutment >10 feet from ground* — *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☐ Visual
- ○ Live ___ *number seen*
- ○ Dead ___ *number seen*
- ☐ *Photo documentation*

☒ Guano (*see Appendix photo 1.6*)
- ☑ *Photo documentation*

☐ Staining definitively from bats
- *More detailed in IV Staining*
- ☐ *Photo documentation*

☐ Audible ☐ Odor ☐ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone: *Grouted*	Stone: *Deteriorated Grout*	Stone: *Non-grouted*	Other
Deck	☒	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☒ ■ Truss ☐ I-beam ☐ Box	☐ ☐ Slab ☐ Cast in place ☐ Beam ☐ Box ☐ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☒	☐	☐	☐
Other components of interest* (please specify below)							
ped. bridge	☒	☐	☒ ☐ Recently Treated	☐	☐	☐	☐
struc. around	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration: Minor	Deterioration: Moderate	Deterioration: Severe
Deck	●	○	○
Structure/Girder	●	○	○
Abutment	●	○	○
Expansion Joints ☒ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
ped. bridge	●	○	○
struc. around	○	○	●
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*
☐ Recessed Area *See Appendix photo 3.2*
☐ Spaces between beams *See Appendix photo 3.3*
☒ Other: openings along deck *See Appendix photo 3.4*

Due to Deterioration

☐ < 3/8 inch *See Appendix photo 3.5*
☒ 3/8 inch to 2 inches *See Appendix photo 3.6*
☐ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☐ Staining observed in structure ☐ *Photo documentation*

Causation

☐ Staining definitively from structural causation *See Appendix photo 4.1*
☐ Staining from bats *See Appendix photo 4.2*
☐ Staining from birds *See Appendix photo 4.3*
☐ Staining unknown causation[#] *See Appendix photo 4.4*

[#] *If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Bridge ID: NH-steel_truss

Overview Photos

I. BRIDGE SUMMARY

1E) Evidence of Bats

Guano

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Other: *openings along deck*

Due to Deterioration

3/8 inch to 2 inches

Appendix C-9 RI-concrete Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
RI-concrete	Wood River	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)
			X		X	Y	Several (at least 4) seen night roosting on girders

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High	Low X	None
All crevices >12" deep & not sealed	X	Spaces between walls, ceiling joists		Possible corridors for netting	None/poor	Marginal X	excellent
All guardrails	X			Evidence of bats using bird nests, if present?	Yes	No X	
All expansion joints	X			Birds' nests observed			
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	X						

Assessment Conducted By: _UMass Research Team___________ **Signature(s):** ____

District Environmental Use Only: Date Received by District Environmental Manager: ______________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes* Bridge ID: RI-concrete

Date of Inspection: Summer 2016 Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

◉ Tree canopy at/near bridge *See Appendix photo 1.1*
○ Dense trees in surrounding area *See Appendix photo 1.2*
○ Minimal tree cover *See Appendix photo 1.3*

1B) Population

◉ Rural ○ Suburban ○ Urban

1C) Features Intersected

◉ Waterway
- ○ Stagnant
- ◉ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

○ High Disturbance *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
◉ Medium Disturbance *Minimal evidence of human disturbance below bridge*
○ Low Disturbance *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ◉ Medium ○ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

○ High ○ Medium ○ Low ◉ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

○ High Access *Abutment <4 feet from ground* *See Appendix photo 1.4*
○ Medium Access
◉ Low Access *Abutment >10 feet from ground* *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☐ Visual
- ○ Live ___ *number seen*
- ○ Dead ___ *number seen*
- ☐ *Photo documentation*

☒ Guano (*see Appendix photo 1.6)*
- ☑ *Photo documentation*

☒ Staining definitively from bats
- *More detailed in IV Staining*
- ☑ *Photo documentation*

☐ Audible ☐ Odor ☐ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☐ ☐ Truss ☐ I-beam ☐ Box	☒ ☐ Slab ☐ Beam ☐ Box ☐ Cast in place ■ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
guard rails	☒	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	◉	○	○
Structure/Girder	◉	○	○
Abutment	◉	○	○
Expansion Joints ☒ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
guard rails	◉	○	○
	○	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*

☒ Recessed Area *See Appendix photo 3.2*

☐ Spaces between beams *See Appendix photo 3.3*

☐ Other: *See Appendix photo 3.4*

Due to Deterioration

☒ < 3/8 inch *See Appendix photo 3.5*

☐ 3/8 inch to 2 inches *See Appendix photo 3.6*

☒ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☒ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*

☒ Staining from bats *See Appendix photo 4.2*

☐ Staining from birds *See Appendix photo 4.3*

☐ Staining unknown causation[a] *See Appendix photo 4.4*

[a]If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats

Bridge ID: RI-concrete

Overview Photos

I. BRIDGE SUMMARY

1E) Evidence of Bats

Guano

Staining definitively from bats

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Recessed Area

Due to Deterioration

< 3/8 inch

> 2 inches

<u>IV. STAINING</u>

<u>Causation</u>

Staining definitively from structural causation

Staining from bats *(see above* ***<u>I.BRIDGE SUMMARY</u>****;* ***1E) Evidence of Bats****; Staining definitively from bats)*

Appendix C-10 RI-precast_concrete Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
RI-precast_concrete	Pawcatuck River	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)
						N*	Staining observed, appears to be structural and not from bats

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High	Low X	None
All crevices >12" deep & not sealed	X	Spaces between walls, ceiling joists		Possible corridors for netting	None/poor X	Marginal	excellent
All guardrails	X			Evidence of bats using bird nests, if present?	Yes	No X	
All expansion joints	X						
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: _UMass Research Team___________ **Signature(s):** ____

District Environmental Use Only: Date Received by District Environmental Manager: ______________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes*

Bridge ID: RI-precast_concrete

Date of Inspection: Summer 2016

Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

○ Tree canopy at/near bridge *See Appendix photo 1.1*
◉ Dense trees in surrounding area *See Appendix photo 1.2*
○ Minimal tree cover *See Appendix photo 1.3*

1B) Population

○ Rural ◉ Suburban ○ Urban

1C) Features Intersected

◉ Waterway
- ○ Stagnant
- ◉ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

○ High Disturbance *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
◉ Medium Disturbance *Minimal evidence of human disturbance below bridge*
○ Low Disturbance *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ○ Medium ◉ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

○ High ○ Medium ○ Low ◉ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

○ High Access *Abutment <4 feet from ground* *See Appendix photo 1.4*
◉ Medium Access
○ Low Access *Abutment >10 feet from ground* *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☐ Visual
- ○ Live ___ *number seen*
- ○ Dead ___ *number seen*
- ☐ *Photo documentation*

☐ Guano (*see Appendix photo 1.6)*
- ☐ *Photo documentation*

☐ Staining definitively from bats *More detailed in IV Staining*
- ☐ *Photo documentation*

☐ Audible ☐ Odor ☒ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☐ ☐ Truss ☐ I-beam ☐ Box	☒ ☐ Slab ☐ Cast in place ☐ Beam ☐ Box ■ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
guard rails	☒	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	◉	○	○
Structure/Girder	◉	○	○
Abutment	◉	○	○
Expansion Joints ☒ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
guard rails	○	○	○
	○	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*
☐ Recessed Area *See Appendix photo 3.2*
☒ Spaces between beams *See Appendix photo 3.3*
☐ Other: *See Appendix photo 3.4*

Due to Deterioration

☒ < 3/8 inch *See Appendix photo 3.5*
☒ 3/8 inch to 2 inches *See Appendix photo 3.6*
☒ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☐ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*
☐ Staining from bats *See Appendix photo 4.2*
☐ Staining from birds *See Appendix photo 4.3*
☐ Staining unknown causation[ᵃ] *See Appendix photo 4.4*

[a]*If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Bridge ID: RI-precast_concrete

Overview Photos

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Spaces between beams

Due to Deterioration

< 3/8 inch

3/8 inch to 2 inches

> 2 inches

IV. STAINING

Causation

Staining definitively from structural causation

Staining definitively from structural causation *continued*

Staining unknown causation

Appendix C-11 RI-precast_concrete_2 Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
RI-precast_concrete_2	Pawcatuck River	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	**Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)**
						N*	Staining observed, appears to be structural and not from bats

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	**Crevices, rough surfaces or imperfections in concrete**		**Human disturbance or traffic under bridge/in culvert or at the structure**	High	Low X	None
All crevices >12" deep & not sealed	X	**Spaces between walls, ceiling joists**		**Possible corridors for netting**	None/poor	Marginal X	excellent
All guardrails	X			**Evidence of bats using bird nests, if present?**	Yes	No X	
All expansion joints	X			Birds' nests observed			
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: _UMass Research Team___________ **Signature(s):** ____

District Environmental Use Only: Date Received by District Environmental Manager: ______________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes*

Bridge ID: RI-precast_concrete_2

Date of Inspection: Summer 2016

Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

○ Tree canopy at/near bridge *See Appendix photo 1.1*
◉ Dense trees in surrounding area *See Appendix photo 1.2*
○ Minimal tree cover *See Appendix photo 1.3*

1B) Population

◉ Rural
○ Suburban
○ Urban

1C) Features Intersected

◉ Waterway
- ○ Stagnant
- ◉ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

○ High Disturbance *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
○ Medium Disturbance *Minimal evidence of human disturbance below bridge*
◉ Low Disturbance *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ○ Medium ◉ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

○ High ○ Medium ○ Low ◉ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

○ High Access *Abutment <4 feet from ground* *See Appendix photo 1.4*
◉ Medium Access
○ Low Access *Abutment >10 feet from ground* *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☐ Visual
- ○ Live ___ *number seen*
- ○ Dead ___ *number seen*
- ☐ *Photo documentation*

☐ Guano (*see Appendix photo 1.6)*
- ☐ *Photo documentation*

☐ Staining definitively from bats
- *More detailed in IV Staining*
- ☐ *Photo documentation*

☐ Audible ☐ Odor ☒ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☐ ☐ Truss ☐ I-beam ☐ Box	☐ ☐ Slab ☐ Cast in place ☐ Beam ■ Box ■ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
guard rail	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
pier	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	○	○	◉
Structure/Girder	○	◉	○
Abutment	○	◉	○
Expansion Joints ☐ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	◉ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
guard rail	○	◉	○
pier	○	○	◉
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☒ Deck Joints *See Appendix photo 3.1*
☐ Recessed Area *See Appendix photo 3.2*
☒ Spaces between beams *See Appendix photo 3.3*
☐ Other: *See Appendix photo 3.4*

Due to Deterioration

☒ < 3/8 inch *See Appendix photo 3.5*
☒ 3/8 inch to 2 inches *See Appendix photo 3.6*
☒ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☑ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*
☐ Staining from bats *See Appendix photo 4.2*
☐ Staining from birds *See Appendix photo 4.3*
☒ Staining unknown causation* *See Appendix photo 4.4*

**If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Bridge ID: RI-precast_concrete_2

Overview Photos

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Deck Joints

Spaces between beams

Due to Deterioration

< 3/8 inch

3/8 inch to 2 inches

> 2 inches

> 2 inches *continued*

IV. STAINING

Causation

Staining definitively from structural causation

Staining unknown causation

Appendix C-12 RI-steel_2 Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
RI-steel_2	Branch River	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)
			X			N*	Dead bat observed under abutment in summer 2015 Staining observed, appears to be structural and not from bats

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High	Low X	None
All crevices >12" deep & not sealed	X	Spaces between walls, ceiling joists		Possible corridors for netting	None/poor X	Marginal	excellent
All guardrails	X			Evidence of bats using bird nests, if present?	Yes	No X	
All expansion joints	X			Birds' nests observed			
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: UMass Research Team	**Signature(s):** ______________________
District Environmental Use Only:	Date Received by District Environmental Manager: ____________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes* Bridge ID: RI-steel_2

Date of Inspection: Summers 2015 and 2016 Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

◉ Tree canopy at/near bridge *See Appendix photo 1.1*
○ Dense trees in surrounding area *See Appendix photo 1.2*
○ Minimal tree cover *See Appendix photo 1.3*

1B) Population

○ Rural ◉ Suburban ○ Urban

1C) Features Intersected

◉ Waterway
- ○ Stagnant
- ◉ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ◉ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

○ High Disturbance *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
◉ Medium Disturbance *Minimal evidence of human disturbance below bridge*
○ Low Disturbance *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ◉ Medium ○ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

○ High ○ Medium ◉ Low ○ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

◉ High Access *Abutment <4 feet from ground* *See Appendix photo 1.4*
○ Medium Access
○ Low Access *Abutment >10 feet from ground* *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☒ Visual
- ○ Live ___ *number seen*
- ◉ Dead 1 *number seen*
- ☑ *Photo documentation*

☐ Guano (*see Appendix photo 1.6*)
- ☐ *Photo documentation*

☐ Staining definitively from bats *More detailed in IV Staining*
- ☐ *Photo documentation*

☐ Audible ☐ Odor ☐ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

Page 1 of 7

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☒ ☐ Truss ■ I-beam ☐ Box	☐ ☐ Slab ☐ Cast in place ☐ Beam ☐ Box ☐ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
pier	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
guard rail	☒	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	◉	○	○
Structure/Girder	○	◉	○
Abutment	○	◉	○
Expansion Joints ☐ Not Applicable	○ ☐ Internal staining* ☐ External staining*	◉ ☐ Internal staining* ☒ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
pier	○	◉	○
guard rail	◉	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☒ Deck Joints *See Appendix photo 3.1*
☐ Recessed Area *See Appendix photo 3.2*
☐ Spaces between beams *See Appendix photo 3.3*
☐ Other: *See Appendix photo 3.4*

Due to Deterioration

☒ < 3/8 inch *See Appendix photo 3.5*
☒ 3/8 inch to 2 inches *See Appendix photo 3.6*
☒ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☑ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*
☐ Staining from bats *See Appendix photo 4.2*
☒ Staining from birds *See Appendix photo 4.3*
☒ Staining unknown causation[#] *See Appendix photo 4.4*

[#]*If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Bridge ID: RI-steel_2

Overview Photos

I. BRIDGE SUMMARY

1E) Evidence of Bats

Visual—Dead Bat

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Deck Joints

Due to Deterioration

< 3/8 inch

3/8 inch to 2 inches

> 2 inches

IV. STAINING

Causation

Staining definitively from structural causation

Staining from birds

Staining unknown causation

Appendix C-13 VT-concrete_arch Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
VT-concrete_arch	Middlebury River	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)
						N*	Staining observed, appears to be structural and not from bats

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High X	Low	None
All crevices >12" deep & not sealed	X	Spaces between walls, ceiling joists		Possible corridors for netting	None/poor	Marginal X	excellent
All guardrails	X			Evidence of bats using bird nests, if present?	Yes	No X	
All expansion joints	X						
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: UMass Research Team	**Signature(s):** ______________________
District Environmental Use Only:	Date Received by District Environmental Manager: ____________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes* — Bridge ID: VT-concrete_arch

Date of Inspection: Summer 2016 — Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

- ○ Tree canopy at/near bridge — *See Appendix photo 1.1*
- ◉ Dense trees in surrounding area — *See Appendix photo 1.2*
- ○ Minimal tree cover — *See Appendix photo 1.3*

1B) Population

○ Rural ◉ Suburban ○ Urban

1C) Features Intersected

◉ Waterway
- ○ Stagnant
- ◉ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance
- ◉ High Disturbance — *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
- ○ Medium Disturbance — *Minimal evidence of human disturbance below bridge*
- ○ Low Disturbance — *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ◉ Medium ○ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

○ High ○ Medium ○ Low ◉ Not Applicable

Predator Access *(i.e. raccoon, etc.)*
- ○ High Access — *Abutment <4 feet from ground* — *See Appendix photo 1.4*
- ◉ Medium Access
- ○ Low Access — *Abutment >10 feet from ground* — *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☐ Visual
- ○ Live ___ *number seen*
- ○ Dead ___ *number seen*
- ☐ *Photo documentation*

☐ Guano (*see Appendix photo 1.6*)
- ☐ *Photo documentation*

☐ Staining definitively from bats — *More detailed in IV Staining*
- ☐ *Photo documentation*

☐ Audible ☐ Odor ☒ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☐ ☐ Truss ☐ I-beam ☐ Box	☐ ☐ Slab ☐ Beam ■ Box ☐ Cast in place ■ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	◉	○	○
Structure/Girder	◉	○	○
Abutment	◉	○	○
Expansion Joints ☒ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
	○	○	○
	○	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*

☐ Recessed Area *See Appendix photo 3.2*

☒ Spaces between beams *See Appendix photo 3.3*

☐ Other: *See Appendix photo 3.4*

Due to Deterioration

☐ < 3/8 inch *See Appendix photo 3.5*

☒ 3/8 inch to 2 inches *See Appendix photo 3.6*

☐ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☑ *Photo documentation*

Causation

☐ Staining definitively from structural causation *See Appendix photo 4.1*

☐ Staining from bats *See Appendix photo 4.2*

☐ Staining from birds *See Appendix photo 4.3*

☒ Staining unknown causation* *See Appendix photo 4.4*

**If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Bridge ID: VT-concrete_arch

Overview Photos

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Spaces between beams

Due to Deterioration

3/8 inch to 2 inches

IV. STAINING

Causation

Staining unknown causation

Appendix C-14 VT-covered Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
VT-covered	Otter Creek	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)
			X	X	X	Y	Little brown bat maternity colony site, observed roughly 20 bats

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	Crevices, rough surfaces or imperfections in concrete		Human disturbance or traffic under bridge/in culvert or at the structure	High	Low X	None
All crevices >12" deep & not sealed	X	Spaces between walls, ceiling joists		Possible corridors for netting	None/poor	Marginal	excellent X
All guardrails	N/A			Evidence of bats using bird nests, if present?	Yes	No X	
All expansion joints	N/A			Birds' nests observed			
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: UMass Research Team ____________ **Signature(s):** ________________________________

District Environmental Use Only: Date Received by District Environmental Manager: ______________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes*

Bridge ID: VT-covered

Date of Inspection: Summer 2016

Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

○ Tree canopy at/near bridge *See Appendix photo 1.1*
◉ Dense trees in surrounding area *See Appendix photo 1.2*
○ Minimal tree cover *See Appendix photo 1.3*

1B) Population

◉ Rural ○ Suburban ○ Urban

1C) Features Intersected

◉ Waterway
- ○ Stagnant
- ◉ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

○ High Disturbance *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
◉ Medium Disturbance *Minimal evidence of human disturbance below bridge*
○ Low Disturbance *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ○ Medium ◉ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

○ High ○ Medium ○ Low ◉ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

○ High Access *Abutment <4 feet from ground See Appendix photo 1.4*
◉ Medium Access
○ Low Access *Abutment >10 feet from ground See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☒ Visual
- ◉ Live ~20 *number seen*
- ○ Dead ___ *number seen*
- ☑ *Photo documentation*

☒ Guano (*see Appendix photo 1.6)*
- ☑ *Photo documentation*

☒ Staining definitively from bats
- *More detailed in IV Staining*
- ☑ *Photo documentation*

☒ Audible ☐ Odor ☐ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☐	☒ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☐ ☐ Truss ☐ I-beam ☐ Box	☐ ☐ Slab ☐ Cast in place ☐ Beam ☐ Box ☐ Precast	☒ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	●	○	○
Structure/Girder	●	○	○
Abutment	●	○	○
Expansion Joints ☒ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*
Other components of interest* (please specify below)			
	○	○	○
	○	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☐ Deck Joints *See Appendix photo 3.1*

☐ Recessed Area *See Appendix photo 3.2*

☐ Spaces between beams *See Appendix photo 3.3*

☒ Other: between timber frame *See Appendix photo 3.4*

Due to Deterioration

☐ < 3/8 inch *See Appendix photo 3.5*

☐ 3/8 inch to 2 inches *See Appendix photo 3.6*

☐ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☒ *Photo documentation*

Causation

☐ Staining definitively from structural causation *See Appendix photo 4.1*

☒ Staining from bats *See Appendix photo 4.2*

☐ Staining from birds *See Appendix photo 4.3*

☐ Staining unknown causation[a] *See Appendix photo 4.4*

[a]*If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

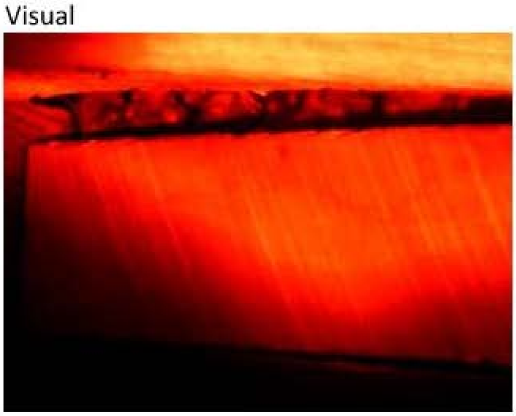
Bridge ID: VT-covered

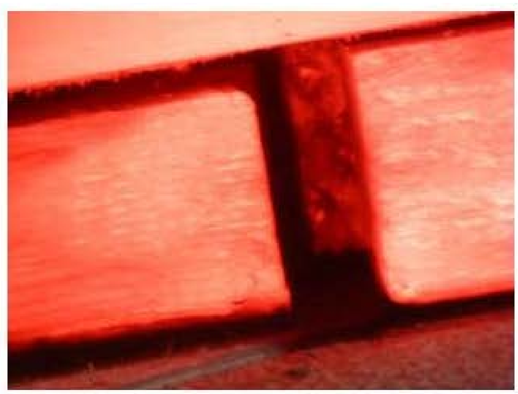
Overview Photos

I. BRIDGE SUMMARY

1E) Evidence of Bats

Visual





Guano

Staining definitively from bats

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Other: *between timber frame*

IV. STAINING

Causation

Staining from bats *(see above* ***I.BRIDGE SUMMARY****;* ***1E) Evidence of Bats****; Staining definitively from bats)*

Appendix C-15 VT-steel Inspection Forms

Bridge Assessment Form

~~DOT Project #~~ Bridge ID	Water Body	Date/Time of Inspection
VT-steel	Middlebury River	Summer 2016

Route:	County:	Federal Structure ID:	Bat Indicators Check all that apply. Presence of one or more indicators is sufficient evidence that bats may be using the structure.				
			Visual	Sound	Droppings	Staining	**Notes: (e.g., number & species of bats, if known. Include the results of thermal, emergent, or presence/absence summer survey)**
					X	N*	Potential guano samples collected Staining observed, appears to be structural and not from bats

Areas Inspected (Check all that apply)

Bridges		Culverts/Other Structures		Summary Info (circle all that apply)			
All vertical crevices sealed at the top and 0.5-1.25" wide & ≥4" deep	X	**Crevices, rough surfaces or imperfections in concrete**		**Human disturbance or traffic under bridge/in culvert or at the structure**	High	Low X	None
All crevices >12" deep & not sealed	X	**Spaces between walls, ceiling joists**		**Possible corridors for netting**	None/poor X	Marginal	excellent
All guardrails	X			**Evidence of bats using bird nests, if present?**	Yes	No X	
All expansion joints	X (with binoculars)			Birds' nests observed			
Spaces between concrete end walls and the bridge deck	X						
Vertical surfaces on concrete I-beams	N/A						

Assessment Conducted By: UMass Research Team ____________	**Signature(s):** ________________________________
District Environmental Use Only:	Date Received by District Environmental Manager: ____________

SUPPLEMENTAL BRIDGE SURVEY FORM FOR NEW ENGLAND

Angela Berthaume, Scott Civjan, Alyssa Bennett, Elisabeth Dumont

Please fill out the entire survey to the best of your ability. All photo documentation requires an explanation of photo location. Use additional sheets as necessary. All photos by the authors unless noted otherwise.

I. BRIDGE SUMMARY*: *Check all applicable boxes*

Bridge ID: VT-steel

Date of Inspection: Summer 2016

Name of Inspector: UMass Research Team

☑ Overview photos of bridge noting direction

1A) Surrounding Area

- ○ Tree canopy at/near bridge — *See Appendix photo 1.1*
- ◉ Dense trees in surrounding area — *See Appendix photo 1.2*
- ○ Minimal tree cover — *See Appendix photo 1.3*

1B) Population

○ Rural ◉ Suburban ○ Urban

1C) Features Intersected

◉ Waterway
- ○ Stagnant
- ◉ Moving w/calm surface
- ○ Riffle and pool
- ○ Rapids
- ○ Other

○ Land/Terrain
- ○ < 0.5 miles from water
- ○ 0.5 to 2 miles from water
- ○ > 2 miles from water

○ Roadway/Railroad

Roadway Traffic Type
- ○ Cars only
- ○ Cars and Trucks
- ○ Pedestrian/bike
- ○ High volume rail (regular service)
- ○ Low volume/speed or abandoned rail

Distance to waterway
- ○ < 0.5 miles
- ○ 0.5 to 2 miles
- ○ > 2 miles

1D) Level of Disturbance

Human Disturbance

- ○ High Disturbance — *Evidence of frequent use/human disturbance below bridge (graffiti, etc.)*
- ◉ Medium Disturbance — *Minimal evidence of human disturbance below bridge*
- ○ Low Disturbance — *No evidence of human disturbance below bridge*

Traffic Disturbance of Roadway Carried – *Considering traffic volume and speeds*

○ High ○ Medium ◉ Low ○ Not Applicable

Traffic Disturbance of Roadway Intersected – *Considering traffic volume and speeds*

◉ High ○ Medium ○ Low ○ Not Applicable

Predator Access *(i.e. raccoon, etc.)*

- ◉ High Access — *Abutment <4 feet from ground* — *See Appendix photo 1.4*
- ○ Medium Access
- ○ Low Access — *Abutment >10 feet from ground* — *See Appendix photo 1.5*

1E) Evidence of Bats

☐ Trained to ID

☐ Visual
- ○ Live ___ *number seen*
- ○ Dead ___ *number seen*
- ☐ *Photo documentation*

☒ Guano (*see Appendix photo 1.6)*
- ☑ *Photo documentation*

☐ Staining definitively from bats
- *More detailed in IV Staining*
- ☐ *Photo documentation*

☐ Audible ☐ Odor ☐ None

**This one-page summary could be sufficient to identify any bats using the structure, however completion of entire survey ensures all necessary data is gathered*

II. CONSTRUCTION: *Check all applicable boxes; See Appendix for detailed photo descriptions of component types*

Component	Material						
	Metal	Concrete	Wood	Stone			Other
				Grouted	*Deteriorated Grout*	*Non-grouted*	
Deck	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Structure Type	☒ ☐ Truss ■ I-beam ☐ Box	☐ ☐ Slab ☐ Cast in place ☐ Beam ☐ Box ☐ Precast	☐ ☐ Recently Treated	☐	☐	☐	☐
Abutment	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
Other components of interest* (please specify below)							
piers	☐	☒	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐
	☐	☐	☐ ☐ Recently Treated	☐	☐	☐	☐

III. CONDITION: *Check all applicable boxes (for potential roost evaluation only, NOT a structural assessment)*

Component	Deterioration		
	Minor	Moderate	Severe
Deck	◉	○	○
Structure/Girder	◉	○	○
Abutment	◉	○	○
Expansion Joints ☐ Not Applicable	○ ☐ Internal staining* ☐ External staining*	○ ☐ Internal staining* ☐ External staining*	◉ ☐ Internal staining* ☒ External staining*
Other components of interest* (please specify below)			
piers	○	◉	○
	○	○	○
	○	○	○
	○	○	○

**Include railings, piping, and/or other components if they are determined to have any features which could be possible roosts for bats*

**See section IV Staining for more detail*

3A) Presence of Cracks/Crevices

Due to Construction

☒ Deck Joints *See Appendix photo 3.1*

☐ Recessed Area *See Appendix photo 3.2*

☐ Spaces between beams *See Appendix photo 3.3*

☐ Other: *See Appendix photo 3.4*

Due to Deterioration

☒ < 3/8 inch *See Appendix photo 3.5*

☒ 3/8 inch to 2 inches *See Appendix photo 3.6*

☒ > 2 inches *See Appendix photo 3.7*

IV. STAINING: *Check all applicable boxes*

☒ Staining observed in structure ☑ *Photo documentation*

Causation

☒ Staining definitively from structural causation *See Appendix photo 4.1*

☐ Staining from bats *See Appendix photo 4.2*

☐ Staining from birds *See Appendix photo 4.3*

☐ Staining unknown causation[#] *See Appendix photo 4.4*

[#]*If staining is of unknown causation, further assessment is needed to determine the likelihood of being caused by bats*

Bridge ID: VT-steel

Overview Photos

I. BRIDGE SUMMARY

1E) Evidence of Bats

Guano

III. CONDITION

3A) Presence of Cracks/Crevices

Due to Construction

Deck Joints

Due to Deterioration

< 3/8 inch

3/8 inch to 2 inches

> 2 inches

> 2 inches *continued*

IV. STAINING

Causation

Staining definitively from structural causation

Appendix D Summary of Monitoring Techniques, Uses, and Considerations

Bridge Bat Monitoring Technique	Uses	Considerations
Rapid Visual Screenings	• Quickly inspect all obvious potential roost locations for signs of bats • Assess the surrounding area for suitability of supporting bat habitat • Preliminary tool to quickly determine the relative roosting potential of a bridge	• Signs of bat presence can be overlooked
Detailed Visual Inspections	• Fully inspect bridge and all potential roosting locations (within means of project) • More confidently determine the presence or likely absence of bats at the bridge	• Bat presence is easy to confirm, but bat absence is nearly impossible to prove • Specialized equipment may be necessary for completion
Boroscope	• Investigate further into small cracks and crevices • Investigate areas inaccessible for visual observation • Determine the cause or source of staining • Eliminating potential roost locations	• Camera head must be small enough to fit in cracks and crevices adequate for bat roosting • Lighting at camera head can potentially harass any bats encountered
Infrared Monitoring	• Observing bats in evenings • Observing location from which bats emerge • Monitor (some) bat house usage	• Cannot be used to identify roost locations in bridges during daytime inspections • Cannot scan through thicker, insulating bridge components
Emergence Studies	• Observe bridge sites from dusk through nightfall to observe bat activity in and around bridges	• Most useful when completed with more than one individual • Helpful to use hand-held acoustic monitors to aid in locating bats and thermal cameras to more clearly observe bat activity • Can be difficult without identified potential emergence locations
Guano Species ID	• Collecting guano samples from bridge sites to identify species roosting in or flying under bridges by using DNA sequencing • Pooled sampling technique allows for larger samples to be sent and can identify species from single pellet in the entire sample. Good for roost locations of unknown species use • Individual pellet testing allows for species confirmation of presence at site	• Can be expensive • May not provide species identification for all samples • Considerations between pooled and individual testing and relative success rate in species identification
Acoustic Monitoring	• Monitor bat activity in local area • Gather information on bat species in local area • Timing of calls can give insight to bats roosting near to monitoring location	• Does not confirm roosting in bridge • Discrepancies between automated bat acoustic identification software programs
Netting	• Positively identify species that are captured	• Only a subset of present bats are captured • Requires permitting

Appendix E Further Acoustical Analyses

	LOCATION "A"											
Bridge ID	**Monitoring Season**	**# files After Scrubbing**	**# files Scrubbed**	**% scrubbed**	**# files classified by SonoBat Consensus**	**% of total files classified by SonoBat Consensus**	**# files classified by SonoBat ByVote**	**% of total files classified by SonoBat ByVote**	**# files classified by SonoBat MeanClssn**	**% of total files classified by SonoBat MeanClssn**	**# files classified by EchoClass**	**% of total files classified EchoClass**
CT-precast_concrete	2016 early	80	112	58%	44	23%	50	26%	50	26%	64	33%
	2016 mid	504	225	31%	211	29%	266	36%	286	39%	438	60%
	2016 late	294	199	40%	169	34%	196	40%	204	41%	252	51%
ME-concrete	2015 mid	885	1,739	66%	361	14%	431	16%	471	18%	714	27%
	2015 late	2,479	144	5%	1,772	68%	1,978	75%	1,981	76%	2,392	91%
	2016 early	274	2,349	90%	109	4%	134	5%	145	6%	239	9%
	2016 mid	1,693	929	35%	1,176	45%	1,292	49%	1,337	51%	1,602	61%
	2016 late	2,395	228	9%	1,371	52%	1,748	67%	1,687	64%	2,962	113%
ME-steel/wood	2015 late	146	64	30%	29	14%	38	18%	61	29%	113	54%
	2016 early	35	2,587	99%	2	0%	2	0%	4	0%	13	0%
	2016 mid	305	2,318	88%	6	0%	7	0%	12	0%	20	1%
	2016 late	167	2,456	94%	4	0%	4	0%	10	0%	29	1%
MA-concrete	2016 early	615	1,184	66%	124	7%	169	9%	172	10%	286	16%
	2016 mid	1,372	996	42%	424	18%	531	22%	615	26%	1,128	48%
	2016 late	2,005	618	24%	67	3%	93	4%	103	4%	214	8%
MA-precast_concrete	2015 mid	372	2,018	84%	40	2%	60	3%	88	4%	214	9%
	2015 late	119	2,505	95%	2	0%	4	0%	4	0%	21	1%
MA-precast_concrete_2	2015 mid	509	591	54%	213	19%	269	24%	276	25%	403	37%
	2015 late	101	2,234	96%	2	0%	3	0%	5	0%	5	0%
	2016 early	126	2,496	95%	20	1%	27	1%	33	1%	55	2%
	2016 mid	298	142	32%	106	24%	137	31%	151	34%	236	54%
	2016 late	173	2,449	93%	3	0%	13	0%	5	0%	18	1%
MA-steel	2015 late	122	2,502	95%	9	0%	12	0%	14	1%	14	1%
	2016 early	181	2,442	93%	2	0%	3	0%	3	0%	10	0%
	2016 mid	223	419	65%	62	10%	69	11%	79	12%	145	23%
	2016 late	479	2,144	82%	30	1%	33	1%	43	2%	232	9%
NH-concrete_arch	2015 mid	886	838	49%	236	14%	348	20%	372	22%	694	40%
	2016 early	356	114	24%	111	24%	142	30%	162	34%	330	70%
	2016 late	2,236	387	15%	999	38%	1,242	47%	1423	54%	2,321	88%
NH-steel	2015 mid	828	1,795	68%	399	15%	450	17%	475	18%	585	22%
	2015 late	1,168	84	7%	738	59%	880	70%	910	73%	1,160	93%

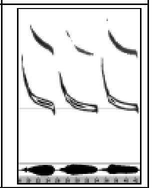
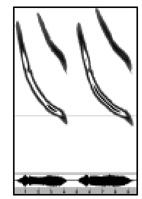
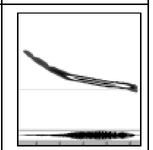
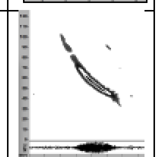
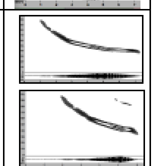
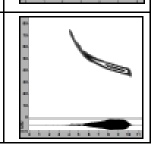
	LOCATION "A" *continued*											
Bridge ID	**Monitoring Season**	**# files After Scrubbing**	**# files Scrubbed**	**% scrubbed**	**# files classified by SonoBat Consensus**	**% of total files classified by SonoBat Consensus**	**# files classified by SonoBat ByVote**	**% of total files classified by SonoBat ByVote**	**# files classified by SonoBat MeanClssn**	**% of total files classified by SonoBat MeanClssn**	**# files classified by EchoClass**	**% of total files classified EchoClass**
NH-steel_truss	2015 mid	335	2,289	87%	43	2%	69	3%	82	3%	244	9%
	2015 late	212	2,411	92%	15	1%	28	1%	37	1%	84	3%
	2016 early	871	1,752	67%	10	0%	10	0%	12	0%	12	0%
	2016 mid	326	2,297	88%	55	2%	67	3%	89	3%	154	6%
RI-concrete	2016 early	399	119	23%	223	43%	252	49%	273	53%	369	71%
	2016 mid	1,791	832	32%	798	30%	909	35%	1,069	41%	1,527	58%
	2016 late	815	1,020	56%	183	10%	196	11%	240	13%	314	17%
RI-precast_concrete	2015 mid	1,807	817	31%	758	29%	943	36%	1,035	39%	1,686	64%
	2015 late	553	2,070	79%	104	4%	137	5%	170	6%	276	11%
	2016 early	581	704	55%	233	18%	280	22%	298	23%	520	40%
	2016 mid	1,323	1,033	44%	304	13%	451	19%	556	24%	1,015	43%
	2016 late	1,655	968	37%	660	25%	878	33%	928	35%	1,421	54%
RI-precast_concrete_2	2015 mid	453	2,171	83%	50	2%	72	3%	102	4%	181	7%
	2015 late	1,904	720	27%	97	4%	138	5%	168	6%	305	12%
	2016 early	257	2,366	90%	35	1%	53	2%	62	2%	111	4%
	2016 mid	640	1,982	76%	231	9%	261	10%	313	12%	458	17%
	2016 late	1,703	920	35%	60	2%	71	3%	86	3%	179	7%
RI-steel	2015 mid	174	2,450	93%	28	1%	35	1%	46	2%	72	3%
	2015 late	1,054	1,569	60%	8	0%	12	0%	18	1%	27	1%
RI-steel_2	2015 mid	647	706	52%	185	14%	249	18%	295	22%	494	37%
	2015 late	625	488	44%	177	16%	250	22%	281	25%	502	45%
	2016 mid	181	1,396	89%	1	0%	2	0%	2	0%	8	1%
	2016 late	382	608	61%	60	6%	101	10%	125	13%	260	26%
VT-concrete_arch	2015 mid	2,574	50	2%	248	9%	591	23%	583	22%	2,577	98%
	2015 late	2590	34	1%	339	13%	954	36%	468	18%	2,638	101%
	2016 early	332	2,291	87%	43	2%	103	4%	57	2%	248	9%
VT-covered	2015 late	2,607	17	1%	508	19%	951	36%	887	34%	2762	105%
	2016 early	1,776	846	32%	310	12%	553	21%	592	23%	1,647	63%
	2016 mid	2,621	2	0%	470	18%	1,012	39%	851	32%	2,772	106%
	2016 late	1,532	1,091	42%	321	12%	556	21%	521	20%	1,283	49%
VT-steel	2015 mid	2,130	493	19%	243	9%	485	18%	542	21%	2,087	80%
	2015 late	2,587	36	1%	447	17%	722	28%	976	37%	2,634	100%
	2016 early	1,232	1,391	53%	295	11%	373	14%	429	16%	893	34%
	2016 mid	2,527	96	4%	486	19%	763	29%	921	35%	2,541	97%
	2016 late	769	1,854	71%	73	3%	112	4%	161	6%	475	18%

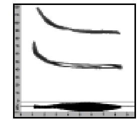
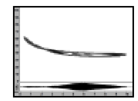
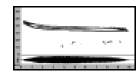
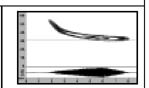
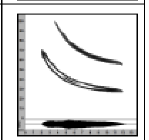
	LOCATION "B"											
Bridge ID	**Monitoring Season**	**# files After Scrubbing**	**# files Scrubbed**	**% scrubbed**	**# files classified by SonoBat Consensus**	**% of total files classified by SonoBat Consensus**	**# files classified by SonoBat ByVote**	**% of total files classified by SonoBat ByVote**	**# files classified by SonoBat MeanClssn**	**% of total files classified by SonoBat MeanClssn**	**# files classified by EchoClass**	**% of total files classified EchoClass**
CT-precast_concrete	2016 early	1,574	1,049	40%	69	3%	93	4%	98	4%	183	7%
	2016 mid	1,116	429	28%	648	42%	766	50%	756	49%	1,048	68%
	2016 late	2,321	302	12%	73	3%	81	3%	95	4%	198	8%
ME-concrete	2015 mid	363	2,261	86%	74	3%	102	4%	108	4%	198	8%
	2016 early	1,980	642	24%	19	1%	34	1%	36	1%	68	3%
	2016 mid	1,151	1,472	56%	443	17%	548	21%	574	22%	769	29%
	2016 late	1,884	739	28%	899	34%	1,115	43%	1,163	44%	1,661	63%
ME-steel/wood	2015 mid	81	580	88%	10	2%	17	3%	22	3%	40	6%
	2015 late	563	136	19%	19	3%	28	4%	11	2%	94	13%
	2016 early	57	2,566	98%	16	1%	18	1%	24	1%	31	1%
	2016 mid	98	152	61%	16	6%	22	9%	37	15%	72	29%
	2016 late	304	2,319	88%	1	0%	3	0%	11	0%	21	1%
MA-concrete	2016 early	769	1,111	59%	140	7%	198	11%	268	14%	604	32%
	2016 mid	1,651	124	7%	338	19%	435	25%	589	33%	1,380	78%
	2016 late	992	749	43%	216	12%	280	16%	413	24%	549	32%
MA-precast_concrete	2015 late	58	419	88%	5	1%	8	2%	11	2%	28	6%
MA-precast_concrete_2	2015 mid	381	2,243	85%	53	2%	70	3%	71	3%	110	4%
	2015 late	132	310	70%	73	17%	11	2%	95	21%	94	21%
	2016 early	92	2,486	96%	7	0%	7	0%	8	0%	14	1%
	2016 mid	502	245	33%	303	41%	337	45%	350	47%	432	58%
	2016 late	612	1,589	72%	202	9%	142	6%	146	7%	423	19%
MA-steel	2015 mid	486	2,138	81%	67	3%	95	4%	120	5%	232	9%
	2016 early	296	1,061	78%	62	5%	69	5%	79	6%	160	12%
	2016 mid	482	185	28%	117	18%	178	27%	209	31%	413	62%
	2016 late	285	1,117	80%	45	3%	56	4%	69	5%	138	10%
NH-concrete_arch	2015 mid	2,521	105	4%	1,079	41%	1,288	49%	1,424	54%	2,272	87%
	2015 late	1,282	1,341	51%	83	3%	120	5%	157	6%	410	16%
	2016 early	157	1,515	91%	22	1%	34	2%	29	2%	94	6%
	2016 mid	900	206	19%	335	30%	472	43%	495	45%	845	76%
	2016 late	766	1,856	71%	82	3%	123	5%	160	6%	460	18%
NH-steel	2015 mid	1,359	1,055	44%	815	34%	935	39%	961	40%	1,221	51%
	2015 late	519	2,105	80%	150	6%	199	8%	217	8%	326	12%
NH-steel_truss	2015 mid	605	2,019	77%	82	3%	123	5%	138	5%	358	14%
	2015 late	195	2,428	93%	15	1%	21	1%	26	1%	56	2%
	2016 mid	125	2,497	95%	12	0%	16	1%	15	1%	33	1%
	2016 late	163	2,460	94%	0	0%	0	0%	2	0%	8	0%

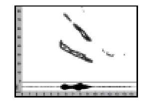
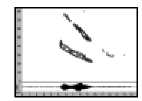
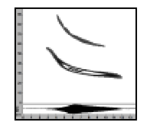
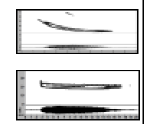
	LOCATION "B" *continued*											
Bridge ID	**Monitoring Season**	**# files After Scrubbing**	**# files Scrubbed**	**% scrubbed**	**# files classified by SonoBat Consensus**	**% of total files classified by SonoBat Consensus**	**# files classified by SonoBat ByVote**	**% of total files classified by SonoBat ByVote**	**# files classified by SonoBat MeanClssn**	**% of total files classified by SonoBat MeanClssn**	**# files classified by EchoClass**	**% of total files classified EchoClass**
RI-concrete	2016 early	689	281	29%	171	18%	199	21%	314	32%	406	42%
	2016 late	665	541	45%	215	18%	235	19%	333	28%	373	31%
RI-precast_concrete	2015 mid	2,511	113	4%	1,211	46%	1,480	56%	1,642	63%	2,383	91%
	2015 late	683	1,940	74%	91	3%	121	5%	190	7%	334	13%
	2016 early	989	46	4%	429	41%	535	52%	630	61%	1,005	97%
	2016 mid	2,236	386	15%	610	23%	793	30%	1,080	41%	2,247	86%
RI-precast_concrete_2	2015 mid	479	2,145	82%	99	4%	114	4%	144	5%	226	9%
	2015 late	840	204	20%	122	12%	174	17%	319	31%	561	54%
	2016 early	232	2,391	91%	7	0%	9	0%	10	0%	33	1%
	2016 mid	542	2,081	79%	116	4%	142	5%	173	7%	270	10%
	2016 late	1,597	1,026	39%	100	4%	116	4%	146	6%	223	9%
RI-steel	2015 mid	115	2,509	96%	12	0%	18	1%	24	1%	54	2%
	2015 late	224	2,400	91%	6	0%	7	0%	14	1%	21	1%
RI-steel_2	2015 mid	1,096	307	22%	457	33%	615	44%	664	47%	1015	72%
	2015 late	824	364	31%	395	33%	489	41%	508	43%	747	63%
	2016 early	1,768	294	14%	883	43%	1,140	55%	1,263	61%	1,738	84%
	2016 mid	557	449	45%	265	26%	344	34%	366	36%	527	52%
	2016 late	337	327	49%	114	17%	132	20%	162	24%	306	46%
VT-concrete_arch	2015 mid	2,575	49	2%	380	14%	932	36%	559	21%	2,608	99%
	2015 late	2,546	78	3%	288	11%	711	27%	418	16%	2,167	83%
	2016 early	357	2,265	86%	44	2%	92	4%	60	2%	271	10%
	2016 late	2,122	500	19%	151	6%	416	16%	235	9%	2,076	79%
VT-covered	2015 late	2,623	17	1%	292	11%	909	34%	468	18%	2,766	105%
	2016 early	2,125	497	19%	214	8%	553	21%	580	22%	1,996	76%
	2016 mid	2,615	8	0%	392	15%	872	33%	676	26%	2,642	101%
VT-steel	2015 late	2,609	17	1%	447	17%	819	31%	763	29%	2,849	108%
	2016 early	795	1,828	70%	143	5%	208	8%	261	10%	640	24%
	2016 mid	2,465	158	6%	471	18%	768	29%	894	34%	2,429	93%
	2016 late	716	1,906	73%	72	3%	129	5%	154	6%	559	21%

Appendix F Echolocation Call Characteristics of Eastern U.S. Bats

Echolocation Call Characteristics of Eastern U.S. Bats

	species	f_c	hi f	lo f	f_{maxE}	dur	uppr slp	lwr slp	slp @Fc	total slp	comments	call shape
40 - 50kHz Myotis	**Gray myotis** *(Myotis grisescens)*	***45.7*** ***47*** ***44*** 41-51	***79.5*** ***91*** ***68*** 53-107	***41.8*** ***44*** ***40*** 37-46	***48.2*** ***52*** ***44*** 41-85	***7.2*** ***8.5*** ***5.8*** 2.4-10	***11.5*** ***15*** ***8.3*** 3.6-29	***2.0*** ***3.1*** ***0.9*** 0.5-12	***2.4*** ***4.2*** ***0.5*** 0.0-13	***4.8*** ***7.6*** ***2.0*** 1.3-20	Longer calls (>5ms) typically display **a strong inflection point at the knee, pronounced downward tail ending call**, and an **extended call body with broad amplitude distribution**. Shorter calls (3-5ms) are typically at a higher frequency than other geographically overlapping Myotis.	
	Eastern small-footed myotis *(Myotis leibii)*	***44.3*** ***46*** ***42*** 38-48	***95.1*** ***104*** ***86*** 55-115	***40.6*** ***42*** ***39*** 31-44	***49.1*** ***52*** ***46*** 40-71	***3.2*** ***3.9*** ***2.5*** 1.7-5.3	***33.5*** ***40*** ***27*** 6.9-48	***9.6*** ***12*** ***7.0*** 2.5-22	***8.9*** ***12*** ***5.5*** 0.0-28	***16.9*** ***22*** ***12*** 4.6-36	**FM sweep a smooth curve** (i.e., no inflection), beginning steeply and then increasing in curvature*. May have a **well-defined downward tail. Peak power of call typically persists for at least 1ms on non–saturated calls.** Forage close to ground or vegetation. **some calls may have an inflection, but the smoothly curved variant is diagnostic.*	
	Southeastern myotis *(Myotis austroriparius)*	***43.6*** ***45*** ***42*** 38-48	***84.3*** ***95*** ***73*** 66-116	***39.6*** ***41*** ***38*** 31-44	***46.4*** ***48*** ***44*** 42-65	***4.6*** ***5.5*** ***3.8*** 2.0-6.2	***17.6*** ***22*** ***13*** 5.9-31	***6.1*** ***8.6*** ***3.6*** 1.8-14	***6.6*** ***11*** ***2.2*** 0.0-22	***9.7*** ***15*** ***4.7*** 4.0-26	**FM sweep a smooth curve** (usually no inflection), beginning steeply and then increasing in curvature*. May have a **well-defined downward tail. Peak power of call typically persists for at least 1ms on non–saturated calls.**	
	Northern myotis *(Myotis septentrionalis)*	***43.2*** ***47*** ***40*** 32-53	***104*** ***114*** ***95*** 60-120	***37.0*** ***42*** ***32*** 25-50	***51.3*** ***62*** ***41*** 37-95	***3.9*** ***4.6*** ***3.1*** 1.7-6.6	***24.2*** ***30*** ***18*** 8.5-55	***11.7*** ***16*** ***7.4*** 3.0-36	***13.1*** ***18*** ***8.0*** 0.0-37	***18.6*** ***24*** ***14*** 6.5-43	**Calls may have up to 100 kHz of bandwidth.** FM sweep may be nearly linear making *f*c difficult to recognize. Quiet but consistent calls. Fly near vegetation, often with a linear flight path when searching.	
	Indiana myotis *(Myotis sodalis)*	***40.8*** ***42*** ***39*** 34-47	***80.9*** ***90*** ***72*** 50-115	***37.5*** ***40*** ***35*** 25-43	***44.0*** ***47*** ***41*** 37-70	***5.8*** ***6.6*** ***5.0*** 1.9-7.8	***16.8*** ***21*** ***13*** 4.1-42	***4.6*** ***5.8*** ***3.3*** 1.0-16	***2.6*** ***4.6*** ***0.5*** 0.0-14	***7.1*** ***9.2*** ***5.1*** 2.3-23	Longer call type (>4.5ms) may have a **secondary inflection leading into a "ledge" or flat section <1.3ms** just prior to terminal sweep or "tail." Note: some MYLU long calls share this feature. Shorter call type also has ending ledge, but ~5–15% of shorter MYLE & MYLU also exhibit this feature.	
	Little brown myotis *(Myotis lucifugus)*	***39.7*** ***41*** ***38*** 34-46	***69.4*** ***78*** ***61*** 47-104	***36.5*** ***38*** ***35*** 27-43	***43.4*** ***47*** ***40*** 38-73	***5.8*** ***6.7*** ***4.9*** 2.0-7.8	***10.5*** ***14*** ***6.7*** 3.0-37	***3.5*** ***4.6*** ***2.3*** 1.0-15	***4.1*** ***6.2*** ***2.0*** 0.0-17	***5.0*** ***6.7*** ***3.4*** 2.2-23	Sometimes with multiple power centers making calls look clumpy. **Longer duration calls recorded in open air are more discriminating. Dur >7 and Lwr slp <3 distinctive.**	

	species	f_c	hi f	lo f	f_{maxE}	dur	uppr slp	lwr slp	slp @Fc	total slp	comments	call shape
40kHz kHz	**Tri-colored bat** (*Perimyotis subflavus*)	***44.3*** ***46*** ***42*** 38-48	***95.1*** ***104*** ***86*** 55-115	***40.6*** ***42*** ***39*** 31-44	***49.1*** ***52*** ***46*** 40-71	***3.2*** ***3.9*** ***2.5*** 1.7-5.3	***33.5*** ***40*** ***27*** 6.9-48	***9.6*** ***12*** ***7.0*** 2.5-22	***8.9*** ***12*** ***5.5*** 0.0-28	***16.9*** ***22*** ***12*** 4.6-36	Strongly inflected, almost vertical FM changing to low slope below 47 kHz for the majority of the call. Calls generally consistent across a sequence. Appear hockey stick–shaped in sonogram when FM sweep is present. Some calls exhibit "squiggles"	
	Eastern red bat (*Lasiurus borealis*)	***41.6*** ***44*** ***39*** 34-50	***89.6*** ***101*** ***78*** 52-120	***36.9*** ***40*** ***34*** 27-44	***48.0*** ***54*** ***42*** 39-89	***4.8*** ***5.9*** ***3.6*** 1.1-8.8	***15.1*** ***19*** ***11*** 4.9-35	***7.7*** ***11*** ***4.1*** 1.1-25	***8.7*** ***13*** ***4.3*** 0.0-25	***12.0*** ***17*** ***7.5*** 4.0-32	U-shaped calls; up–turn at end of call; may exhibit variable fc across sequence. Power smoothly centered in call. Low frequency can go as low as 30 kHz.	
	Seminole bat (*Lasiurus seminolus*)	***40.8*** ***42*** ***39*** 35-48	***74.5*** ***86*** ***63*** 48-103	***38.1*** ***40*** ***36*** 28-44	***44.5*** ***49*** ***40*** 36-74	***6.0*** ***7.3*** ***4.6*** 2.0-9.0	***13.1*** ***20*** ***6.5*** 2.7-38	***3.9*** ***6.5*** ***1.3*** 0.8-15	***4.2*** ***7.7*** ***0.8*** 0.0-19	***6.2*** ***10*** ***2.2*** 1.6-23	**(*In progress*)** U-shaped calls; up–turn at end of call; may exhibit variable fc across sequence. Power smoothly centered in call. Low frequency can go as low as 30 kHz. **Likely acoustically indistinguishable from LABO.**	
	Evening bat (*Nycticeius humeralis*)	***38.9*** ***41*** ***37*** 36-53	***54.6*** ***60*** ***49*** 44-102	***38.8*** ***41*** ***37*** 36-52	***41.6*** ***44*** ***39*** 37-61	***10.7*** ***13*** ***8.9*** 2.9-14	***4.0*** ***5.4*** ***2.7*** 1.9-30	***0.7*** ***0.9*** ***0.6*** 0.3-10	***0.0*** ***0.1*** ***0.0*** 0.0-8.6	***1.5*** ***1.9*** ***1.2*** 0.6-19	Sweeping curved calls that may lack any inflection. Calls have more slope in body (lower slope) than do similar-shaped shorter and longer PISU calls. Sequences may display fc alternating up and down.	
30 kHz	**Northern yellow bat** (*Lasiurus intermedius*)	***34.3*** ***36*** ***33*** 29-43	***78.5*** ***93*** ***64*** 46-119	***28.1*** ***31*** ***26*** 23-43	***39.1*** ***43*** ***35*** 31-71	***3.7*** ***4.5*** ***2.9*** 1.1-6.5	***20.5*** ***28*** ***13*** 6.1-58	***8.7*** ***12*** ***5.0*** 2.3-34	***10.0*** ***14*** ***6.0*** 0.1-34	***13.5*** ***19*** ***7.9*** 4.9-42	U-shaped calls; up–turn at end of call; may exhibit variable fc across sequence. Power smoothly centered in call. Low frequency can go as low as 25 kHz. Calls similar in shape and variability to other *Lasiurus* spp, but intermediate in frequency range between LABO/LASE and LACI.	 
	Big brown bat (*Eptesicus fuscus*)	***28.2*** ***30*** ***27*** 24-55	***56.6*** ***63*** ***50*** 33-84	***27.2*** ***29*** ***26*** 23-33	***31.9*** ***36*** ***28*** 25-52	***7.8*** ***10*** ***5.3*** 2.3-18	***8.5*** ***12*** ***5.5*** 1.2-24	***2.1*** ***3.2*** ***1.0*** 0.3-8.7	***1.3*** ***2.6*** ***0.0*** 0.0-14	***4.0*** ***5.8*** ***2.2*** 0.6-13	Variable; calls with high f below 60 kHz can be confused with LANO and/or TABR. **Calls w/hi-f above 65 kHz distinguish from LANO**, even long calls have some FM component, i.e., never flat. The end of calls may hook up. ⇒ *see note at end*	
	Silver-haired bat (*Lasionycteris noctivagans*)	***26.5*** ***27*** ***26*** 23-31	***41.5*** ***50*** ***33*** 26-63	***25.4*** ***27*** ***24*** 14-30	***28.8*** ***31*** ***26*** 24-44	***9.2*** ***13*** ***5.0*** 2.3-24	***5.2*** ***8.9*** ***1.6*** 0.0-22	***1.3*** ***2.5*** ***0.0*** 0.0-8.8	***1.0*** ***2.4*** ***-0.4*** 0.0-8.3	***2.5*** ***4.6*** ***0.4*** 0.0-12	Shorter calls reverse J-shaped; often w/distinct inflection. Some call variants can be confused with EPFU and/or TABR. **Flat calls >=26 kHz diagnostic.** Flat LACI calls are lower f. Low slope calls in the 25-26 kHz range may be distinguished from LACI by presence of an inflection. EPFU has more FM, w/smooth curvature. ⇒ *see note at end*	 

	species	f_c	hi f	lo f	f_{maxE}	dur	uppr slp	lwr slp	slp @Fc	total slp	comments	call shape
20 kHz20 kHz Myotis	**Townsend's big-eared bat** (*Corynorhinus townsendii*)	***23.4*** ***26*** ***21*** 18-32	***42.5*** ***45*** ***40*** 36-51	***21.4*** ***23*** ***19*** 17-30	***31.1*** ***34*** ***28*** 22-41	***4.6*** ***6.3*** ***3.0*** 1.7-11	***7.1*** ***13*** ***1.2*** 0.2-70	***4.9*** ***6.6*** ***3.2*** 1.1-13	***4.2*** ***6.5*** ***1.9*** 0.0-13	***5.0*** ***6.5*** ***3.5*** 1.0-11	Low intensity, difficult to detect; harmonics often present. Call-shape **simple linear FM sweep**, (sometimes with upsweep at onset). *fmax* may alternate between fundamental and second harmonic. This species sometimes applies more amplitude in the 2nd harmonic than in the 1st.	
	Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)	***22.8*** ***25*** ***20*** 23-23	***39.8*** ***42*** ***37*** 40-40	***22.5*** ***25*** ***20*** 22-22	***33.2*** ***37*** ***30*** 33-33	***2.6*** ***5.1*** ***0.1*** 2.6-2.6	***6.2*** ***8.6*** ***3.7*** 6.2-6.2	***7.4*** ***8.9*** ***5.9*** 7.4-7.4	***6.7*** ***8.9*** ***4.4*** 6.7-6.7	***6.7*** ***8.1*** ***5.2*** 6.7-6.7	Low intensity, difficult to detect; harmonics often present. Call-shape **simple linear FM sweep**, (sometimes with upsweep or flat tone at onset before sweeping downward). *fmax* may alternate between fundamental and second harmonic. This species sometimes applies more amplitude in the 2nd harmonic than in the 1st.	
	Mexican free-tailed bat (*Tadarida brasiliensis*)	***25.5*** ***28*** ***23*** 18-33	***32.3*** ***39*** ***25*** 19-61	***24.1*** ***26*** ***22*** 17-33	***28.0*** ***31*** ***25*** 18-46	***11.5*** ***14*** ***9.5*** 3.5-20	***1.6*** ***3.2*** ***0.0*** 0.0-17	***0.5*** ***0.8*** ***0.1*** 0.0-4.5	***0.4*** ***1.0*** ***-0.3*** 0.0-4.1	***0.7*** ***1.4*** ***0.0*** 0.0-4.8	Variable; FM to flat; can be confused with EPFU, LANO, or LACI. **Long calls that "turn on" power rapidly with high energy at beginning** (carrot–shaped oscillogram). Calls often **upswing into call and downswing** out of call (chaise lounge shaped pulses).	
	Hoary bat (*Lasiurus cinereus*)	***20.1*** ***22*** ***18*** 16-32	***26.0*** ***31*** ***21*** 17-58	***19.7*** ***22*** ***18*** 16-31	***20.8*** ***23*** ***18*** 17-49	***11.0*** ***15*** ***7*** 4-26	***2.2*** ***4.1*** ***0.3*** 0.1-14	***0.4*** ***0.8*** ***0.1*** 0.0-5.7	***0.0*** ***0.2*** ***-0.1*** 0.0-4.6	***0.7*** ***1.4*** ***0.1*** 0.0-8.3	**Pronounced or subtle U–shape;** very flat calls may have slight downturn into call or upturn at end. **Low *f* may vary across sequence, power builds toward center then gradually declines**. Short calls can be confused with LANO, EPFU, or TABR.	

How to use this table: Ranges listed cover mean ± standard deviation. Bold text indicates the most species–discriminating characteristics. Analyze 1) well–formed calls, i.e., search phase calls recorded from bats in a steady mode of flight and not accelerating or performing some other maneuver that elicits rapid, short calls, e.g., like that from a hand–released bat, and 2) calls with a strong signal that clearly rise above the background noise level. It is generally preferable to avoid analyzing calls that saturate, i.e., overload, the detector or recorder. However, saturated call specimens may be used to interpret non- saturating low power call characteristics such as low and high *f*; but do not use saturated call specimens for interpreting power characteristics.
Terminology and Key: lo-*f*: lowest apparent frequency (kHz); **hi-*f***: highest apparent frequency (kHz), this can vary depending upon the distance to the bat; f_c: characteristic frequency, i.e., the frequency of the call at its lowest slope, or the lowest frequency for consistent FM sweeps (kHz); f_{max}: the frequency w/the greatest power (kHz); **dur**: call duration from the beginning to the end of the call (ms), **upper**: the slope of the upper portion or onset of the call (kHz/ms), **lower**: the slope of the lower portion or body of the call (kHz/ms). **FM**: frequency modulation, i.e., change in frequency with time, **flat**: a call or portion of call w/a very low slope or no slope (horizontal), **inflection**: a pronounced change in the slope of a call, sometimes called a "knee," **power**: the amplitude or sound energy of a call or portions of a call, **squiggle**: an S-shape variation in frequency w/time over a portion of the call.

Sources: Characteristics gleaned from recordings acquired by J.M. Szewczak, Humboldt State University Bat Lab (and Aaron Corcoran, Jean-Paul Kennedy), T.J. Weller, USFS Redwood Sciences Lab, and Patricia C. Ormsbee, USFS Pacific Northwest Research Station, and various contributors to the Pacific Northwest Bat Grid.

Note regarding distinguishing *E.fuscus* and *L.noctivagans*: Shorter EPFU calls (<7) recorded with full detail, i.e., ones that closely approached the microphone, as indicated by the presence of harmonics, regularly have F-hi that exceeds 65-70 kHz. Shorter LANO calls (<7) recorded with full detail, i.e., ones that closely approached the microphone, as indicated by the presence of harmonics, still do *not* exceed 50-55 kHz.