Structure Surveys for Bats: Emerging Trends in Frequency of Bat Use in North Carolina Bridges

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Abstract

Bats (Chiroptera) are essential for maintaining ecosystem health but, worldwide, bats are experiencing severe population declines for a variety of reasons including white nose syndrome, habitat destruction and habitat modification. Anthropogenic structures such as bridges and culverts are therefore becoming increasingly important as roosting alternatives to bats. Habitat assessments for bats on transportation structures are standard practice for the North Carolina Department of Transportation (NCDOT). All data collected is entered into a database managed by NCDOT which helps expand the collective knowledge of bat use within transportation structures in North Carolina. The goal of this study was to find relationships between bat use and bridges in North Carolina. Statewide, 20.2% of NCDOT bridges had evidence of bat use (n=410). By region, 16.0% of bridges surveyed in the western part of the state had evidence of bat use (n=231) and 30.7% of surveyed bridges in the eastern part of the state (n=179). In North Carolina, 88.8% of bats were found roosting in the crevices of decks compared to roosting out in the open (11.2%). Therefore, given all the components of a bridge and mixed materials that could be used in those different components, using the deck material to define bridge ‘type’ would provide the most useful information for managers as it relates to bat use. The North Carolina Department of Transportation maintains 13,778 bridges statewide, 95.9% (n= 13,215) have a concrete deck, 4.0% (n=551) have a timber deck and <0.1% (n=12) have a metal deck type. Because most of the samples are from concrete material type, there is more opportunity to view bats within them as confirmed by the results, 93.6% of positive bat use records statewide were observed in concrete bridges. However, the effort put forth to survey timber bridges was greater than concrete. We have surveyed 53.9% of timber deck bridges statewide (n=297) while only 10.6% (n=1,399) of concrete deck bridges have been surveyed statewide. With that higher level of effort at timber bridges, we have still only found 1.0% (n=3) of timber bridges that were surveyed had bat use. Alternatively, with a lower level of surveying effort at concrete bridges, we found that 20.0% (n=280) of concrete bridges that were surveyed had bat use. This level of effort data further demonstrates that surveyors are more likely to find a bat in a concrete bridge versus a timber bridge.

Introduction

Bats (Chiroptera) are essential for maintaining ecosystem health by fulfilling their roles as pollinators (Flemming et al. 2009, SDBWG 2004), seed dispersers (SDBWG 2004, Preciado-Benítez et al. 2015, da Silva 2024), and insect predators (Whitaker 1993, Keeley and Tuttle 1999, Kunz et al. 2011).Bats are also beneficial to advances in medicine as anticoagulants in the saliva of Vampire bats (subfamily Desmodontinae) have been utilized to develop similar medications that saves human lives (Apitz-Castro et al. 1995, Fernandez et al. 1998, Low et al. 2013) and studying bats has led to development of navigations aids to the blind (Zhu et al. 2023). Worldwide, bats are experiencing severe population declines for a variety of reasons. In North America, white nose syndrome (WNS) is a fatal fungal (*Pseudogymnoascus destructans*) disease affecting hibernating bats that has caused significant declines in bat populations since its discovery in New York in winter 2006. By 2018, WNS killed 90% of *Myotis septentrionalis*, *Myotis lucifugus*, and *Perimyotis subflavus* in North America (Cheng et al. 2021). The fungus that causes WNS, *Pseudogymnoascus destructans*, spread to North Carolina in 2011 (USFWS 2020; K. C. Etchison, North Carolina Wildlife Resources Commission, personal communication) where eight bat species are susceptible to the disease (NCWRC 2018).

Declines in bat populations have also been attributed to habitat destruction and modification (Fenton 1997; Keeley and Tuttle 1999; Hendricks et al. 2005; Shiel 1999; SDBWG 2004). As a consequence of natural roost loss, alternative anthropogenic structures such as bridges and culverts are becoming increasingly important as roosting alternatives to bats. It is widely accepted that bats use bridges as roosting sites across the United States (Keeley and Tuttle 1999; Feldhamer et al. 2003; Felts and Webster 2003; Hendricks et al. 2005, Gore and Studenroth 2005; Bektas et al. 2018; Stevens et al. 2021; Detweiler and Bernard 2023). This has fundamental ecological relevance and importance, particularly if transportation departments can use this data to better understand when bridge replacement, repair, or rehabilitation projects have the potential to impact bat species listed as federally threatened or endangered under the United States Endangered Species Act (ESA 1973, as amended).

Habitat assessments for bats on transportation structures are standard practice for the North Carolina Department of Transportation (NCDOT). These surveys are completed as part of compliance efforts for the Endangered Species Act. When construction or maintenance activities are proposed, surveys are completed to establish presence or absence and determine potential impacts to species that are federally listed as endangered or threatened (ESA 1973, as amended). All data collected is entered into a database managed by NCDOT which helps expand the collective knowledge of bat use within transportation structures in North Carolina.

The purpose of this study is to summarize the findings of nearly 30 years of data, collected statewide to help determine how many bridges maintained by NCDOT are being used by bats, which species of bats are most likely to be found on these bridges, and to note any differences in use by species, bridge material, and relative location in the state. Because the effects of WNS have been so impactful to bat populations, we decided it was worthwhile to mark a separation in the data using the year of when WNS was first detected in North Carolina (2011). While the focus of this study is not to correlate changes in bat use of bridges to the discovery of WNS in North Carolina, the disease represents an important benchmark in the life history of North American bats and therefore, the date of its arrival to North Carolina must be considered during analysis. The following is a summary of the results of NCDOT structure surveys for bats through 2023. Our goal is to offer natural resource managers and transportation agencies insight into the frequency and emerging trends of bat use within North Carolina bridges.

Methods

In the early 2000s, the NCDOT Biological Surveys Group developed a paper datasheet to collect information regarding bats on transportation structures and recorded results in an Excel spreadsheet. The type of data we collect includes general identifiers, such as bridge number, date of survey, stream crossing, road crossing, as well as data on surrounding habitat and bridge characteristics as they relate to potential bat use. Bridge characteristics include alignment and height of the bridge, presence of suitable roosting areas such as expansion joints or clogged deck drains, and material (e.g., concrete, metal, timber) for each component of the bridge that bats are known to use as roosts (e.g., deck, girders, end walls, guardrails). The data form also captures information relating to observed bat use, including species found, where they were found (e.g., roost type, roost material), and the description of other evidence such as staining or guano.

In 2014, the NCDOT Biological Surveys Group created an electronic data collection method for Global Positioning System (GPS) enabled field data collection units in the form of a data dictionary. At that time, the original spreadsheet and coordinates were converted to a geometric location point layer with attributes that matched the data form fields and redesigned as the NCDOT Bat Bridge Inspection Geographic Information System database. To accompany the new data collection methods, we developed a Standard Operating Procedure (NCDOT 2015) for surveying structures for bat habitat. The Standard Operating Procedure and data dictionary further increased data collection consistency Department-wide for internal staff and external contractors.

In 2019, many surveyors moved away from using GPS units and started collecting information on phones or tablets. At that time, we provided an updated format for use on those devices through the Environmental Systems Research Institute, Inc. (ESRI, Redlands, CA) Survey123 form builder and software. This enabled users to capture data with mobile devices and analyze results in real time with the ESRI software program ArcGIS Online. The paper form was digitized to create a field application which can sync to a group created in ArcGIS online. To date, we continue to maintain records of every NCDOT bridge that has been surveyed for bats. The full NCDOT procedures for assessing potential bat roosting habitat within structures are described in the NCDOT Standard Operating Procedures: Preliminary Bat Habitat Assessments (NCDOT 2015). Surveys for bats on bridges are conducted by internal staff and experienced contractors. We also receive survey data from partners who are surveying NCDOT bridges for their own interests, such as the North Carolina Wildlife Resources Commission or university researchers. Field training sessions have been provided every few years, since 2014, to ensure all surveyors are using the same standardized data collection and survey techniques. North Carolina Department of Transportation Standard Operating Procedures for Preliminary Bat Habitat Assessments on structures can be divided into several steps outlined in the following sections.

Office assessment

The office assessment starts with a query of the USFWS Information for Planning and Consultation (IPaC) site (https://ipac.ecosphere.fws.gov) to determine which federally protected bat species are potentially present within a NCDOT project area. Features identified as potential hibernacula (cave features, abandoned mines and underground quarries) or summer roosting habitat located within 0.5 mile of the project are assessed prior to field surveys. These habitat features are identified using United States Geological Survey topographic and geologic quadrangle maps and a mine data layer available on the Mineral Resources On-Line Spatial Data United States Geological Survey webpage (http://mrdata.usgs.gov/mrds/find-mrds.php). The mine layer does not provide information on caves; surveyors use United States Geological Survey topographic maps and North Carolina Natural Heritage Program occurrence data to find bat records that indicate cave locations.

Field assessment

Equipment needed to complete the assessments includes binoculars, spotlights (>1,000 lumen), a mirror on a pole to view tight areas and a camera or borescope. Because of the limited active season for bats in western North Carolina due to hibernation and migration patterns (Weber et al. 2020), bridge surveys in that region would occur from May 15 – August 15, following guidance from USFWS (USFWS 2024). However, occasional surveys outside of this time period have occurred and are included in the database. This would occur when a monitoring commitment has been agreed to, for example a pre-demolition bridge survey to ensure no roosting bats are present. This amounts to 27% of the records occurring from September – May in the western dataset. Bridges in eastern North Carolina (USFWS Raleigh Ecological Services Field Office) may be surveyed year-round as bats have been documented to be active year-round in much of eastern North Carolina (Grider et al. 2016; Jordan 2020). Because of the difference in survey season methodology between USFWS field offices, and given the high variation between geographic regions of North Carolina, the results are separated using the USFWS Asheville and Raleigh Ecological

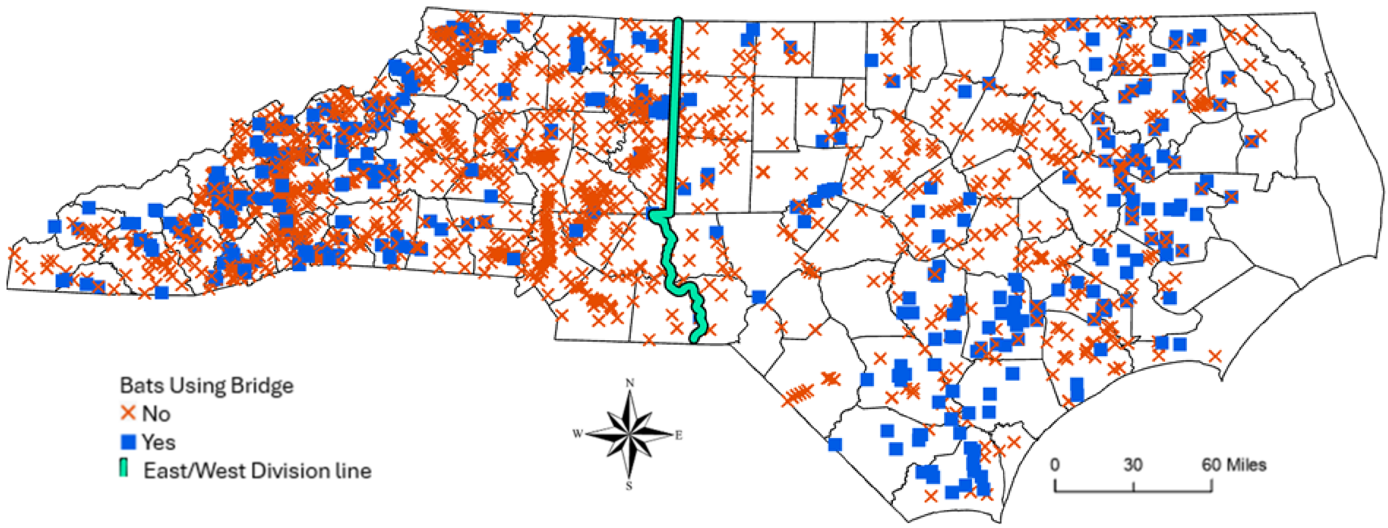

Figure 1. To find relationships between bat use and bridges in North Carolina, 3,032 surveys were conducted between 1994-2023 and all presence or absence data from habitat assessments for bats on transportation structures was analyzed. The results were separated using western and eastern regions of the state (aqua blue line). Bat use is defined as either direct observation of a bat roosting on the bridge or observation of evidence in the form of body or urine staining or guano.

Services Field Offices assigned counties to delineate western (NCDOT Divisions 9-14) and eastern regions of the state (NCDOT Divisions 1-8), Figure 1. Inspectors survey the structural elements of each bridge as described in the structure diagram provided in the NCDOT Standard Operating Procedures (Figure 2).

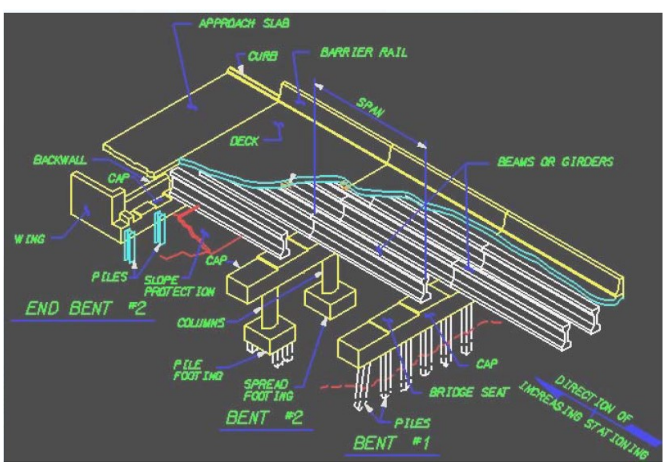

Figure 2. To find relationships between bat use and bridges in North Carolina, 3,032 surveys were conducted between 1994-2023. Habitat assessments for bats on North Carolina transportation structures use standardized terminology and procedures for assessing potential bat roosting habitat. This bridge structure diagram describes the anatomy of a bridge and defines bridge components for consistency between surveyors.

The surveyor walks the bridge deck to inspect all barrier/guardrail crevices and gaps between metal or wood posts and the bridge structure. From the bridge deck, the surveyor looks over the guardrail or edge of the bridge to check surfaces on top of bridge bent caps for accumulated guano. If inaccessible, a mirror on a pole may be used to inspect deck crevices and expansion joints open at the sides of the bridge. Underneath the bridge, a spotlight is used to examine all visible parallel and perpendicular crevices for bats. Crevices over pier caps are inspected by backing several feet away from the bridge to look into deck crevice/expansion joints with binoculars and a spotlight, allowing a deeper view into the crevice. Surveyors search every exposed wall under the bridge and behind or alongside bird and wasp nests for roosting bats. Clogged deck drains are also inspected from below. Horizontal and vertical surfaces underneath the bridge are examined for guano pellets using the spotlight to look for guano hanging on the walls or inside vertical crevices. Staining on vertical walls, around crevices, and on bent caps is noted. The ground beneath crevices or near pillars is also surveyed closely for guano pellets that may have fallen from a roost site or as bats emerged.

All data collected was entered into an ESRI ArcGIS Pro (recent version 2.9.9) database and then exported to a Microsoft Office 365 Excel (Version 2407) spreadsheet for analyzing summary statistics (Data S1). A logistic regression model was constructed to examine the impact of bridge material and location (predictor variables) on bat presence (response variable). A model of this family is appropriate as the raw data consists of binary observations (bat present or bat not present) at the bridge level. The regression analysis was completed using R software (Version 4.2.3) and R Studio software (Version 2023.12.1). For analyses, duplicate records at the same bridge have been removed so results are not skewed from multiple visits to known bat bridges. However, if new species were observed during a duplicate visit, those are included in the 'species commonly observed' analysis below and therefore results would include that bridge in both time period data (pre- and post-WNS).

Results

The dataset contains positive and negative records for bat use (Figure 1). As of 2023, there are 3,032 survey records, with the earliest dating back to the mid-1990s. Duplicate bridge survey efforts are represented separately, so, if the same bridge is surveyed over multiple years, each survey is treated as a separate record. Statewide, the NCDOT maintains 13,778 bridge structures (D.S. Stutts, P. E., NCDOT Structures Management Unit, personal communication). Removing duplicate bridge survey efforts, the surveys conducted for bat habitat assessments represent 14.7% (n=2,032) of total bridges sampled in the state.

Either direct observation of a bat roosting on the bridge or observation of staining or guano on the bridge is considered sufficient positive evidence of bat use. Using all bridge records, including duplicate bridge visits, the western positive records indicated 82% (n=469) of evidence was in the form of observed bats, 17% (n=100) of evidence was in the form of guano/staining (no bat) and 1% (n=5) of evidence had no type indicated. In the east, 67% (n=171) of evidence was in the form of observed bats, 31% (n=79) of evidence was in the form of guano/staining (no bat) and 6% (n=6) of evidence had no type indicated. Interestingly, when studying the duplicate surveys, only 16.5% (n=23) deviated from an original survey, in other words, 83.5% (n=116) of duplicate surveys had the same result each time - either it was a bat positive bridge from survey to survey or it was a bat negative bridge from survey to survey. The bats that are known to roost on or in North Carolina bridges are listed in Table 1 along with federal protection status (if any) and species name abbreviation.

Because duplicate records at the same bridge were removed so results are not skewed from multiple visits to known bat bridges, 2,032

Table 1. To find relationships between bat use and bridges in North Carolina, 3,032 surveys were conducted between 1994-2023. Bats known to roost on or in North Carolina bridges, summarized by federal protection status and species abbreviation used in text.

Scientific Name	Common Name	Federal Protection Status	Species Name Abbreviation
Corynorhinus rafinesquii	Rafinesque's big eared bat	None	CORA
Eptesicus fuscus	Big brown bat	None	EPFU
Lasionycteris noctivagans	Silver haired bat	None	LANO
Myotis austroriparius	Southeastern bat	None	MYAU
Myotis grisescens	Gray bat	Endangered (USFWS 1976)	MYGR
Myotis leibii	Small footed bat	None	MYLE
Myotis lucifugus	Little brown bat	None	MYLU
Myotis septentrionalis	Northern long eared bat	Endangered (USFWS 2022a)	MYSE
Myotis sodalis	Indiana bat	Endangered (USFWS 1974)	MYSO
Nycticeius humeralis	Evening bat	None	NYHU
Perimyotis subflavus	Tricolored bat	Proposed Endangered (USFWS 2022b)	PESU
Tadarida brasiliensis	Mexican free tailed bat	None	TABR

bridge records were left for analysis. Statewide, 20.2% of surveyed bridges had evidence of bat use (n=410). In the western part of the state, there were 1,448 bridge records, 16.0% of surveyed bridges had evidence of bat use (n=231), and 5.7% of bridges had evidence of federally protected bat species use (MYGR 3.6%, MYSE 0.2%, MYSO 0.2%, PESU 1.5%). In the eastern part of the state, there were 584 bridge records and of those, 30.7% of surveyed bridges had evidence of bat use (n=179), 11.3% of bridges had evidence of federally listed bat use (PESU). Figure 3 and Figure 4 show the bat species that were observed during NCDOT bridge surveys in western and eastern North Carolina, respectively. These figures show the percent of occurrence of bat species observed during NCDOT bridge surveys broken down into two periods. The first period displays data from 1994-2010 (representing pre-white nose syndrome entering the state) and the second period displays data from 2011-2023 (representing post-WNS entering the state). This method of display was chosen because the disease serves as an important benchmark in the life history of bats, and we wanted to illustrate any trends that might emerge with the introduction of WNS on bat populations in North Carolina. The percentage of occurrence is not an abundance count, rather, these numbers represent how frequently a species was observed during surveys at bridges.

The most observed bat roosting on or in NCDOT bridges in western North Carolina (pre-WNS) was EPFU (Figure 3). Pre-WNS, MYGR, TABR and MYSO had no observations on bridges. Pre-WNS, MYLE and MYLU were found more frequently during bridge surveys. The most observed bat at western bridges post-WNS remained EPFU; however, the percentage

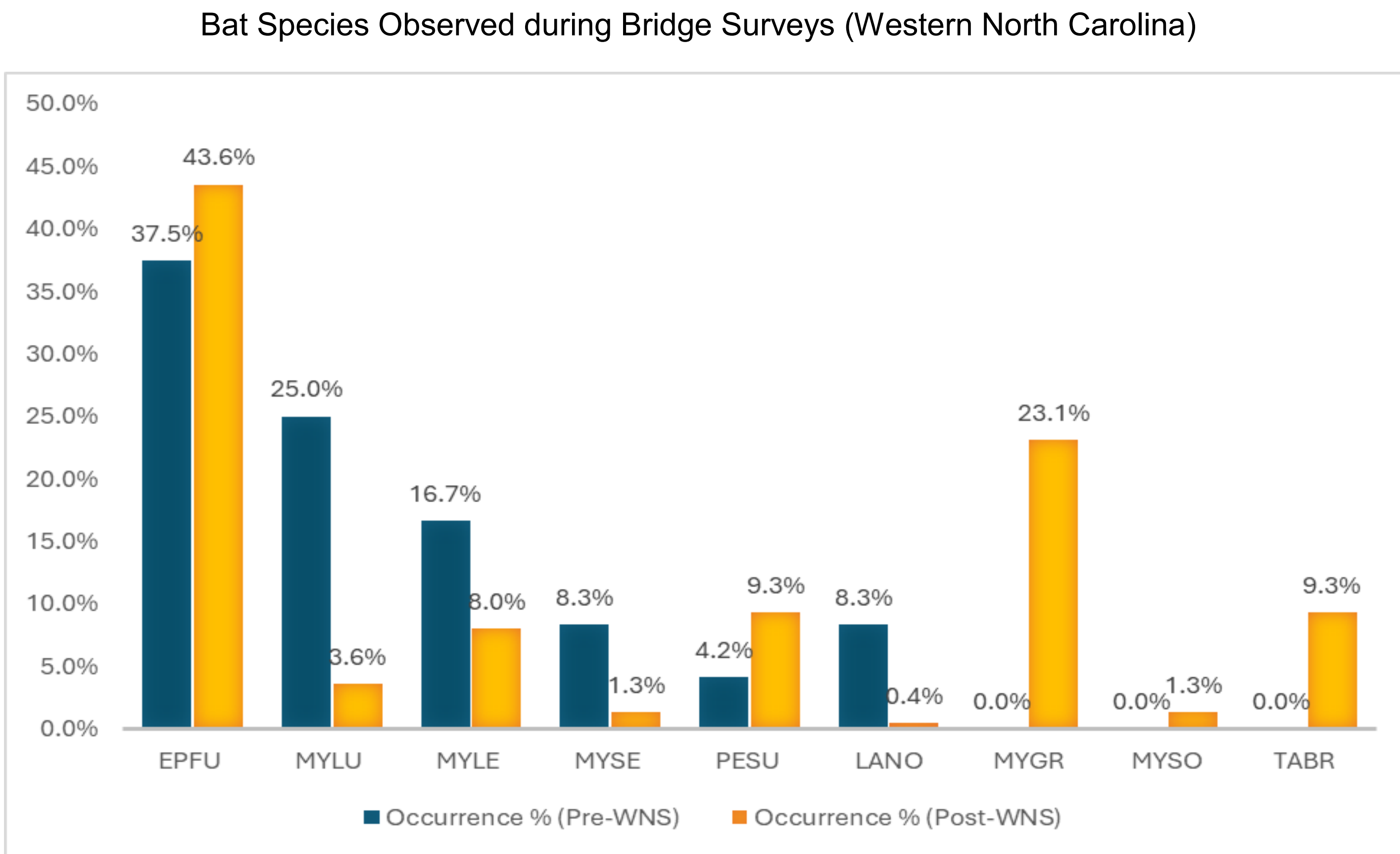

Figure 3. To find relationships between bat use and bridges in North Carolina, 3,032 surveys were conducted between 1994-2023. Bat species observed during western bridge surveys separated in two periods: 1994-2010 (pre-white nose syndrome entering the state), 2011-2023 (post-white nose syndrome entering the state). Percent of occurrence is not an abundance count; these numbers represent how often a species was observed during surveys at bridges. Bat species are *Eptesicus fuscus* (EPFU), *Myotis lucifugus* (MYLU), *Myotis leibii* (MYLE), *Myotis septentrionalis* (MYSE), *Perimyotis subflavus* (PESU), *Lasionycteris noctivagans* (LANO), *Myotis grisescens* (MYGR), *Myotis sodalis* (MYSO) *and Tadarida brasiliensis* (TABR).

of occurrence increases from 37.5% to 43.6%. Pre-WNS, MYLE represented 16.7% of occurrences observed during surveys, but their occurrences declined to 8.0% post-WNS. Pre-WNS, MYLU represented 25.0% of occurrences, declining to 3.6% post-WNS. Pre-WNS, MYGR and TABR were not observed during any bridge surveys in western North Carolina, but post-WNS, they represent the second and third most observed bats on or in western North Carolina bridges.

The most frequently observed bats roosting on or in eastern NCDOT bridges are PESU and CORA pre-WNS and EPFU and TABR had very few to no observations pre-WNS (Figure 4). While PESU remained the most frequently observed bat post-WNS, EPFU was the second most observed bat on or in eastern bridges post-WNS at 35.4%, compared to pre-WNS at 3.4%. Pre-WNS, CORA represented 39.3% of occurrences observed during surveys, but their occurrences declined to 10.8% post-WNS. Pre-WNS, PESU represented 47.2% of occurrences, but the species occurrences declined to 36.9% post-WNS. Pre-WNS, MYAU represented 10.1% of occurrences and declined to 0% - post-WNS. Pre-WNS, EPFU and TABR were not frequently observed during bridge surveys in eastern North Carolina, but post-WNS, they represent the second and third most observed bats on or in eastern North Carolina bridges, respectively.

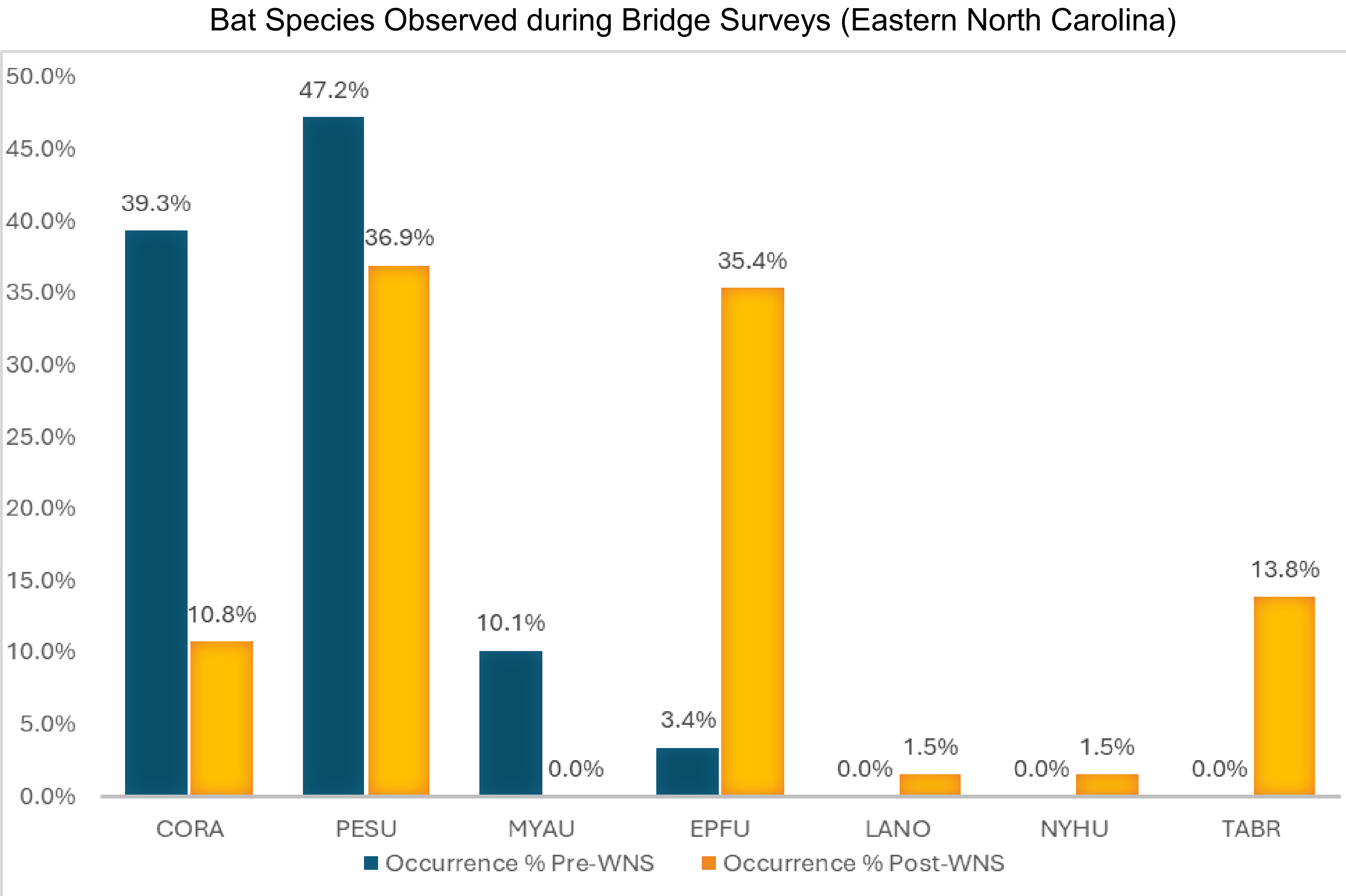

Figure 4. To find relationships between bat use and bridges in North Carolina, 3,032 surveys were conducted between 1994-2023. Bat species observed during eastern bridge surveys separated in two periods: 1994-2010 (pre- white nose syndrome entering the state), 2011-2023 (post- white nose syndrome entering the state). Percent of occurrence is not an abundance count, these numbers represent how often a species was observed during surveys at bridges. Bat species are *Corynorhinus rafinesquii* (CORA), *Perimyotis subflavus* (PESU), *Myotis austroriparius* (MYAU), *Eptesicus fuscus* (EPFU), *Lasionycteris noctivagans* (LANO), *Nycticeius humeralis* (NYHU) *and Tadarida brasiliensis* (TABR).

Some survey data are received from sources outside of NCDOT. For various reasons, not all attributes are provided to NCDOT for every survey. To be included in the NCDOT database, survey data must include, at a minimum, the survey date, the survey location and the positive/negative evidence of bat use on or in the bridge. Of all positive records for bats roosting on or in western NCDOT bridges (n=164 records), 122 had information pertaining to the material where the bat was observed roosting. Of the 122 records with information on material, 89 records had information on roost type, for example, if the bat was roosting within an expansion joint in the deck or open roosting on a girder. This information gives us an understanding of not only structure material but the bridge components that are favorable for bat use. The data showed that 88.8% (n=79) of bats were roosting in the crevices of the deck (i.e., expansion joints) and 11.2% of bats were roosting in the open (i.e., beams/girders or backwalls). Therefore, given all the parts of a bridge and mixed materials that could be used in those different parts, it was determined that using the deck material to define bridge type would provide the most useful information as it relates to bat use. According to western bridge

Table 2. To find relationships between bat use and bridges in North Carolina, 3,032 surveys were conducted between 1994-2023. A logistic regression model was constructed to examine the impact of bridge material and location on bat presence (model coefficients, measures of uncertainty, p-values, and test statistics are displayed below). Converting from log odds to odds ratios, the odds ratio of observing bats increases by 1.088% for every one-unit increase in forest coverage (Mixed Forest). The odds ratio of observing bats increases by 209% if a bridge's structure is concrete. The odds ratio of observing bats decreases by 66% if a bridge 's structure is timber. The odds ratio of observing bats increases by 55% if a bridge is located in the western part of the state.

Predictor	Estimate	Std. Error	Test Statistic	P-Value	Lower Bound 95% CI	Upper Bound 95% CI	Description
Intercept	-1.885	0.173	-10.912	<0.0001	-2.228	-1.551	
Mixed Forest	0.011	0.002	5.122	<0.0001	0.007	0.015	Ranges from 0 to 100; indication of forest coverage.
Concrete	1.127	0.139	8.127	<0.0001	0.859	1.403	1 if bridge was noted as containing concrete, 0 if not.
Timber	-1.085	0.169	-6.407	<0.0001	-1.425	-0.761	1 if bridge was noted as containing timber, 0 if not.
West	0.440	0.118	3.710	0.0002	0.209	0.674	1 if the bridge was located in the western half of the state, 0 if in the eastern half.

records, 95.1% (n=116), had bat use recorded on or in areas of the bridges with concrete materials, 4.9% (n=6) had bat use on or in areas of the bridges with metal materials and 0% had evidence of bats use on or in areas of the bridges with timber materials. Of all positive records for bats roosting on or in eastern NCDOT bridges (n=124 records), 102 had information pertaining to the material where the bat was observed roosting. The majority of those records 92.2% (n=94) had bat use on or in areas of the bridges with concrete materials, 6.9% (n=7) had bat use on or in areas with timber materials and <1% (n=1) had evidence of bats roosting on or in areas of the bridges with metal materials. Concrete appears to be the preferred roosting material for bats that were observed roosting on or in NCDOT bridges statewide.

A logistic regression model was constructed to examine the impact of bridge material and location (predictor variables) on bat presence (response variable). The model coefficients and their associated measures of uncertainty are displayed in Table 2. Logistic regression showed that the amount of surrounding forest, the location of the bridge in the state (west or east) and the bridge material type all had a significant probability for predicting the occurrence of bats in bridges. This suggests that the probability of bats increases as the percentage of forested surrounding habitat increases and if the structure is made of concrete material. Concrete had the highest parameter estimate. The parameter estimate measures the rate of change in the logit (log of odds) corresponding to a one-unit change in the predictor variable. Holding all other variables equal, and converting from log odds to odds ratios, the odds ratio of observing bats increases by 1.088% for every one-unit increase in forest coverage (Mixed Forest). The odds ratio of observing bats increases by 209% if a bridge's structure is concrete.

The odds ratio of observing bats decreases by 66% if a bridge 's structure is timber. The odds ratio of observing bats increases by 55% if a bridge is located in the western part of the state. A confusion matrix was calculated to ensure the model fit well to the observed data. This is not intended to evaluate the model's predictive capabilities on out-of-sample observations. The model displayed approximately 78% accuracy against field-observed bat presence.

Discussion

As the data spans over decades and across all seasons, these data are helpful to assess species trends. The goal of this study was to find relationships between bat use and bridges in North Carolina. One relationship is that between bridge use and material type. In North Carolina, 88.8% of bats were found roosting in the crevices of decks compared to roosting out in the open (11.2%). Therefore, considering all the components of a bridge and mixed materials that could be used in those different components, using the deck material to define bridge 'material type' would provide the most useful information for managers as it relates to bat use. Given that definition, it is important to then discuss the prevalence of materials in the system being managed. North Carolina Department of Transportation maintains 13,778 bridges statewide, 95.9% (n= 13,215) have a concrete deck, 4.0% (n=551) have a timber deck and <0.1% (n=12) have a metal deck type (D.S. Stutts, P. E., NCDOT Structures Management Unit, personal communication). Because most of the samples are from concrete material type, there is more opportunity to view bats within concrete bridges as confirmed by the results (statewide 93.6% of positive bat use records were observed in concrete bridges). However, it is worth discussing the level of sampling effort for each bridge type as well. The effort to survey timber bridges is greater than concrete. We have surveyed 53.9% of timber deck bridges statewide (n=297) while only 10.6% (n=1,399) of concrete deck bridges have been surveyed statewide. With that higher level of effort at timber bridges, we have still only found 1.0% (n=3) of timber bridges that were surveyed had bat use. Alternatively, with a lower level of surveying effort at concrete bridges, we found that 20.0% (n=280) of concrete bridges that were surveyed had bat use. This data on level of effort further demonstrates that you are more likely to find a bat in a concrete bridge versus a timber bridge. Structure roosting information and bat species use on concrete has been well documented within this dataset and it has been widely published that concrete is a preferred roosting material for bats, both nationwide, and in the southeast (Keeley and Tuttle 1999; McDonnell 2001, Gore and Studenroth 2005; Bektas et al 2018; Weber et al. 2020; Detweiler and Bernard 2023, Wetzel and Roby 2023). However, the literature is lacking regarding the prevalence of concrete structures in other state's so we are unable to compare our numbers regarding bridge material and prevalence.

Several bat species found in transportation structures are federally protected under the Endangered Species Act as endangered or threatened (ESA 1973, as amended).

Therefore, it is important for NCDOT to understand the habitat preferences for federally protected bat species to help ensure transportation project compliance with the ESA. When determining the best conservation measures to reduce impacts to bats, tracking and understanding which bridge types are preferred by bats can help make local, data-based decisions while also considering fiscal responsibility. The NCDOT Bat Bridge Inspection database informs the NCDOT and resource agencies on what species of bats are using bridges and what bridge parameters were preferred by bats in North Carolina. Then efforts can be focused on areas considered preferred bat habitat. This is especially true for species like PESU that are still considered proposed for listing.

In western North Carolina, 5.7% of surveyed bridges had evidence of federally protected bat species use (MYGR, MYSE, MYSO, PESU). In eastern North Carolina, 11.3% of surveyed eastern bridges had evidence of use by a bat species with a federally listed status under the Endangered Species Act (PESU). In eastern North Carolina, MYGR and MYSO are not known to occur. While MYSE does occur there, it has not been documented during bridge surveys associated with this study, nor was it documented in previous studies of bat bridge use in coastal North Carolina (McDonnell 2001, Felts and Webster 2003). This could be a result of coastal North Carolina being on the periphery of the overall range for MYSE. Like MYSE, a portion of the PESU's range overlaps with coastal areas of the southeast US where the species' behavior, habits and habitat use differ significantly from the rest of the species' range. In these areas, PESU are active year-round and are not known to utilize traditional hibernation strategies exhibited in the rest of the species range (USFWS 2024). It is plausible that human-made structures like bridges serve as a surrogate for natural caves in this portion of the species' range and provide suitable locations for the random bouts of torpor needed to survive during the coldest periods of the year. Bridges provide options as non-ephemeral roosts that could support the bats that survive WNS or are in population decline due to habitat loss.

In western North Carolina, observations of EPFU increased after the discovery of WNS in 2011. Similarly, TABR and MYGR were observed on bridges there for the first time since surveys began in 1994, while observations of MYLE and MYLU declined. It is possible that this pattern is an example of species filling a niche through competitive release from the bats impacted by WNS. Multiple studies have demonstrated cases where less impacted species were able to exploit spatial and dietary niche spaces vacated by WNS-susceptible bats (Bombaci et al. 2021; Jones et al. 2018; Jachowski et al. 2014). Species that are considered highly and moderately susceptible to WNS include MYLU, MYSO, MYSE, MYLE and PESU (Bombaci et al. 2021). Species that have tested positive for *Pd* presence but are relatively unaffected by WNS include LABO, *L. cinereus,* LANO*,* EPFU, and NYHU. The Bombaci et al. study's authors suggest that the variability in competitive release across sites may be related to the variation in morphology, diets, and foraging habitat among species considered in their study. They explain that although many species consume similar prey, they often forage in different habitats so competitive interactions may be more strongly related to the exclusion of non-susceptible species within spaces when there were larger numbers of susceptible species present. For example, during the interactions between species such as MYLU and EPFU, there is likely little direct competition over prey, as the two species typically consume different diets. Rather, the Bombaci et al. authors suggest competition is more likely related to the sheer numbers and amount of activity of MYLU in the aerial space. Their activity is creating foraging and/or space utilization challenges for the other non-susceptible species (i.e., auditory interference) (Jones et al. 2018). However, Morningstar et al. (2019) found that, post-WNS, EPFU shifted their diet to include prey formerly consumed by MYLU, indicating that competition between susceptible and non-susceptible bats for prey may also occur. This may be happening not only in dietary shifts but in the roosting space formerly occupied by MYLU as we've seen here in North Carolina, that MYGR, TABR and EPFU are being observed more in bridges formerly occupied by the more WNS susceptible species.

While EPFU remained one of the most observed species on eastern North Carolina bridges, the percentage of observations increased tenfold post-WNS. It is unclear why this increase occurred. White nose syndrome is unlikely to occur in eastern North Carolina because no *Pd* spores have been detected on WNS-susceptible species in the Middle Atlantic Coastal Plain or Southeastern Plains ecoregions (Griffith et al. 2002) of North Carolina (Jordan 2020). Further, as of September 2024, no WNS or *Pd* spores have been confirmed east of Wake County, North Carolina which is in the Piedmont and Rolling Coastal Plains ecoregions (K. C. Etchison, North Carolina Wildlife Resources Commission, personal communication). Similarly, the declines in the percentage of PESU cannot be explained by WNS in eastern North Carolina since this species does not appear to be affected by the disease in this portion of its range. While this may preclude the theory of competitive release associated with WNS, the effects of WNS on migrating bats and population dynamics at a larger scale are unknown and could contribute to some of the changes we observed. The decreases in observations of CORA and MYAU cannot be easily explained. Anecdotal evidence collected during our surveys suggested that MYAU take flight more often during surveys, indicating individuals of this species may be more prone to disturbance when compared to other bats, perhaps making it harder for surveyors to have identified the species before. There is also evidence that since 2007, TABR have expanded their range into North Carolina, eastern Tennessee, and Virginia (McCracken et al. 2018). This could explain why TABR were not observed in NCDOT bridges pre-WNS but observations have increased considerably since 2011. Researchers propose that the rapid northward expansion of TABR is facilitated by climate change and their tendency to explore new habitats and use a wide diversity of roost sites (McCracken et al. 2018).

Range expansion and disease mediated competitive release may explain why some bat species in North Carolina experienced increased observations in bridges from the pre- to post-WNS period while other species saw a decline. The ability to examine trends in data using a centrally organized database helps inform decision making during ESA consultation between NCDOT and USFWS to determine where conservation measures are best utilized, focusing more on species that are most imperiled in habitat types that they prefer most. While reporting observational survey data is important for the collective knowledge of the frequency of bat use in North Carolina bridges, we recognize this is not an empirical study that was developed using a stratified random study design. Bridges included in this dataset were mainly surveyed in anticipation of construction or maintenance activities, not a designed study and the bridges surveyed pre-WNS and post-WNS are usually not the same bridge so direct correlations cannot be made. The purpose in this paper was to summarize structure surveys for bats through 2023 to help determine how many bridges maintained by NCDOT are being used by bats, which species of bats are most likely to be found on these bridges, and to note any differences in use by species, bridge material, and relative location in the state. Because the effects of WNS have been so impactful to bat populations, we decided it was worthwhile to make a separation in the data using the year of when WNS was first detected in North Carolina (2011). While the purpose of this study is not to correlate changes in bat use of bridges before and after the discovery of WNS in North Carolina, the disease represents a significant benchmark in the life history of bats and was included as a discussion point. Additional research is needed to test hypothesis of bat use in bridges, potential impacts of bridge use from WNS and to further investigate preferred bat roosting habitat in North Carolina bridges.

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